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MANUAL OF PATHOLOGY

J. COATS, M.D.

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A MANUAL OF PATHOLOGY.

A MANUAL

OF

PATHOLOGY.

BY

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TO

JOSEPH LISTER, M.B., F.R.S.,

WHOSE METHOD OF REGARDING PHYSIOLOGICAL AND PATHOLOGICAL PROCESSES AFFORDED TO THE AUTHOR, DURING THE EARLIER YEARS OF HIS CAREER, AN EXAMPLE OF SCIENTIFIC INSIGHT FOR WHICH HE HAS NEVER CEASED TO BE GRATEFUL,

AND TO

W. T. GAIRDNER, M.D.,

WHOSE ENTHUSIASM IN THE STUDY OF PATHOLOGY, IN THE POST-MORTEM ROOM AND AT THE BEDSIDE, HAS BEEN TO THE AUTHOR, DURING THESE FOURTEEN YEARS, A PERPETUAL STIMULUS, WHILE HIS GENEROUS FRIENDSHIP HAS BEEN A CONSTANT ENCOURAGEMENT,

This Work is,

WITH GREAT RESPECT AND ESTEEM,

DEDICATED.

PREFACE.

THE teaching of Pathology in the British schools of medicine has, of late years, assumed greatly enlarged proportions, while the publication of native text-books has by no means kept pace with it. Since the publication of Wilks and Moxon's excellent work on Pathological Anatomy in 1875, no complete English work has appeared, Green's "Introduction," though improving both in scope and fulness with successive editions, laying no claim to be a complete systematic treatise. In the paucity of English works we have had several translations of foreign manuals. The Sydenham Society, in 1872, issued a translation of Rindfleisch's Manual of Pathological Histology, and during the last few months we have had the first instalments of translations of Cornil and Ranvier's "Manuel d'Histologie Pathologique," and of Ziegler's "Lehrbuch der Pathologischen Anatomie und Pathogenese." These two latter translations were announced after the author had undertaken the present work.

The want of a complete English text-book, felt by the author in the course of teaching, suggested this undertaking. It will be seen from the Contents that the scope of this work is somewhat more extensive than that of most works on the subject. These, for the most part, are limited either to Pathological Anatomy or General Pathology, while in this work an endeavour has been made to include both. It will be acknowledged that the whole aim of pathological anatomy is to elucidate the actual vital processes of disease, and it has been felt by the author

in lecturing on Pathology that the subject gains in interest and intelligibility when the etiology, anatomy and general pathology are all taken into account in forming a general conception of each morbid condition. The author is conscious of many imperfections and omissions now that he contemplates his completed task; he can only ask for the indulgence of the reader, and he may be allowed to hope that an opportunity will be given of improving on the present work.

It was in the plan of the author to indicate the literature of the various subjects treated of; this, however, has been necessarily left over. In the meantime it may be stated that the author has been much indebted to the works of VIRCHOW, WAGNER, RINDFLEISCH, COHNHEIM, PAGET, WILKS and MOXON, PAYNE, KLEBS, CORNIL and RANVIER, FÖRSTER, ROKITANSKY, BIRCH-HIRSCHFELD, BILLROTH and ZIEGLER for general guidance in the preparation of the work. As the author for the last fourteen years has been constantly engaged as a practical Pathologist and in teaching large classes of students, the work in most of its departments rests upon his own observation and experience.

In the preparation of the work for the press and in arranging the index the author has been under great obligation to Dr. Geo. S. Middleton and Dr. J. Lindsay Steven, the former of whom has also supplied, in the index, the derivations of words.

GLASGOW, *March*, 1883.

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A MANUAL OF PATHOLOGY.

INTRODUCTION.

PATHOLOGY may be defined as THE STUDY OF DISEASES not in their manifestations merely but in their essential nature. There are various conditions met with from day to day which we name diseases. They produce certain alterations in the feelings of the person affected which induce him to say, He is not well, and they in many cases lead to changes in the condition of the bodily frame which can be actually observed by the physician, and may enable him to come to a conclusion as to the actual disease which is present. These subjective phenomena and those objective signs are mere indications of the presence of something which we call the disease or morbid process; and it is surely incumbent on every one who undertakes to treat disease, not to content himself with a knowledge of its manifestations merely, but to satisfy himself as to its real nature.

And here, at the very outset of our study of Pathology, it is to be remarked that we have to do with diseases, not disease in the abstract. There are certain definite conditions which the body presents, and which are recognized as morbid states, or conditions different from those of health, and our object is to find out what is the nature of these morbid states. Endless discussions might be raised as to the nature and causes of disease in the abstract; but we shall arrive at much more reliable conclusions if we study the individual states of disease and leave those more general discussions aside.

Without going into any general discussion as to the nature of disease as a whole, there is one subject which here calls for some consideration, namely, THE RELATION OF DISEASED TO HEALTHY CONDITIONS. Physiology is the study of the body and its actions in health, and it is not to be supposed that in disease these physiological processes suddenly cease. So far as the diseased condition is concerned, these processes are modified, and they must be studied under the altered circumstances; but in the study of each pathological condition the physiological must be taken as the basis. A knowledge of physiology is the necessary preliminary to the study of Pathology. It may be said, indeed, that the pathological processes are merely the physiological ones altered. In disease there is something disturbing the natural processes, and there is an endeavour, as it were, on the part of the body to get over the disturbance, and the phenomena of the disease are not infrequently the expression of the resistance which the natural processes present to the disturbing element. These normal processes must be taken into account therefore, and, as we shall see further on, the physiological laws are really in essence identical with the pathological.

We have to study the nature of diseases, and this will bring us into close connection with their CAUSES. Much has been written concerning the causes of disease in general, and much that is valuable, but this study of itself would be almost sufficient to fill a volume. It will be enough here if we consider, as each disease comes under review, whether it is traceable to any definitely distinguishable cause or causes. In some acute febrile diseases, we are able to predicate the existence of viruses, and even the nature of some of these viruses is to some extent known. Whatever is known as to the cause of diseases will assist in elucidating their nature.

In the study of diseases in their nature, there are three main sources from which assistance is to be obtained; one may be designated EXPERIMENTAL PATHOLOGY, another PATHOLOGICAL ANATOMY, and the third CLINICAL OBSERVATION. John Hunter may be said to have laid the foundation of experimental pathology. So far as it can be prosecuted, this mode of study is calculated to afford us the most directly trustworthy information as to the nature of diseases, and much of the advance in modern pathology is due to this

line of study. If we can actually induce a given disease in an animal, we have found out much as to its causation, and are in the way of finding out much as to its nature. In some cases we are able actually to observe the morbid processes in the living animal. Or, we can kill the animal at various periods after the onset of the disease, and observe the results at various stages. We can vary the experiment in different ways so as to eliminate on one side and another the various elements, and so reduce the problem to its simple and necessary parts. Experimental pathology has carried us far towards understanding many of the conditions in disease. Reference need only be made to the reformations which this line of study has effected in our knowledge of Inflammation, Embolism, Tuberculosis.

The study of morbid anatomy is not likely to effect such revolutions in Pathology as experimental pathology, but in the training of the individual medical student it is calculated to play an even more important part in giving him an understanding of the nature of the diseases he has to deal with. Morbid anatomy gives us the physical changes which disease produces in the body. These changes are, as it were, the expression of the pathological processes, and are only to be regarded as indications of the existence of these processes. It is probable that all morbid processes produce changes in structure, although the changes may elude our observation. For the most part, however, we are able to associate the change of structure with the morbid process, and the observed change leads us up to the actual nature of the disease. In fact, the nature of disease might be studied on the basis of the morbid structure, advantage being taken also of all information from the side of experimental pathology and clinical observation.

Morbid Anatomy is the study of the structural changes in all periods and stages of the disease. It is sometimes objected to this mode of study that in observing the state of the tissues after death we see only the last stages of disease, and in some cases only the results. This, however, is not the case. Every clinical observer will admit that in the same disease the fatal issue occurs in different cases under the most diverse circumstances. Death ensues, as a rule, when by reason of defective nutrition, or a deficiency in the supply of oxygenated blood mainly by interference with the respiration, the functions of the body can no longer be carried on. Now there is in different individuals an

infinite variety in the vigour of the vital processes, so that a condition which in one will very slightly affect the essential phenomena of life, will, in another, seriously compromise them. This is an experience of our every-day life. And so it happens that patients die in all stages of disease. Even in the same case we are often able to study the various changes in their different stages.

As an illustration of what is meant, take the case of pneumonia or acute inflammation of the lungs. Patients die in this disease, as a rule, from failure of the heart and consequent cessation of the circulation; but the paralysis of the heart is not related solely to the condition of the lungs. It is often much more closely related to the elevation of temperature which is to be traced to changes in the nervous system, while the powers of resistance of the heart in each person are an important element in the matter. And so it happens that one man will die with a limited and advancing pneumonia, while another will survive through a very extensive condensation. The lung at death in the one case is in the same stage of the disease as in the other at a certain date during life. We can study the nature of the disease in the former and we are surely warranted in assuming that in the patient who survived the state of the lung is virtually identical with that of the patient who died.

Again, in a carcinoma growing up to death, we have, at the growing margins of the tumour, changes which are the same as those by which the tumour has all along been extending, and we can study the methods of its growth as well as its relations to the structures in which it has been growing.

Thus it is that, although morbid anatomy by itself may in some cases throw little light on the nature of the disease, yet, taken as an expression of the morbid process, it is of the highest value. It may be added that as similar processes must have similar changes as their correlatives, we may take these changes as a kind of test of the existence of the processes.

In referring to processes and changes it must be understood that the finer structure of the body is taken into account. In Pathological Anatomy, we include PATHOLOGICAL HISTOLOGY, and it may indeed be said that, as the coarser, naked-eye appearances are merely the expression of the finer structural details, so we shall not understand the former

unless we are able to refer them to the latter. We can have no accurate idea of the proper structure of the normal liver by simply looking at it with the naked eye, and we can have little insight into its morbid conditions by the same method of observation. The morbid conditions, however, do generally cause changes in the naked-eye appearances, and this is of great consequence as enabling us, when roughly examining an organ, to infer that its structure is changed. But these MACROSCOPIC appearances are only useful when they are used to throw light on the MICROSCOPIC changes or to direct attention to them. The really important processes are those which concern the finer elements of the tissues, and so it is to these that we shall chiefly attend in studying the various forms of disease.

Clinical observation is of great importance in the study of pathology, and that in various ways. If what has been stated above be correct, then it is the processes occurring during life that are the real subject of study in pathology, and it is only by careful clinical observation that we are able to get, as it were, into close relations with these processes during their actual currency. Clinical Observation and Pathological Anatomy should thus be taken as mutually elucidating each other, and as working together towards just conceptions as to the nature of the conditions concerned.

There is another aspect in which clinical observation is of importance in relation to pathology. The pathologist, if conversant only with morbid anatomy and experimental pathology, is apt to form a too mechanical and simple conception of the processes involved, and is likely to theorize on the basis of a too-limited view of the subject. Clinical Observation is a needed corrective to this, bringing the pathologist back to the practical aspects of the matter, and checking the tendency to theorize by the discipline of facts.

In the systematic treatment of the various forms of disease, the plan adopted has been to take up first the diseases in their general aspects, and afterwards the diseases of the special organs and systems. The work, therefore, divides itself naturally into a General Part and a Special Part.

In the General Part will be taken up those diseases which are not confined to any organ or tissue; most of them, indeed, may affect any

organ of the body. In this part are included the following subjects:—The Affections of the Circulation and of the Blood, Inflammation, Retrograde Changes, Hypertrophy Repair and Regeneration, Infective Tumours, Tumours proper, and Parasites. In order to make this general part complete the subject of Malformations should be included. With the general subject of Malformations, however, the author has little practical acquaintance, and he has thought it better to leave it to special works on that subject.

In the Special Part, the diseases as they manifest themselves in the individual organs and tissues will be considered. It is clear that the diseases described in the General Part will again come under review in each division of the Special Part, and they will be taken up very much in the same order as in the General Part. But each disease presents various specialties according to its locality, and, from a practical point of view, it is important to understand the modifications thus occurring. The Special Part will be, in a certain sense, an expansion and amplified illustration of the general principles educed in the General Part.

PART FIRST.—GENERAL DISEASES.

AFFECTIONS OF THE CIRCULATION AND OF THE BLOOD.

WE have here two somewhat diverse conditions to consider, namely, the abnormal variations in distribution of the blood, and the changes in its actual condition. In regard to distribution we may have too much or too little blood in the vessels, or the blood or its constituents may get outside the vessels. On the other hand, the blood may undergo changes in its constitution, or it may change its condition by coagulating inside the vessels.

In order to understand what is to follow it will be necessary, in the first place, to refer briefly to certain points in the PHYSIOLOGY OF THE CIRCULATION. If we are to study alterations in the distribution of the blood, then we must have in our minds clear ideas as to the arrangements by which the normal distribution is regulated. In the distribution of the blood the capillaries and veins may be regarded as virtually passive channels. They are able to accommodate more or less blood according to circumstances, but of themselves they have probably little to do with the variations in the supply. It is obvious that the supply of blood to the tissues varies, chiefly according to their needs; the working brain or muscle requires and gets a fuller and more rapid supply of blood than when at rest. Although there may be some assistance to the circulation by the attraction to the tissues of needed material, yet essentially the supply is regulated by the arteries; when they dilate more blood passes into the capillaries and on to the veins, and when they contract less blood reaches the capillaries and veins. We may regard the arteries as regulating the supply of blood, the capillaries as distributing

the blood, bringing it within reach of the elements of the tissues, and the veins and lymphatics as carrying it off. The amount of blood admitted by the arteries depends on the state of contraction or relaxation of the muscular fibres in the middle coat, and this, like all other muscular actions, is under the command of the nervous system. When the vaso-motor nerves are stimulated the muscular coat contracts, when these nerves are paralysed it relaxes, and when a moderate amount of stimulus is supplied, then we have that state of slight contraction to which the name of TONICITY is applied.

Much attention has been bestowed on the exact nervous relations of the middle coat of arteries. There is no doubt that it is under the influence of centres situated in the cerebro-spinal axis, but there is reason to believe that there are, as well, in or near the walls of the arteries, peripheral ganglia, which are the immediate regulators of their calibre. The heart is often compared with arteries in its structure, and we know that it possesses intrinsic ganglia. By means of these ganglia it is able to persist in its contractions after separation from all higher centres or even when cut out of the body. We know, also, that the higher centres influence these ganglia in two ways, either by stimulating them (through the sympathetic) or by inhibiting them (through the vagus). In the arteries we see somewhat similar phenomena. When arteries are cut off from all central connections they are still capable of varying their calibre. If the sciatic nerve in a frog is divided the arteries indeed dilate, but after a time they resume, at least partially, their state of tonicity and are capable of still further variations. Again, an excess of carbonic acid in the blood will cause arteries to contract after all their central connections have been severed, and they may be made to dilate by means of chloral or atropine. It is well known that irritation of the vaso-motor nerves causes *contraction* of the arteries, and this is readily enough understood without supposing the existence of peripheral ganglia, but it has now been shown that the arteries may be caused to *dilate* by the stimulation of nerves passing to them, and this can only be by means of local ganglia. It is known, for instance, that dilatation of the arteries of the salivary gland may be produced by irritation of certain nerves passing to them, and so is it with the vessels of the penis. Lately it has been shown that the arteries of the skin may be thus caused to dilate. In these cases the nervous influence paralyses the local ganglia. In studying inflammation we shall see still further proof of the existence of these peripheral nerve centres, the existence of which Lister long ago inferred.

Besides these local centres there are higher and more general centres situated chiefly in the spinal cord and medulla oblongata. From these centres there seems to pass a continuous slight stimulation inducing that moderate contraction which we name tonicity. If the connection be severed the tonicity ceases, the arteries dilate. There is a general centre for the whole vaso-motor system in the medulla oblongata. When this is stimulated all the arteries appear to contract. When it is destroyed all the arteries in the body dilate. But without being destroyed the centre may be paralysed or inhibited. It is inhibited by the inhalation of nitrite of amyl, and the arteries dilate. It may also be inhibited by the stimulation of a nervous branch which passes upwards from the heart, the depressor nerve. This general centre, therefore, has nervous connections of a similar kind to the local ganglia.

It may be added that each organ seems to have nervous arrangements of its own by means of which, either reflexly through the spinal cord and sympathetic system, or more locally, it is in a position to regulate the contraction of its arteries and the supply of blood.

HYPERÆMIA AND ANÆMIA.

These physiological considerations would lead us directly to the consideration of the local variations in the distribution of the blood in the body. But prior to that we have to consider alterations in the quantity of the blood as a whole. It is clear that with regard to both local and general variations the blood may be either excessive or deficient in quantity, and to express these the terms HYPERÆMIA and ANÆMIA are used. It will, therefore, be possible to consider this subject under the four divisions of General Hyperæmia, General Anæmia, Local Hyperæmia, and Local Anæmia.

1. GENERAL HYPERÆMIA.—This term designates the condition in which the total quantity of blood in the body is in excess. The term PLETHORA is used in a similar sense. The first question that arises here is, whether the vascular system is capable of accommodating more blood than it contains normally. There is no difficulty in answering this question in the affirmative. If the vessels as a whole could contain no more blood than they normally hold, then there could be no local variations, no blushing, no increase in the quantity of blood during activity of organs. The capillaries present great varieties in the amount of blood they contain at different times, and if we take the whole capillaries of the body into

account, it will appear that in them there is a great reserve space which may possibly on occasion be used for the accommodation of an excess of blood. This matter has been brought to the test of experiment, and as there are several points of interest in this regard, we shall refer more specially to the observations made.

TRANSFUSION OF BLOOD is the artificial introduction into the vascular system of blood from another animal.

In the experiments of Worm Müller, which are chiefly of importance here, the defibrinated blood of dogs was injected, with precautions, into the vessels of animals of the same kind. It is not remarkable that the vascular system can accommodate a large additional quantity of blood, but it is remarkable that it should do so with little disturbance to the health of the animal. A quantity equal to a half or three-fourths of the blood normally present in the animal may be injected without endangering the life of the animal, and the quantity needs to be double the normal, or over it, before the animal's health is seriously impaired. It might be expected that when the vascular system is thus overfilled the blood-pressure would be greatly raised, but actual registration of the pressure, by a cannula introduced into the carotid and connecting with a kymographion, shows that though during the actual operation there is a rise of pressure, yet it soon falls to within normal limits. If a quantity is injected beyond double the normal bulk of the blood, then the pressure begins to show remarkable elevations and depressions, and the animal usually dies in the course of the same day or the next. Life is immediately endangered when one and a-half times the normal bulk is injected.

When blood is transfused then in large quantity it finds accommodation chiefly in the capillaries and veins, the arteries being relaxed in order to admit of its passing into these, and the blood-pressure is not raised. It appears that the capillaries and veins of the abdominal organs form a great reservoir for the accommodation of excessive blood, and that the blood lodges here chiefly after transfusion.

The excess of blood thus supplied to an animal does not, however, remain permanently as a part of its organism. There seem to be arrangements in the body for disposing of it. Worm Müller endeavoured to determine what time it took TO DISPOSE OF A LARGE EXCESS OF BLOOD. After the transfusion the animals were starved, and the blood and urine examined at intervals. It was concluded that the fluid of the blood is rapidly disposed of, being excreted by the

urine. A few hours after transfusion much of the excess of liquor sanguinis had already gone, and even when 60 to 80 per cent. of the entire blood was injected, the whole excess had disappeared in the course of two or three days. The rapid disposal of the liquor sanguinis leaves the blood corpuscles greatly in excess, and the rate of disappearance was determined by counting them by means of Malassez' method. If the quantity transfused is small, the corpuscles may be disposed of in a few days; but in the case of large transfusions it may take two or even three weeks. In this comparatively short period of time, however, the whole excess of blood, both plasma and corpuscles is removed, and we may infer that there are arrangements in the body for the regulation of the amount of blood.

These experiments all refer to the transfusion of defibrinated blood. If blood is injected when just ABOUT TO COAGULATE, or if when it has just begun to coagulate some of the serum is pressed out and injected, then in some cases the animal dies rapidly with symptoms referrible to pulmonary embolism. The blood in the right side of the heart and pulmonary artery is found after death to be coagulated. The explanation of this is, that at the time of coagulation of the blood, the fibrinoplastic substance and the ferment, which Schmidt's observations have shown to be so directly concerned in coagulation, are both set free. It appears that even a small quantity of these substances introduced in the free state into the blood of a living animal induces coagulation of it. The importance of these facts in regard to transfusion in human beings will not be overlooked.

Hitherto the transfusion of blood from an animal of the same kind has been referred to, dog's blood injected into a dog. But when blood FROM A DIFFERENT SPECIES of animal is used, there are frequently symptoms of poisoning developed. The urine is blood-coloured, and it contains albumen and tube casts; there is vomiting of bloody material, diarrhœa, etc. It is as if the foreign blood had acted as a poison, and we may enquire what is the nature of the poison. The observations of Ponfick (Virchow's *Archiv*, vol. lxii.), and others, have thrown considerable light on this matter. It has been already mentioned that the urine is blood-coloured, but microscopic examination shows that this is due, not to the presence of red blood corpuscles, but to that of the colouring matter of the blood in solution. It is not a bloody, but a blood-coloured urine, not a hæmaturia but a HÆMOGLOBINURIA. The fact seems to be that there is no poison in the foreign blood plasma, but that the corpuscles are unable to survive in the alien blood; they dissolve, and their

hæmoglobin being dissolved in the plasma acts as a poison, and is eliminated by the kidneys. It seems to exercise its deleterious influence chiefly on the kidneys themselves, the tube casts, and albumen in the urine being evidences of the irritation of these organs. The general symptoms, in fact, are largely referrible to the irritation of the kidneys.

If hæmoglobin be introduced into the blood in other ways it acts equally as a poison. The red corpuscles of animals may be destroyed by repeatedly freezing and thawing the blood, and when that has been done, the blood of the same kind of animal will produce symptoms such as those referred to.

It is to be observed that all animals are not exactly in the same relation to each other in this respect. It is found, for instance, that a much smaller quantity of lamb's blood than of hen's blood produces hæmoglobinuria in a dog. The importance of these facts in regard to transfusion in the human species will be apparent.

In this place it may be mentioned that the blood transfused does not, according to Panum, act as food or take its place. If an animal is undergoing starvation, transfusion does not avert or delay the process of inanition, it rather hastens it by increasing the waste. In using transfusion as a means of treatment the object is to make up a deficiency of red corpuscles or blood plasma.

Having now seen that, by transfusion, an artificial plethora may be induced in animals, we may be prepared to admit the possibility of its existence in the human subject. It will presumably occur when the blood-forming organs are unduly active, and will manifest itself in an over-fulness of the capillaries and veins throughout the body, but especially in those of the abdominal viscera. Persons of vigorous digestion and active habits have often a florid appearance, as if the vessels, of the skin at least, were overfilled. The excess of blood is used, to a considerable extent, in the formation of fat, and we know that the subcutaneous adipose tissue and that of the abdomen are often much increased. But the observations mentioned above show that any excess of blood is disposed of with considerable rapidity, and we may infer that in the human subject a moderate tendency to plethora will be overcome. It will develop when the formation of blood keeps in advance of its destruction by the arrangements provided for that purpose.

2. General Anæmia.—By this name is meant strictly a defect in

the blood as a whole, a real want of blood, but the term is habitually used to designate conditions in which the blood is defective in any of its important constituents.

A true anæmia or want of blood, such as occurs in consequence of a severe hæmorrhage, is designated OLIGÆMIA, and this term may be regarded as virtually equivalent to ACUTE TRAUMATIC ANÆMIA. When such a condition develops from a single large hæmorrhage, the condition of simple reduction of the bulk of the blood does not long remain, but various processes occur which modify the state of the blood. We have now to consider what these processes are, and how they modify the condition of the blood.

To begin with, the bulk of the blood does not long remain under the normal; it is rapidly made up, but not by a plasma of normal concentration. The blood is unduly watery, and so the oligæmia gives place to a HYDRÆMIA. The process by which this is brought about is not very obscure. As the hæmorrhage proceeds the arterial blood-pressure diminishes; in slight hæmorrhages it soon recovers, but in severe cases the reduction continues for some time. The consequence of this must be a diminution in the transudation of the normal parenchymatous fluid from the capillaries. If the reduction of pressure is considerable, there may even be a reverse current, the fluid from the tissues being absorbed into the blood. Again, the secretion of urine depends on the blood-pressure in the vessels of the Malpighian tufts in the kidneys, and the pressure here depends largely on the general arterial tension. Any diminution of the general blood-pressure will therefore lessen the amount of urine secreted, and will diminish the loss of water by the blood. In this way, and by the absorption of water from the alimentary canal, the bulk of the blood is soon made up, but, as already mentioned, it is a watery blood.

After such a hæmorrhage also, there is an excess of leucocytes in the blood, especially as compared with the red corpuscles which are much diminished. This condition of LEUCOCYTOSIS is brought about in various ways. During the actual hæmorrhage the white corpuscles being more adhesive pass less freely out of the ruptured vessels, and so fewer are lost than of the red corpuscles. But the principal cause of the leucocytosis is, that the white corpuscles are much sooner replenished than the red. The thoracic duct pours into the jugular vein lymph containing leucocytes both during and after the hæmorrhage. Moreover, the organism seems to have a very great power of forming leucocytes. If we consider the excessive quantities of them which are

formed during an active suppuration, we may have some idea of the rapidity with which they may be produced.

The red corpuscles are much more slowly regenerated. If the hæmorrhage has been at all severe it takes many weeks to make up their number. The number of corpuscles to a given bulk of blood can readily be estimated by the instruments devised for the enumeration of the corpuscles, of which one of the most convenient is that of Thoma, manufactured by Zeiss of Jena. By this method it can be observed how the corpuscles are gradually replenished.

The exact mode of formation of the red corpuscles, even the site of their formation, is very obscure. It has been generally believed that the spleen, lymphatic glands, and bone-marrow, have to do with the formation of these corpuscles. The observations of Neumann and others have caused great importance to be attached to the bone-marrow in this regard, and the fact that nucleated red corpuscles are to be found here, especially in young persons, has been regarded as an indication that this tissue is specially concerned in the formation of these bodies. It has generally been supposed that the red corpuscles develop out of the white, but considerable doubt has always existed as to this. Recently, it has been asserted that they arise by a process of budding from existing red corpuscles.

It is not necessary to assume that the red corpuscles are replenished only by an excessive activity in the blood-forming organs. It may be, rather, that with an ordinary, or even reduced, activity, the corpuscles are made up by fewer of them being consumed than under ordinary circumstances. The colouring matters of the bile and of the urine are derived from the blood, and their existence implies that red corpuscles are destroyed in order to yield their colouring matter. In the case of the bile, this destruction probably takes place in the liver, but in the case of the urine, the colouring matter exists pre-formed in the blood, and the destruction of corpuscles takes place elsewhere, perhaps in the spleen. After a severe hæmorrhage, there is much less activity of all the functions of the body, and, presumably, less consumption of red corpuscles. In accordance with this the bile and urine are paler than normal; often very much so. It may be, then, that in the generally reduced activity of the body, there is no increased formation of red corpuscles, but that their slow replenishment is really due to an economy of them.

In the above, the case of a single considerable hæmorrhage has been taken. Where there are frequent small hæmorrhages, as from piles,

bleeding from the uterus, etc., there will be a recurrent loss of blood, and a continuous hydræmia.

SPONTANEOUS ANÆMIA is a term used to designate conditions in which, without any loss of blood, there is a deficiency chiefly in the red corpuscles. There is generally an actual deficiency in the number of the corpuscles as determined by counting, but there are cases where, without any great reduction in number, there is a great deficiency of hæmoglobin. The normal proportion of red corpuscles to the plasma is 13 per cent., and in spontaneous anæmia it has been found as low as 6, 5, and even 4 per cent. Various forms of spontaneous anæmia are met with, of which two call for special note—namely, Chlorosis and Pernicious Anæmia.

CHLOROSIS occurs most frequently in young women about the age of puberty, and it is remarkably amenable to treatment by means of iron. There is reason to suppose that this condition may be due to a congenital defect in the organs for preparing the blood—they are unable to meet any extra strain on them, such as occurs at puberty. It is interesting, in this regard, that chlorosis has been found in a certain number of cases to be associated with a visible defect in the circulatory system, which gives some corroboration to the supposition of a defect in the blood-preparing organs (Virchow). The most constant defect is narrowness and thinness of the aorta. There is also frequently an irregularity in the origin of the branches from the aorta, especially the intercostal ones. The narrowness of the aorta may lead to hypertrophy of the heart. It is sometimes stated that chlorosis is related to congenital defect of the organs of generation, but there is no sufficient evidence in support of this.

There are certain anæmias of a very serious kind which come on without any apparent connection with other abnormal conditions. These are sometimes designated ESSENTIAL ANÆMIAS, of which the most important is PERNICIOUS ANÆMIA. This name is used to designate a disease in which, without apparent cause, the blood deteriorates, becoming deficient in red corpuscles. The deterioration goes on progressively to a fatal issue and nothing has been found to arrest it. In this disease there is a marked deficiency in red corpuscles, but besides that there are corpuscles present which are not represented at all in normal blood. These are red corpuscles of a much smaller size than the normal ones, as shown in the accompanying figure. They are usually about half the size of the red ones; instead of being bi-concave

they are globular, and they have a much deeper colour than the ordinary red corpuscles. They are generally present in considerable abundance and may even exceed in number the normal ones. It is asserted that these small corpuscles (microcytes) are present in all cases of this disease. This is denied by some, but they are certainly present in a large proportion of cases. In addition, red corpuscles of larger size than normal and nucleated red corpuscles, have been met with in the blood in some cases of pernicious anæmia, and nucleated corpuscles may be found in the blood after death when examination has failed to detect them during life. In some cases also of this disease, the medulla of bone is altered. Instead of the yellow adipose tissue, which is the normal structure in some parts of the medulla, a red semi-fluid marrow has been found, in the shaft of the femur for instance. Under the microscope, in these cases, the normal adipose tissue is found to be replaced by aggregations of cells in the midst of which are found nucleated red corpuscles, while the non-nucleated corpuscles present great variety in size (figure 2). This change in the medulla, however, can hardly be regarded as distinctive of this form of anæmia. It has been found in ordinary forms of anæmia, and it is sometimes absent in pernicious anæmia. Probably it indicates an alteration in the organs having to do with the preparation of the blood, but nothing further can be definitely asserted.

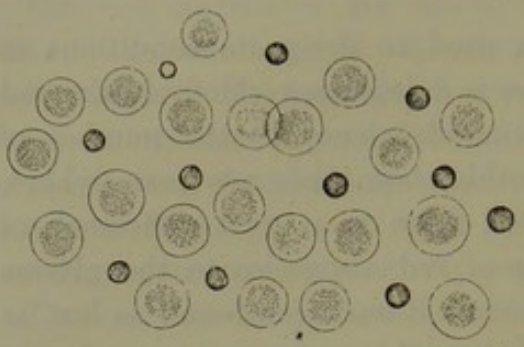


Fig. 1.—Blood in Pernicious Anæmia. The larger bodies are the normal red corpuscles. The smaller are the round more deeply coloured ones usually found—so called Microcytes. (EICHHORST.)

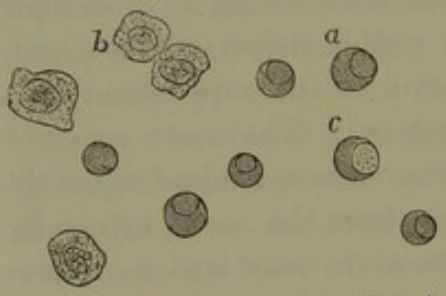


Fig. 2.—From Red Medulla of bone in Pernicious Anæmia. *a*, Nucleated red corpuscles. *c*, A red corpuscle with granular nucleus. *b*, Large nucleated cells, forming the bulk of the altered marrow. × 350.

Besides these forms of anæmia already described in which there is an actual loss of blood or else a grave defect in the formation of the blood, there are some conditions in which the blood is impoverished in consequence of some other disease which either causes a waste of the constituents of the blood, or, by lowering the nutrition as a whole, leads to defect in the formation of the blood. This is called SECONDARY

ANÆMIA, and it may occur in all debilitating diseases such as malignant tumours, febrile conditions, albuminuria, etc.

ANÆMIA, in its various forms, not unfrequently PRODUCES SECONDARY CHANGES in various organs, and it will be proper briefly to refer to these. The foundation of all these changes is the deterioration of the blood, and we must be prepared to find functional activity reduced, and, above all, the nutrition of the tissues interfered with. A prominent result of this interference with the nutrition is the frequent occurrence of degenerative changes.

Fatty degeneration of the muscular tissue of the heart is one of the commonest of these. Experiment on dogs shows that successive large hæmorrhages leading to inanition rapidly produce fatty degeneration of the muscle of the heart. The author has met with a case in which, after a single very severe hæmorrhage from the stomach, with a fatal issue three weeks later, there was extreme fatty degeneration of the heart. Fatty degeneration also occurs in the epithelium of the uriniferous tubules of the kidney and in the hepatic cells of the liver. A fatty degeneration of the intima of the aorta, producing a figured appearance in the wall of the vessel, has been seen in chlorosis and in other forms of anæmia (Virchow). This may be part of the defect of the vascular system in chlorosis already mentioned, but more probably it is a secondary degeneration. The state of the medulla of bone in pernicious anæmia has been referred to, and it has been remarked that a similar red marrow has been seen in other forms. We meet with it in secondary anæmias, and, perhaps, especially in old persons.

3. LOCAL HYPERÆMIA.—We have next to consider the local variations in the distribution of the blood. The term local hyperæmia is applied to conditions in which there is an excess of blood in the vessels of a particular part. It may be due to an abnormal amount of blood being admitted by the arteries, and in that case the blood will generally be at a higher pressure and flow more quickly than normal; or to some interference with the passage of the blood away from the part by the veins, in which case the current will probably be unduly slow. In this way we distinguish two forms of local hyperæmia—an active or arterial and a passive or venous.

ACTIVE HYPERÆMIA or ACTIVE CONGESTION.—This occurs when an excess of blood is admitted by the arteries into a part. The terms Atonic

and Arterial Hyperæmia may be regarded as synonymous with active hyperæmia, and also the expressions Fluxion and Determination of Blood. This condition will come about either when there is some increase of the blood-pressure forcing more blood in, or when the arteries are dilated so as to allow the blood freer access.

INCREASE OF BLOOD-PRESSURE is not often local, and even when it is, a rapid accommodation is usually effected by which the pressure is brought to an equilibrium. This accommodation is effected, as we have seen, by means of the arteries, their state of contraction being subject to variation. There is one situation, however, in which arteries possess little tonicity, and hardly at all regulate the supply of blood except passively, and that is in the lungs. It is to be noted, therefore, that any increase of blood-pressure affecting the pulmonary circulation is apt to be followed by an active hyperæmia. In studying ACTIVE HYPERÆMIA OF THE LUNGS, we shall see that increased activity of the heart may lead to active congestion in the lungs.

There is a condition designated COLLATERAL HYPERÆMIA, and it might be supposed that this is due essentially to increase of blood-pressure. It occurs when, on account of deficiency of blood in one part (local anæmia), there is excess of blood in another. If the blood is deficient in one part, it must be excessive in another or in the system in general. The local anæmia is due to some impediment to the circulation, chiefly obstruction of the arteries, and it may be supposed that the direct result of such obstruction will be to raise the blood-pressure in the neighbouring vessels and so lead to an active hyperæmia. As we shall see afterwards, this is probably the explanation of the congestion of the lungs which follows the drinking of large quantities of cold water. The cooling of the stomach causes contraction of the arteries in the abdomen, and this increases the blood-pressure. But for the most part the blood-vessels are so fully under the control of the nervous system, and the mechanism for the regulation of the circulation is so well arranged, that when a local anæmia occurs the accommodation of the excess of blood is not left to mere accident, but is provided for according to the needs of the organism. Thus, if the carotid artery is obstructed, the dilatation and hyperæmia do not occur in the arteries of the arm, which are the nearest to the obstructed artery, but in the other arteries passing to the brain. If one renal artery is obstructed, there is a collateral hyperæmia of the kidney opposite, and the secretion of urine is restored to the normal. Most collateral hyperæmias, therefore, are due rather to dilatation of the arteries than to increase of blood-pressure.

Turning to cases in which the hyperæmia is more directly due to DILATATION OF THE ARTERIES, a simple example is afforded by the congestion which follows the application of warmth to the skin in the form of poultices, etc. It is believed that this hyperæmia causes a collateral anæmia in certain subjacent parts, and this, like collateral hyperæmia, has not a merely accidental distribution. On this principle, as some suppose, poultices and fomentations are useful, although probably this is not the entire explanation of their action.

But, again, the arteries dilate when an unusual pressure to which they have long been subject is suddenly removed. The arrangements for the regulation of the circulation are such that when arteries are subjected to pressure, as the arteries of the abdomen in ascites, the circular muscular fibres become less active, the external pressure causing narrowing of the arteries without their contraction. Should the pressure be suddenly removed, however, these vessels, taken as it were at a disadvantage, dilate, and an active hyperæmia results. Hence after removal of a large accumulation of ascitic fluid it is usual to apply a supporting bandage which will partly take the place of the pressure removed, till the arteries accommodate themselves afresh to their new circumstances. After removal of an ovarian tumour there may be a hyperæmia of the kidneys, which may even lead to a transitory albuminuria.

Further, paralysis of the vaso-motor nerves may lead to relaxation of the arteries. The author met with a case in which an accident caused a traumatic lesion of the medulla oblongata. The injury had apparently destroyed the vaso-motor centres of the kidneys. There was a most remarkable active hyperæmia of these organs, evidenced after death by an enormous overfilling of all the vessels with blood. During the few hours of life after the accident, a very excessive quantity of watery urine was twice drawn off by the catheter, and after death the bladder was found highly distended. Division or injury to the spinal cord is likely to produce hyperæmia in the parts supplied with nerves by the cord beneath the point of injury. Nerve stems may be interrupted in their continuity and dilatation of arteries so produced. Lastly, in neuralgias we sometimes have dilatation of the arteries. Whether this is produced by the vaso-motor fibres being directly involved in the morbid process, or reflexly by stimulation of sensory fibres, it is impossible to say.

As a RESULT of the dilatation of the arteries, there is not simply an increased access of blood to the part, but the blood flows more quickly.

The first effect of a sudden dilatation of a considerable number of arteries will be a reduction of the arterial blood-pressure. But by contraction of arteries elsewhere this will soon be restored unless the number of arteries dilated be very great. If the blood-pressure remain the same then, the blood will pass with less resistance through the dilated arteries, and will reach the capillaries and veins at a higher pressure than normal. As a matter of fact the blood current is accelerated and the pulse may be propagated through the capillaries into the veins.

The most obvious SIGNS of active hyperæmia are redness, slight swelling, and elevation of temperature. The swelling is due partly to the overfilling of the vessels, but also to an increased transudation from the vessels into the lymph spaces. It has been found that if a cannula is introduced into a lymphatic vessel in the leg of a dog, and the sciatic nerve cut, there is an increased flow of lymphatic fluid from the cannula. If the hyperæmia continues long, and no other element occurs, there will probably be a hypertrophy of the affected part. The vessels especially are liable to enlarge, and very insignificant ones may become of considerable size.

It has been said that active hyperæmia may lead to hæmorrhage, but experiment seems to prove that even a very great rise in the blood-pressure in the capillaries does not lead to hæmorrhage unless the vessels are badly supported, or else defective in some way. By obstructing the respiration in a dog you may raise the arterial pressure enormously, but there is no rupture of the capillaries, or only in such delicate structures as the retina, brain, or conjunctiva. The increase in pressure in a pure active hyperæmia is, of course, greatly less than this.

PASSIVE HYPERÆMIA or PASSIVE CONGESTION is a condition in which the blood stagnates in the vessels; they are overfilled with blood which, as it remains too long in the vessels, has a venous character, hence passive hyperæmia is also called Venous Hyperæmia.

This condition frequently occurs as a consequence of WEAKNESS OF THE HEART. In the normal state the forces of the circulation have to overcome gravitation, in order to remove the blood from depending parts. The force of the heart propagated through arteries and capillaries to the veins is generally sufficient to do this. But if the heart is weak, the blood is apt to linger in depending parts, or in parts far removed from the centre. Weakening of the heart occurs in many forms of disease. It is often very marked in fevers, such as typhus and

typhoid, or in long-continued debilitating diseases, which produce anæmia. In these cases the blood often stagnates in the dependent parts of the lung where it produces the so-called hypostatic engorgement. It also stagnates frequently in depending parts of the skin, over the sacrum and shoulder blades in persons lying on their backs, over the trochanters in persons lying on their sides. In these situations the weakness of the circulation along with the mechanical effects of the weight of the body and irritation of decomposing material, leads frequently to the sloughing of the skin and the formation of bed-sores. In fevers there may be hyperæmia of the extremities of the fingers or toes, resulting even in necrosis or gangrene.

Again, there may be difficulty in overcoming gravitation on account of the force of the heart being partly lost by reason of ABNORMAL CONDITIONS IN THE ARTERIES. If there be partial obstruction in the arteries, as in atheroma, where there is thickening of the internal coat sometimes with a deposition of thrombi on the surface, the force of the heart may be lost in friction, and consequently the blood may stagnate in the parts supplied.

OBSTRUCTION OF VEINS, however, is the most direct cause of passive hyperæmia. This may be produced by pressure of tumours, exudations, bandages, the pregnant uterus, even hard masses of fæces, by coagulation of blood within the veins, or by the bursting of tumours into veins, or their growth through their walls.

Lastly, DISEASE OF THE VALVES OF THE HEART produces in a large proportion of cases a general venous hyperæmia.

We have now to consider the RESULTS of this engorgement of the vessels. Taking the simplest case, that of obstruction of a venous stem, the first result is an increase of blood-pressure in the veins behind the point of obstruction, and an accumulation of blood in the part. Considering the rapid manner in which increase of pressure in the arteries is compensated, it might be expected that the increase of pressure would soon be relieved, and the engorgement recovered from. If the vein have abundant anastomoses, then to a considerable extent the blood will find its way by other channels and the normal conditions be restored. But from the list of causes of passive hyperæmia it will be seen that most of these involve sets of veins, or whole regions of the body; even in the case of thrombosis, the coagulation usually extends to a number of veins. Apart from relief by anastomosis, however, it might be supposed that when obstruction in a vein occurs the increase of pressure would, as in

the case of obstruction of an artery, be compensated by changes in the state of contraction of the arteries. But a local relaxation of the arteries would only intensify the result by superinducing an active hyperæmia; consequently the desired compensation could only be effected by a reduction of the blood-pressure throughout the system, which will scarcely happen. The increase of pressure remains, and it affects not only the veins but, more particularly, the capillaries, the blood in which is as it were jammed between two pressures, the normal pressure from arteries and the abnormal from the veins.

The further effects are to be traced to the excessive pressure in the capillaries. The blood accumulates in excessive quantity in these vessels and at an excessive pressure. In consequence of this an increase in the natural transudation of fluid through the capillaries occurs, and the blood corpuscles, especially the red ones, escape from the vessels. Each of these phenomena merits more special consideration.

The term DIAPEDESIS, or hæmorrhage by diapedesis, is applied to the escape of the red corpuscles from the blood-vessels when it occurs, as in the present case, without rupture of their wall. This process occurs mainly, if not entirely, in the capillaries, and it can be shown by experiment that it does not involve rupture of these vessels. If the tongue of a frog is ligatured at its base so as to include all the veins, but excluding the artery, there will be the phenomena of hyperæmia greatly intensified, and among these phenomena diapedesis. But if the ligature be loosened within a moderate period, the circulation is restored, and the phenomena disappear. If the escape of blood corpuscles had been by rup-

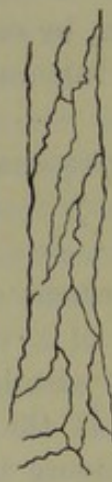


Fig. 3. — Normal capillary, with endothelium mapped out by treatment with nitrate of silver.

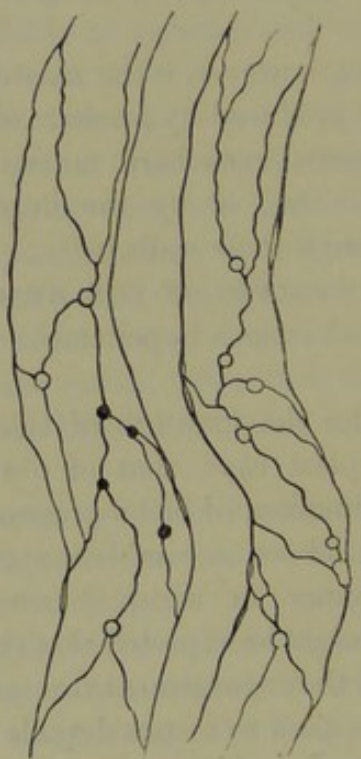


Fig. 4. —Capillaries after passive hyperæmia. Apertures between the cells greatly enlarged; the so-called stomata. (ARNOLD.)

ture, it would have continued after resumption of the circulation. As to the manner in which the corpuscles escape, it is believed by some that they are pushed through the endothelial plates, but by others it is asserted, with more probability, that they pass between the endothelial cells. Fig. 3 shows the appearance of the endothelium of a capillary mapped out by treatment with nitrate of silver, and Fig. 4 shows capillaries similarly treated after passive hyperæmia had existed. The latter illustration is taken from Arnold, who asserts that while in the normal condition there are minute apertures between the endothelial cells, chiefly at the angles where two or three meet, these are found much enlarged in passive hyperæmia. The small apertures may be called stigmata, and the larger ones stomata. The excessive pressure in the capillaries seems to be the chief agent in causing the escape of the corpuscles, as well as the increased transudation of fluid.

That there is an increased transudation of fluid can be directly proved by experiment. The flow in the lymphatic vessels has been proved to be excessive. If the lymphatics are not capable of disposing of the entire excess, then the fluid accumulates in the serous spaces and cavities of the body, giving rise to Œdema and Dropsy, which are to be more fully considered afterwards. This accumulation will occur if, on the one hand, the transudation be too excessive for the lymphatics to dispose of it, or if on the other, for some reason, the lymphatics do not take it up sufficiently. The current in the lymphatics depends on the blood-pressure, and we have just seen that the cause of the increased transudation is excess of blood-pressure, and so the same condition which determines the increase will, to a certain extent, cause it to be more rapidly disposed of. Hence it is that a simple passive hyperæmia from obstruction of a vein, let us say, is not usually associated with much œdema. When the hyperæmia depends on weakness of the heart, then the attraction of gravity which prevents the return of blood will also interfere with the flow in the lymphatics, and there will be no excessive blood-pressure to accelerate the flow. Hence, in these cases, œdema is more common and more serious.

The exuded fluid, as may be inferred, contains red corpuscles, but it does so much less in actual pathological processes than might be supposed from experiments in animals. In the latter there is a sudden obstruction, with exaggerated results; in actual disease in man the processes usually develop slowly, and there is some accommodation of the vessels. It should be added that the white corpuscles pass out of the vessels as well as the red, but not to such an extent, and that the

corpuscles, both red and white, escape from the small veins as well as from the capillaries.

When œdema does not occur, there is frequently developed some swelling of the connective tissue of the parts concerned. This is a true hypertrophy, and is not to be confounded with inflammatory increase of connective tissue which will afterwards come frequently before us. The increased transudation, by providing an increase of nutritious material, causes hypertrophy of the connective tissue, which is swelled, and also denser. This increased density is often seen in the heart, when, from disease in its own valves, there is a general venous engorgement in which the veins of the heart take part. We see it also very often in the kidney and in the lungs in cases of valvular disease. The tissue, as a whole, is rendered hard and resistant.

The part which is the seat of passive hyperæmia will be unduly red, and the colour will be dark or livid. It will be swollen, both from the overfilling of the vessels and from the œdema, and it will usually be lowered in temperature.

4. Local Anæmia.—In this condition the vessels of a part are more or less deficient in blood. It may be due to various causes. The capillaries may be emptied by pressure on the part. For instance, an abscess approaching the surface may, by its pressure, prevent the blood reaching the capillaries of the skin and a slough is the result. A cavity in the lung may, by undermining the pleura, cause sloughing of it. Tumours or clots of blood, etc., by their pressure, may cause anæmia of surrounding parts, and if the part thus rendered anæmic be a structure whose function is important to life, such as the brain, serious results may follow.

Interference with the arteries will produce anæmia if the flow of blood through them be obstructed. There is such a thing as spasm of arteries—this, probably, produces the shivering which is so common at the outset of fevers, the arteries of the skin being spasmodically contracted. So also in some neuralgias a spasm of the arteries has been seen. The application of cold causes contraction of the arteries—the ether spray causes complete anæmia by this means. Besides this, the arteries may be narrowed by disease of their coats. There is a rather common disease in small arteries which consists in a thickening of the internal coat and has somewhat the character of atheroma. This condition is often called endarteritis obliterans, and is in some cases a syphilitic manifestation. It is clear that, by reducing the calibre

of arteries, it will produce anæmia. In arteries of the brain atheroma produces narrowing of the calibre which may be so considerable as to produce anæmia. More frequently, however, anæmia is produced to a serious extent only when blood coagulates on the atheromatous patch and completely occludes the artery. Again, tumours, blood-clots, exudations may cause narrowing of arteries by pressure. Arteries also may be completely obstructed by ligature or by plugging.

In considering the RESULTS of local anæmia the case of complete closure of arteries will be here omitted, because it will come up for consideration under the head of embolism. In cases where there is incomplete obstruction, some blood will pass by the arteries, but the capillaries will be imperfectly filled. The part will be pale, reduced in temperature, flaccid. Its nutrition will be diminished, and its elements prone to undergo atrophy and degeneration, and even, as we have already seen, necrosis. The function will be interfered with if the nutrition is depreciated. If the anæmia affect an important organ the results may be serious. Thus, obstruction of the coronary arteries may cause paralysis of the heart from this cause. Again, anæmia of the blood-vessels interferes so much with the nutrition of their own walls that, if after its suspension the circulation be renewed, the vessels may rupture and serious hæmorrhage result. Lastly, a local anæmia produces a hyperæmia elsewhere, but this has already been considered under collateral hyperæmia.

THROMBOSIS AND EMBOLISM.

These two conditions are often associated, but must be carefully distinguished. Thrombosis is the coagulation of blood within the vessels or heart. Embolism is the obstruction of a vessel by a plug brought from a distance. The coagulum which forms in thrombosis is a *thrombus*, the plug which obstructs in embolism is an *embolus*. A thrombus detached from its place becomes an embolus, and an embolus, whether consisting of coagulum or not, may grow by successive deposition of clot or thrombosis.

1. THROMBOSIS.—In considering the mode of occurrence of thrombosis, it is necessary to refer to the conditions under which the blood coagulates. According to the views which are identified with the name of Alexander Schmidt, three agents are necessary for coagulation, the

fibrinogen, the fibrino-plastic substance or paraglobulin, and the fibrin-ferment. The two former unite to form fibrine in the presence of the latter. The fibrinogen is dissolved in the blood-plasma, the paraglobulin and ferment reside in the white corpuscles. It is only by destruction of the white corpuscles that the paraglobulin and ferment are set free; so long as the white corpuscles circulate in the blood and remain alive fibrine cannot form. Fibrine will form when the conditions are such that the white corpuscles are no longer preserved alive. Fibrine, it will thus be seen, is the result of a chemical combination, and the resulting albuminous substance, the fibrine, is not a vital structure but a dead chemical compound. In order to the preservation of the white corpuscles they must not be exposed to the contact of dead matter. You may keep blood fluid for a long time if you simply ensure that it is in contact with living tissue. Lister long ago showed that if an artery be ligatured in two places, and cut out while full of blood, it may be hung up and the blood will remain fluid for some days. Within the body if a vessel be ligatured carefully in two places, the middle portion remaining in connection with the living tissues, then the blood may be kept fluid from twelve to fifteen days.

The main cause of coagulation, then, is the contact of the white corpuscles with dead matter or altered living tissue. In the living body anything which interferes with the integrity of the vessel wall or the endocardium is likely to predispose to coagulation. Stagnation of the blood is often set down as a cause of coagulation, but this will act chiefly by altering the vessel wall, and by keeping the white corpuscles removed from contact with the living tissue. As it is the endothelium of the vessels and endocardium which is in most immediate contact with the blood, it will be interferences with it that will conduce to coagulation.

If a portion of blood inside a vessel be cut off from the circulation, then it will by and by coagulate just as it does outside the body, the main agent in the coagulation being the disintegrating white corpuscles. In this way a RED THROMBUS is produced. But vessels are rarely so situated as to allow of a complete coagulation such as this; much more frequently the thrombus is formed from the blood which is still moving, although, it may be, slowly, and it is of gradual growth. The formation of thrombi in the living vessels has been carefully studied by ZAHN (Virchow's *Archiv*, vol. lxii.), whose EXPERIMENTS throw much light on the process.

The mesentery of a frog is exposed and subjected to microscopic

examination. A vessel of some size, an artery or vein, is chosen, and its wall in some way injured, as by twitching it slightly with the forceps, or placing a small crystal of common salt near it. Very soon white blood-corpuscles begin to adhere at the injured part. As the blood passes over it successive layers of white corpuscles adhere, and a growing clump of them is formed. Along with the white corpuscles a stray red one may be insinuated, or there may be several red ones. The clump so formed, be it wholly white or partly mixed with red corpuscles, may be carried off, in which case a new one begins to form; but the clump may remain fixed and be continuously enlarged by successive depositions of corpuscles from the circulating blood. In course of time a change occurs in the appearance of the clump, the white corpuscles lose their individual outline to a great extent, and the clump gathers itself together into a grey granular mass in which neither by acetic acid nor by staining are the majority of the white corpuscles to be discovered. It has, indeed, very much the characters of fibrine which has been obtained by whipping the blood outside the body. The clump of white corpuscles, in fact, by the disintegration of the corpuscles and the attraction of the fibrinogen from the blood plasma has converted itself into a fibrinous coagulum. All the white corpuscles, however, are not disintegrated, some are still recognizable in the mass. A similar mode of formation is observed when a vessel is injured by pricking with a needle, or by cutting it. The presence of foreign bodies if they are rough on the surface produces adhesion of white corpuscles and their conversion into thrombi in similar fashion, but when smooth pieces of glass are introduced, there does not seem to be the same tendency to adhesion of the white corpuscles. It will be understood that thrombi formed in this way often contain a few red corpuscles. If by any alteration in position, or tearing of the clump, a channel is formed, then the red corpuscles will be wedged in and retained. The WHITE THROMBI and the MIXED THROMBI are therefore to be regarded as forming a single class. The RED THROMBI composed of the entire blood form another class.

Having learned so much as to the formation of thrombi, we may be prepared to consider the special circumstances under which they occur in actual cases. It may be said that in most cases of thrombosis there is either such a STAGNATION OF THE BLOOD as to cause a serious deterioration of the endothelium, or else some PALPABLE INJURY TO THE VESSEL compromising its endothelium, and the various thrombi may be studied according as they are formed in one of these ways or the other,

while in some cases the action of both may be traced. As we have already seen, the stagnation is rarely complete, and accordingly the thrombi are mostly white or mixed, being formed in the way just described.

THROMBI form IN THE HEART from the blood stagnating in its chambers. This will occur when, from any cause, the cavities of the heart are imperfectly emptied, as from dilatation or weakness of the muscular substance. The coagulation will occur most readily in the parts of the cavities from which the blood is least likely to be emptied during the imperfect contractions. Hence we find them near the apices of the ventricles and in the auricular appendages more frequently than elsewhere. So also they form most commonly behind the columnæ carneæ, and are frequently found peeping out between these muscular columns. These thrombi are frequently of a pearly-white colour, and are never composed of the whole blood, although they may be brown from admixture of red corpuscles. As dilatation occurs more frequently in the right heart than in the left, these thrombi (which were called by Lænnec, globular vegetations) are more frequent in the right cavities than in the left, although by no means rare in the left ventricle.

Weakness of the heart not infrequently produces THROMBOSIS IN THE VEINS. In debilitating diseases, such as typhoid fever, phthisis, etc., the heart is weak and the blood current sluggish, especially in the veins. These thrombi are, at their commencement, usually related closely to the valves. In the sluggish state of the circulation the valves lie half closed, the force of the blood being insufficient to press them back against the vessel wall. Hence the blood will stagnate in the pouches of the valves and coagulation will begin there. Coagula so formed grow up the veins, but even when they have become continuous they often present a knotted condition from the parts corresponding with the valves being bulkier. In such cases the knotted character can often be detected through the skin. The coagulation occurs primarily in the larger veins, the femoral, jugular, sinuses of the dura mater, but according to Virchow this is only due to certain local relations.

In the cases hitherto mentioned, stagnation of blood has been the primary factor, but in the thrombosis sometimes occurring IN THE UTERINE VEINS after childbirth we have this combined with a palpable injury to the vessel wall. In some cases, after parturition, the uterus contracts imperfectly, and the blood, stagnating in the uterine sinuses, is apt to coagulate. In this case the starting point of the coagulation is often

the open mouths of the veins on the raw uterine surface, which in many respects resembles the surface of a wound.

A more definite WOUND OF A VESSEL may induce coagulation. The coagulation may occur at the ruptured edges, or a clot may form in the effused blood outside the vessel, and by successive deposition from the escaping blood grow through the gap into the vessel. In case of ligature of a vessel the internal and middle coats are ruptured, and coagulation occurs as in the case of a wounded vessel. If stagnation already exists in a vein a very trivial wound may induce coagulation. Thus in cardiac disease where passive hyperæmia has led to œdema, the punctures made to relieve the œdema or the ulcers which form spontaneously not infrequently lead to thrombosis in the veins. It is important to bear this in mind in connection with the general venous hyperæmia of valvular disease of the heart.

Diseases of the vessels and heart which interfere with the endothelium induce coagulation on the surface. Thus ACUTE ENDOCARDITIS produces thrombosis on the valvular structures of the heart, and CHRONIC ENDOCARDITIS does so sometimes by the formation of calcareous plates which may by and by tear through and expose themselves in the current. ATHEROMA of arteries, by causing roughness and ulceration, or by producing calcareous plates, may lead to coagulation, which is more serious in such small arteries as those of the brain, where thrombi may completely obstruct, than in such a vessel as the aorta. The well-known coagulation of blood in ANEURISM is susceptible of similar explanation. Here the internal wall is much altered, and usually deprived entirely of its endothelium. Another occasional cause of thrombosis is the PROTRUSION OF TUMOURS through the walls of vessels. It is very seldom that arteries are thus involved, and, as we shall afterwards see, thrombosis does not occur in the capillaries, but veins are occasionally attacked by malignant tumours and their walls so altered as to induce coagulation.

THROMBI which have once formed ARE LIABLE TO GROW. The thrombus is composed of dead fibrine, and the surface is rough, so white corpuscles adhere and disintegrate, and coagulation occurs readily in successive layers. In the case of the veins the blood will be for the most part stagnant above and very often below the thrombus, and it is in these vessels particularly that they are apt to grow very extensively. Thus a coagulation starting in the uterus may travel along to the internal and common iliac veins, and thence pass into the veins of the legs. In a case observed by the author, coagulation had its origin in a cancer of the kidney which involved the wall of the renal vein, and it

extended thence to the inferior vena cava, and to the veins of both legs which were distended with old thrombi.

In regard to the character of the thrombi formed under these various circumstances, it may be said that almost all are of the white or mixed character, as most of them form where the circulation, although it may be stagnant, is not absolutely at a stand-still. The more the blood is at rest, however, the more is it likely to contain red corpuscles. It is clear that thrombi forming at the edges of a wounded vessel as the escaping blood passes over them will be white thrombi, and, indeed, Zahn determined this in his experiments. Thrombi forming on the inflamed valves, on the diseased endocardium or intima of vessels, or in consequence of the projection of foreign bodies or tumours, will be white. The globular vegetations of the heart are also white or mixed—they are, indeed, often of a pearly whiteness, and even those occurring in veins from weakness of the heart are largely composed of white corpuscles. Growing thrombi will be mainly white or mixed, but as the blood above and beneath a growing thrombus is usually at a stand-still, or nearly so, we are apt in this case to have more nearly the entire blood entering into the constitution of the thrombus, and these are often redder than most. The stratified clots in an aneurism are white or mixed, and it may almost be said that, except in the case of coagulation in an aneurism after ligature of the artery, it is seldom that the whole blood is concerned in the formation of a thrombus.

It is important to distinguish THROMBI which have formed during life from mere POST-MORTEM COAGULA. It will be clear from what has gone before that the thrombi are mostly either white or grey, but being formed largely of white corpuscles they are of a dead or opaque white or grey appearance. Post-mortem clots are sometimes pale from the sinking of the red corpuscles or otherwise, but they are gelatinous and smooth on the surface and mostly transparent, whereas the thrombi are firmer, drier, more opaque and granular on the surface. The thrombi also adhere to the wall to some extent, whereas the clots do not, although in the heart, from getting entangled among the columnæ carneæ, they may have an appearance of adhesion. Lastly, the thrombi are often stratified, indicating their deposition in successive layers.

We have now to consider the CHANGES WHICH THROMBI UNDERGO after their formation. It is to be remembered that the coagulum is virtually a piece of dead matter, fibrine being merely a chemical com-

pound, not a living structure. There are two directions, chiefly, in which thrombi are liable to change—the one is softening, and the other an apparent organization.

SOFTENING is a frequent result, especially in the coagula in the heart and veins. It should be said that the softening which occurs in connection with pyæmia is here left out of account, as the whole processes in connection with this disease will be studied afterwards. The globular vegetations in the heart frequently present very good examples of softening. It begins in the central parts of the thrombus, and the coagulum breaks down into a turbid brownish juice, the softening extending gradually outwards.

The juice is often like a mixture of pus and blood, or in very white thrombi it may be like pure pus. It consists of the debris of the thrombus, and no well preserved corpuscles are to be found in it. The softening may extend outwards till a mere rind of clot is left, and this may give way and cause the juice to be launched into the circulation. In veins also, softening may take place, and here the colouring matter of the blood may be deposited in the form of hæmatoidin crystals (see Fig. 5). Of course, where softening has occurred there is much more probability of bits of the thrombi being torn away or carried forward so as to produce embolism.

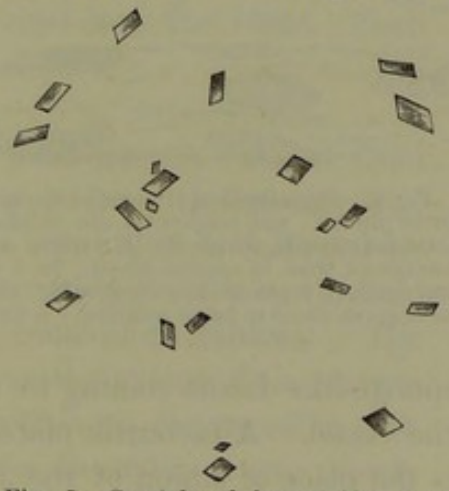


Fig. 5.—Crystals of hæmatoidin found closely aggregated in the midst of an old thrombus in a vein. The crystals have a deep red colour. × 350.

Thrombi, instead of softening, may dry in and shrivel. In such case we may have lime salts deposited, and even through time the formation of little stony masses—VEIN-STONES or Phleboliths.

The ORGANIZATION of a thrombus is a process of some interest. As the coagulum is dead, it is clear that it cannot take part in the process of organization. In studying inflammation this subject will come up for fuller discussion, but it may here be stated that when a piece of dead animal substance is present among the living tissues, the first step towards its absorption is usually its replacement by an elementary tissue, the dead structure forming, as it were, a mould on which the new tissue forms itself. The constituents of the thrombus are, therefore, pushed aside or disintegrated by masses of round cells (as shown in Fig. 6 *b*); and at the same time blood-vessels springing from the

vasa vasorum extend into the substance of the new-formed tissue. The thrombus is thus converted into, or replaced by, a vascular tissue which subsequently develops into connective tissue. Like other new-formed connective tissue of this kind, this tissue tends to contract. The result of this sometimes is the drawing together of the walls of the vessel, and the permanent obliteration of its calibre. The vessel is thus converted into a solid cord. In other cases the contraction acts on the walls of the proper vessels of the new-formed tissue, dragging them outwards. By this means the vessels are widened, and in time may come to assume a cavernous character. This may result in the re-establishment of the circulation, the wide spaces of the sponge-like tissue coming to communicate with the regular calibre of the vessel. A favourite place for the formation of this cavernous tissue is the place of union of the iliac veins to form the vena cava. Here, the vessels are sometimes found filled with a spongy tissue through which the circulation is carried on. By a still further contraction of the new-formed tissue, the calibre of the vessel may be completely re-established, the sinus-like blood-channels expanding into the calibre of the vessel.

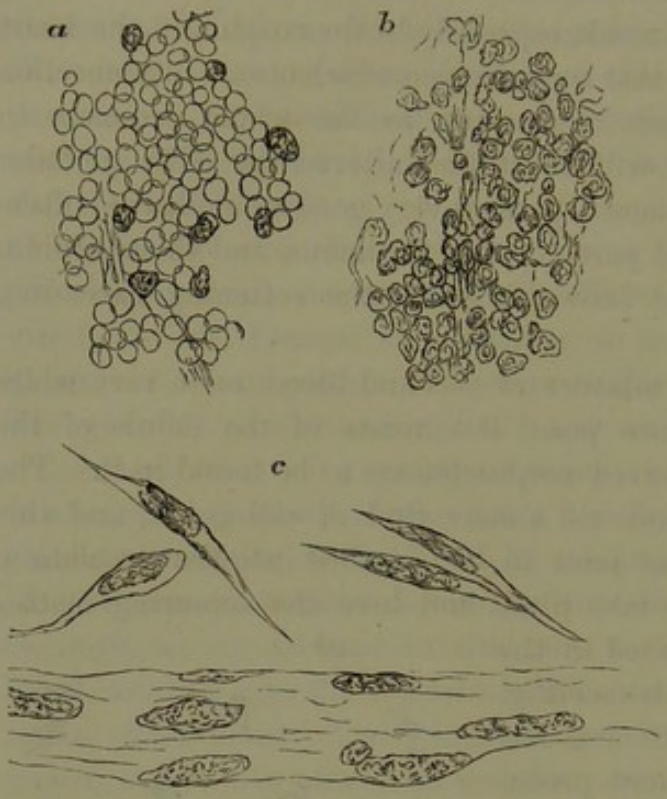


Fig. 6.—Organization of blood-clot. *a* represents the clot little altered; red corpuscles are chiefly seen, with a few solid round cells, which are like white corpuscles, but more numerous than in normal blood. In *b* the red corpuscles are entirely replaced by round cells. In *c* the round cells have given place to large spindles. × 350.

Before leaving this subject of thrombosis, it may be well to consider WHETHER COAGULATION OCCURS IN THE LIVING CAPILLARIES. It is to be remembered that the deterioration of the endothelium is the proximate cause of the coagulation of the blood in the vessels. The capillary wall consists entirely of endothelium, and the deterioration of it means the deterioration of the entire capillary wall. Such an interference with

the capillaries as to induce coagulation will only occur when actual necrosis takes place. Moreover, as the tissues depend on the capillaries for their nutrition, obstruction by thrombosis will involve the death of the tissues themselves. Hence thrombosis of the capillaries, or even complete stagnation in them, may be put out of the question except in connection with necrosis. The non-occurrence of thrombosis in the capillaries is of great practical consequence. If it were not so the thrombi in veins, growing against the current as they so readily do, would grow into the capillaries, and through them into the arteries. The capillaries, not admitting of this, form a barrier to the extension of the coagulation. It thus happens that, after extensive coagulation in the veins, the circulation is largely maintained by arteries, capillaries, and lymphatics, and necrosis rarely occurs. It is worthy of note in connection with this matter that the blood found in the capillaries after death is nearly always fluid.

In studying thrombosis, we have left out of account all cases of what is called SEPTIC THROMBOSIS, where the coagulation arises in connection with the introduction of decomposing material into the veins. Such processes will receive consideration in another part.

We have still to consider the EFFECTS OF THROMBOSIS. Apart from the occurrence of embolism, which may result from thrombosis anywhere, it will be mostly thrombosis of the veins that is followed by serious results. The most direct effect of obstruction of veins by thrombi is of course PASSIVE HYPERÆMIA with its consequent ŒDEMA. The occurrence of serious œdema depends largely on the extent of the anastomosis of the obstructed vein, and also somewhat on the rapidity with which the thrombosis has occurred. If the thrombus forms slowly the functions of the plugged veins may be largely taken up by the lymphatics and by other veins which remain unaffected. In the case already referred to, where a cancerous tumour in the kidney had burst into the renal veins, and thrombosis had extended to the vena cava and down the veins of both legs, there was comparatively little œdema at any time, although all the main venous trunks of both legs were plugged. One circumstance renders this compensation, especially by the lymphatics, the easier, namely the fact that the thrombosis does not extend into the capillaries, and consequently not into the arteries. The cause of this has been already explained, but it is clear that if the circulation is still maintained in the arteries and capillaries, the lymphatic circulation will not suffer.

It is important to know that these secondary effects of thrombosis, and especially œdema, will not usually show themselves for some time after the onset of the process. A coagulation beginning in a vein will take some time before it completely obstructs it, and even when it has done so, it may be necessary for it to grow into other veins before any pronounced œdema will develop. Hence it is that a thrombosis may lead to embolism by detachment of portions of the thrombi before it has manifested its presence by hyperæmia and œdema.

Thrombosis in veins seldom leads to GANGRENE, and in the few cases in which gangrene actually occurs some additional interference with the circulation will usually be discoverable. Weakening of the heart, in conjunction with thrombosis, may cause it, and so may disease of the arteries diminishing the force of the blood.

2. EMBOLISM.—This, as we have seen, is a process frequently associated with thrombosis. Embolism will affect arteries or capillaries, and, as the portal vein is distributed in the liver like an artery, it is also liable to embolism. The plug or embolus is most frequently a thrombus or a part of one. It may be a bit of tumour which has found its way into a vessel, or a foreign body which has obtained entrance. It may be a piece of cretaceous material from a degenerated valve or vessel. It may be a parasitic animal, as the echinococcus, which has found its way into the circulation.

In the case of many arteries the effects of embolism are very trivial. The ANASTOMOSES are so FREE that they readily compensate completely, and the circulation is restored almost at once. For the purposes of the tissues it is the capillary circulation which is of importance, and if the blood, by any route however circuitous, reaches the capillaries, there is no serious result.

When an artery with free anastomosis is obstructed by an embolus there will be at once an increase of blood-pressure on the proximal side of the plug. The anastomosing branches by dilatation will reduce this excessive blood-pressure, but the excessive blood-pressure may itself assist in opening up the anastomosing channels. In this way the circulation is restored. At the seat of obstruction thrombosis occurs on each side of the embolus, and goes on upwards and downwards to the nearest branches. By the organization of the thrombus the calibre of the artery is destroyed and the vessel reduced to a solid cord. In this way a piece of artery is lost, and that is all the permanent result.

It is similar with CAPILLARY EMBOLISM. The ultimate result is the

loss of a piece of capillary between the two nearest communications. At the time of its occurrence, the embolus in a capillary will produce very little disturbance, as the communications are so free in the capillary system. It sometimes happens, however, that *multiple* embolisms cause more serious derangements of the circulation.

It is very different in the case of ARTERIES WHICH HAVE NO ANASTOMOSES. There are parts of the body in which the arteries are distributed to a perfectly definite piece of tissue, and have no anastomotic connections. In the case of such arteries, to which Cohnheim gives the name of END ARTERIES, the results of obstruction are very serious. The part is entirely deprived of its blood supply through the arteries, and if any blood reaches it, it must be by the connection with neighbouring capillaries or by the veins. The most direct result of obstruction of an end artery, therefore, is anæmia, and consequent death or necrosis of the tissue. But there are some cases in which an apparent exception to this occurs; there is the necrosis, but instead of anæmia there is an excessive engorgement with blood. This is very well seen in the case of the lung, where embolism often produces the hæmorrhagic infarction. We have to consider how this is to be explained.

COHNHEIM'S EXPERIMENTS in elucidation of the pathology of embolism are of such importance in this regard that more particular reference to them may be here permitted. The subject of experiment was the tongue of the frog. The two main lateral arteries of the tongue are not end arteries, but their lateral branches are. Cohnheim introduced little blackened pellets of wax into the division of the aorta which communicates with the arteries of the tongue, and these were sometimes carried to the tongue, obstructing the arteries there. Sometimes one pellet obstructed the anastomosing branch between the main arteries while another stuck in one of the main arteries, so that the latter was converted into an end artery. Whether a main artery thus conditioned or a plugged lateral branch was observed, the process was virtually the same. The blood was, immediately after the plugging, at a standstill, in artery, vein, and capillaries. These vessels might be moderately full of blood or might contain only blood plasma. Soon, however, a backward flow of the blood from the veins was observed (diagrammatically shown in Fig. 7), and by and by this produced an engorgement of the entire vessels, veins, capillaries, and arteries. After a time a remarkable diapedesis began to manifest itself through the capillaries into the surrounding tissue, which became engorged with blood. The

portion of tissue concerned would, in accordance with the area of distribution of the artery, be wedge-shaped, and the result was a wedge-

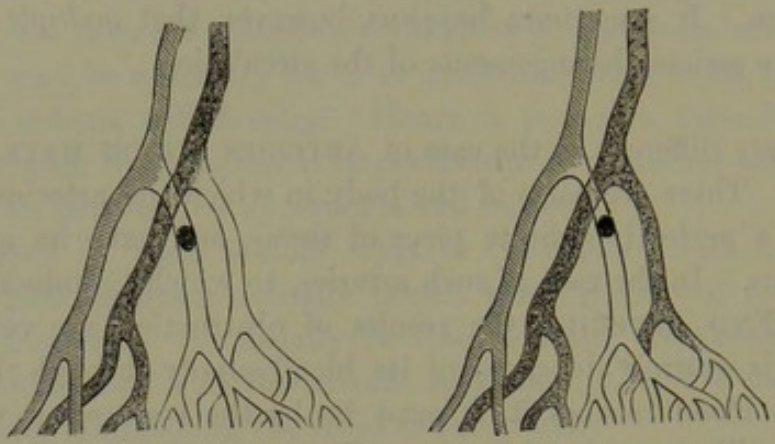


Fig. 7.—Diagram of conditions following embolism of an end artery. In the figure to the left the state of anæmia immediately after the embolism is shown. In the other figure the regurgitant current from the vein is indicated (after COHNHEIM).

shaped red pulpy piece of tissue, not unlike a blood clot—the HÆMORRHAGIC INFARCTION. If the frog survived, the piece of tissue by and by sloughed off.

The explanation of these phenomena is not very difficult. The obstruction of the artery reduces the pressure in the vessels supplied by it to nothing. The veins are still in open communication with the veins of the part, in which, although the blood-pressure is low, it is still something. Accordingly, the backward flow occurs from the veins to the capillaries, and so to the obstructed artery. Thus the engorgement of the vessels is not difficult to explain. The diapedesis is to be referred to the fact that the capillaries, being deprived of blood, have the integrity of their walls impaired. We have already seen that passive hyperæmia produces diapedesis, owing to interference with the capillary wall. Much more serious is the nutritive deterioration in this case, and so the diapedesis is very great, leading to a marked infiltration of blood into the tissues around. The deprivation of fresh blood causes death of the tissue, which here, as it is an external part, sloughs.

In applying these facts to human pathology we have to consider, in the first place, what arteries of the body are end arteries. These are the renal and splenic arteries and their branches, the nutritive arteries of the brain, the central retinal artery, the pulmonary artery and its branches, to which we may add the portal vein, as in its relations an end artery. We have not, in all of these, the typical hæmorrhagic in-

farction, and it is necessary to consider each individual case separately, and endeavour to explain the divergencies which they present.

EMBOLISM IN THE LUNGS frequently presents the most typical hæmorrhagic infarction, but it has been known since Virchow's important researches that embolism of the pulmonary artery does not always lead to its formation. In the same lung you may have a number of obstructed arteries, in connection with some of which there is the hæmorrhagic infarction, while in the case of others it is entirely absent. This apparent puzzle is explained when we come to consider more closely the relations of the circulation in the lungs. It has already been said that it is the circulation in the capillaries that is of consequence in considering the results of embolism, and we know that the capillaries everywhere anastomose freely with each other. It is conceivable, therefore, that the anastomosis of the capillaries might come to act like an arterial anastomosis, and that the circulation might be maintained through the capillaries. In the lung the capillaries of the pulmonary artery are wider than those of most other parts, and so the loss of force by friction will be less than elsewhere. There is, besides, less tendency to necrosis of the tissue here, as the connective tissue of the lung, the bronchi and the larger vessels, are supplied with blood by the bronchial arteries. In some cases, then, the circulation in the capillaries behind the plug is sufficient to maintain the capillary wall and prevent the formation of the hæmorrhagic infarction, and, indeed, experiment seems to show that in normal animals embolism seldom results in the infarction.

If we consider the usual situations of the hæmorrhagic infarctions of the lung we shall obtain still clearer views on the subject. If an artery is obstructed near the root of the lung, then the capillaries of the piece of tissue concerned will be in communication on all sides with capillaries in which the circulation is still active. The piece of tissue is, as it were, buried in the spongy lung substance whose capillaries are filled with actively moving blood. It is not surprising that, in this case, the capillary circulation in the affected piece of tissue, although rendered sluggish, is still maintained; the movements of respiration also assisting in maintaining the circulation. In accordance with these considerations the hæmorrhagic infarction seldom occurs in the central parts of the lung. But if the obstructed artery has a peripheral distribution, if the piece of tissue is covered on one side by the pleura, or if, being situated at the edge of the lung, it has two sides covered by pleura, or even, being at the edge of a lobe as

well as of the lung, it has three sides covered with pleura, then it will be in a much less favourable position. On one, two, or three of its sides the capillaries are not in communication with other capillaries in which the circulation persists. It is not surprising, therefore, that the hæmorrhagic infarction is nearly always peripheral, and that it frequently has its seat at the edge of the lung, or at the edge of a lobe. The infarction is wedge-shaped, and it is interesting, in relation to the points we are considering, to observe that the plug is usually not exactly at the apex of the wedge but a certain distance nearer the heart, so that sound tissue intervenes between the beginning of the plug and the infarction. The explanation of this is, that in the neighbourhood of the plug, that is to say, at the apex of the conical piece of tissue supplied by the artery, the tissue is still surrounded on all sides by capillaries in which the circulation is active, and for a certain distance this is sufficient to carry on the circulation. It may even be said that all around the periphery of the infarction, so far as it is in connection with lung tissue, there will be a zone in which the surrounding capillaries keep up the circulation in the affected capillaries, and that the actual infarction is less in all these directions than the area of distribution of the obstructed artery.

It appears that if the heart is of normal strength, it, with the movements of respiration, is capable of maintaining the circulation in the capillaries even when a peripheral branch is the seat of embolism, and it is mostly in cases of weakness of the heart, or when the pulmonary circulation is already in a state of engorgement, or where multiple embolisms obstruct numerous neighbouring trunks, that the infarction occurs. When embolism occurs in the pulmonary artery, there will always be stagnation of the blood, and even if the hæmorrhagic infarction does not form, there will be great interference with the circulation.

In the case of the SPLEEN there are no such compensating conditions as in the lung, and here the hæmorrhagic infarction seems to occur with great uniformity.

In the KIDNEY, embolism always produces necrosis of a wedge-shaped piece of tissue, but even in recent embolism this is not always engorged with blood. The very wideness and freeness of communication of the capillaries in the lung which so frequently prevents the formation of the hæmorrhagic infarction will ensure that when it does occur there will be a very great engorgement of the vessels and abundant diapedesis. In the case of the kidney, the capillaries are smaller, and their communications with the veins more circuitous, and so it often happens that necrosis

occurs before the backward flow has been established. In that case the whole wedge-shaped piece of tissue coagulates into a solid mass (see Fig. 8). This is an instance of the so-called coagulation necrosis, which we shall have a better opportunity of studying afterwards. We may have, therefore, a hard, solid, whitish wedge, instead of a hæmorrhagic infarction. A true hæmorrhagic infarction is sometimes met with, especially when a small artery is obstructed.

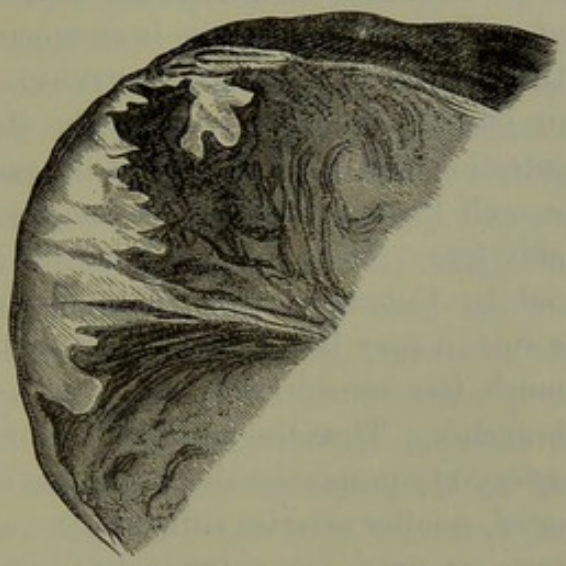


Fig. 8.—Embolic infarction of kidney, showing the wedge-shaped piece of tissue affected (after RAYER).

In the case of the BRAIN, necrosis of the tissue occurs, and sometimes so rapidly that the capillaries are rendered incapable of receiving the blood before the backward flow from the veins is sufficient to cause engorgement. The necrosis here does not result in coagulation of the tissue, but in its softening, so that as a result of embolism of the brain we have softening, which may, or may not, be accompanied by hæmorrhage, but is never associated with very considerable bleeding. Embolism of the RETINA is similar to that of the brain.

We have still to consider the case of the PORTAL VEIN, which, in its distribution, is comparable to an end-artery. The conditions here, however, are peculiar, inasmuch as the liver is supplied with blood from the hepatic artery as well as from the portal vein. It has already been more than once noted that it is the condition of the capillaries which is of importance in relation to the hæmorrhagic infarction. A study of the circulation in the liver shows that when the portal vein is closed, blood still passes from the hepatic artery into the hepatic capillaries. The hepatic artery supplies blood to the connective tissue, the walls of the ducts and larger blood-vessels of the liver. The capillaries from these are collected into veins which open into the interlobular veins, which, of course, are the terminals of the portal vein. So that when the portal vein is obstructed the blood from the hepatic artery passes into the interlobular veins, thence into the hepatic capillaries, and so on into the intralobular and hepatic veins. The capillaries of the portal system are thus kept supplied with blood, and their nutrition does not suffer. Experiment has even shown that when the entire portal vein is obstructed

the secretion of bile is not entirely at a standstill; the blood of the hepatic artery affording material for a limited production.

It has been said that the hæmorrhagic infarction forms in the case of end-arteries, but there is an apparent exception to this in the case of the SUPERIOR MESENTERIC ARTERY. If the superior mesenteric artery or one of its larger branches be obstructed, hæmorrhage occurs in the intestine and mesentery, and the portion of gut suffers necrosis, but it is well known that the anastomosis of the mesenteric arteries is tolerably free. The explanation of this apparent anomaly has been worked out by Cohnheim and his pupils in a very interesting manner. As a rule, it may be said that main stems have, in proportion to their size, much less considerable anastomotic communications than the smaller branches. Thus the anastomotic communications of the iliac or femoral artery are proportionally much less considerable than those of the tibial or of smaller arteries still, and the anastomoses of the superior mesenteric are much less voluminous in proportion than those of its branches nearer to the gut. If the main stem be obstructed, therefore, the restoration of the circulation occurs much more slowly than when a small stem is the seat of obstruction. Another illustration of this is afforded by embolism of the femoral artery. The temperature falls rapidly, the limb is numb and half-paralysed, and this is doubtless due to insufficient supply of blood by the artery. It takes some days before the collateral vessels dilate sufficiently to restore the temperature and function of the limb. The contrast is very great when a small stem is obstructed; in that case comparatively little inconvenience is suffered, and recovery is rapid, unless, indeed, several small stems are simultaneously affected, in which case, as we shall afterwards see, the results may be very serious. It is similar in the case of the superior mesenteric and its larger branches. Obstruction here is slowly recovered from, and for a time the circulation is virtually at a standstill.

But here a very important element comes into consideration. The vessels of all parts of the body are not equally resistant. Those of the skin and muscles (and here it is of course the capillaries and small veins that are concerned) are peculiarly resistant, and are able to stand a considerably prolonged deprivation of blood. It is different with those of the intestines. In order to test the vulnerability of the vessels of the intestine, the following experiment was made. A ligature was tied on the superior mesenteric artery, and the precaution was taken of tying it over leather, so that it might not destroy the vessel, and thus admit of its being subsequently unloosed. It was found that if after two to two

and a half hours the ligature was untied, hæmorrhage occurred from the capillaries. The meaning of this is that within this period the deprivation of blood so seriously disorganizes the capillaries that they are no longer able to prevent the escape of blood at the normal pressure. A much longer time is required in order to the occurrence of hæmorrhage at the pressure of the venous blood; a period of ten to twelve hours is needed. But it was found that for the establishment of the collateral circulation a period exceeding even this was required, namely fourteen hours. Accordingly, before the anastomosis can be established, the backward flow from the veins has already begun, and even the diapedesis. The re-establishment of the circulation even increases the tendency to hæmorrhage, as it subjects the blood to a higher pressure than that of the venous blood. The experiments referred to showed that when the superior mesenteric artery is obstructed the hæmorrhagic infarction forms with a backward flow from the veins just as in other cases.

It will be obvious that ARTERIES POSSESSING FREE ANASTOMOSES MAY BE REDUCED TO THE CONDITION OF END-ARTERIES if their anastomoses are no longer available. If, as sometimes happens, an embolus passing to the leg breaks up, say, by being propelled against a bifurcation, and is scattered to a number of stems simultaneously, then the circulation will be re-established very slowly or not at all, and necrosis is liable to occur, especially if the circulation is already feeble. Thus, we may have gangrene of the toes occurring in this way. It is to be added that in old people obstruction of a number of arteries sometimes occurs from thrombosis as a result of atheroma, and this may likewise lead to necrosis.

Hitherto we have considered only the more immediate results of embolism in end-arteries, we have still to pass under review the FURTHER CONSEQUENCES. We have seen that the regular result is necrosis of the piece of tissue concerned with or without the occurrence of hæmorrhage. In the case of the lungs there is a doubtful exception to the uniform necrosis of the piece of tissue. The lung tissue is nourished to a great extent by the bronchial artery, and obstruction of a branch of the pulmonary artery will not interfere with the nutrition of the connective tissue stroma and the bronchi, and it is probable that only a partial necrosis occurs. The air vesicles, however, are nourished by the capillaries of the pulmonary artery, and it is to be expected that, for the most part, these at least will either necrose or atrophy. As a

matter of fact the whole infarction often undergoes necrosis, and in cases of hæmorrhagic infarction of the lung which recover, symptoms like those of phthisis sometimes develop, and lung tissue has been known to be spit up. As the necrosed lung tissue is disposed of, a cicatrix will take its place. In the case of the spleen and kidney, the solid infarctions are gradually absorbed (see Fig. 9) like foreign animal

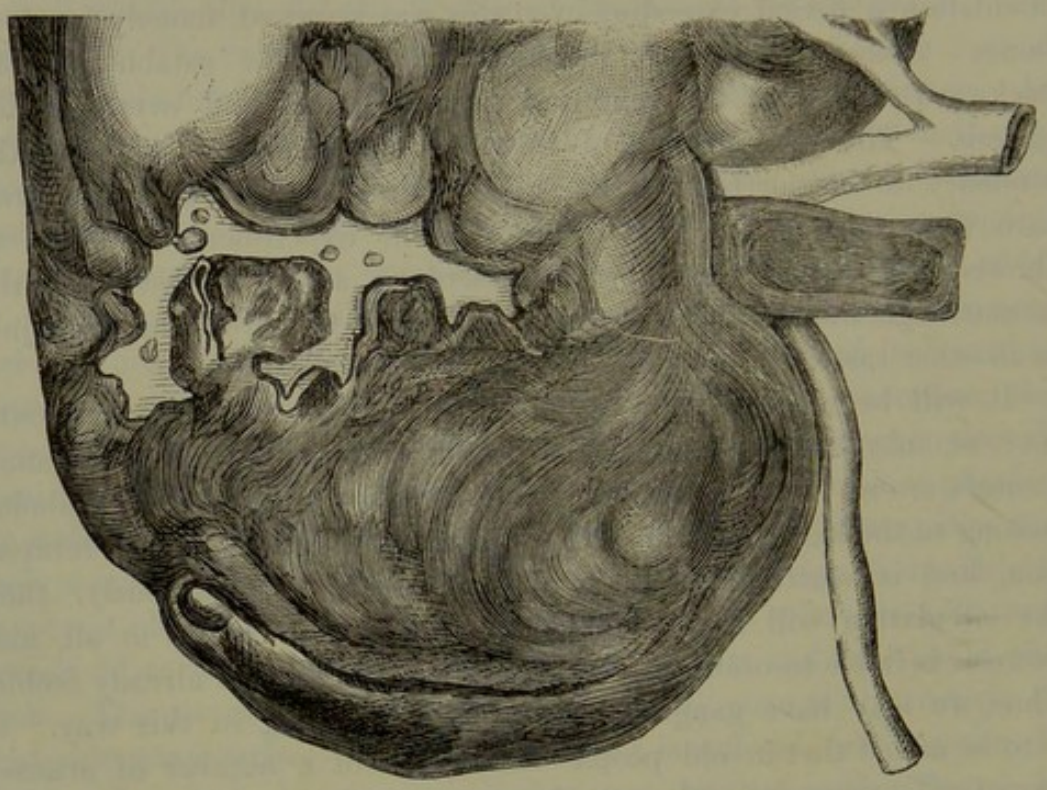


Fig. 9.—Infarction of kidney undergoing absorption. The infarction is white and depressed below the level while the tissue is puckered around it (after RAYER).

matter in the living body generally, a preliminary decolorisation first occurring. Their place is taken by cicatrices in the midst of which, even at a late date, little pieces of solid cheesy-looking material may often be seen. The softened brain tissue is also absorbed, and a cicatrix or a cyst takes its place. So is it with the retina, the piece of tissue is lost and absorbed. In the case of the superior mesenteric artery, the slough of the bowel and hæmorrhage lead on mostly to a fatal result, but cases do occur in which, after the separation of a slough, an ulcer is left which may ultimately cicatrize.

We have still to consider two rarer forms of embolism, namely, by OIL and by AIR. Oil or fluid fat not unfrequently gets into the blood-

vessels. It does so where, by fracture of a bone or injury to the subcutaneous adipose tissue, the fat cells in the bone marrow, or adipose tissue are broken up so as to set free the oil, and, at the same time, the vessels and especially the veins are laid open so as to absorb the oil. Oil also occurs in the blood in cases of diabetes, and, as in Fig. 10,

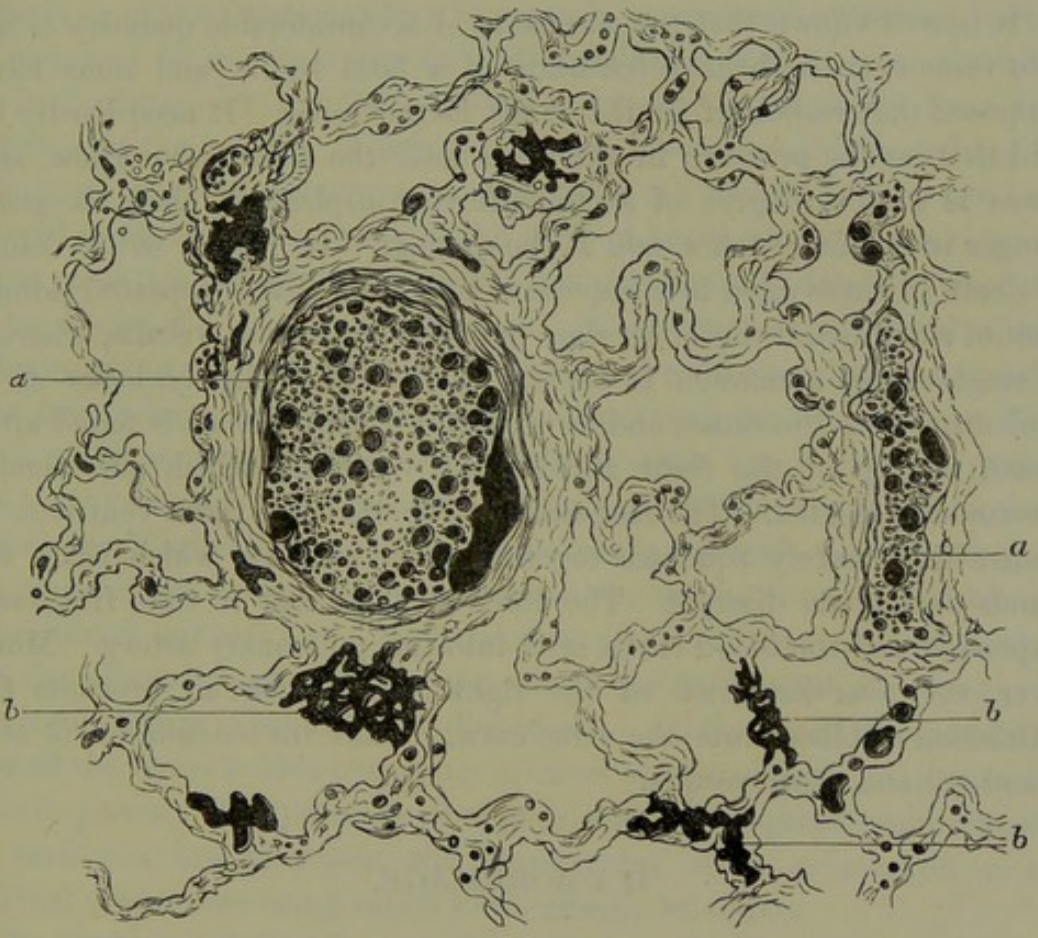


Fig. 10.—Oil embolism of lung. The fat is seen in larger and smaller drops in branches of the pulmonary artery (*a a*) as well as in the capillaries. From an osmic acid preparation (SANDERS and HAMILTON).

may produce embolism. The oil is carried, of course, to the right heart, and on into the lungs where it sticks in the capillaries and the smallest arteries. If the capillaries are obstructed at considerable intervals then no evil results, the anastomosis being so free that no serious disturbance occurs, and the oil itself does not irritate. But, if a considerable number of small arteries near each other be obstructed or even a large number of capillaries, we may have a condition resembling the hæmorrhagic infarction. It has been found on experiment that abundant fat embolisms in the ear of a rabbit, by obstructing numerous capillaries, may lead to necrosis. In some cases the oil may, to

some extent, pass through the lung capillaries, and it is found mostly in the Malpighian tufts of the kidney, one or two loops being here and there filled. There are a few rare cases on record in which extensive embolism has occurred in the smallest vessels of the brain, conjunctiva, skin, muscles, heart, intestines, liver, and kidneys, and has apparently been the cause of death.

It is well known that the admission of a considerable quantity of air into veins near the heart often leads to a fatal result, and some have supposed that embolism in the lungs is the cause. It need hardly be said that, as the pressure in the veins near the heart is very low, and there is even a degree of suction during inspiration, there is great danger in opening such a vein as the jugular. In regard to the cause of death in these cases it is important to notice that a repeated admission of small quantities of air does not produce serious results, whereas a single large admission is rapidly fatal. This hardly looks as if embolism were the cause, and, as a matter of fact, the air is found after death mainly in the right auricle and ventricle, which are usually enormously dilated. The fact seems to be that the right ventricle, in contracting, merely squeezes together the elastic air which again expands during the diastole. The force of the heart is thus fruitlessly expended and the blood is not sent into the pulmonary artery. Moreover, the over-distension of the right auricle with air prevents the admission of blood from the venæ cavæ. Thus the circulation is at a standstill and death results.

HÆMORRHAGE.

This is the escape of blood from the living vessels or the heart. It may take place in minute drops, perhaps frequently repeated, or in larger quantities. The blood may pass outside the body or make a place for itself and form an extravasation inside the body, or it may infiltrate the tissues over a considerable area, forming an ecchymosis.

From what has gone before it will be understood that there are two forms of hæmorrhage which should be kept apart, namely that by RUPTURE OF VESSELS and that by DIAPEDESIS. The former may effect any size or kind of vessel, and when it occurs there will be an escape of the whole blood. The latter occurs only in the finest vessels, mainly the capillaries, and it is chiefly the red corpuscles which escape, and with them, of course, some fluid, but the fluid has not the constitution of the entire blood-plasma. These two forms of hæmorrhage are different not only

in kind but in the CAUSES which lead to them, and yet in some cases it may be difficult to determine which is the form present.

Taking first the case of hæmorrhage by rupture, it is most obviously produced by some agent acting on the vessel from without, as in the case of a wound by a weapon or a piece of broken bone, etc. Then also ulceration may cause penetration of a vessel. Disease of the walls of vessels, or of the heart, may lead to rupture, as aneurism, atheroma, varix. It may here be said that new-formed vessels, whether in inflammations, or in tumours, are peculiarly prone to rupture, presumably from the thinness of their walls. There are further some cases of hæmorrhage in which we have to assume some change in the vessels arising from an altered condition of the blood, as the cause of hæmorrhage, and in most of these cases it is doubtful whether the hæmorrhage takes place by rupture or by diapedesis. In scurvy there is a deterioration of the blood which presumably has a direct effect on the structures comprising the vessel-wall. The hæmorrhage here is probably by rupture, judging from the rapidity with which sometimes large extravasations occur, but it is not impossible that it may be by diapedesis. In purpura hæmorrhagica (or morbus maculosus Werlhofii) there is also hæmorrhage traceable to weakening of the walls of the vessels from a change in the constitution of the blood. In anæmias and leukæmia, hæmorrhages are very frequent, and doubtless the altered constitution of the blood has to do with it. In these the hæmorrhage is probably by diapedesis. Alteration of the constitution of the blood is also frequently a cause of hæmorrhage in the acute specific fevers. The petechiæ of typhus, and the frequent hæmorrhages in small-pox are examples, the latter being often so marked as to warrant some cases being called hæmorrhagic small-pox.

In the hæmorrhagic diathesis there is a peculiar fragility of the walls of the vessels, and this is doubtless congenital and often inherited. In such persons a slight injury produces rupture, and there is difficulty in getting the hæmorrhage stopped. Even a temporary excess of pressure in the vessels may lead to hæmorrhage in these cases.

In poisoning by phosphorus the vessels become fatty, and there is a tendency to hæmorrhage, but whether by rupture or by diapedesis is unknown.

Of hæmorrhages undoubtedly by diapedesis we have already considered two good examples, in passive hyperæmia and the hæmorrhagic infarction. In inflammation also there is escape of the blood corpuscles by the same method.

We have next to consider the STOPPAGE OF HÆMORRHAGE, and in

regard to diapedesis it is clear that it will cease when its cause ceases to act. There is in this case no rupture of the vessel, and so soon as circumstances restore the vessel to its normal state of impermeability to the blood corpuscles the hæmorrhage will cease. In the case of hæmorrhage by rupture, the problem is more complicated, and various elements enter into it. It is well-known that such hæmorrhages tend to cease spontaneously, and we have now to see how that result comes about.

The direct means of stoppage is COAGULATION OF BLOOD, so that a thrombus obstructs the orifice. The thrombus may form at the ruptured edges, or the blood may coagulate outside the vessel, and the coagulum by successive deposition, grow in. The actual thrombus, as it is formed by flowing blood, will be a white or mixed one. The stilling of the hæmorrhage being directly the result of thrombosis, it is to be added that various circumstances favour the formation of the thrombus, and aid in preventing its displacement. These circumstances are for the most part the direct results of the hæmorrhage itself. In the first place as a hæmorrhage proceeds the white corpuscles become proportionately excessive, and this is itself favourable to the formation of thrombi. In the case of an artery again, the narrowing of the ruptured orifice by contraction of the muscular coat favours the stilling of the hæmorrhage, and so does its retraction within its sheath, thus leaving a space in which a clot has room to form. This contraction of the muscular coat is brought about in the first instance by the stimulus of the agent which caused the rupture, and it will be kept up by the irritation of the blood on the exposed and torn structures. Then the bleeding as it progresses leads to anæmia, and this in two different ways assists in stilling the hæmorrhage. It causes weakness of the heart, and so the arterial pressure is reduced and the thrombus is not so liable to be washed away. It also produces irritation of the vasomotor centre in the medulla oblongata, and this leads to contraction of the finer arteries throughout the body. It is clear that in the case of an artery a longitudinal wound will be more difficult to close than a transverse one, as the contraction of the muscular fibre will only make it gape further. On this account it is customary when bleeding is serious from an artery thus wounded, to cut it right across in order to still the hæmorrhage.

We have now to study the further history of THE BLOOD WHICH HAS ESCAPED. Blood which has escaped by diapedesis is mostly carried off by the lymphatics, but there is no doubt that to some extent

it may also undergo partial transformations such as will be described immediately, and which result in pigmentation.

In the case of hæmorrhage by rupture the blood is sometimes entirely absorbed, and that with considerable rapidity, especially when it is infiltrated into the tissues where it occupies the serous and lymphatic spaces, as in ecchymoses. In the case of larger hæmorrhages the blood either accumulates in an existing cavity, or by tearing makes a cavity for itself. It may remain for some time as an independent mass, forming a kind of permanent tumour, the hæmatoma, which is specially considered below. The blood may remain for some time fluid, but usually it coagulates by and by.

After a longer or shorter period of time the blood is disposed of, and we have now to consider the manner of its disposal. It is easy to understand how the fibrine is dealt with, it disintegrates, and is through time absorbed. The red corpuscles undergo more considerable changes, and their history we have to trace. The colouring matter is frequently dissolved out of the red corpuscles, and in solution it is largely absorbed. The solution may stain the intercellular substance of the tissues, and possibly may lead to a more or less permanent pigmentation of them. In true pigmentations, however, the colouring matter is in cells, and it is doubtful whether living cells are capable of being simply stained by a solution of colouring matter. The peculiar bright red colour which one sees in the neighbourhood of a hæmorrhage in the brain, or the various colours seen in the skin after an effusion of blood into it, are due to staining of the tissues with the dissolved colouring matter of the blood, but neither of these is permanent. The colouring matter after being dissolved out of the corpuscles is often, after a time, deposited in the solid form, appearing as crystals of hæmatoidin (see Fig. 11), or as granules.

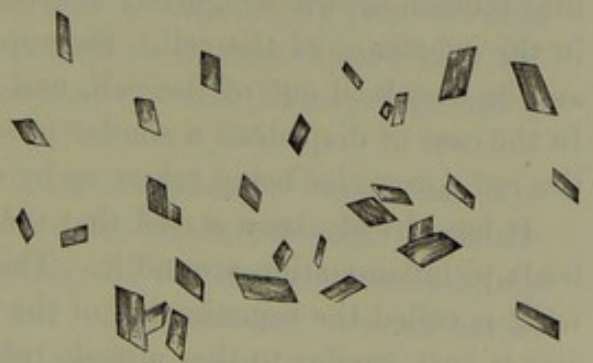


Fig. 11.—Crystals of hæmatoidin from an old hæmorrhage in the brain. Their colour is reddish brown. × 350.

Again, the red blood corpuscles may be taken into the substance of other cells, and so disposed of. The effused blood acts as an irritant in the tissues, producing inflammation around, and numbers of leucocytes collect in the neighbourhood. These take into their substance red corpuscles, thus becoming blood-corpuscle-holding cells (see Fig. 13),

concerning which much has been written. The leucocytes, as shown in the figure, may take up several red corpuscles, and of course they

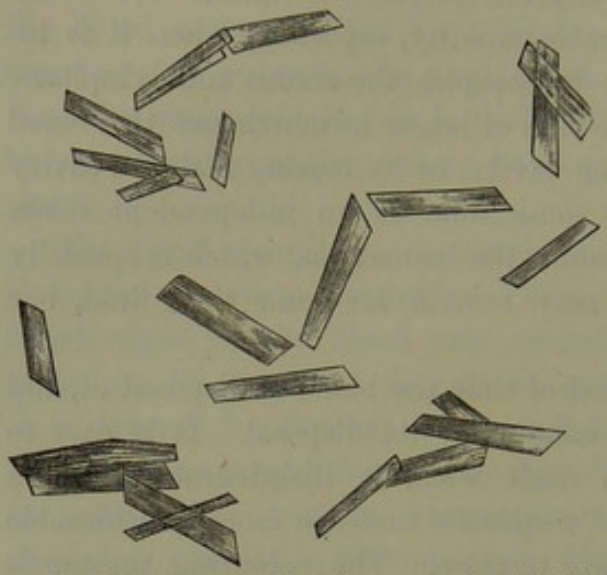


Fig. 12.—Crystals of hæmin prepared artificially by adding glacial acetic acid to a drop of blood, heating and evaporating to dryness. × 350.

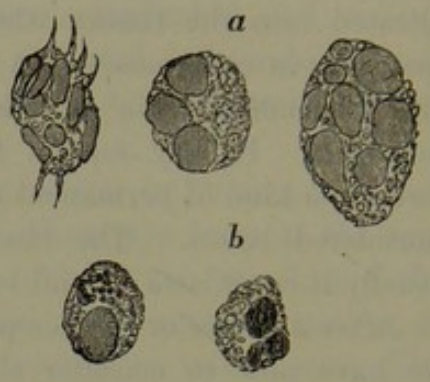


Fig. 13.—Cells containing blood corpuscles from the neighbourhood of a hæmorrhage: *a*, with fresh corpuscles; *b*, with dark granules from disintegration of red corpuscles.

become greatly enlarged. Besides that, the giant-cells which we shall afterwards refer to in connection with inflammation, may take up red corpuscles. These cells pass in part into the lymphatics, and the red corpuscles are thus absorbed. But it appears that to some extent they remain permanently, or else that the red corpuscles are taken up also by the fixed connective tissue cells, and so a true PIGMENTATION is brought about. In either case the red corpuscles within the cells shrink into reddish-brown irregularly shaped bodies (see Fig. 13, *b*), which lie in the substance of the cell. Subsequently the pigment may break up and be dissolved out of the cell, and so the colouration will disappear. In the case of diapedesis a similar process of pigmentation may occur by the red corpuscles being taken up by cells.

It has already been stated that the blood acts as a foreign body, and leads to inflammation around it. This inflammation sometimes leads to what is called the organization of the blood clot. In this case the process is very similar to that already referred to in the organization of the thrombus, and the result is usually the formation of a cicatrix. Sometimes a process in some respects similar to the formation of the cavernous tissue in place of a thrombus occurs, but instead of the meshes being filled with blood they are filled with serous fluid. Thus in the case of a hæmorrhage in the substance of the brain the new-formed connective tissue which replaces the effused blood, is unable, from the

brittle nature of the brain tissue, to form a cicatrix by its contraction. Instead of that, by its contraction it leaves spaces which are filled with serous fluid, and so we have the apoplectic cyst.

An old clot which is not in a position to be readily disposed of in any of the ways described may dry in and finally become impregnated with lime salts. It need hardly be said that when exposed to septic influences, a clot is liable—perhaps very liable—to undergo decomposition.

Blood which has been effused occasionally takes up a somewhat permanent position in the body, and when masses of blood thus remain for a time they may assume the appearance of TUMOURS. Sometimes a class of blood-tumours is distinguished under the name HÆMATOMA, although they do not come under the strict definition of tumours. It will be proper here to enumerate the various conditions to which this name is given.

The CEPHALHÆMATOMA is a condition sometimes met with in the child immediately after birth, and produced during delivery. In the act of delivery the pericranium is separated from the surface of the skull and vessels are ruptured. Blood collects between the pericranium and the skull, and is apt to remain long there, retaining its fluidity for an unusual time. The raised pericranium produces new-bone and at first chiefly at its margins. There is thus a shell of new-bone in the shape of a ring covering in the edges of the collection of blood. This produces the peculiar character that when the prominence is handled the impression is as if there were a gap in the skull. The shell of new-bone is continuous with the cranium, and as the fingers pass inwards they suddenly dip into the gap, and it feels as if they dipped into the soft brain substance. In some cases there is also hæmorrhage inside the skull.

The Othæmatoma or HÆMATOMA AURICULARE or insane ear is a condition in some respects comparable to the last-mentioned. In it the perichondrium is raised from the cartilage of the ear, sometimes bringing little bits of cartilage with it, and blood collects between cartilage and perichondrium. This occurs on the anterior surface of the concha, and the result is that the hollows are filled up and become prominences. It appears to be sometimes produced by violence such as blows, but only in persons predisposed to it. It is met with almost alone in insane persons, and chiefly those suffering from general paralysis. As the blood is absorbed the ear does not recover, but shrivels up with great consequent deformity.

The HÆMATOMA OF THE DURA MATER is also of most frequent occurrence in insane persons, though by no means confined to them. In persons dying with apoplectic symptoms there is sometimes found a flat layer of blood on the internal surface of the dura mater, in some cases an inch or an inch and a half thick. On careful examination there is a thin false membrane on the surface of the clot, and the disease is usually the result of a chronic inflammation of the dura mater, pachymeningitis chronica hæmorrhagica.

The HÆMATOMA OF THE HEART is an interesting form. It sometimes happens that large masses of fibrine are deposited on the valves or elsewhere, and these may come to form permanent projections. In one case met with by the author there were immense festoons hanging from the mitral valve and filling the greatly enlarged left ventricle. In some parts there was calcareous infiltration of the hard dry clot, but no proper organization had occurred.

The UTERINE HÆMATOMA is a polypoid mass of blood, coagulation having occurred on a placental surface or retained placenta. It is sometimes called the fibrinous polypus. It projects into the cavity of the uterus and may simulate a polypoid myoma.

Blood may collect in the peritoneal pouch behind the uterus, forming a kind of RETRO-UTERINE HÆMATOMA.

ŒDEMA AND DROPSY.

In order to understand these conditions it is necessary to refer to certain points in the normal relations of THE LYMPHATIC CIRCULATION. The connective tissue throughout the body is as it were permeated with spaces of various shapes in which the connective tissue corpuscles lie. These lacunæ or serous spaces are lined with endothelium like the blood and lymphatic vessels themselves. The serous spaces are provided (as shown in Fig. 14) with numerous anastomosing processes, and they communicate on the one hand with the interior of the blood-vessels, and on the other with the lymphatics. Arnold and others (see Fig. 15) have succeeded in injecting the serous spaces from the blood-vessels, especially when, as in passive hyperæmia, the channels of communication between blood-vessels and spaces have been widened. We are to suppose that a circulation is continually proceeding from the capillary blood-vessels into these spaces, and so into the capillary lymphatics. The serous cavities of the body are to be regarded as large serous spaces. They also are lined with endothelium, and are continuous with the

lymphatic capillaries. The serous spaces, therefore, and the serous cavities, are virtually the same in nature, and their pathology is similar.

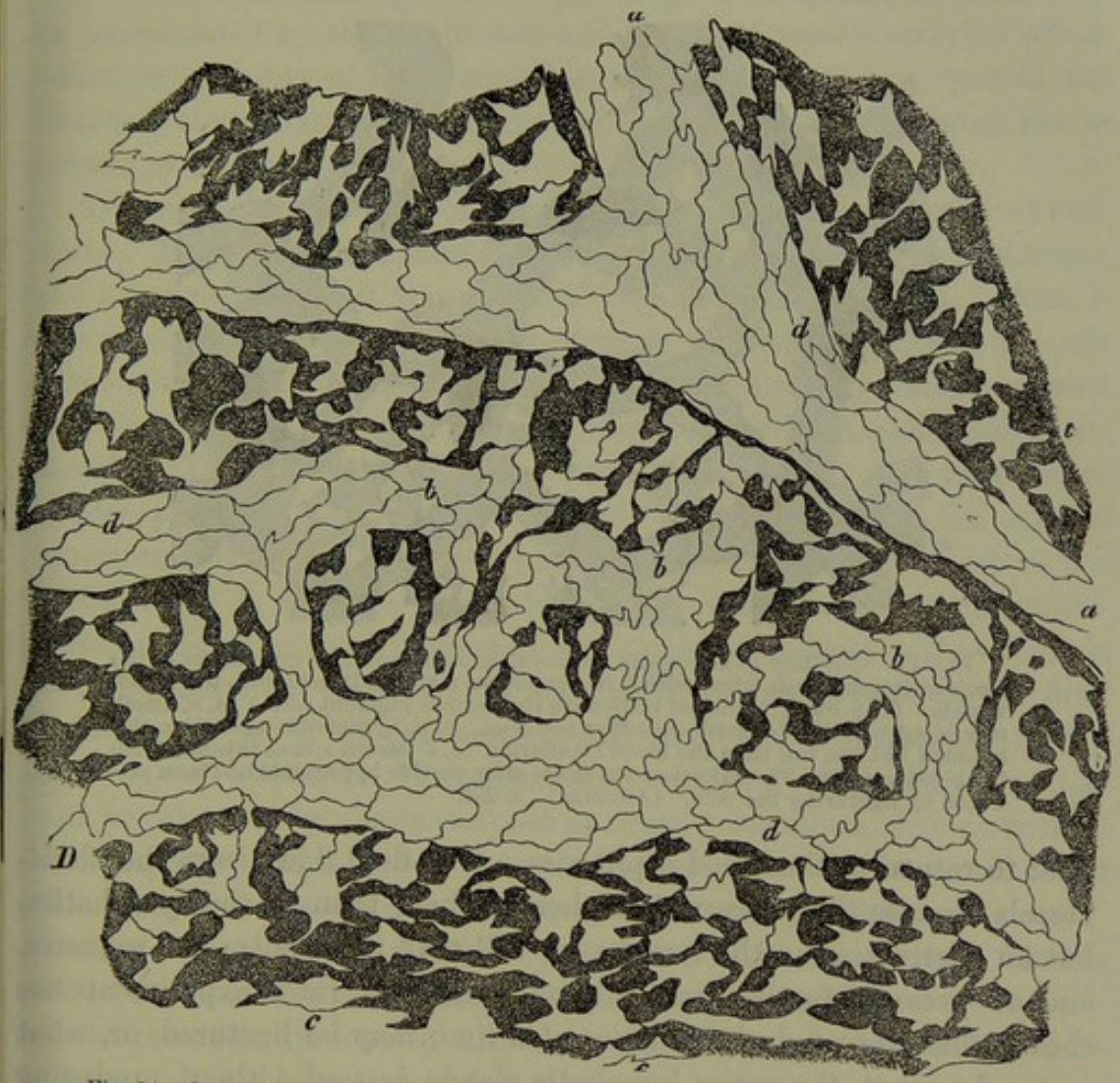


Fig. 14.—Serous spaces (*cc*) and lymphatic capillaries (*dd*) in pleural surface of diaphragm in preparation treated with nitrate of silver. The connection of the branched spaces with the commencing lymphatic vessels is shown. (RECKLINGHAUSEN.)

Œdema is over-filling of the serous spaces with fluid, dropsy is over-filling of the serous cavities, and so the two conditions are virtually identical.

Anything which causes an excess of fluid in these spaces or cavities will produce œdema or dropsy, and the first condition which suggests itself is obstruction of the lymphatics. The force which carries on the lymphatic circulation is largely the blood-pressure propagated from the capillaries, and it may be expected that OBSTRUCTION TO A LYMPHATIC STEM would produce accumulation of fluid in the spaces. But it is to be remembered that the serous spaces are in as close relation to the blood

capillaries as they are to the lymph capillaries, and any obstruction to the lymphatics will probably have the effect of causing the transuded



Fig. 15.—Capillary blood-vessels, serous spaces and capillary lymphatics of the frog's swimming web, filled with (blue) injection material thrown into the blood-vessels. (The black branched bodies are the normal pigment cells.) *a*, *a*, Capillary blood-vessels filled with injection material. *b*, *b*, Lymphatic capillaries also injected but less full than the blood capillaries. *c*, *c*, Serous spaces injected from the blood-vessels. The injection was made after passive hyperæmia had been produced by ligaturing the vein. (ARNOLD.) × 250.

fluid to return to the blood capillaries. The fluid flows from the blood-vessels because the pressure is higher in them than in the lymphatics, but an obstruction in the lymphatics will tend to equalize the pressure, and so prevent further transudation. At any rate, experiment has shown that the whole lymphatics of a limb may be ligatured, or, what is equal to that, the entire lymphatic glands excised without producing œdema. The blood-vessels take up the functions till new lymphatic channels are formed. Even when the thoracic duct is obstructed there is not necessarily any œdema or dropsy. It is true that obstruction of the thoracic duct sometimes leads to distension, especially of the chyle vessels, and even the bursting of them so as to lead to a chylous ascites. It may even lead to an ordinary ascites. So far as human pathology is concerned, however, it must be exceedingly rare to find obstruction of the thoracic duct apart from other conditions which more directly lead to dropsy. We may say at least that, with this possible exception, obstruction of lymphatics does not of itself lead to œdema, or dropsy, although it is clear that it may aggravate an œdema whose cause is to be found in some other condition.

Looking to these facts it may be said that the conditions which lead to œdema and dropsy do so by causing INCREASED TRANSUDATION FROM THE CAPILLARIES into the serous spaces. A considerable increase may be compensated by the lymphatics and the blood-vessels carrying off an additional quantity of fluid, but when the limits of this are passed the fluid will accumulate in the spaces and distend them, thus giving rise to œdema or dropsy.

The most obvious cause of increased transudation is VENOUS HYPERÆMIA. Here there is increased pressure in the capillaries and veins, and a greatly increased transudation. From what has gone before, it will appear probable that here the increase of pressure is not the only element in the case. The circumstances of the capillary wall are altered in such a way that we may presume that it is rendered abnormally permeable. This view appears more probable when we find that active hyperæmia does not, if uncomplicated, produce œdema. In arterial hyperæmia, it is true, the blood-pressure is not so much raised in the capillaries as it is in the venous form; still it is raised, but the transudation is never so much increased as to produce œdema, unless there is an inflammatory element in the case. In passive hyperæmia the fluid exuded will be a watery serum, and as there is diapedesis it will contain red corpuscles in considerable numbers. The red corpuscles will be taken up by the leucocytes as already described, and carried to the lymphatic glands where they will disintegrate. It should be added that it requires considerable increase of pressure in the capillaries to produce an œdema by passive hyperæmia when acting alone. It has even been stated that a simple passive hyperæmia, apart from vaso-motor paralysis (producing also active hyperæmia), does not lead to œdema. It has been shown that if the iliac vein of a dog be ligatured there is no œdema till the sciatic nerve is cut. The explanation of this, however, may be that this vein has such free anastomoses that its ligature does not raise the blood-pressure sufficiently to induce œdema, whereas a coincident vaso-motor paralysis producing dilatation of the arteries raises the blood-pressure sufficiently. Experiment proves that if a sufficient number of veins be obstructed œdema will result without vaso-motor paralysis. Sotnitchewsky, by introducing plaster of Paris into a peripheral vein of the leg of a dog while the thigh was constricted by an elastic band, succeeded in obstructing a number of veins by the gypsum hardening in them. In this case œdema followed without the induction of vaso-motor paralysis. In passive hyperæmia from thrombosis of veins there are usually many veins obstructed before œdema occurs. In the

case of passive hyperæmia from heart-disease it may well be supposed that the prolonged venous engorgement will produce a more than usual deterioration of the capillary wall, besides a depreciation of the blood itself.

We now come to a question which is not so easy of answer as that we have just been discussing. It has been customary to say that a watery state of the blood, a HYDRÆMIA MAY INDUCE ŒDEMA, and the case of the so-called cachectic œdemas is cited. This, however, has been rendered doubtful by a series of experiments by Cohnheim and his assistants. A simple hydræmia, induced in a dog or other animal by repeated blood-lettings and the replacement of the blood withdrawn by a solution of common salt, does not lead to œdema. On the other hand it may well happen that a prolonged hydræmia as opposed to this more acute form, such as we meet with in cases of chronic emaciating disease, may so depreciate the capillary wall as to give rise to œdema under comparatively trivial circumstances. In such persons the heart is weak, and the blood has a tendency to stagnate in depending parts, as has already been described, and this comparatively slight increase in pressure may induce the occurrence of œdema.

Next we have the frequent ŒDEMA of the skin in BRIGHT'S DISEASE to account for. There is undoubtedly here in many cases a hydræmia, induced in two different ways. There is the loss of albumen, which renders the blood directly more watery But in many cases there is also an abnormal retention of the water in the blood. In acute Bright's disease, especially, there is great reduction in the amount of urine secreted, and this implies an increase in the water of the blood. It is in these cases, it will be observed, that the occurrence of œdema is most frequent. These facts naturally suggest that if the œdema in Bright's disease is not due simply to the hydræmia, it may be due to this in conjunction with the increased bulk of the blood, to a HYDRÆMIC PLETHORA. This view has obtained much support. It has been supposed that, the entire bulk of the blood being increased, there will be increased pressure in the capillaries and increased transudation from the watery blood. But there are some objections to this view. We have already seen that plethora, even when suddenly induced, does not raise the blood-pressure. There is a form of Bright's disease in which the arterial tension is raised, and the increased tension is related to hypertrophy of the left ventricle of the heart. But it is just in this form of Bright's disease (the cirrhotic form) that œdema is least usual, and a case may proceed to a fatal issue without the occurrence of any œdema.

Then there are cases of absolute suppression of urine, as in hysterical females, etc., in which we must presume an exaggerated hydræmic plethora, but without a trace of œdema.

In some experiments by Cohnheim and Lichtheim, a hydræmic plethora was induced by injecting a solution of common salt into the vessels of animals. Enormous quantities could be injected without seriously compromising the animal. We have seen that when blood is transfused in the dog, the limit consistent with the survival of the animal is one and a half times the bulk of the blood, but more salt solution than three times the bulk of the blood could be injected without killing the animal. From the previous reference to tranfusion, it will be understood that these injections did not produce any permanent rise in the blood-pressure. The most direct result was a great acceleration in the speed of the blood current, presumably from the diminished friction of the watery blood. There was also a greatly increased transudation and consequent increased flow of lymph. But this was remarkably localized. There was a greatly increased flow of lymph in the thoracic duct, showing that in the viscera the transudation was increased; while the lymphatics of the limbs showed no increase, indicating that in the skin and muscles the transudation was not increased. There was also greatly increased secretion from the salivary glands, stomach and intestine, liver, lachrymal glands, and kidneys. In these organs an œdema was developed, that is to say, in the mucous membrane and submucous tissue of the stomach and intestines, in the lymphatic glands of the mesentery, in the pancreas, kidneys, gall bladder, salivary glands; there was also ascites, but no œdema of the skin. The explanation suggested for this localization of the increased transudation and the œdema is, that these organs are all normally concerned in the removal of water from the blood, and that probably their blood-vessels are unusually permeable to water. The experiments produce a great increase in the water of the blood, and the vessels give ready passage to it.

It will be observed that in these experiments the œdema was present in parts where it is absent in Bright's disease, and was not present at all in the skin. So that the œdema of Bright's disease cannot be ascribed altogether to the hydræmic plethora, however much that may predispose to it. To explain the œdema of Bright's disease, it seems necessary to suppose some alteration in the vessels of the skin rendering them unduly permeable. There are many facts indicating a relation between the skin and the kidneys in Bright's disease, and it is very possible that the

morbid agent which affects the kidney may also affect the skin. In scarlatina we have during the fever an inflammatory hyperæmia of the skin, and it is natural to suppose that when subsequently a kidney affection induces a hydræmic plethora the œdema will manifest itself in the previously damaged skin. In the experiments above referred to, it was found that although the normal skin did not become œdematous, yet when it had been previously inflamed, as by pencilling with iodine solution, or by exposing to a strong sun, then œdema shows itself. It may hence be inferred that, although hydræmic plethora is not by itself a cause of œdema of the skin, it is a strong predisposing element.

We shall find in studying inflammation that the alteration in the vessels produced by this condition induces œdema, so that inflammatory œdemas are of frequent occurrence.

LEUKÆMIA.

By this name is meant a condition in which the white blood corpuscles are greatly increased, the name meaning literally white blood. This was the name applied by Virchow. Another name Leucocythæmia applied by Bennett, although literally more correct, is cumbersome, and is now generally disused. The condition of the blood gives its name to the disease and this will first engage our attention.

The normal proportion of white corpuscles to red in the blood is stated as about 1 in 300 to 1 in 450, but it may vary within normal limits. There is after hæmorrhage, as we have seen, a slight increase in the proportion of white corpuscles, a leucocytosis, but it is of no special significance. In leukæmia the relative proportion of white to red corpuscles is greatly altered. A case is not a very severe one in which the corpuscles are as 1 to 10, and they may be as 1 to 2 or even equal. This alteration in the proportion of white and red is not the only alteration in the blood. The white corpuscles are more varied in size than normal, some larger and some smaller, and they are sometimes more distinctly nucleated. Then the red corpuscles are not only proportionately few in number, but they are absolutely reduced, and that to a very high degree. Occasionally nucleated red corpuscles have been found in the blood, these corpuscles being of larger size than the normal red corpuscles. The specific gravity of the blood is considerably reduced; it may fall from 1055, which is the average normal, to 1040 or 1035. The blood has thus the character of anæmia along with a great increase of the white blood corpuscles. In leukæmic blood, after

death, there are found small, colourless, glancing crystals of an octahedral shape, which are usually called from their discoverer Charcot's crystals (see Fig. 16). There are also certain other abnormal chemical constituents, chiefly glutine and hypoxanthine.

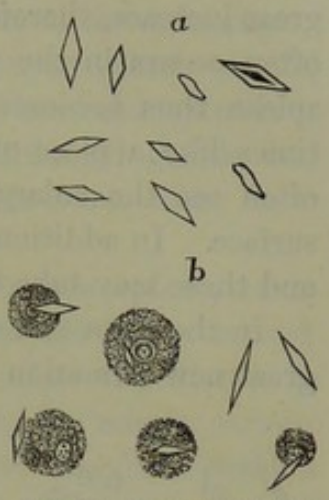


Fig. 16.—Charcot's crystals from the blood in leukæmia after death. In *b*, the crystals are partly inside the white corpuscles. (ZENKER.) × 500.

With regard to the probable explanation of this peculiar condition of the blood, it must always be remembered that there is a very great diminution in the red corpuscles as well as a great increase in the white. There must be either a greatly increased new formation of white corpuscles and destruction of red ones, or a serious interference with the conversion of the white into the red corpuscles. This latter is the view originally taken by Virchow, and is the more probable. There may be an increased formation of white corpuscles, but the diminution in the number of the red is probably due to a reduced conversion of white into red. The nucleated red corpuscles have been regarded by some as transition forms, their presence indicating a delay in the conversion.

The blood in persons affected with this disease is unduly pale, but it has not a watery appearance. It is even a thicker fluid than usual and distinctly more opaque, resembling a mixture of pus and blood.

The alteration in the constitution of the blood is associated with changes in certain organs which have generally been regarded as concerned in the preparation of the blood, namely, the spleen, the lymphatic glands, and the medulla of bone. In different cases of leukæmia these structures are variously affected. The medulla of bone seems to be affected in all or nearly all cases, the spleen with the medulla in a considerable number, the lymphatic glands with the medulla in a smaller number, and all three in many cases.

The condition of THE SPLEEN IN LEUKÆMIA will first concern us. In all stages of the disease it is enlarged. The enlargement in the earliest period appears to be due to an active congestion, and is accordingly of rapid development. Rindfleisch mentions a case which he saw at Virchow's demonstrations in which the enlargement had been so rapid as to cause a rupture of the capsule of the spleen. This enlargement is merely from overfilling of the vessels, but it is succeeded by, or developes into, a solid enlargement. The Malpighian bodies of the

spleen have the structure of lymphatic follicles, and it is mainly by the enlargement of these that the permanent solid enlargement occurs, a great increase, therefore, of lymphoid tissue. But the new-formation often occurs in the pulp as well as in the Malpighian follicles. The spleen thus becomes converted into a hard, dense, bulky organ, sometimes like a piece of wood. It is also paler than normal, and we can often see the enlarged Malpighian bodies as whiter areas on the cut surface. In addition, there are frequently hæmorrhages in the spleen, and these may take the form of the regular wedge-shaped infarction.

In the MEDULLA OF BONE the changes are very similar. There is a great new-formation of round-cell tissue which occurs at the expense of the adipose tissue and also of the bone. This new tissue consists mainly of cells as large as white blood-corpuscles, and has the structure of lymphatic tissue, showing the reticulum and round cells as in Fig. 17. Sometimes there are larger cells than these, and there may be also nucleated red corpuscles. There is thus a great new-formation in the medulla and that mainly of lymphatic tissue. As the medulla of bone, especially the red medulla of spongy bone, normally contains lymphatic tissue, the change in leukæmia may be regarded as a hypertrophy of this, and the amount of hypertrophy is sometimes very great. Thus, the whole yellow marrow of the hollow shaft of the femur may be replaced by lymphatic tissue. The cavity of the shaft may also be widened at the expense of the bone, and many smaller trabeculæ here and in the spongy bone may be destroyed. In this respect as well as in intimate structure the leukæmic bone-marrow differs from the red marrow of pernicious anæmia, as the latter does not cause a proper atrophy of the bony tissue. The occurrence of hæmorrhages or even infarctions has been observed in the bone-marrow just as in the spleen. The appearance of the medulla is, of course, greatly altered. It has generally a greyish red colour without any of the normal greasy appearance, but it may be pale so as to look like solidified pus, or dark red, these differences depending on the degree of the new-formation and the state of fulness of the vessels. It has, however, the character of a tolerably solid tissue, not a semi-fluid material as in anæmias. These changes may occur in all the bones in the body, and in both



Fig. 17.—Medulla of bone in leukæmia, from the cavity of the shaft of the femur. Adenoid reticulum and lymphoid cells are shown × 350.

spongy and hollow bones, the affection being, however, variously distributed.

The lesion IN THE LYMPHATIC GLANDS consists in an enlargement of them. This begins mostly in a particular set of glands usually situated externally, as in the axilla, groin, neck, etc., and spreads to other sets, generally first to those nearest. The enlarged glands may be three, five, or even ten times their normal size, but there is no tendency to any degeneration of their tissue.

The RELATION OF THESE ORGANIC CHANGES in the spleen, bone-marrow, and lymphatic glands to the disease in its essence is exceedingly obscure. An attempt has been made to associate the disease in its origin with the bone-marrow, but even this is by no means certain. There seems little reason to doubt, however, that the bone-marrow along with the lymphatic glands and spleen, and perhaps in a more important manner than they, is concerned in the formation of the blood corpuscles. The discovery of nucleated coloured cells in the normal red marrow of spongy bone seems to show that the red corpuscles are either formed or undergo important changes here.

Besides these organs others are frequently attacked, but the lesions in them are of later manifestation, by no means uniformly present, and undoubtedly secondary. THE LIVER is nearly always enlarged, and this enlargement may be due simply to parenchymatous changes in the hepatic cells, but is often associated with a distinct new formation in the liver. This is in the form of minute collections of round cells occurring in myriads throughout the organ, as shown in Fig. 18. These are, at first sight, not unlike miliary tubercles, but they have no giant-cells and do not present any tendency to degeneration, while they are much less definite in size and shape. Sometimes, instead of definite aggregations, there is an extensive infiltration of the connective tissue stroma of the liver with round cells. The exact nature of these lesions is doubtful. They may be simple aggregations of white blood corpuscles, but they have usually too regular a form for this, and they have been regarded as small lymphatic formations.

THE KIDNEY is affected not infrequently, and here the appearance to the naked eye very often is as if the organ were greatly enlarged by the presence of large pale tumours in the cortical substance. On microscopic examination the lesion is seen to consist in an enormous infiltration of the stroma of the kidney with round cells, the proper secreting tissue remaining, but, of course, greatly pressed on. This infiltration occurs in definite areas, as if some agent had addressed itself to certain defined portions of the organ.

The CLOSED FOLLICLES OF THE INTESTINES, both the solitary ones and those aggregated in Peyer's patches, may be enlarged, and as they are of lymphatic structure, their enlargement is a simple hyperplasia. This is not of frequent occurrence, and still less frequent is the formation of leukæmic tumours IN THE SKIN, these tumours consisting of infiltrations of round cells.

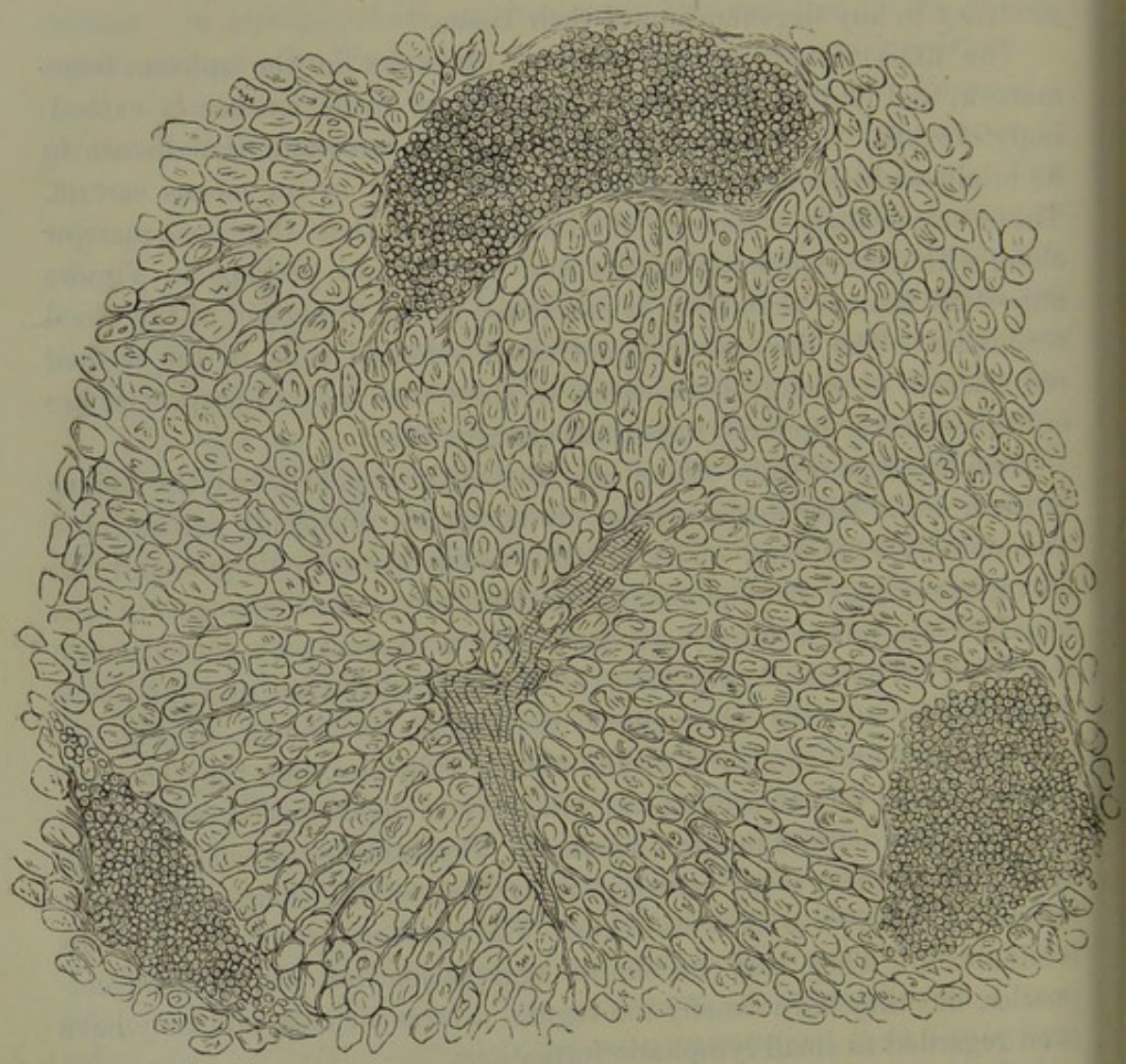


Fig. 18.—Leukæmic formations in the liver. × 75.

The connective tissue in other regions may also be infiltrated. The author met with a case in which the connective tissue of the mediastinum was enormously infiltrated, so that the tissue formed a bulky tumour. The infiltration extended to the pericardium much in the fashion of a lympho-sarcoma.

It is proper here to mention that there is a disease called variously HODGKIN'S DISEASE and PSEUDO-LEUKÆMIA, in which the organic lesions appear to be identical with those of leukæmia, but without the increase of white blood corpuscles, the blood being simply anæmic. There may be great enlargement of the spleen and of the lymphatic glands, and the characters of the enlargement may be essentially like those mentioned above.

MELANÆMIA.

By this name is meant, literally, black blood. It is used to designate a condition in which pigment occurs abnormally in the blood and is deposited in the tissues. The pigment is in the form of solid granules, and, although black in colour, it is derived from the blood pigment, and contains iron. It is met with in cases of malarial fever, but not in every case, as a rule only in the more severe forms. The view usually entertained is that during the acute paroxysm of an ague, blood-corpuscles are destroyed in the spleen, and their pigment is set free in the granular form. Lately, Arnstein (Virchow's Archiv, vol. lxi. p. 494) has brought forward the view that the destruction of blood corpuscles occurs not in the spleen, but in the blood generally. Whether the spleen be the seat of its formation or not, it is certainly stored up there for years, and may pass into the blood by degrees, although it is more abundant immediately after the acute paroxysm.

When the pigment gets into the blood it is rapidly taken up by the white blood corpuscles, so that these appear in the blood as pigmented cells. These pigmented cells are often larger than the white corpuscles, being enlarged by their abnormal contents. It will thus be seen that very little free pigment will be present in the blood except immediately after the acute paroxysm, the white corpuscles picking up the solid granules just as they do when a solid pigment, such as vermillion, is artificially introduced into the blood of an animal (see Fig. 19). The white corpuscles containing the pigment accumulate in certain organs, especially the spleen, liver, and bone-marrow. In the spleen

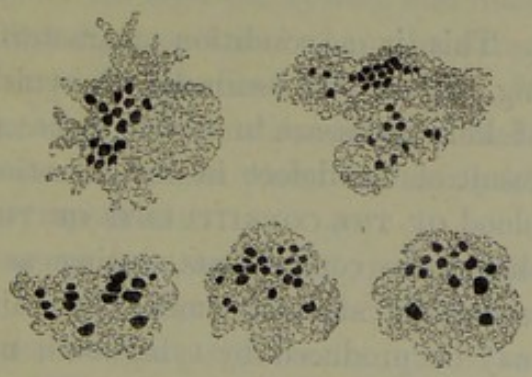


Fig. 19.—White blood corpuscles of the frog, containing granules of vermillion, and showing amœboid movement. (After KLEIN.)

and bone-marrow the pigmented cells appear to leave the capillaries readily, and pass into the tissues, producing an actual pigmentation of them, but in the liver they linger longer in the capillaries, which may be seen with many such corpuscles in them (see Fig. 18), although here also the latter may pass out into the surrounding tissue. In very severe cases, other organs and tissues may be pigmented in this way. The brain is very often pigmented, especially in cases where there has been much cerebral excitement. This will be in very acute cases, but it is doubtful whether the pigment has much to do with the cerebral symptoms, which may be merely a consequence of the acute attack. The kidneys are sometimes the seat of it as well as other tissues, such as pancreas, intestine, etc.

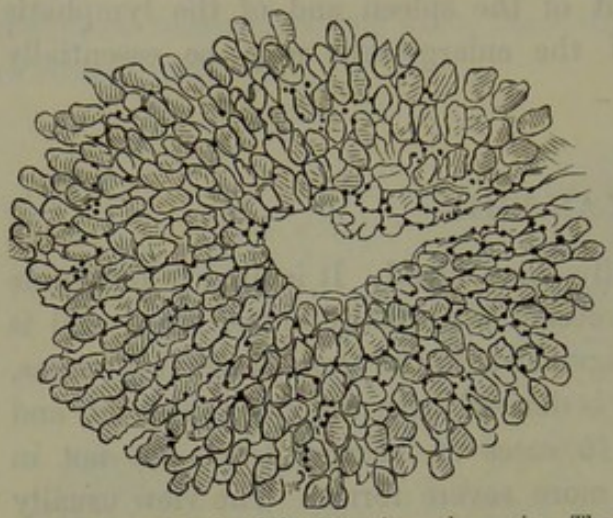


Fig. 20.—A lobule of the liver in melanæmia. The black pigment granules are seen between the hepatic cells, being really in the capillaries. × 75.

This abnormal pigmentation of course produces changes in the colour of the organs affected. The spleen is slaty-grey or almost black, the liver is steel-grey or blackish, the grey substance of the brain is of a dark chocolate or graphite colour, and the kidneys present greyish spots.

URÆMIA.

This is a condition characterised by nervous symptoms, vomiting, sleepiness, headache, convulsions, coma, and it occurs in cases of kidney-disease in which the secretion of urine is diminished. The result of the defect in the secretion of urine is ACCUMULATION in the blood OF THE CONSTITUENTS OF THE URINE, and it was natural to infer that these constituents, acting as poisons, produced the symptoms; hence the name uræmia. In animals, symptoms essentially similar may be produced by tying both ureters, and here also doubtless there is retention of urinary constituents. The urea is readily detected in the fluids and tissues in such animals, and it has been frequently detected clinically in cases of uræmia.

And yet it is very difficult to be sure that the symptoms are due to poisoning by the urinary constituents. For one thing, the injection of

urea, and even of filtered urine, into living animals does not produce uræmia, the only effect being an excessive secretion of urine. These facts have led to theories to account for the uræmic symptoms apart from the presence of urea in the blood. Frerichs' theory at one time received great acceptance. He said that the symptoms were due, not to the urea or other urinary constituents, but to the products of their decomposition, and mainly CARBONATE OF AMMONIA. It was asserted that carbonate of ammonia was to be found in the blood of uræmic patients, and that it was often to be detected in their breath. But there is a mistake here. More correct chemical investigation shows that there is no excess of carbonate of ammonia in the blood. Carbonate of ammonia is to be found abundantly in the intestines, where it is the result of putrid decomposition. Moreover, the injection of carbonate of ammonia into animals does not produce uræmic symptoms, but symptoms of a different kind.

Again Traube started a very ingenious theory, according to which the uræmic symptoms are due to ŒDEMA OF THE BRAIN and its membranes, and consequent anæmia of that organ. It is known that œdemas occur sometimes very suddenly in Bright's disease, and it was supposed that a sudden œdema of the brain would produce such symptoms, the varying locality of the œdema determining the variations in the symptoms. But this theory is also scarcely tenable, because œdema of the brain is by no means constant in uræmia.

It is rather probable that the ORIGINAL VIEW is fundamentally the correct one. So long as there is a free outlet, the blood may contain a large quantity of urinary constituents, and so when urine is injected into the blood of animals it passes rapidly through the system and does little harm. But if the ureters be first ligatured and then the urine injected, the uræmic symptoms will rapidly manifest themselves. It will be understood that the urea is not the only constituent concerned, but that the other nitrogenous substances and salts probably take part in the production of the entire set of symptoms.

It has already been said that in uræmia urea is present in excess in the blood and fluids of the body, and has frequently been detected during life, and it is in cases where the secretion of urine is diminished or suppressed that these symptoms occur. The secretion may be diminished in various ways, by obstruction in the outflow, by disease of the secreting tissue, by defect in the water of the blood so that the urinary constituents are not duly carried off, or even, as has been supposed in the case of eclampsia, by spasm of the renal arteries preventing the due

passage of blood through the kidneys. In all these cases the one common element is a defective separation of the urinary constituents, and their consequent accumulation in the blood, and the presumption is that these constituents have a poisonous effect, although it may be impossible to say whether one or more of them is specially deleterious.

DIABETES MELLITUS.

The pathology of diabetes is a subject of considerable difficulty, and it may be well at the outset to set forth the problem which requires solution.

The BLOOD AND URINE CONTAIN NORMALLY A SMALL QUANTITY OF GRAPE SUGAR, but in diabetes this undergoes an enormous increase. In the normal condition the sugar is at a constant minimum, unaffected by the amount or kind of food taken. IN DIABETES there is commonly a very obvious RELATION BETWEEN THE FOOD TAKEN AND THE SUGAR. There are some diabetics who cease to excrete any excess of sugar so long as they abstain from starch or sugar, but whenever they take any such food it is mostly converted into grape sugar and so excreted in the urine. On the other hand, there are diabetics who excrete an excess of sugar whatever the kind of food they take, and though the sugar may be diminished by the use of a mainly nitrogenous diet, yet it cannot be thus made to disappear. In that case it is obvious that sugar is formed not only from carbo-hydrates, but also from the albuminous principles of the food. According to Traube, diabetes is divided into a slighter and a more severe form according as the sugar is formed from the carbo-hydrates alone, or from nitrogenous principles as well, and it is probable that these forms represent an earlier and a later stage in the disease. Donkin, in view of the relation of the sugar production to the food, distinguishes three stages; first, that in which only the starch or sugar of the food furnishes the grape sugar; second, that in which fats as well as these are converted; and third, that in which albuminous foods, as well as starchy and oily, undergo conversion into grape sugar.

It is obvious that in this latter stage there is a great CONSUMPTION OF ALBUMEN, and in the process of formation of the sugar urea is formed as a waste product in the chemical transformation. We find, therefore, that the UREA is also GREATLY INCREASED in the urine, amounting sometimes to two or three times the normal quantity in the twenty-four hours. In this stage of the disease there is no doubt that

the fatty and ALBUMINOUS CONSTITUENTS OF THE TISSUES are also used for the formation of sugar, and that the albuminous principles of the tissues, like the albumen of the food, furnish sugar and urea which appear in the urine.

The problem which we have to face then is, that in diabetes there is, for some reason or other, an EXCESSIVE DEMAND FOR SUGAR in the organism. The greed for sugar seems to acquire intensity as the disease advances, so that while at first it is only the carbo-hydrates which fall a victim to it, there is ultimately a consumption of the nitrogenous foods and even of the nitrogenous tissues. We have to enquire what may be the meaning of this immense demand for sugar. Looking to the manner in which the processes of the body are arranged, we may take it for granted that there is some need to be supplied or else such an excess of material would not be furnished.

Sugar is a crystallizable substance, and wherever it is formed it will readily be dissolved by the juices and find its way into the blood. Its occurrence in the blood and its excretion by the urine are therefore simply a result of the ready solubility and diffusibility of the substance. Its presence in these fluids throws no direct light on its place of origin.

It is natural to look to THE LIVER as the source of the sugar. It is well known that the liver is the place of formation of a substance nearly allied to sugar, namely GLYCOGEN. This substance, as its name implies, has a great tendency to become converted into sugar. It is true that in the living body the liver, apparently, contains glycogen and not sugar. If the liver of an animal be cut out immediately after death and without delay placed in boiling water after being cut into small pieces, then it will be chiefly glycogen that will be found, and any sugar that exists has probably formed after death by the transformation of the glycogen. It is difficult indeed to avoid the occurrence of traces of sugar in this experiment, and if the removal of the liver be delayed a large amount of sugar will be found. These facts show that glycogen is always just ready to be converted into sugar; its conversion is, as it were, every moment imminent. During life this conversion does not take place to any considerable extent, and it is even doubtful whether the small amount of sugar existing normally in the body is due to a conversion of the glycogen in the liver, a comparison of the blood in the hepatic vein with that in the portal giving doubtful results.

We have to consider, however, whether a PATHOLOGICAL CONVERSION OF THE GLYCOGEN INTO SUGAR may not occur in the liver, and in this regard the observations of Bock and Hoffmann are of great interest. These observers succeeded in the production of an ARTIFICIAL DIABETES mellitus by injecting into the blood of rabbits large quantities of a watery solution of common salt. The animals, soon after the injection was made, began to secrete a large quantity of urine, and this urine soon became saccharine. If the injection of salt solution was persisted in, the sugar by and by diminished in the urine and ultimately disappeared.

The question now was as to the source of the sugar, and the condition of the liver was examined with this in view. It became abundantly clear that the sugar in the urine came from the liver and was caused by the conversion of the glycogen into sugar. In all cases where the animal was killed after the diabetes had passed off, the liver was found free both of the glycogen which exists normally and of sugar. If, on the other hand, the animal was killed while the mellituria existed, then glycogen and sugar were both present in the liver. The inference from these observations is perfectly obvious. The abnormal condition of the blood causes the transformation of the liver glycogen into sugar, and the latter being a crystalloid and readily diffusible, it is at once washed out of the hepatic cells and passes into the circulation and on into the urine. The diabetes ceases because all the glycogen in the liver has undergone conversion into sugar and the source of supply is exhausted, the liver in these cases being found free of both glycogen and sugar. We may say, therefore, that a glycosuria *may* be produced by the conversion of the glycogen within the liver into sugar.

It may be said that the diabetes thus produced is temporary and not comparable with the permanent disease in the human subject. Let us suppose, however, that diabetes is due to the conversion of the liver glycogen into sugar, then the problem with which we started will undergo a considerable modification. We saw that there is an excessive production of sugar, but in the view now brought forward this will resolve itself into an excessive production of glycogen which undergoes conversion into sugar. The problem therefore presents itself—Is THERE ANYTHING TO ACCOUNT FOR THE EXCESSIVE FORMATION OF GLYCOGEN?

It is to be presumed that glycogen has an important function in the animal body. Whether it be used in the production of muscular force, as many suppose, or otherwise, it seems clear that such an organ as the

liver would not be engaged in its formation unless it had an important part to play. It is to be presumed then that glycogen supplies some need in the organism, and that it is formed in the liver for that purpose.

But if, as soon as it is formed in the liver, it is transformed into sugar, then the need in the organism will not be supplied. The sugar being a crystalloid will be washed out, and very little glycogen will get into the blood. In such circumstances the organism will have, as it were, a hunger for glycogen, the liver will be stimulated to supply it, and will produce more glycogen. As soon as it is formed, however, the glycogen will be transformed into sugar, and the excessive demand for glycogen will only result in an excessive supply of sugar. In this case the liver will be stimulated to an ever-increasing formation of glycogen which will immediately pass into sugar. We can understand how in the earlier stages all foods which are near to glycogen in their chemical composition will be at once utilized, and how as the disease goes on and the demand becomes more urgent, the other kinds of foods and even the tissues of the body will be used.

So long therefore as the hepatic cells retain their activity we may presume that they will react to the hunger for glycogen, and the production of sugar will be the result. If the hepatic cells be destroyed or weakened the probability is that the diabetes will diminish, the disease requiring that the hepatic cells retain their energy.

It would appear from the above that diabetes is explainable on the supposition that the glycogen undergoes abnormally a transformation into sugar, and that this occurs in the liver itself. We have now to inquire whether any indication exists as to THE CAUSE OF THIS TRANSFORMATION OF THE GLYCOGEN.

In the experiments of Bock and Hoffmann already alluded to it appears that a particular abnormal condition of the blood is capable of producing this transformation. An enormous dilution of the blood with salt solution seems capable of inducing the liver glycogen to pass into sugar. A temporary diabetes has been produced in a variety of other ways, and all of them are explicable on the ground of an abnormal condition of the circulation of the liver.

The inhalation of nitrite of amyl induces a temporary glycosuria. We know that this agent produces a general vaso-motor paralysis, and a general dilatation of the systemic arteries. With the other arteries those of the abdomen will dilate, and the blood passing through the capillaries at an increased rate will reach the portal vein at a higher

pressure than normal. The circulation in the liver will therefore be accelerated and the blood will be less venous in character, having passed rapidly through the capillaries of the intestines and other organs.

The celebrated diabetic puncture of Bernard is made in the medulla oblongata, and we know that in this part of the nervous system are situated the principal vaso-motor centres of the body. There is therefore here also a paralysis of the arteries just as after the inhalation of nitrite of amyl. Injuries to the brain, spinal cord, and sympathetic sometimes produce a temporary glycosuria, and they also may cause vaso-motor paralysis.

The observations of Pavy are important in this regard. He produced glycosuria by the injection of defibrinated arterial blood into the portal vein, and here again there is an excessive supply of blood to the liver. But then Pavy also produced glycosuria by ligaturing the portal vein, and so cutting off the blood supply except through the hepatic artery, and at first this result seems a very contradictory one.

The effect of that experiment would be to cause the liver to be supplied with arterial blood alone, and we may presume that the hepatic artery would dilate and so allow of an additional flow of blood. According to the researches of Cohnheim and Litten (Virchow's *Archiv*, vol. lxvii.) the blood of the hepatic artery, after supplying the connective tissue, gall ducts, and walls of the large blood-vessels, passes into the inter-lobular veins and on into the proper hepatic capillaries, so that the blood of the hepatic artery is finally distributed with that of the portal vein. When the portal vein is closed, the circulation in the liver will be kept up, but only by the blood of the hepatic artery.

From these observations Pavy concluded that the cause of the glycosuria when the portal vein was ligatured was the circulation of arterial blood in the liver, and he proceeded to determine whether it was possible in animals to produce diabetes by supersaturating the whole blood with oxygen, so that the blood in the portal vein would be virtually arterial. He effected this in various ways; by causing the animals to inhale oxygen; by using artificial respiration till the fact that the animals ceased to make any spontaneous respiratory movements showed a deficiency of carbonic acid; by causing the animals to inhale carbonic oxide. In all these ways glycosuria was produced. It would appear therefore that when diabetes is artificially produced in animals, the one essential condition is that the liver should be supplied with unduly oxygenated blood, such blood causing the glycogen to be transformed into sugar in the liver itself.

We have now to consider the question whether this view will explain the occurrence of diabetes in the human subject. Is there any evidence of such an alteration of the CIRCULATION IN THE LIVER IN CASES OF DIABETES? It is to be noted here that in order to an active hyperæmia of the portal circulation there must be an active hyperæmia in the parts to which the cœliac and mesenteric arteries are distributed. The circulation in the portal vein depends entirely on that in these vessels, and unless the blood passes in greater abundance and more rapidly than it does normally through the vessels of the abdominal viscera from which the portal blood comes, then it cannot pass more quickly through the portal vein. It is not, therefore, as is sometimes stated, a question directly of vaso-motor paralysis of the liver. Moreover, if diabetes depends on the blood in the portal vein being unduly oxygenated, then the only possible explanation of this will be that the blood passes so quickly through the capillaries of the alimentary canal and other organs that it is imperfectly deoxygenated. The question to be answered then is, whether there is any evidence of diabetes being due to a vaso-motor paralysis inducing an active hyperæmia of all these organs.

Such a vaso-motor paralysis might arise by disease of the central nervous system, or of the local centres in the abdomen, mainly the cœliac plexus. In regard to the latter, some cases have been recorded (by Frerichs, Klebs, and Recklinghausen) in which diabetes has coexisted with atrophy, formation of calculi, or cancer of the pancreas. In cases observed by Klebs there was, along with the atrophy of the pancreas, a very marked change in the cœliac plexus consisting of a great destruction of ganglion cells. It seems very probable, considering the nearness of the pancreas to the cœliac plexus, that a cancer or the changes resulting from the formation of calculi in the ducts of the gland, might extend to the cœliac plexus, and Klebs accounts for the diabetes in his cases on the view that there was vaso-motor paralysis produced by the destruction of the ganglion cells of this plexus. In one of his cases indeed there was observed after death an extraordinary dilatation of the hepatic and splenic arteries and the gastric branches of the cœliac axis, the last named branch attaining the size of a goose quill and presenting a highly convoluted course. These facts seem to confirm the view that in man diabetes may be produced by paralysis of the arteries in the domain of the cœliac plexus.

There have been also cases in which diabetes seemed to follow injury to the spinal cord or medulla oblongata, but these have been cases of

temporary glycosuria comparable to that following Bernard's diabetic puncture. On the other hand there have been a few instances of softening of the brain and intra-cranial tumours in cases of diabetes, but these have been too rare to be regarded as of much importance in the pathology of diabetes. For the most part there is little or no alteration visible to the naked eye in the central nervous system.

Recently Dickinson has described minute changes in the central nervous system, consisting mainly in excavations around the arteries, produced apparently by exudation from these vessels with disintegration of the brain substance around. In very recent cases there was even accumulation of leucocytes or hæmorrhage around the arteries, but in the older cases a cribriform appearance, the arteries being surrounded by widened canals. These lesions are scattered through the brain, the largest and most striking being present in the corpora striata, optic thalami, pons, medulla oblongata, and cerebellum. They are less marked in the cord where in addition there is usually great dilatation of the central canal. The white matter of the cerebral convolutions also frequently presents similar changes.

These lesions are held by Dickinson to be primary and directly related to the cause of the disease. If this view be correct, then we should have lesions of the central nervous system leading to diabetes, and doing so probably by vaso-motor paralysis of the arteries of the abdominal viscera. This view is open to the objection, however, that these lesions in the nervous system may possibly be secondary, due to a dilatation of the arteries, not to exudation from them, especially as we know that exudation occurs rather from capillaries and veins than arteries.

Turning to the abdominal organs themselves, there have been in many cases indications of congestion observed. We have already referred to the enlargement of the arteries in one of the cases described by Klebs. The liver itself is generally described as congested, and in a few cases there has been thrombosis of the portal vein.

The characteristic red tongue of advanced diabetes has been cited by Pavy as evidence of a progressive congestion of the alimentary canal. The congestion at first is confined to the abdominal organs, but in the later periods extends to the mouth, the vaso-motor paralysis being progressive.

All the facts may be held as indicating that diabetes depends on the liver being supplied with blood of an abnormal character and at an accelerated rate of speed. The congestion of the liver depends on

abnormal nervous arrangements, and these may be local, affecting the cœliac plexus, or possibly situated in the central nervous system. The observations of Dickinson would seem to point in the latter direction, but they stand in need of confirmation, and besides, the lesions may possibly be the effect rather than the cause of the affection.

In regard to the other changes in diabetes mellitus, little has to be said. The tissues appear to be peculiarly vulnerable, wounds heal badly, inflammations are generally very severe, often going on to suppuration and gangrene, phthisis pulmonalis often closes the scene, and is frequently very acute. General emaciation is a striking feature in advanced cases. The kidneys may be found enlarged and their epithelium fatty, but this has no direct connection with the essential pathology of the affection.

INFLAMMATION.

THIS is a subject whose importance in pathology can hardly be overestimated. From the time of John Hunter its phenomena have been taken as the basis of various speculations on the nature of pathological phenomena in general. Following the course we have hitherto adopted, we have first to consider the conditions under which inflammation occurs.

ETIOLOGY OF INFLAMMATION.—In many cases the causes of inflammation are obscure, and this applies mainly to internal organs whose actions are greatly hidden from our view. Inflammation is PRODUCIBLE ARTIFICIALLY, and if we study the modes of production we shall find that agents are used to which the general name of IRRITANTS is applied. The inflammation is produced, it is said, by irritating the part in some way. This name irritant is apt to be misleading, as it very readily gives rise to the conception of a stimulating action; whereas if we consider the nature of the so-called irritants we shall find that they are rather of a deadening than of a stimulating kind. They are agents which, when acting strongly, are calculated to kill the tissues, and acting less strongly they may be supposed to damage it; it is in this case that they produce inflammation. A certain degree of heat or cold will kill, a less degree will lead, if sufficiently prolonged, to inflammation. Such agents as croton oil, nitrate of silver, chloride of zinc, have a damaging action on the tissues, and they are some of the commonest in use when inflammation is to be produced. Again, traumatic causes produce inflammation; a direct injury inflicted may kill, but acting less vigorously it may produce inflammation.

It may be said, perhaps, that in inflammation of internal organs there is no such definite cause to be discovered. In pneumonia it might be supposed that there is no direct irritant or deleterious agent

attacking the lung tissue. But even here there is reason to believe that there is some such agent at work. In one of the hospitals in Glasgow a medical man prescribed a table-spoonful of cough-mixture; the nurse gave a table-spoonful of carbolic acid instead. The result was an acute pneumonia presenting the usual physical signs and symptoms. In this case there was a deleterious agent introduced into the stomach and so into the circulation, and it acted on the tissue of the lungs (perhaps mainly on the blood-vessels), possibly during the process of excretion by these organs; the result was an acute inflammation.

Again, when large blisters are applied, it sometimes happens that the active chemical principle is absorbed, and, passing into the blood, produces inflammation of the kidneys probably during the process of excretion. We have seen also that after transfusion of blood the hæmoglobin is sometimes dissolved out from the blood corpuscles and produces inflammation of the kidneys. And so in all inflammations we are to infer the existence of some deleterious agent, although it is very often difficult to tell whence it has come and what is its nature.

At this point it may properly be enquired, whether THE NERVOUS SYSTEM has anything to do with the causation of inflammation. There are not a few facts which suggest, at least, some connection. In some of the instances the connection is clearly an indirect one. For instance, when inflammation of the eye results from division of the fifth nerve, the inflammation is really traumatic in its origin. By the severance of the nerve the reflex action of winking is abolished as well as the secretion of tears, and so the organ is exposed to injuries and unable to get rid of foreign bodies. The inflammation is the result of irritation from without, and, if the eye be carefully preserved against such injuries, the inflammation does not occur.

But there are cases where nervous action has a very important and apparently direct relation to the cause of the inflammation. A man with a stone impacted in his urethra will have an inflammation of the testicle. Or after the passage of a bougie through a urethra with a partially healed wound, there will be a rigor with immediate suppression of urine and an acute inflammation of the kidney. These results can only be effected by reflex action, and there are various ways in which we may suppose them to occur. Reflex irritation may produce, through the vaso-motor nerves, a contraction of the arteries of an organ, and in the case of the kidney this contraction may conceivably be sufficient virtually to bring the circulation to a standstill. The immediate

suppression of urine resulting on the passage of a bougie can scarcely be accounted for except on the supposition of such a spasmodic contraction amounting almost to occlusion of the renal arteries. If such a stagnation of the blood continues long enough the vessels will be so damaged that when the circulation is restored inflammation must result.

But there are cases of internal inflammations which cannot be explained merely on the supposition of a reflex stimulation of the vasomotor nerves. The manifest relief which many inflammations undergo in consequence of counter-irritation has been pointed out by Lister as indicating the influence of the nervous system in producing inflammation. The application of the actual cautery to the skin over an inflamed and painful joint will often relieve the pain and inflammation instantaneously. It is as if there was in the nerves of the part a state of over-action which affected injuriously the tissues. This over-action being relieved by a still greater stimulation of nerves connected reflexly, the inflammation subsides.

It is probable that even in such cases nervous action alone is not sufficient to produce inflammation. It is more likely that under certain conditions of the local nervous arrangements the tissues are specially weak, and are liable to be damaged by agents which, under normal conditions, they would resist. It has been shown that a mild inflammation of the bone marrow produced by caustics may be converted into an intense inflammation by causing the animal to eat putrid food. Here an existing damaged state makes the tissues unable to resist the attack of a further damaging agent which normally they are able to withstand. It may be similar in the case of many internal inflammations produced apparently by exposure of the surface of the body to cold. Such exposure may produce, by reflex action, a state of the nervous system rendering the organ peculiarly liable to damage from conditions of the blood which otherwise would not produce any such effect. In all these cases, also, it is to be borne in mind that the reflex action may affect specially the vascular system.

It may be added that besides conditions brought about through the nervous system there may be individual peculiarities, hereditary or acquired, rendering different persons variously liable to the action of irritants, and even in the same person the various organs of the body may show different degrees of resistance. The character of the inflammation also will, to some extent, be influenced not merely by the nature of the agent causing it, but also by the state of the individual.

In studying individual cases of inflammation it will be important to consider BY WHAT PATH THE IRRITANT HAS REACHED THE PART which has become inflamed. In many cases it reaches it by the blood, and as the blood is distributed in every part of the organ, the inflammation will not probably show any special localization. And so, when we find two symmetrical organs both of which are attacked in every region, we generally infer that the agent causing the inflammation has come by the blood or, at least, by a path common to both. Of course, there may be local differences in the organ itself of such a character that every part will not be equally susceptible to the action of an agent calculated to produce inflammation, and so the disease may develop more in one part of the organ than in another, although the general character of its distribution will generally still suggest the path by which the agent has come.

THE PRINCIPAL PHENOMENA OF INFLAMMATION.

The classical signs of inflammation are redness, swelling, heat, and pain, but in studying the nature of the process it will not be proper to follow this division. We have to investigate the exact nature of the processes occurring in the inflamed part, and in order to obtain a comprehensive view of the subject we shall, in the first instance, give an illustration which exhibits the main phenomena, and afterwards consider the subject under headings suggested by that illustration.

A simple EXPERIMENT may be performed to illustrate the principal phenomena at the outset of an acute inflammation. If a frog be paralysed with curare, the web of the foot may be spread out and observed under the microscope. With a pair of scissors a superficial longitudinal wound may be made, taking care to remove little more than the epithelium. By this operation the connective tissue of the web, with its vessels, is exposed; the action of the scissors in cutting, and the unusual exposure to the air, affect these structures, and the various phenomena of inflammation soon begin to manifest themselves, care being taken to keep a moist atmosphere around the web so as to prevent the wound, deprived of its epidermis, from drying. At first the circulation goes on in the bottom of the wound as before, the area is merely more transparent from the absence of the epithelium. But very soon, if an artery is near or in the wound, it dilates, and there is an acceleration of the stream in

the capillaries and veins. But this soon disappears, and the circulation, especially in the capillaries, becomes slower and slower, till here and there the blood corpuscles now and then stand still for a moment or two. By and by a peculiar condition becomes visible in the veins. Normally, the blood corpuscles flow down the middle of the vein, and the peripheral zone contains plasma with a few white corpuscles rolling along. As the inflammation proceeds, the white corpuscles come to occupy this zone, and to adhere to the inner surface of the vessel. The individual corpuscles may not be all absolutely stagnant, they adhere for a time and then depart, but the result of the process is that there is a nearly complete filling up of the zone with white blood corpuscles, so that the vein seems pavemented internally with these cells. This is seen not only in any vein which may happen to be in the bottom of the wound, but also in those for a short distance outside it.

If the attention be now directed to the surface of the wound, it soon becomes manifest that certain peculiar bodies are appearing there. These are at first seen mostly towards the edge of the wound, and are especially numerous in the neighbourhood of veins where the white corpuscles are adherent. They are of various shapes, and present a transparent gelatinous appearance. If observed carefully they are seen to be altering their shapes, presenting the well-known amœboid movement, such as shown in Fig. 21. These cells gradually increase in numbers, and by their contractile power they move from the periphery towards the centre of the wound till they may come to cover it entirely. These bodies may be removed from the wound by placing the end of a capillary glass tube on the surface. A fluid runs up into the tube, and in this fluid are these free cells. The fluid may now be blown on to a glass slide and examined under a higher power of the microscope, when the slow amœboid movement will be still more manifest. If, in the drop of fluid, these bodies are allowed to die or are killed by the addition of a reagent, they become globular and granular, in fact, have the characters we recognize as those of white blood corpuscles, lymph corpuscles, pus corpuscles—of leucocytes in general. The addition of acetic acid to the living cells will first cause them to assume the globular form, and then will bring out the nucleus or nuclei as in an ordinary white corpuscle. The fluid in which these corpuscles are found is



Fig. 21.—A leucocyte from human blood showing amœboid movement. (KLEIN.)

coagulable, and if it be kept till the corpuscles have died strings of fibrine will be found in it. If this experiment be made in summer, the whole of these phenomena will manifest themselves in a few hours, and in five or six hours the entire wound may be plastered over with amœboid cells.

In the course of a few more hours the wound begins to be covered in with new-formed flat epithelium. This begins at the margins, and if the wound is small it may be wholly covered within twenty-four hours. The amœboid cells are covered in, but they very soon disappear, and the connective tissue of the web remains with a thin transparent epithelium covering it.

Without following out this experiment further, we may now proceed to consider the principal phenomena of inflammation, which have been partly illustrated. We shall consider, first, the state of the vessels; secondly, the condition which is illustrated in this experiment by the fluid on the surface of the wound containing amœboid cells; and lastly, the condition of the tissues in inflamed parts.

I.—THE STATE OF THE VESSELS IN INFLAMMATION.

When an irritant is applied to a transparent vascular tissue, such as the tongue or web of the frog, it produces effects which vary slightly, according to its nature. If croton oil be applied, there is first a slight contraction of the arteries, soon followed by a dilatation of them. If ammonia be used, there is dilatation without previous contraction. The DILATATION OF THE ARTERIES leads to an ACTIVE HYPERÆMIA, the current is accelerated in the arteries, capillaries, and veins, and these vessels are overfilled; there is a great excess in the quantity of blood passing through the vessels. The acceleration of the current does not persist, however, in the most affected parts; on the contrary the blood corpuscles begin to lag, especially in the capillaries and veins, although there is still acceleration in the arteries, and in the capillaries and veins in the less inflamed parts. This stagnation in the capillaries and veins may assume a high degree, especially in the part most acted on by the irritant. Although the current is slow in these vessels they remain overfilled, a passive hyperæmia supervenes on the active hyperæmia; at the same time the white corpuscles accumulate on the internal wall of the veins in the manner already described, and they also adhere at intervals in the capillaries. The circulation may come almost to a standstill in the capillaries of the parts most affected, while at various distances out from this there will be manifest a less and less

amount of retardation till a zone is reached where the retardation disappears, and by and by gives place to acceleration.

We have now to consider what may be the explanation of these various phenomena which the vessels manifest. The observations of Lister (*Phil. Trans.* for 1858, vol. 148) present us with a view of this subject which has been largely confirmed by other observers, and has only been corrected in one or two particulars. Saviotti has also published some very excellent researches (Virchow's *Archiv*, vol. l.) which are for the most part confirmatory of Lister's views.

CONTRACTION OF THE VESSELS, which is in some cases the primary phenomenon, is probably reflex. It is frequently absent, and when it occurs is always very transitory. Irritation of sensory nerves is known to produce contraction of arteries by reflex action. If the web of the frog be observed under the microscope, and, at the same time, the skin irritated by tapping or by twitching with the forceps, the arteries will be seen to contract, and this contraction does not occur if the sciatic is first divided. In the case of inflammation, therefore, we may conclude that the primary contraction when it occurs is reflex, produced by the irritation of the sensory nerves.

The dilatation of the arteries leading to acceleration of the stream, or ACTIVE HYPERÆMIA (also called DETERMINATION OF BLOOD), is not, like the contraction, of reflex origin. In order to enforce what follows, it is important here to recall the fact that irritants act injuriously on the tissues, and, in a certain sense, paralyse them.

That the effect of IRRITANTS is to PARALYSE THE TISSUES was long ago shown by Lister in his important researches on inflammation. The skin of the frog is supplied with pigment cells. These cells are branching bodies (they are shown in Fig. 15, p. 52), and they possess the power of scattering the pigment into many branches, or of concentrating it more or less into the central parts of the cell. They are under the command of the nervous system, and by their means the animal is capable of changing its colour, presenting a dark hue when the pigment is dispersed, and a lighter colour according to the degree of concentration. Some irritants have the immediate effect of dispersing the pigment, and this itself is so far an evidence of paralysis as the dispersed condition seems to be the state of rest of the cells; but whether the pigment is dispersed or not, the animal loses control of its pigment in the affected area, which does not change its colour with the rest of the skin, and may be found dark while the animal is pale, etc.

We have already had occasion to remark that, as Lister long ago inferred, there are probably, in connection with the arteries, peripheral ganglia which are the immediate regulators of the state of contraction of these vessels. If these ganglia be paralysed the arteries will dilate, and this is apparently the cause of the dilatation under consideration. That the DILATATION IS NOT REFLEX seems sufficiently proved by the fact that it occurs after all connection with the central nervous organs has been severed. For instance, the sciatic nerve has been divided in a frog's leg with resulting dilatation, but the application of an irritant to the web produces an increase of the dilatation. Again, the brain and spinal cord in the frog have been destroyed (Cohnheim), but the application of an irritant to the tongue still produces dilatation of its arteries. The acceleration of the blood-current in the arteries, capillaries, and veins, will be understood from what has gone before to be a direct result of the dilatation of the arteries; we have, in fact, an active hyperæmia. It will not be understood, however, that, apart from inflammation, active hyperæmia is never produced by reflex action; it is frequently so, but inflammatory active hyperæmia is a local phenomenon. It is not impossible that an inflammatory may be associated with a reflex hyperæmia, and the problem may in this way be complicated.

The cause of THE RETARDATION may not at first be apparent, but the researches of Lister afford an explanation of it. The cause of the retardation is an INCREASED ADHESIVENESS of the blood corpuscles. This is a matter of direct observation. The corpuscles in the inflamed area can be seen to move sluggishly along the wall as if attracted by it, and the PAVEMENTING OF THE VEINS with white corpuscles is clearly due to increased adhesiveness. It has been pointed out by Lister that, when the blood is removed from the vessels and comes in contact with dead matter, the blood corpuscles acquire an adhesiveness which they do not possess inside the normal vessels. The red corpuscles stick together by their flat surfaces and form the well-known rouleaux. The adhesiveness of the white corpuscles is not so obvious when a drop of blood is examined outside the body, but we have reason to believe that it is even greater than that of the red. Now inflammation damages the walls of the vessels, with the result that the corpuscles behave as if in the presence of dead matter—they become adhesive. This is excellently shown in an experiment of Lister's. He ligatured the leg of a frog, producing thereby stagnation of the blood in the vessels, but on examining the web it could be seen that the corpuscles were able to move freely among one another—there was

obviously no adhesiveness. But now, if a piece of mustard was applied to the web, this free movement ceased in the area affected; the corpuscles became adherent among themselves and to the wall of the vessels. The result of this was an accumulation of the corpuscles in the irritated area; any corpuscles which happened to glide into the area remained adherent there, and so, by degrees, the vessels became overfilled—a state of hyperæmia superinduced on stagnation. If any corpuscle happened to escape from the affected area, it ceased to be adhesive, and moved freely about.

We may therefore infer that the retardation of the current and the pavementing of the veins with white corpuscles are the result of the injury to the vessel wall, and it may be added that, in connection with inflammations, all degrees of stagnation up to absolute stoppage or STASIS may be produced, and are often manifested together in the same case.

We may now sum up the conditions presented by the blood-vessels in the early periods of inflammation as follows: the arteries dilate by a relaxation of their muscular coats, due to a paralysis of the peripheral ganglia. In some cases this dilatation is preceded by an evanescent contraction. The immediate result of the dilatation of the arteries is active hyperæmia, or determination of blood, involving overfilling of the arteries, capillaries, and veins, with acceleration of the current. This is followed by retardation of the current, the vessels remaining dilated and hyperæmic, and this retardation may go on to almost complete stasis in the capillaries. The retardation is due to adhesiveness of the corpuscles, and to the same cause is to be traced the pavementing of the veins with white corpuscles.

It is sometimes possible in acute inflammation of the skin, as in the case of a boil, to observe conditions directly traceable to the state of the vessels here indicated. Thus at the peripheral parts of such a focus of inflammation the skin presents a fiery-red appearance due to determination of blood; the red colour may be pressed away with the finger, but it immediately returns. Inside this zone there is an area in which the redness is not so vivid, and when the red colour is pressed away it returns sluggishly; the corpuscles are here already adherent, and the current retarded. Then in the more central parts a dusky red appearance is presented, and on pressure it may be impossible or very difficult to remove the redness; here a condition of extreme stagnation exists.

In connection with the state of the vessels, we have to consider the

TEMPERATURE OF INFLAMED PARTS. It is well known that heat is one of the so-called cardinal symptoms of inflammation, and in external parts a feeling of heat is almost universally complained of. The nerves of internal parts seem incapable of communicating the sense of differences in heat and cold. A hot potato swallowed gives an impression of pain, and it may be argued that the pain in internal parts during inflammation is partly due to increase of temperature. We have to enquire whether there is an actual production of heat in inflamed external and internal parts.

There is no doubt that the temperature of inflamed external parts is increased in inflammation. John Hunter long ago determined this by actual observation. He had a case of hydrocele to deal with, and undertook its treatment by the old operation of laying open the sac and inserting lint dipped in an irritating salve with a view to producing inflammation. At the time of the operation he found that the temperature in the tunica vaginalis was 92°, but next day, inflammation having been induced, the temperature had risen to $98\frac{3}{4}°$. The question here arises whether this increase of temperature is due to an actual production of heat in the inflamed part, or to an increased supply of hot blood, due to dilatation of the arteries.

That there is A GREATLY INCREASED SUPPLY OF BLOOD to inflamed external parts has been proved by experiment (Cohnheim). If the foreleg of a dog be inflamed by scalding or by painting with croton oil or any other method, the quantity of blood coming from the limb may be compared with that on the sound side by introducing cannulas into the corresponding veins on the posterior aspects of both legs. In a recent inflammation the amount of blood on the inflamed side may reach nearly the double of that on the sound side, and it may even be as great as when the arteries have been relaxed in a limb by dividing the axillary plexus of nerves. This extreme degree of difference may not continue long, but even for some days it is frequently very considerable. The relaxation of the arteries, it is clear, produces a determination of blood which extends beyond the immediate focus of the inflammation, and is not counter-balanced by the retardation.

John Hunter, having determined the great increase in temperature above referred to, yet came to the conclusion that it was due to the determination of blood, for he found that the temperature of an inflamed external part never exceeded or even quite reached that of a normal internal part, or, in other words, of the blood in internal organs. Since Hunter's time, Simon has thought to prove that there is some develop-

ment of heat in inflamed parts. His experiments seemed to show that the arterial blood passing to an inflamed external part is not so warm as the focus of inflammation, and that the venous blood returning from the part is warmer than the arterial blood, although not so warm as the focus of inflammation. But the experiments of Jacobsen, made with more exact instruments, entirely confirm the views of Hunter. It appears that the most acute inflammation of the skin or muscle never causes an elevation of temperature sufficient to reach that of the rectum, vagina, or abdomen, the difference being generally 1° to 2° C. Again, in artificial inflammations of internal parts, as in peritonitis or pleurisy, the temperature was never raised to that of the left ventricle, being always from ·2° to ·5° C. under it. This means that in these parts, the temperature being already near that of the blood in the left ventricle of the heart, inflammation, leading to an increased supply of blood of a similar temperature, causes virtually no elevation above the normal heat. Again Cohnheim has found that, when in one fore-paw of a dog, a state of acute inflammation is induced, while in the other active hyperæmia is produced by dividing the axillary plexus of nerves, the temperature in the inflamed foot is always slightly less than that in the other. We may safely infer, then, that in inflammation there is no local production of heat.

II.—THE INFLAMMATORY EXUDATION.

In the experiment sketched at the outset the inflammatory exudation was the fluid which collected on the surface of the wound. We saw that this fluid contained amœboid cells, and that it was coagulable. We may thus consider the inflammatory exudation as consisting of cells, serous fluid, and fibrine, and we shall in the first place pass each of these under review.

The Exudation Cells.—The resemblance of the cells met with in acute inflammations to the leucocytes in the blood long ago suggested the idea that they are white blood corpuscles. In the year 1846 Waller observed the pavementing of the internal coat of the veins with white blood corpuscles in the inflamed tongue of the frog, and as he saw similar cells outside the vessel he inferred that the white corpuscles had got through the wall. It was, however, difficult to believe that the solid globular white corpuscles could pass through the intact wall of a blood-vessel, and Waller's views, although supported by

Wm. Addison, were lost sight of. By and by, however, Recklinghausen demonstrated that pus corpuscles and white blood corpuscles possess contractile power by virtue of which they are able to move from place to place, and to alter their shapes in the most diverse fashion. This paved the way for the actual observation of their passage through the walls of the vessels made by Cohnheim. He made his observations on the mesentery of the frog. When this exceedingly delicate and transparent structure is drawn out of the body through a wound in the lateral aspect of the abdomen, the mere exposure to the air is sufficient to set up an acute inflammation, the phenomena of which can be readily observed under the microscope. Let us suppose that the pavementing of the veins has occurred, and that there is an occasional white corpuscle adherent in the capillaries, and the following surprising phenomena show themselves, as described by Cohnheim himself. "One sees, as a rule, first in a vein which presents the pavementing with white corpuscles, but sometimes in a capillary, a pointed projection in the external contour of the vessel; it pushes itself farther and farther outwards, it increases in thickness, and the pointed projection develops into a colourless rounded knob; this increases in length and thickness, sends out fresh points, and draws itself gradually outwards from the vessel wall, with which it comes to be connected only by a long thin stem. Finally, this also lets go the vessel, and there lies outside a colourless, dull, glancing, contractile corpuscle, with several short processes and a long one, of the size of a white blood cell, with one or several nuclei; in a word, a white blood corpuscle."

In the investigation of inflamed tissues in the usual way after death, there are often indications to be met with of this process of emigration of the white blood corpuscles. The leucocytes in the tissues, for instance, are frequently aggregated especially around the blood-vessels. In the accompanying Fig. 22, the appearances in the human omentum are shown in a somewhat diagrammatic form, and the appearances there are sufficiently suggestive.

There is no longer any doubt then that the white corpuscles of the blood wander out of the vessels, and they become the so-called exudation cells of recent inflammations. But, besides the leucocytes, the RED CORPUSCLES also pass out of the vessels, and this they do by the process of DIAPEDESIS of which we have already seen examples. The white corpuscles are active contractile cells, and they generally pass through the vessels to a larger extent than the red ones, but there are some inflammations in which these red corpuscles also pass through in

large numbers. So far then as the cells which appear at the outset of an inflammation are concerned, they are doubtless, mainly, if not entirely, blood corpuscles.

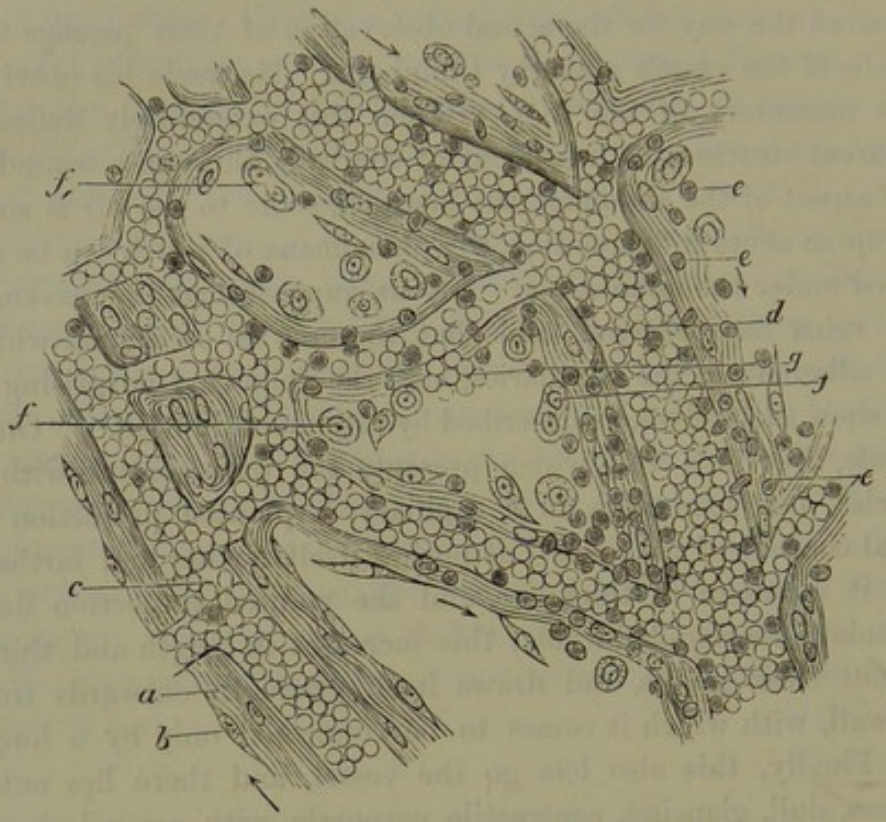


Fig. 22.—Inflamed human omentum. The phenomena of inflammation are seen in the veins and capillaries, the condition being normal at the artery (*c*) where *b* represents endothelium covering the trabecula (*a*). In the vein (*d*) there are many white corpuscles along the wall. Some of these are emigrating (*e*); *f*, desquamated endothelium; *g*, extravasated red corpuscles. (ZIEGLER.)

THE SEROUS EXUDATION.—This has obviously its source in the blood. In inflammation there is a greatly increased transudation of the fluid of the blood from the vessels, and this passes primarily into the serous spaces. If these are, naturally or by reason of a wound, in communication with a surface, the fluid will appear on the surface. The INFLAMMATORY ŒDEMA indicates a greatly increased circulation in the serous spaces and lymphatics, and this can be proved by actual observation. If the leg of a dog be irritated with croton oil, the foot swells greatly, and if the lymphatics on the external aspect of the leg be then exposed they will be found greatly dilated; a cannula being introduced, the lymphatic fluid will flow from it, drop rapidly following drop, whereas in the sound leg the circulation is very slow. If before setting up the inflammation a cannula be introduced, and an inflammation set

up by placing the foot in hot water, then it will be seen that almost immediately an increase in the flow of lymph occurs, while the œdema comes on later and is not followed by further increase in the flow. The meaning of this is that the œdema only develops when the increase of transudation is too great for the lymphatics to dispose of.

But not only is the transudation increased, it is altered in quality. We have seen that in passive hyperæmia the transudation is a watery fluid, more watery than the normal lymphatic fluid. In inflammation it is a concentrated fluid, containing a great deal more albumen and corpuscles, and on being shed, or even in the cannula, it coagulates.

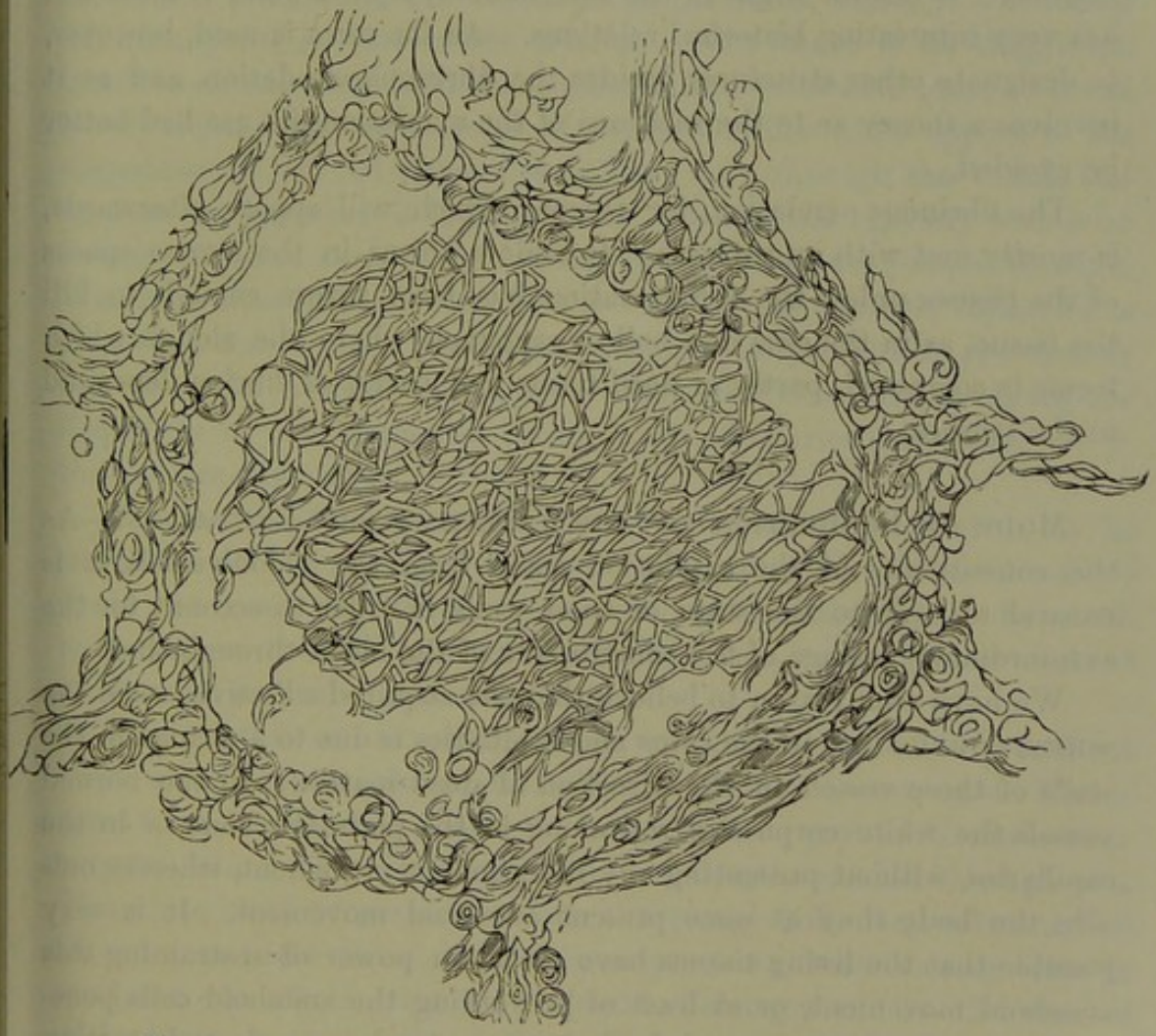


Fig. 23.—Lung alveolus in acute pneumonia. A plug of fibrine, with a few leucocytes in it, fills the alveolus. × 350.

THE FIBRINOUS EXUDATION.—It is a familiar fact that after the infliction of a wound there occurs a glazing of the surface within a few hours, and this glazing is due to the coating of the surface with a layer of fibrine. In addition to this there is discharged from the surface a

greater or smaller quantity of serous fluid. This deposition of fibrine on the surface of a wound may be taken as typical of the fibrinous exudation, but a similar deposition of fibrine occurs in many other inflammations, in acute inflammations of serous membranes as in pleurisy, in acute inflammation of the lungs, etc. The fibrinous exudation has all the characters of fibrine seen in a blood clot. Figure 23, for instance, is taken from the lung in acute pneumonia, and it is seen that a lung alveolus is filled with a network of fine fibres.

The fibrinous exudation, especially the yellow layer seen on serous membranes, is often called lymph, but this term is a somewhat confusing one. It has its origin in the coagulable lymph of John Hunter and has very interesting historical relations. As the term is used, however, to designate other structures besides the fibrinous exudation, and as it involves a theory as to the relations of the exudation, its use had better be avoided.

The fibrinous exudation, for reasons which will appear afterwards, is mostly met with on surfaces. It seldom forms in the serous spaces of the tissues unless the inflammation has been severe enough to kill the tissue, as in the case of a boil or carbuncle where the slough which forms is composed, partly of dead tissue and partly of fibrine deposited in the meshes.

Mode of Production of the Inflammatory Exudation.—As the constituents of the exudation come from the blood-vessels, it is natural to look to the state of their walls in order to account for the extraordinary passage of the constituents of the blood through them.

We have seen reason to believe that the acquired adhesiveness of the WHITE CORPUSCLES in the veins and capillaries is due to a change in the walls of these vessels in the direction of dead matter. In the normal vessels the white corpuscles roll along in the plasmatic zone or in the capillaries, without presenting any independent movement, whereas outside the body they at once present amœboid movement. It is very possible that the living tissues have a certain power of restraining this amœboid movement, or at least of preventing the amœboid cells penetrating them. If a piece of dead tissue containing canals and cavities, such as the cornea, be placed in the peritoneal cavity, then the leucocytes in the cavity penetrate into these cavities. In the state of inflammation the capillaries are altered, their walls have undergone a change which renders them more permeable, and being more like ordinary matter they may allow a freer contractility of the corpuscles. It

is therefore the alteration of the wall of the vessel which is the principal agent. It has been supposed that an increase in pressure of the blood in the vessels may have something to do with the emigration of the white corpuscles. But we must be certain to begin with that there is an increase of pressure. As Cohnheim has pointed out, the conditions here are not such as to cause an increase of pressure. There is no obstruction in the veins, in fact the circulation through them is unduly abundant as has already been seen, and any stagnation which exists in the capillaries has its origin in the adhesiveness of the blood-corpuscles. If this stagnation in the capillaries produces any increase of pressure it will do so not in the veins, where it will rather diminish pressure, but in the arteries. Now there is no emigration from the arteries, but from the capillaries and veins alone, and so it can hardly depend on the increase of pressure. The same applies to the diapedesis of the red corpuscles. They pass through the vessels not because the pressure is increased, but because the capillary wall is so deteriorated that even at the existing pressure they are pressed through. We have already seen that in the case of the embolic infarction a diapedesis occurs under conditions in which the pressure is presumably less than the normal. It is to be remarked that here as there the diapedesis of red corpuscles occurs in the capillaries alone, and not in the arteries and veins.

The INCREASED TRANSUDATION OF THE BLOOD PLASMA is to be accounted for on similar principles. Alteration in the vessel wall is again the main condition; and seems in inflammation to be much more serious than in passive hyperæmia, as a much greater amount of albumen and salts pass through.

The FORMATION OF FIBRINE, as we have seen, is a prominent occurrence in many inflammations, and as the constituents of the fibrine come from the blood, it also is to be regarded as part of the inflammatory exudation. The fibrinogen is contained in the exuded blood plasma. The white blood corpuscles contain the paraglobulin and ferment, but in order to yield these, it is necessary, as we have already seen in studying thrombosis, that they should disintegrate. In the case of thrombosis an alteration of the wall of the heart or blood-vessel is necessary in order to the disintegration of the white corpuscles. In the present case it is the tissues outside the vessels that are concerned, and these, as we have seen, are damaged as a necessary condition of the inflammation.

It has already been noted that fibrine forms usually on inflamed

surfaces, and rarely in the substance of the inflamed tissues unless necrosis has occurred. This may be set alongside the fact that thrombosis does not occur in the capillaries unless they have undergone necrosis. The serous spaces in the tissues, like the capillaries, are lined with endothelium ; and these spaces, being small, the white corpuscles will hardly be sufficiently removed from the endothelium to allow of coagulation, so that this will not occur unless the endothelium be dead or shed. In some very acute inflammations of connective tissues (acute phlegmon) there is, however, not uncommonly a fibrinous exudation in the meshes of the tissue, forming a kind of fibrinous œdema. This may be seen not uncommonly in the skin in erysipelas. But where the exudation occurs on a surface and the white corpuscles are removed from immediate contact with the endothelium, then many of them perish and coagulation occurs.

In this connection it may be remarked that the epithelium, like the endothelium, seems to have the power, and perhaps to a greater extent, of preventing the disintegration of the white corpuscles and the formation of fibrine. As a rule, a fibrinous exudation does not form on a mucous membrane, and when it does form it may be taken for granted that the epithelium has died or been shed.

It will be understood that the INFLAMMATORY EXUDATION PRESENTS VARIOUS CHARACTERS, under different circumstances, even apart from the question of coagulation. In some cases it is exceedingly watery, partaking chiefly of the characters of an ordinary transudation. This will be the case mainly in slight inflammations, and in those occurring in persons whose blood is watery. For instance, the inflammations which so frequently occur in Bright's disease have usually a watery exudation. In such cases the exudation-cells will be also small in number.

On the other hand, there are inflammations in which the exudation-cells are exceedingly abundant, so abundant that the inflammation rapidly assumes a suppurative character. This is peculiarly the case with septic inflammations. For instance, in septic inflammation of joints such as occurs in pyæmia we have the exudation rapidly becoming purulent, the pus corpuscles having all the characters of the ordinary exudation-cells, and being doubtless white blood corpuscles. It will be observed that these suppurative inflammations are severe in character, and presumably imply serious alteration of the vessel-walls, such as to allow of the enormous emigration of the white corpuscles which is here presupposed.

It may further be said regarding inflammatory exudations that they

VARY considerably ACCORDING TO THEIR SITE and other relations. We have already said that a serous exudation may flow from a surface, may accumulate in a cavity, or may lie in the serous spaces, causing œdema. We shall afterwards see that the serous fluid may be taken up by cells. Again, the exudation MAY BE MIXED with the secretion of a mucous-membrane or gland. In the former case the exudation will have more or less of the characters of the mucous secretion, variously modified according to the amount of the constituents; thus we may have a mucous, sero-mucous, muco-purulent exudation, and in these exudations epithelium cells, ciliated and otherwise, will often be found. In the case of the kidney, the exudation is to be found mixed with the urine, so that we have albuminuria.

It may here be remarked that the EXUDATION PASSES IN THE DIRECTION OF LEAST RESISTANCE, and will be found to accumulate or escape where it best can; thus in the kidneys it passes largely into the uriniferous tubules, in the lungs it occupies the air-vesicles, in the connective tissue it fills the serous spaces, producing œdema. In some cases the œdema manifests itself mainly where the tissue is loosest; for instance, in inflammations of the larynx, œdema occurs mainly at the base of the epiglottis and the aryteno-epiglottidean folds, giving rise to so-called œdema glottidis.

We have still to consider HOW INFLAMMATORY EXUDATIONS ARE DISPOSED OF. In slight cases the exudation is carried off by the lymphatics, passing by that route back into the circulation, the exudation-cells being perhaps partly retained by the lymphatic glands. In more severe cases, and especially when the exudation is retained in cavities, its disposal is more difficult. The serous fluid will rapidly be absorbed, but the fibrine and the exudation-cells where these are so abundant as to constitute a purulent inflammation, or are entangled in the fibrine, are not got quit of so easily. Pus corpuscles readily undergo fatty degeneration, and we shall afterwards see that structures which have undergone this change by and by disintegrate, and the fat is absorbed. Sometimes, however, the fat is too abundant, or the conditions are not suitable to absorption, in which case the pus may dry in to a cheesy mass, which may afterwards be impregnated with lime-salts. Similarly the fibrine may disintegrate and be absorbed, or dry in and become calcareous.

III. CHANGES IN THE TISSUES AND THE INFLAMMATORY NEW-FORMATION.

We enter here on a somewhat debatable department, especially as under this heading will be included the subject of new-formation in inflammation.

It is undoubted that THE TISSUES in inflammations sometimes UNDERGO RETROGRADE CHANGES. The inflammation, if very severe, may kill the tissue, but short of that there are certain inflammations which are characterized by the occurrence of fatty degeneration in the cells constituting the tissues. It may be said that in severe inflammations, and probably at the outset of all acute inflammations, the tissues take no active part in the processes, and if affected in their structure at all, are affected for the worse. We have already seen that inflammations paralyse the tissues. But it may be presumed that when an inflammation has lasted for some time and has diminished in intensity, the tissues may recover, and it will not be surprising to find that they undergo changes of a kind different from the retrograde processes already mentioned.

This leads us up to the question of the NEW-FORMATION OF TISSUE which is so characteristic of many inflammations. It may here be stated that two views are held as to the origin of such new-formations, the one being that the formative cells are the white blood corpuscles, and the other that the existing tissues, and especially the connective tissues, supply the formative cells. We shall first mention certain facts connected with new-formation and afterwards recur to this disputed point. It need hardly be said that by new-formation is meant the production of a properly organized tissue, the form of tissue produced being for the most part connective tissue containing blood-vessels.

A GRANULATING WOUND, with the resulting cicatrix, may be taken as typical of the inflammatory new-formation, and by considering the occurrences which present themselves there, we shall become acquainted with certain facts connected with the subject. Granulation-tissue is already an imperfectly organized but highly vascular tissue. In the accompanying woodcut (Fig. 24) the injected blood-vessels of a granulating wound are shown, and the degree of vascularity may be inferred.

It is to be observed in the first place that in order to the production of granulations, the INFLAMMATION MUST BE OF SOME DURATION. If a

wound close within the first few days, no granulations are formed. The damage done by the knife in inflicting the wound produces an inflammatory exudation in the form of a glaze of fibrine and a serous

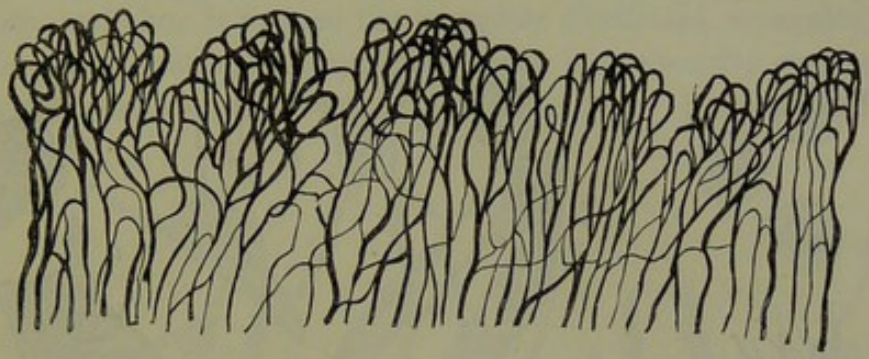


Fig. 24.—Vessels of a granulating wound injected. (BILLROTH.)

discharge. But if the wound be protected from further irritation it will not produce granulations even should it not heal by the first intention. Under antiseptic treatment, if the wound be protected from carbolic acid vapour and other sources of irritation, granulations do not form. Even in the case of a septic wound, after the preliminary glazing of the surface, there is what surgeons call "a pause" of two or three days before the granulations appear. There is in this case a prolongation of the inflammation for several days before the occurrence of new-formation. But, on the other hand, the inflammation must not be too severe, else the new-formation will not occur. Inflammations which rapidly pass on to suppuration are not accompanied by new-formation. Again, in order to new-formation an abundant supply of blood is necessary, and in this connection it may be mentioned that the new-formation of blood-vessels is one of the most marked, as it is frequently the earliest visible manifestation of this process.

A granulating wound appears at first sight to be composed simply of round cells of nearly uniform size. But on more careful examination it is seen that, putting out of view the blood-vessels in the meantime, it consists of TWO KINDS OF CELLS (see Fig. 25). The one kind has the size and general appearance of the white blood corpuscle, and gives with acetic acid a similar reaction (a and a_1). The others (b, b) are about twice as large as these, and as they present a distinct outline and possess an oval nucleus, they have a considerable resemblance to epithelial cells, and are hence sometimes called epithelioid cells. These cells may possess two nuclei (c). Sometimes there are still larger cells with multiple nuclei (c_1), the so-called giant cells, but these are not uniformly present,

and may be left out of sight in the further consideration of the subject. In the new-formation of the tissue these epithelioid cells are mainly concerned, in so much that Ziegler, whose observations are here of very great value, has designated them FORMATIVE CELLS. This author studied

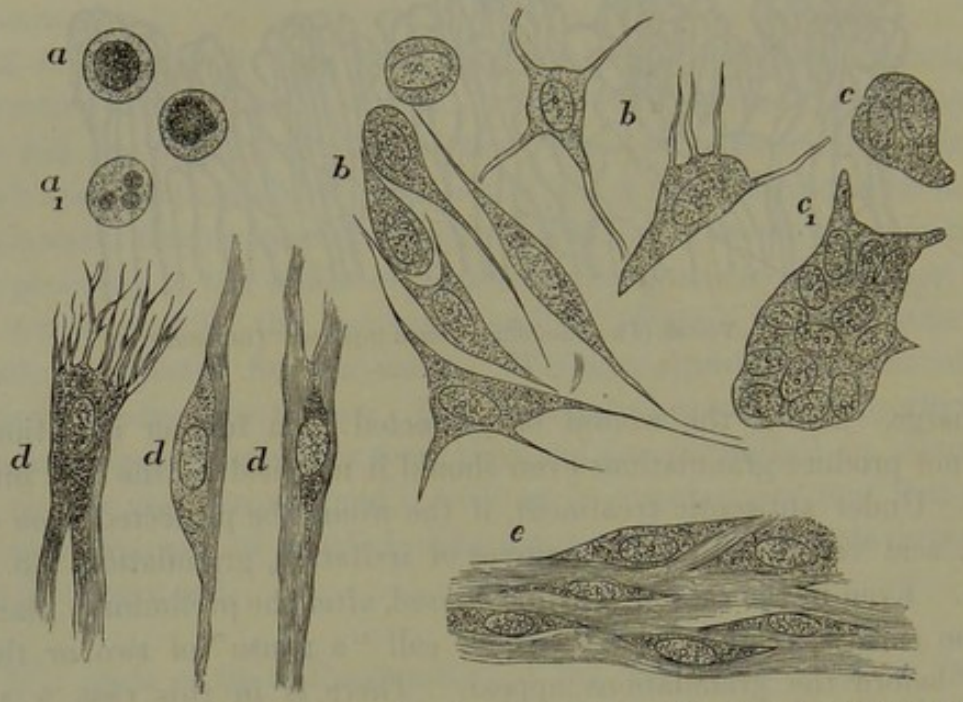


Fig. 25.—Granulation cells. *a* and *a*, leucocytes; *b*, *b*, various formative cells; *c*, formative cell with two nuclei; c_1, with many nuclei; *d*, *d*, *d*, Formative cells developing connective tissue; *e*, complete connective tissue. × 500, Picrocarmine preparation. (ZIEGLER.)

the new-formation of tissue by introducing under the skin or periosteum, or into the peritoneum of animals, two pieces of glass cemented together in such a way that there was free access between them, while the distance apart was no more than a fraction of a line. One of the pieces of glass was a microscopic cover glass, so that anything between the glasses could be studied under the microscope afterwards. These foreign bodies set up inflammation, and through time vascular connective tissue formed around them, and penetrated between the plates of glass. In these ingenious experiments the formative cells did not appear till about the fifth day after the occurrence of the inflammation. These cells are, like pus corpuscles, contractile, but they are much less active, and we shall see immediately that they subsequently assume the characters of fixed cells.

By and by these formative epithelioid cells elongate, and send out processes (*b*, *b*), becoming stellate or spindle-shaped. After a time the processes grow out and become, with a certain part of the substance of

the cell, converted into fine fibres (*d*). In this way it appears the fibres of the new-formed connective tissue are formed, the rest of the protoplasm of the cell remaining as the spindle-shaped, fixed, connective tissue cell (*e*). The fibrillæ, developed out of neighbouring cells, communicate, and thus is formed the complete fibrillated connective tissue.

This new-formation of connective tissue is necessarily connected with NEW-FORMATION OF BLOOD-VESSELS (see Fig. 26). If epithelioid cells are

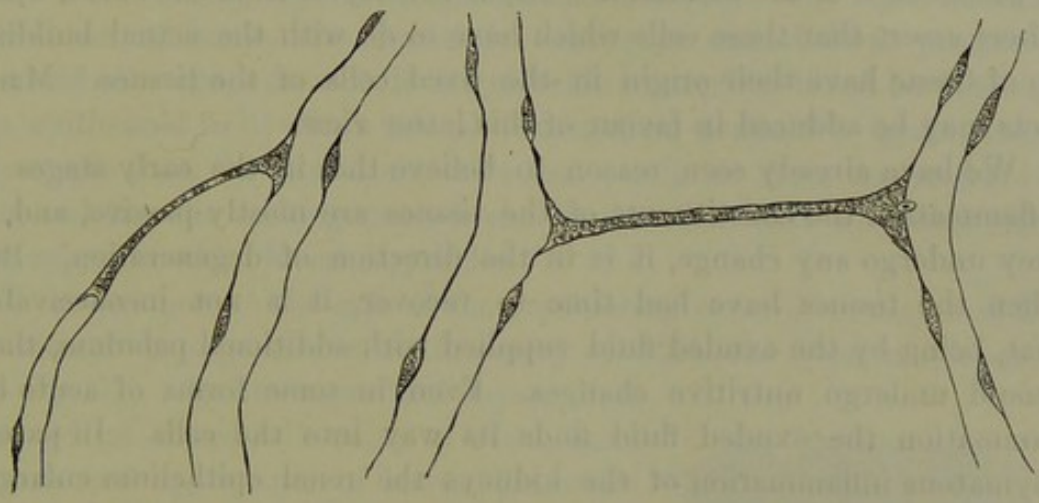


Fig. 26.—New-formation of blood-vessels in a granulating wound. (After ARNOLD.)

formed in advance of the blood-vessels, they do not proceed to the formation of tissue, but undergo fatty degeneration. The formation of the blood-vessels always occurs in connection with the pre-existing vessels, usually the capillaries, and by a process of budding apparently. An elongated process extends out from the wall of the capillary. It meets another process, and so is converted into an arch. The arch and buds increase in thickness, and, by and by, a tunnelling of them begins, and they are by degrees converted into vessels, the blood passing into them. It has been stated by some that in the formation of the blood-vessels from the buds and arches, the tunnelling takes place partly by a conversion of the substance of the solid arch or bud into red blood corpuscles, in a manner similar to what occurs in the original formation of blood-vessels in the embryo. But this seems to be doubtful, and the probability is that no such new-formation of blood corpuscles takes place. The vessels formed are at first mere tubes, and the demarcation of endothelial plates seems to be of subsequent occurrence. The new-formed vessels are then regular capillaries, and by subsequent changes they may increase in size and thickness, and take on the characters of arteries and veins. It is marvellous how rapidly such new-formation of vessels occurs not merely

in inflammations, but also in the formation of tumours, and we may regard this as consistent with the wonderful adaptability which we have already seen the vascular system to show to the needs of the system.

In the formation of the permanent tissue, we have referred to the important part played by the epithelioid cells, but we have not made any reference to the ORIGIN OF THESE FORMATIVE CELLS. Their origin is a matter of dispute. Ziegler asserts that they arise by the conjunction or coalescence of the exudation cells, or leucocytes from the blood, while others assert that these cells which have to do with the actual building up of tissue have their origin in the fixed cells of the tissues. Many facts may be adduced in favour of this latter view.

We have already seen reason to believe that in the early stages of inflammation the constituents of the tissues are mostly passive, and, if they undergo any change, it is in the direction of degeneration. But when the tissues have had time to recover, it is not inconceivable that, being by the exuded fluid supplied with additional pabulum, they should undergo nutritive changes. Even in some forms of acute inflammation the exuded fluid finds its way into the cells. In parenchymatous inflammation of the kidneys the renal epithelium enlarges and becomes cloudy, often undergoing degeneration subsequently. But if the inflammation subside to some extent, the epithelium cells may be found with double nuclei and showing other signs of germination. From the researches of Klein and others it is rendered evident that in certain inflammations of the peritoneum the endothelium shows active germination, and as a result of such active processes these cells may produce amœboid leucocytes which are not to be distinguished from white blood corpuscles. It is even doubtful whether in the normal condition the endothelium does not take part in the formation of the white corpuscles.

Looking to the fact that the connective tissue throughout the body is so intimately related to the lymphatic system we may possibly find here a means of reconciling divergent views. The endothelium cell and the connective-tissue corpuscle may be regarded as essentially similar structures. We have reason to regard the serous cavities as virtually the same as the serous spaces in the connective tissue. The endothelium of the peritoneum is normally beset with frequent aggregates of round cells which may be regarded as lymphatic follicles, and similar aggregates are frequent in the connective tissues, for instance, in that of the lung, as has been pointed out by Burdon Sanderson and recently confirmed by Arnold (Virchow's *Archiv*, vol. 80). In view of all these

facts we may, perhaps, regard the connective tissue and the lymphatic system as a single system, and the lymphatic glands as simply larger developments corresponding with the smaller cellular aggregates which we meet with throughout the connective tissue. In this view the white blood corpuscles themselves would be connective tissue structures, and have their seat of origin not only in the lymphatic glands, spleen, and bone marrow, but in all parts of the connective tissue.

At least we may say that in inflammations, when they have become chronic or sub-acute, the connective tissue or endothelium produces amœboid cells which are not distinguishable from white blood corpuscles. The epithelioid cells which are the immediate formative agents may take origin from the fixed connective tissue cells or from the amœboid ones, and there is nothing inconsistent in the view that they may also take origin in white blood corpuscles.

To return now to the case of the granulating wound, we may find in a section of it appearances confirmatory of what has been said above (see Fig. 27). In its superficial layers it is composed of round cells many of which have the size and appearance of leucocytes, while others have the characters of epithelioid cells. The leucocytes are probably in great part white corpuscles in process of migration, but they may also be to some extent derived from the fixed connective tissue of the part. Some of them pass to the surface and appear in the discharge as pus corpuscles. Others, however, will pass into the lymph spaces or even into the capillary vessels, and in either case resume their position as white blood corpuscles. As we pass deeper in the granulating wound there are evidences of the changes in the epithelioid cells described above. We find parts where large spindle cells are abundant, forming sometimes an actual spindle-cell tissue. Still deeper, and at the base of the wound, we find new-formed connective tissue.

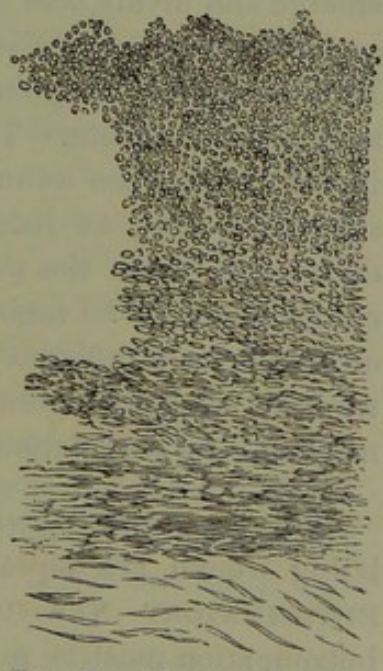


Fig. 27. — Semidiagrammatic section of a granulating wound. × 85.

Towards its base the granulating wound shows a striking tendency to contract, and we may account for this in two ways chiefly. The leucocytes, to a large extent, disappear when we pass a short distance beneath the surface; and at the same time the epithelioid cells, by be-

coming spindle-shaped and arranging themselves in parallel bundles, occupy less space than before. The new-formed connective tissue also shows a remarkable tendency to draw together, becoming more compact and drier. This shrinking of the connective tissue continues long after the wound has healed, the cicatrix tending to become smaller and harder. By the contraction at the base of the wound its area is diminished as a whole. The blood-vessels also which form loops passing to the surface are partially constricted, and so the superficial granulations are less supplied with blood. We may suppose that another consequence of this will be a less considerable emigration of the white corpuscles from the vessels.

We have still to consider how THE GRANULATING WOUND BECOMES COVERED WITH EPITHELIUM. This process is one which it is rather difficult to observe, apparently because the new-formed epithelium is very delicate and transparent. The new epithelium always arises from that already existing. The epithelial cells at the margin of the wound enlarge and divide, and so provide fresh cells which gradually cover the surface and assume the place and character of the usual flat epithelium. It is said that the young epithelium sometimes shows even a slight amœboid movement. The formation of epithelium sometimes begins in the midst of the wound, but this only happens when some epithelial structures, such as hair follicles or sebaceous glands, have escaped destruction when the wound was made. It is known also that living epithelium may be transplanted from one part of the body to another or even from a different person. When grafting is performed in this way the epithelium germinates like that at the margin and covers the neighbouring granulations.

THE PROCESSES which we have sketched as occurring in the granulating wound are repeated with slight modifications IN ALL OTHER INFLAMMATORY NEW-FORMATIONS. For new-formation to occur the inflammation must be prolonged for some time, and it must not be too severe. These are the characters of chronic inflammations, and it is in connection with them especially that we have new-formation occurring. In these chronic inflammations we have a tissue comparable to granulating tissue, consisting essentially of round cells, but in which when the process is active epithelioid cells may be distinguished. The round cells have the characters of leucocytes, and in some cases they pass outwards from the tissues and form pus. In most cases, however, they pass into the lymphatics and disappear.

If two surfaces in the condition of granulation come in contact they coalesce, and their vessels communicate so that they form a common layer. In that case when the inflammatory tissue develops into connective tissue the surfaces will be united by a permanent vascular connective tissue. In this way the flaps of a stump unite after granulating, and thus also permanent adhesion of the pleura and of the pericardium is often brought about.

It should be noticed that the inflammatory new-formation does not always develop into connective tissue, but that it may produce OTHER FORMS OF THE CONNECTIVE-TISSUE SERIES, AS BONE AND CARTILAGE. A chronic inflammation of the periosteum results in considerable new-formation of bone, in which the formative cells take part. The formation of callus round a broken bone is an instance of this. Then cartilage is sometimes formed in connection with inflammations, though much less frequently. The callus formed after fractures in the lower animals has often cartilage in it, and it may be so also in man.

Of considerable importance is the NEW-FORMATION of tissue AROUND FOREIGN BODIES. If a foreign body be introduced among the living tissues, if not very virulent in its own nature, it sets up a mild chronic inflammation, with the result of producing a vascular rudimentary tissue like granulations. If the foreign body be permeable by this tissue then the granulations will grow into it and, as it were, devour it, replacing it first by their own rudimentary tissue, which afterwards gives place to connective tissue. As this connective tissue is comparatively small in bulk, and tends to contract more and more, the result of the whole process is an absorption of the foreign substance and the gradual disappearance of all trace both of it and of the tissue which has replaced it. But if the foreign body is not permeable, then the inflammation results in the production of a layer of connective tissue around it, and so the body becomes encapsuled.

Many instances of this might be given. If a piece of dead animal tissue be introduced into the body, as, for instance, a piece of liver previously hardened in chromic acid solution, or a piece of prepared catgut used to ligature a vessel, then the dead tissue is first replaced by rudimentary tissue which gradually shrinks away. If a piece of the tissue of the body dies, and if severe inflammation is kept off, then its replacement by rudimentary tissue and absorption occur. In fractures of bones it often happens that a piece is entirely separated and dies. Such a piece of bone may lie exposed in the wound in a compound fracture,

and it has frequently been seen how it has been eaten into by the granulations and absorbed by them.

This tendency has been recently taken advantage of in a very ingenious manner by Hamilton of Aberdeen in the treatment of wounds. He finds that a piece of sponge decalcified and placed on a granulating wound, becomes filled with granulations and replaced by them. By this means it is possible to encourage the growth of granulations and get them to fill spaces, etc. This process has been named SPONGE-GRAFTING.

The encapsuling of foreign bodies is frequently seen. A parasite such as the trichina or echinococcus obtains a connective tissue capsule. Dead material in the body which is not permeable by the granulations is similarly treated, such as dried-in inflammatory products, which have formed first a caseous and then a calcareous mass. We frequently find such calcareous material surrounded by a fibrous capsule in the lungs and elsewhere.

IV.—INDIVIDUAL FORMS OF INFLAMMATION.

We have already seen that all the phenomena of inflammation which we have been studying are not always present in the same case, and that they exist in varying proportions in different cases. The variations in this regard have been already to some extent indicated, but it may be well briefly to refer to some of them here.

In almost all cases of inflammation hyperæmia occurs, even in the more chronic. Some slight inflammations of an acute character show little beyond HYPERÆMIA. The redness of the skin produced by exposure to the sun in a single day in summer is an instance of this. Doubtless there is along with the hyperæmia increased transudation through the vessels, and the subsequent desquamation of the epidermis shows that it has been damaged and in fact partly killed. It is similar with the cutaneous rashes in scarlet fever and measles.

There is probably more or less EXUDATION in all inflammations. The fluid constituents of the blood permeate the tissues and we frequently find them œdematous, and leucocytes are to be found in the tissues frequently in great abundance. In the examination of the tissues after death the presence of round cells is the most unequivocal sign of inflammation. These cells are found permeating the tissues generally in acute inflammations, but they are usually more localized in the chronic forms, and in that case they are associated with the new-formation of tissue. In very acute inflammations they may be produced

in such abundance as to break up the tissue and come together to form an ABSCESS. In the formation of an abscess there is nearly always some destruction of tissue, not necessarily the death of considerable pieces of tissue so as to form sloughs, but the molecular disintegration of the tissue which breaks down before the crowding leucocytes. These two circumstances, namely the great exudation of leucocytes and the necrosis of the tissue, imply that the irritant is a very severe one. In a large proportion of cases the irritant is of a septic nature, and we know that abscesses most frequently form in connection with septic wounds, etc. It may be said then that where we find leucocytes in abnormal numbers in a part we conclude that inflammation has been present, and if they be in very extraordinary numbers we infer that the inflammation has been very acute.

There are some cases which warrant the application of the term INFECTIVE INFLAMMATION. This term infective is to be carefully distinguished from infectious, which involves the idea of a disease communicable from one person to another. By infective is meant a morbid condition which has a tendency to spread from its original seat to parts around or at a distance. An inflammation is infective when it is what is called "spreading," and it is to be inferred that in these cases the products of inflammation contain some irritating or phlogogenic material. The products of ordinary inflammations are not infective, and inflammations are not naturally "spreading." When an inflammation has the infective characters there are always bacteria present in its products, and we may presume that these are related to this peculiarity.

The term PHLEGMONOUS INFLAMMATION is used to designate an acute inflammation of the connective tissue of the body, usually that beneath the skin. The inflammation is nearly always due to some specific infective material, as in erysipelas. There is rapid development of redness and œdematous swelling of the tissue, generally going on to suppuration, and frequently with some necrosis, evidenced by the formation of sloughs.

Sometimes an inflammation of a surface is associated with progressive destruction of tissue called ULCERATION. This means that the vitality of the tissue is being gradually destroyed and the structure breaking down, the process being well expressed by the designation molecular necrosis. Now, in order to this the presence of some very virulent irritant is necessary. Probably it does not occur except under the action of very specific forms of irritation, such as we shall have an opportunity of studying afterwards. Sometimes the ulceration pro-

gresses very rapidly, so that considerable sloughing may combine with the molecular necrosis. Ulcers of this kind are sometimes called PHAGEDÆNIC. The irritation may be so intense and the necrosis so rapid that there is no time for much exudation of leucocytes. As a rule, however, profuse suppuration exists along with ulceration, the intense irritation inducing a very abundant emigration of leucocytes.

Again, an acute inflammation sometimes produces DEGENERATION of tissues in a more pronounced manner than usual. This applies especially to cases in which the parenchyma of organs is engaged, as in inflammations of the kidney where the renal epithelium is specially involved. We have already seen that the inflammation produces cloudy swelling in this case, and this readily goes on to fatty degeneration. Fatty degeneration is also manifested in inflammations of the brain, where it is sometimes almost the only evidence post mortem of the existence of inflammation.

We have already adduced a sufficient number of instances of NEW-FORMATION in inflammation. It is to be remembered that all such new-formations have a striking tendency to contract and form a very dense connective tissue. When chronic inflammation exists in an organ such as the liver or kidney, this contraction frequently gives rise to considerable contortion of the normal tissue, which is often the seat of degeneration. The tissue, by the presence of the new-formed connective tissue, is pressed on, and, after degeneration, is absorbed. In this connection, we may speak of INDURATIVE INFLAMMATIONS, the structures being rendered hard by the dense contracting connective tissue.

RETROGRADE METAMORPHOSIS.

UNDER this designation are included a number of conditions, all of which imply a degradation of the nutritive processes in the tissues. As the cells are concerned in the nutrition of the tissues, it is for the most part these which are at fault, although it may be that in some cases the most manifest visible changes are not in them. The most extreme case is, of course, where the nutrition ceases altogether, and the structure dies. Short of that, we have various forms of change manifesting themselves. Thus there is a simple diminution of the vitality, and the structures dwindle. Again, the chemical constituents of the structures change, splitting up, it may be, into more elementary principles. Or the tissues are unable to prevent the deposition in them of extraneous material, which is thus infiltrated into them. These last are called infiltrations, whereas the conditions in which there is a degradation of the normal constituents into lower chemical substances are designated degenerations.

NECROSIS : GANGRENE.

Under the designation necrosis are included conditions in which the vitality of portions of the tissues entirely ceases; there is a local death. We have here to consider the conditions under which necrosis occurs, the appearances of and changes in the dead portions of tissue, and the effects on neighbouring parts and on the organism as a whole.

CAUSES OF NECROSIS.—The vitality of a part will be lost (1) if it be deprived of its supply of nutriment by interference with the circulation, or (2) if by some deleterious agent, or otherwise, the constituent elements, the cells, are so interfered with that they cannot carry on the vital processes. It is obvious that under varying circumstances the

tissues will have different powers of resistance, and that the tissues differ among themselves in this respect. The tissues of an old person will be less able to survive the attacks of certain agents than those of a young person, and any preceding degradation of a tissue, from whatever cause, will render it more susceptible to necrosis.

INTERFERENCE WITH THE CIRCULATION causes necrosis, and here it is the CAPILLARY CIRCULATION we have to do with. If a tissue be of normal vigour, there must be complete stasis in the capillaries before necrosis occurs; any survival of the circulation in these vessels, however small, is sufficient to enable the capillaries and surrounding tissues to live on. We have already seen that obstruction of AN END-ARTERY, by embolism or otherwise, leads to this stasis in the capillaries and resulting necrosis of the tissues. A complete obstruction of the VEINS will have the same effect, but they anastomose so completely that this can occur but rarely. It does occur approximately when a piece of intestine is incarcerated in a sac with a narrow neck, and we know that under these circumstances gangrene is very liable to occur. Even extensive thrombosis, especially when other conditions such as weakness of the heart conspire, may lead to gangrene, as in fevers.

The obstruction of the CAPILLARIES may be directly produced. If a cavity approaches the surface of a lung, it may undermine the pleura, and, by obstructing the capillaries, cause a slough to form. Very often adhesion of the two layers of the pleura occurs, and vessels pass from the parietal to the pulmonary layer and nourish it; but where such adhesion does not take place there is frequently sloughing, and pneumothorax may result from the partial separation of the slough. Similarly, an ulcer of the intestine may undermine the peritoneal coat, and so cause sloughing and perforation.

Less directly, WEAKNESS OF THE HEART may so far interfere with the circulation in the capillaries, especially of distant and dependent parts, as to contribute to necrosis. It is obvious that this cause alone can never produce necrosis, but we shall see afterwards that it is a powerful predisposing cause.

Turning next to cases where the necrosis is due to a DIRECT ACTION ON THE TISSUES, it may be said that the vitality of the cells of a tissue may be compromised by chemical agents acting on them, by direct traumatic agents, or by excessively high or low temperature. The CHEMICAL PRODUCTS of putrid decomposition are often peculiarly virulent. We have already seen that they frequently cause the most intense inflammation, and the inflammation is commonly accompanied by necrosis. In

fact, the infective inflammations, such as those of pyæmia, are, for the most part, necrotic. When, in pyæmia, ulcerative endocarditis, etc., bacteria exist alive in the body, and form colonies in places to which they are carried, they produce necrosis of the immediately surrounding tissues, not probably by their direct action, but by that of their products. We know also that decomposing urine in the tissues produces the most intense inflammation, generally along with extensive sloughing. It is obvious that direct TRAUMATIC INJURIES may destroy the vitality of the tissues, either directly or else by interfering with the supply of blood. In cases of traumatic necrosis it is probable that, besides killing the tissues, the agent will so far interfere with surrounding parts as to induce inflammation. In fact, it can hardly fail to be seen that there is commonly a close connection between the causes of necrosis and those of inflammation. Excessive HEAT or COLD is a cause of necrosis, the vitality of the cells being destroyed by excessively low or high temperatures. A very short immersion of a living part in water heated to 130° to 136° F., or in a freezing mixture reduced to 4° to 0° F., suffices to kill it. If the temperature be slightly less extreme, a short immersion produces a violent inflammation, and a long immersion may still result in necrosis.

There are certain forms of necrosis still to be considered that depend on causes which cannot be absolutely brought under one or other of the categories already mentioned. One of the most interesting of these is SENILE GANGRENE. It is known that in certain cases a slight injury to the toe, such as cutting a nail too deeply or tearing off of a rag-nail, may lead to a necrosis which spreads from the seat of origin to the foot, or even to the lower part of the leg. Such a trivial injury in a healthy person would lead at most to a trifling inflammation, but in these old persons gangrene is the result. The explanation is that, to begin with, the circulation is so seriously interfered with that the tissues are already, as it were, half dead, and a very slight cause suffices to suspend their vitality altogether. In addition to weakness of the heart, there is in these cases always atheroma of the arteries, and sometimes even thrombosis on the atheromatous patches. To this must be added the weakness of the tissues which may be presumed to exist in old age.

Of somewhat similar significance is the SOFTENING OF THE BRAIN which often occurs IN OLD PEOPLE from simple atheroma of the arteries, even without thrombosis. In a healthy person complete obstruction of an artery is necessary in order to softening of the brain substance,

but in old persons the mere lessening of the calibre of an artery by an atheromatous patch is often sufficient to cause softening. These softenings are very often on the surface of the brain, and lead as much to weakness of the mind, etc., as to motor paralysis, whereas the softenings from embolism are much more frequently central, and lead to more definite loss of motion.

In former days there used to be epidemics of what is now recognised as ERGOTISM from eating bread made of grain mixed with ergot of rye. In these epidemics the symptoms frequently culminated in gangrene, usually beginning in the toes, but extending thence, and sometimes attacking the ears, nose, etc. The gangrene is usually accounted for by the anæmia due to the spasmodic contraction of the arteries from the action of the ergot. This explanation has been doubted, and the anæsthesia which is a concurrent symptom has been adduced as the cause. Possibly the interference with the circulation, the directly poisonous action of the agent, and the exposure to injury to which a part devoid of sensation is liable, may all have to do with the occurrence of the gangrene.

In HOSPITAL GANGRENE there is a progressive necrosis of the tissue, beginning usually in a granulating wound, and resulting either in considerable sloughing or molecular necrosis. The gangrene travels mostly along the loose connective tissue, and so may undermine the skin, or isolate muscles or blood-vessels. The disease is due to a specific virus, which spreads in the spaces of the loose connective tissue.

CHANGES IN THE DEAD TISSUE. When a tissue dies in the living body there is, at first, no obvious change in its anatomical characters by which it could be distinguished after death from that which has survived. But the dead tissue is liable to undergo changes, chiefly chemical, by which its structure is altered, and it becomes obviously different from the remaining tissue. The different forms of necrosis, indeed, have been divided according to the character of the changes assumed by the dead tissue. It will be understood that, in the case of external parts, ordinary putrefactive decomposition will often occur and dominate all other changes, so that it is chiefly in internal parts that we find those which occur independently of decomposition.

1. COAGULATION NECROSIS is a term which has recently come into use to designate a condition described very fully by Weigert (Virchow's *Archiv*, vol. 79). The process is to be compared with the coagulation of the blood, the coagulated tissue being equivalent to the fibrine. In fact, the formation of a thrombus is a kind of coagulation necrosis

implying the death of leucocytes, and the formation of a dead structure, the fibrine.

We have already seen that the coagulation of the blood is related to the death of white blood corpuscles. In dying these cells set free the paraglobulin, which is one of the principles that go to form fibrine. Now the active cells of the tissues generally contain paraglobulin, and if the fibrinogenetic substance be present, as it is present in the lymphatic fluid which bathes the tissues, then coagulation may take place if the cells die and yield their paraglobulin and ferment. In order to this coagulation the tissue must be a very cellular one, and an abundant supply of fluid containing the fibrinogenetic substance must be present.

We meet with this change, chiefly in cases where death has occurred suddenly, in a limited piece of tissue, while the parts around remain vigorous. It is seen very typically in many cases as a result of embolism; the EMBOLIC INFARCTION owes its dense character largely to the coagulation of the tissue. Sometimes this occurs without much hæmorrhage, and, in the kidney for instance, we often find a pale wedge-shaped infarction of almost cheesy consistence. But even when there is hæmorrhage the tissue is commonly coagulated as well.

Another example is sometimes afforded by MUSCLE which undergoes a change to which the name COLLOID DEGENERATION is sometimes



Fig. 28.—Coagulation necrosis or hyaline degeneration of muscle. ×75

given, but which is perhaps better called waxy or HYALINE DEGENERATION. In typhoid fever, and, to a less extent, in acute tuberculosis,

scarlet fever, small-pox, etc., this peculiar change is frequently observed in the muscles, chiefly the adductors of the arms, the rectus abdominis, diaphragm, etc. To the naked eye a portion of the muscle is seen to be pale and glassy-like, resembling the flesh of uncooked fish. This occurs in patches, and where thus affected the muscle appears to be more brittle, hæmorrhages sometimes occurring in the patches. Under the microscope, the primary change is seen to be a disappearance of the transverse striæ, and a greatly increased transparency of the muscular fibre. Fibres affected in this way may be seen close beside unaffected ones. The affected fibre is obviously unduly brittle, having a tendency to break transversely, and to crumble (see Fig. 28). By this process it often happens that an oval piece of degenerated fibre gets isolated, the two tapering ends being irregularly crumbled (see Fig. 29) while the

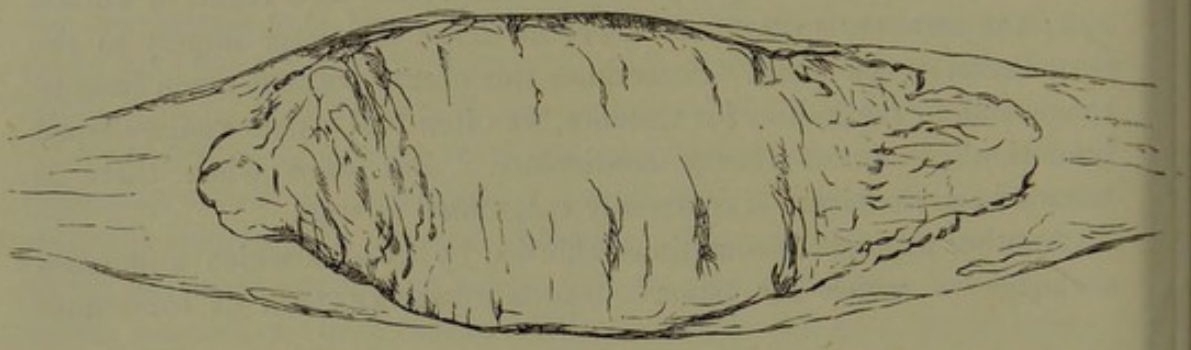


Fig. 29.—A coagulated clump of muscle more highly magnified. The sarcolemma surrounds it, drawing together at the ends. ×350.

sarcolemma collapses on the ends of the oval piece. A similar glassy transformation occurs in the unstriated muscle in the acute diseases mentioned.

A somewhat similar condition is occasionally seen in paralyzed muscles, where it may exist side by side with ordinary atrophy and fatty infiltration. It has also been produced artificially in living animals by freezing the muscles.

The process here is a coagulation of the contractile substance. This coagulation may even be brought about in the muscles after death if they be injured before the occurrence of the cadaveric rigidity, which may be regarded as the expression of the normal post-mortem coagulation of the sarcocele. In the case of typhoid fever it may be supposed that there is a premature death of individual muscular fibres, induced by the phenomena of the disease, and, perhaps, assisted by traumatic causes.

Another example of coagulation necrosis is afforded by DIPHTHERIA.

In this disease the exudation which appears on the fauces is, indeed, in part a true fibrinous exudation, but it is also in part composed of the coagulated superficial portions of the mucous membrane.

The TUBE CASTS of the kidney are also, to some extent, the result of coagulation of the epithelium of the uriniferous tubules, the death of the epithelium occurring in connection with inflammation of the organ.

In all cases of coagulation necrosis the tissue becomes more firm and solid. Sometimes the coagulum assumes a fibrillated character, but perhaps more frequently it is homogeneous, the structure of which the tissue is composed being obscured.

It is characteristic of the process that the nuclei of the cells become obscured and are no longer brought into view by staining the tissue.

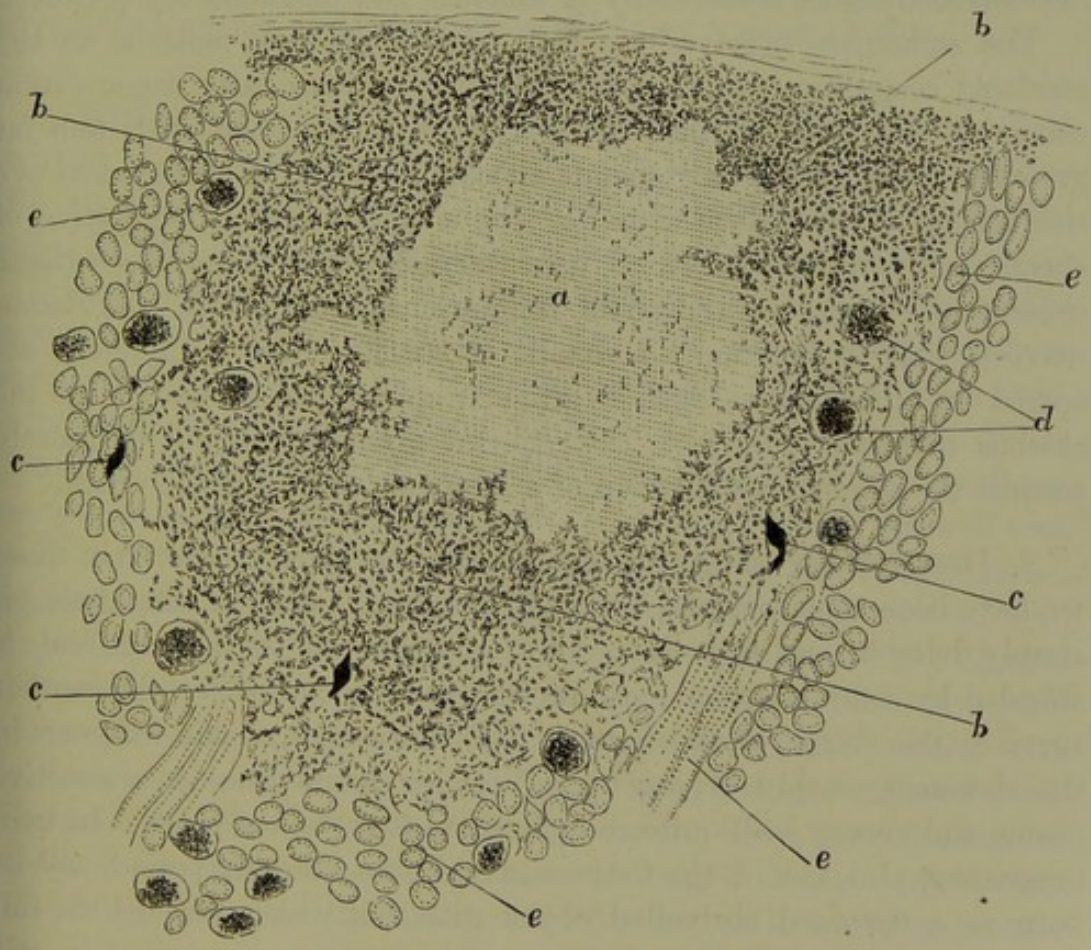


Fig. 30.—Formation of a pyæmic abscess in the kidney. Section stained with aniline brown. The necrosed portion *a* shows no structure and is not stained. The surrounding inflamed area (*b*, *b*, *b*) is deeply stained.

Referring back to the formation of the white thrombus (p. 27) it will be remembered that the disappearance of the nucleus is there a char-

acteristic occurrence, and in coagulation necrosis it may be regarded as of similar significance, implying the death of the cell. This peculiarity may be used to distinguish the existence of this process. If we stain a section of a tissue, as in the accompanying figure (Fig. 30), and find that a piece shows no nuclei, we may infer that necrosis has occurred.

2. Caseous necrosis is a condition in many respects analogous to coagulation necrosis. We have seen that the latter is an acute process, but caseous necrosis mostly occurs when the loss of vitality is brought about more gradually. It is met with mostly in tuberculosis and syphilis, and in both of these we have a specific virus acting on the tissues. It may be a question how far the death of the tissue is due to the action of the virus or to the obstruction of the circulation. This form of necrosis also occurs occasionally in tumours and inflammatory products.

The structures involved are cells, and so we have material for the resulting coagulum. But before the actual necrosis fatty degeneration occurs in the cells, so that the coagulum is furnished with fine fat granules which give a very opaque appearance to it. To the naked eye the density of the tissue with its opaque appearance is suggestive of cheese, and hence the name. Under the microscope the necrosed tissue presents the same obscuration of the nucleus as we find in coagulation necrosis, but in addition all details of structure are completely obscured by the general opaque granular appearance presented by the caseous material. In fact, this general granular opacity frequently renders the original constitution of a structure exceedingly obscure.

3. Desiccation and mummification is a simpler process than those we have been considering. The part dies, and instead of coagulating it simply dries in and shrivels. An example of this on the large scale is afforded by some cases of extra-uterine pregnancy, where the mother survives the death of the fœtus. The latter may remain for years in the abdomen, simply drying up. Virchow found muscle, connective tissue, and vessels still quite recognizable after twenty years. In twin pregnancy, also, one of the fœtuses may die at an early period, and be born as a flattened shrivelled object with that which reached the full time. It will be obvious that cases of caseous metamorphosis and coagulation necrosis may be brought under this heading, the resulting material having often a tendency to dry and contract. Calcareous infiltration frequently overtakes such structures finally if they are not absorbed by the processes to be presently considered.

But under certain circumstances an external part also undergoes

desiccation, and the condition is called DRY GANGRENE or mummification. In some cases the drying-in will be facilitated by the part being at the time of death deficient in moisture, as where the gangrene has resulted from embolism or in senile gangrene. It will not probably occur if there has been much coincident inflammation. The part undergoes a gradual deepening of colour; at first merely livid, it passes on into purple, deep blue, and even black. This is due to the blood-colouring matter being dissolved out and staining the tissues which deepen in colour as the pigment becomes concentrated by drying. The cuticle by and by gets raised by red fluid accumulating beneath it, and when it has separated evaporation goes on more rapidly, and the piece of tissue withers, shrinks, and is converted into a hard black mass often with a mouldy smell. In the case of dry gangrene the deficiency of fluid prevents the agents of decomposition obtaining a proper nidus.

4. SOFTENING or COLLIQUIFICATION is seen typically in those necroses of the brain substance which are so frequent in connection with embolism. The breaking down of the brain substance is accompanied by fatty degeneration, so that a kind of fatty emulsion is formed.

When external parts die they very often undergo SOFTENING WITH DECOMPOSITION. This occurs chiefly in cases where there has been considerable inflammation, so that the parts are saturated with fluid. An ordinary slough in an external wound is an instance of this. When a considerable portion of a limb is killed and separated by sloughing, then we speak of it as moist gangrene. The appearances are well seen where a portion of a leg has died in consequence of a traumatic cause. The parts which were at first hot, red, and painful, become mottled with brown, blue, and black, and may even present blisters. They become cold and darker except at the margin where a dusky red line of demarcating inflammation appears. The tissues get universally stained with blood-colouring matter, the cuticle gives way, and decomposition advances and causes breaking down of the tissues, which are separated as sloughs in all stages of softening, and exhaling a strong odour. The fluid which permeates the tissues contains fat, phosphates, and other salts, as well as extractives from the tissues.

We have now to trace the further course of events in necrosis. In many cases THE NECROSIS LIMITS ITSELF almost at once; the agent has been at work once for all and has killed a certain portion of tissue, and it only remains, by processes which we shall now describe, to get

rid of the dead piece. In other cases the agent acts also on surrounding parts, though, being less severe, it only produces inflammation, while necrosis may occur at a subsequent period. This will happen the more readily if decomposition occurs in the gangrenous part. The juices of decomposition extending to the inflamed parts may cause a further serious extension of the necrosis. Thus in traumatic gangrene it may be long before a proper line of demarcation forms, and the necrosis becomes definitive. The importance in such cases of preventing decomposition in the dead part will be obvious. But, again, in predisposed tissues which are less able to resist than normal ones, as in old persons, or in persons the subject of diabetes, the gangrene may extend without there being any considerable inflammation or decomposition.

THE FINAL DISPOSAL OF THE DEAD TISSUE.—In this, INFLAMMATION plays a most important part. We have seen that violent inflammation is often produced by the same cause as the necrosis, or may supervene on it. This will mostly be the case in external parts where decomposition often comes in to increase the inflammation. The inflammation is accompanied by exudation and hyperæmia, like other inflammations, and commonly goes on to suppuration. A layer of pus comes thus to divide the dead tissue from the living, and the dead is cast off as a slough. There remains a suppurating wound or ulcer. This loss of tissue, whether molecular or as a massive slough, is the essential feature of an ulcer of whatever kind, and a suppurating surface will usually be left.

In internal parts, if the necrosis be accompanied or followed by the production of irritating chemical substances, then a violent inflammation will be produced around. It is so in the case of pyæmia, where there is septic embolism. In this case the inflammation will usually be violent enough to produce suppuration, and the result will be the formation of an abscess. (See Fig. 30.)

In the case of internal parts where there is no disturbing decomposition, or even in external parts which are protected from septic contamination, the inflammation is of a much milder character. The necrosed portion now comes to act as a foreign body or dead piece of tissue, and is subject to the changes already described at p. 97. The dead tissue is often eaten into and replaced by vascular granulations, which finally contract and leave a small residue of connective tissue; or the dead piece is encapsuled and may lie quiescent. Not infrequently the encapsuled tissue undergoes infiltration with lime salts, as we shall see

afterwards. In the case of necrosis in bone the external capsule is frequently composed of new-formed bone.

SIMPLE ATROPHY.

There comes up here for consideration, to begin with, what may be called PHYSIOLOGICAL ATROPHY. At certain periods, for instance, the milk teeth drop off, and this is effected by an atrophy of the fang so that the crown is shed. At a still earlier period the thymus gland atrophies. Then again throughout life there is a continual shedding of the hair, and if a cast-off hair from the eyelash, for instance, be examined under the microscope, it will be seen that its bulb is atrophied, and this is the cause of its being shed. In some persons the hair of the scalp is largely shed at a comparatively early age, without being properly reproduced, there being here an atrophy of the hair sheath and papilla. Then there is the normal atrophy of the tissues generally, which occurs in old age. The atrophy of old people may in many cases be due to some organic disease whose symptoms are not manifest; but we are all familiar with the healthy old person with shrivelled hands and face and plicated skin.

In all these cases there is a kind of intention in the tissues, so to speak, according to which they live a certain period and then decay. As Paget has pointed out, such atrophies may almost be regarded as active processes. The fall of the leaf is due to an active absorption or atrophy of the fibres uniting it to the stem; if the leaf dies before its time, or is killed, it remains hanging, but in the natural course it drops when its time is come. So with our tissues and the whole organism, there is a period to their activity. The period varies in different persons, and in this regard hereditary influences have an important bearing. Just as these largely determine the period of growth of the body and its rapidity, so do they influence the duration of activity of the tissues. This is plainly seen in the case of the hair; baldness runs in families, just as longevity does.

Turning to more strictly pathological atrophies, we may distinguish three forms—1, those dependent on the supply of nutrition being defective; 2, those in which disuse of a structure causes its atrophy; and, 3, those in which the atrophy is related to some change in the nervous system.

GENERAL EMACIATION is the most obvious example of the first class,

occurring, as it does, either directly from interference with the supply of food, or from impoverishment of the blood by excessive waste. The food may be procured in insufficient quantity, or a stricture of the œsophagus may interfere with its passage to the stomach, or the stomach may reject it after it has been swallowed. On the other hand, there is frequently, in advanced phthisis or ulcerating cancers, a large consumption of the nutritious material available to the body, and the tissues suffer accordingly. In these and other cases of general atrophy, the tissues dwindle in different proportions, the fat most; next to it the spleen, testicles, liver, muscles, bones, and least of all the central nervous system.

As belonging to this class also may be mentioned the ATROPHIES OF FEVERS, although perhaps the atrophy here is to some extent more of an active process. In fevers there is, with the high temperature, an increased combustion of the nitrogenous constituents of the tissues. If the supply of nutritious material were abundant, then this would not necessarily lead to atrophy, but the febrile patient eats little or nothing, and, besides, the constitution of the blood is altered, and so the structures atrophy, sometimes with great rapidity.

To the same class belong LOCAL ATROPHIES from local interference with the blood supply. The overgrowth of connective tissue in interstitial inflammations of parenchymatous organs causes atrophy of the secreting structure of these organs, as in the case of the liver, kidney, testicles, etc. Growing tumours or aneurisms cause atrophy of the tissues around, etc.

Of the second class, the most obvious are the atrophies of MUSCLES FROM DISUSE. Paralysis or anchylosis of a limb results in its emaciation. In conjunction with the atrophy of the muscle, there is often an overgrowth of the adipose tissue between the muscular fibres. The retrograde changes which occur in the uterus after delivery may possibly be regarded as another example.

As to the ATROPHIES DEPENDING ON NERVOUS LESIONS, these are somewhat obscure in their essential pathology. It is true that after motor paralyses of all sorts, atrophy of the muscle occurs, after hemiplegia, for example; but the atrophy in this case may be from disuse of the muscle, just like atrophy after anchylosis of a joint. There are, however, some atrophies following nervous lesions which are rapid in their development, and appear to be due not directly to the paralysis, but rather to an interference with the nerve-centres concerned in the nutritive processes. It has been abundantly shown by experiments in

animals that when a nerve stem containing motor fibres is divided, there is a coagulation, disintegration, and subsequent absorption of the medullary sheaths of the nerve fibres in the stem. Erb states that the axis cylinder persists, while others assert that it too atrophies. In any case the muscles supplied by the nerves also atrophy. Even in the first week there is considerable wasting, and after a month the muscle has scarcely half its former thickness. This is a simple atrophy, the muscular fibres getting thinner, and presenting the nuclear change to be referred to afterwards. The atrophy which occurs in a common hemiplegia is not nearly so rapid as this, and is often scarcely perceptible after a month. In comparing the lesions in the nervous system in these two cases, the difference will at once appear; in the one the interruption to the motor fibres is high up above the spinal cord, while in the other it is low down, after the fibres have left the cord.

But there are some forms of paralysis in which atrophy is a peculiarly pronounced feature. Infantile paralysis is one example; progressive muscular atrophy is another; and glosso-pharingeal or bulbar paralysis a third. In these the atrophy is even more striking than the paralysis, and in other forms of paralysis there is often a greater loss of function with much less atrophy. These forms of atrophy have been classed as TROPHO-NEUROSES, as it is evident that besides the mere paralysis there is some lesion of the structures which command the nutrition of the muscles. These structures are, presumably, trophic nervous centres situated in the spinal cord, and, as we shall see afterwards in connection with diseases of the nervous system, it is to be inferred that these trophic centres are near the motor centres, or are identical with them. Now the motor centres of the cord are in the anterior grey cornua, and the trophic centres are presumably there also, taking part in the destruction which affects the cornua in this class of diseases. In infantile paralysis, for instance, there is an acute inflammation, with destruction of centres in the anterior cornua.

Another case of a supposed tropho-neurosis is the atrophy with paralysis which occurs in LEAD POISONING. Here the paralysis and atrophy affect the extensors of the arm, and the localization of these to a group of muscles has led to the view that here also the ganglion cells of the anterior cornua are involved. This localization has not been made out, and there is no apparent reason why the lead should specifically attack this particular group of ganglion cells. Still we

know that poisons have frequently special affinities, and the possibility is not to be excluded.

In all these forms of muscular atrophy certain changes occur in the muscles. There is an increase in the nuclei of the muscular fibres, and sometimes an increase of the connective tissue, a condition which some have regarded as an interstitial inflammation. Sometimes also a great development of fat occurs in the connective tissue of the muscles. These changes are secondary; they are found in the muscles after division of nerves, and are therefore not to be regarded as the cause of the atrophy and paralysis. The muscular fibre itself becomes smaller, and is occasionally the seat of fatty degeneration. As the disease proceeds, the muscular fibre may altogether disappear.

Among the tropho-neuroses is also commonly included that peculiar ATROPHY OF HALF THE FACE, of which a few cases have been published. This atrophy affects all the structures, bones, muscle, skin, etc., but is not accompanied by paralysis. It does not follow strictly the distribution of any nerve, although closely approximating to that of the fifth. The pathology is obscure, but it is usually regarded as due to an affection of the trophic centres wherever they are.

ALBUMINOUS INFILTRATION.

This is a term having a meaning equivalent to Cloudy Swelling as used by Virchow, and to Parenchymatous degeneration. The condition has been incidentally referred to in considering inflammation. Its essential nature may be expressed by stating that in it cells increase in bulk, while the added material is not properly assimilated and so deposits in the cells in visible albuminous granules. The enlarged cells are therefore clouded (see Fig. 31), and the nuclei obscured. The condition implies a qualitative defect in the nutrition of the cells, while quantitatively there is increase. The qualitative defect is very often still further mani-

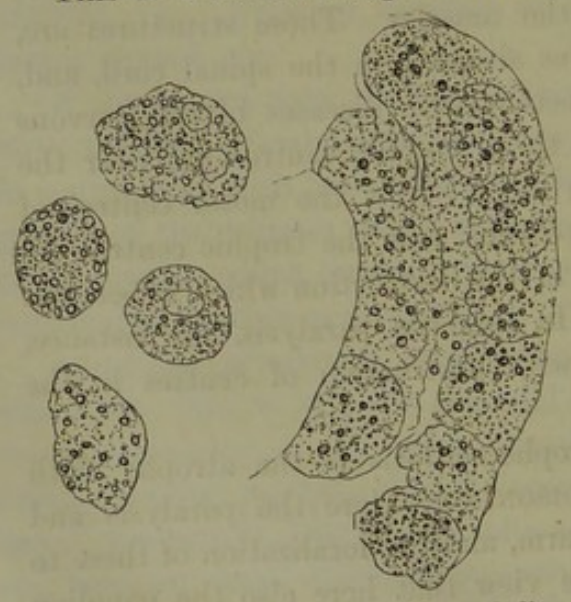


Fig. 31.—Cloudy swelling of renal epithelium with slight fatty degeneration. A portion of a tubule is shown, and some isolated cells. From a case of acute phthisis pulmonalis. × 350.

fested by the occurrence of fatty degeneration (as in the figure) along with the cloudy swelling, and these two conditions, in fact, frequently run into each other.

The condition is brought about by causes which irritate cells and at the same time increase their supply of nutritious fluid. One of these is inflammation, and cloudy swelling is the most pronounced change in the earlier stages of the parenchymatous inflammations of organs, especially of the kidneys. Besides by inflammation, it is produced by nearly all febrile diseases, and seems to bear some relation to the elevation of temperature. It is met with in the acute specific fevers, in pneumonia, erysipelas, pyæmia, acute phthisis pulmonalis with high temperatures, etc. It is as if the blood, altered by the elevation of temperature and otherwise, acts as an irritant, producing a kind of sub-inflammatory condition. As the blood is carried throughout the body the parenchymatous change is not limited to any single organ, but is found in the liver, kidneys, muscular fibre of the heart, voluntary muscle, and elsewhere.

The name cloudy swelling implies that the affected cells are enlarged. It is to be observed also that the cells concerned here are the proper cells of organs, that is to say the structures which are concerned in their functions and make up the greater part of their bulk. Hence it arises that considerable enlargement of the organs as a whole may occur from this cause, and this is especially seen in the liver, which sometimes shows great increase in size and weight in acute fevers. The kidneys are also sometimes considerably enlarged from this cause.

FATTY DEGENERATION.

In this condition, which affects the cells of tissues, we have a change in the chemical composition of the cell-contents; the albuminous constituents split up and yield fat. Before going further it may be well to remember that fat exists in the tissues in two conditions, in the first place as free fat, and in the second place in such close chemical union with the albuminous constituents that it no longer responds to the ordinary reactions of fat. For instance, besides free fat in muscular fibre there is much combined fat, and in order to detect the latter, by extraction with ether for example, it is necessary in the first place to decompose the albuminous combinations. When these combinations are decomposed the fat can be seen in the muscle as minute drops, and it can be extracted with ether. It may be well, in the first place, to

take one or two typical examples of fatty degeneration, and endeavour to gather from them some conception of its pathology.

The well-known experiments of Bauer on the effects of POISONING dogs WITH PHOSPHORUS afford an excellent example to begin with. This author deprived a dog of food for a period of twelve days, till it had consumed all its available store of fat, and the excretion of nitrogen in the urine had reached a constant minimum of eight grammes in the twenty-four hours. He then gave the animal small doses of phosphorus and found that the excretion of nitrogen markedly increased on to death, reaching treble its former amount, namely, 23·9 grammes. The phosphorus in the blood had induced a marked consumption of the albuminous tissues, manifested in a great increase in the urea excreted. But now when the animal was killed, an enormous increase in the free fat in the organs was found, the liver and muscles contained about three times their normal amount of fat, and other structures such as the renal epithelium, and the walls of the blood-vessels, presented marked fatty degeneration. Here was an agent circulating in the blood, whose effect was the decomposition of the albuminates and the formation of fats.

Again, it has been mentioned above that in ANÆMIAS there is often a marked fatty degeneration of the muscle of the heart, of the hepatic cells, and of the renal epithelium. In this case a deterioration of the blood, and especially a defect in the hæmoglobin, determines the occurrence of fatty degeneration.

When an ARTERY IN THE BRAIN IS OCCLUDED we have already seen that necrosis frequently occurs, accompanied by softening; but, along with this or preceding it, there is a pronounced fatty degeneration affecting the brain-substance and resulting in the formation of large cells filled with finely divided fat (the so-called compound granular corpuscles). A similar aggregation of fat occurs at intervals in the walls of the capillaries (see Fig. 32). It is true that the fat here may be partly derived from the myelin of the disintegrated medullary sheath, but it is not probable that the fat of the capillary nuclei can have this source. Here is a case in which a local deprivation of blood has the effect of inducing a fatty degeneration.

We have also instances of fatty degeneration in INFLAMMATIONS, where the vitality of the cells is compromised, and in quickly growing tumours, where, perhaps, the nutritive processes are subordinated to the unduly active formative ones.

We have now to endeavour to EXPLAIN THE OCCURRENCE of fatty

degeneration in these various circumstances. There are some of them which we can account for on the same principles as we account for the

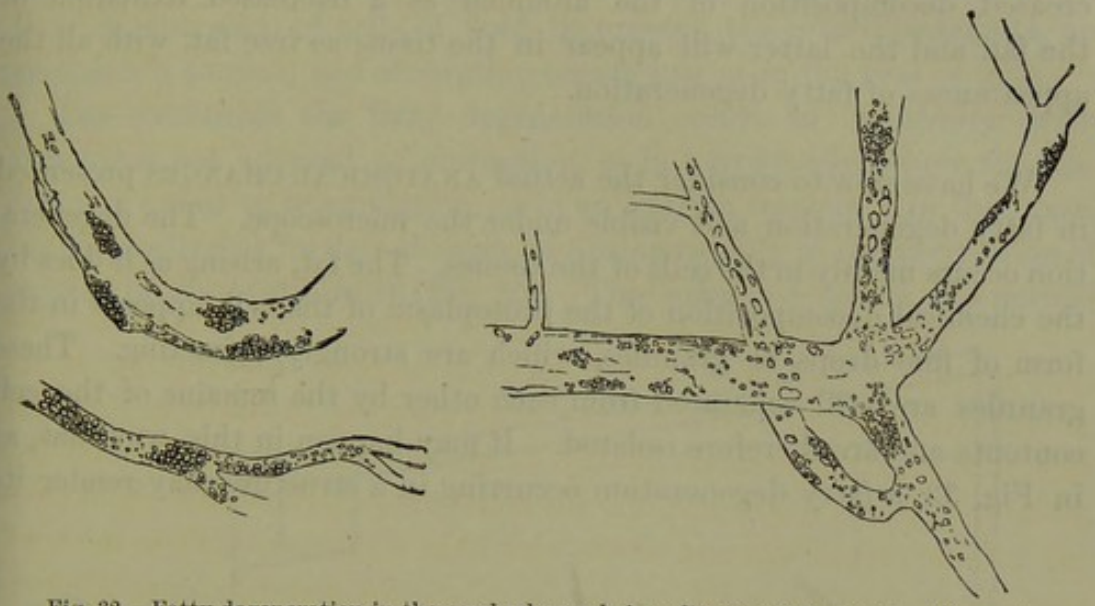


Fig. 32. –Fatty degeneration in the cerebral vessels in softening of the brain. (PAGET.)

fatty degeneration in phosphorus-poisoning. In acute yellow atrophy of the liver the hepatic cells break up, and present the characters of pronounced fatty degeneration; this is, presumably, due to the action of some poisonous agent, and it has even been supposed that phosphorus is the agent. Then, again, we have fatty degeneration frequently associated, as we have seen, with cloudy swelling in fevers, etc. In this case the fatty degeneration may be due to the splitting up of the loosely combined fatty-albuminous principles. The same applies to some of the more local fatty degenerations. The mere degradation of the tissue may allow of these decompositions occurring, as when fatty degeneration occurs in yellow softening of the brain.

But there are some cases in which more fat appears in the tissues than the mere breaking up of the normal combinations would account for. In these cases we must suppose a different mode of origin.

It seems to be a function of most of the active cells in the body to form fat, which is oxidized or burnt either in the same place or elsewhere. The cells may form fat even from albuminous material. The mammary glands secrete milk just as abundantly when the animal feeds on meat free from fat as on a richly fatty diet. Muscular tissue contains fat loosely combined with the albumen, and probably it is continually forming fat, which is continually being oxidized. But something may interfere with its oxidation. The supply of blood may be insufficient, the quality of the blood may be altered, or the vitality of the cells may

be so reduced as to render the process of oxidation imperfect. It is possible, then, that there may be in these cases, not so much an increased decomposition of the albumen as a decreased oxidation of the fat, and the latter will appear in the tissue as free fat, with all the appearances of fatty degeneration.

We have now to consider the actual ANATOMICAL CHANGES presented in fatty degeneration and visible under the microscope. The degeneration occurs mainly in the cells of the tissues. The fat, arising as it does by the chemical decomposition of the protoplasm of the cell, appears in the form of fine drops or granules, which are strongly refracting. These granules are still separated from each other by the remains of the cell contents and are therefore isolated. It may happen in this way that, as in Fig. 33, a fatty degeneration occurring in a structure may render its

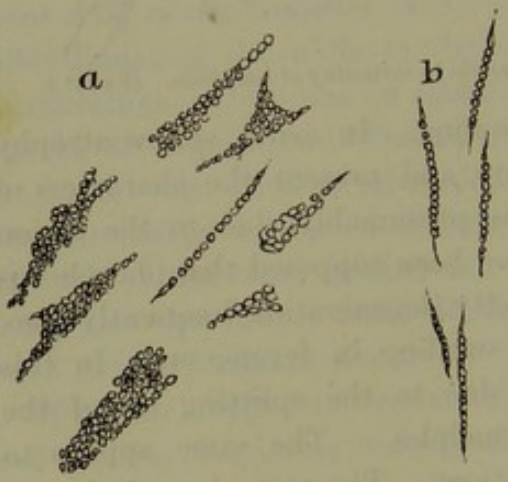


Fig. 33.—Fatty degeneration in an atheromatous aorta. The shapes of the cells brought out by the fat; *a*, from internal coat; *b*, muscle cells from middle coat. ×350.

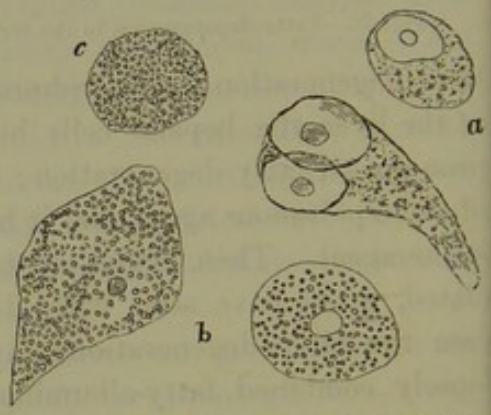


Fig. 34.—Fatty degeneration of cells in a cancer of the mamma; *a*, slightly affected; *b*, more so; *c*, completely fatty—the compound granular corpuscle. ×350.

constituent cells unusually distinct, their form being brought prominently out by the fat in them. As time goes on, the fat granules increase till the whole cell is filled with fine refracting oil drops, which still remain isolated (see Fig. 34), being each surrounded by an albuminous envelope. The process is, in fact, very much like what occurs in the cells of the mammary gland in the secretion of milk, the colostrum cells being like the fully degenerated cells, which are often described as compound granular corpuscles.

When finely divided fat suspended in fluid is present in the living tissues, it is very readily absorbed. We know how readily the emulsionized fat in the alimentary canal is taken up by the epithelium, and

passed on into the lacteals. When milk is injected into the abdominal cavity of a living animal, or even laid on the surface of the diaphragm after death, it very quickly passes into the lymphatics. In the case of fatty degeneration of cells, if fluid be present, the cells disintegrate, an emulsion is formed, and absorption occurs just as in the case of milk.

But sometimes the fatty degeneration occurs in connection with structures not adapted to absorption, as in a hydrocele, where the tendency is rather to transudation, or in an ovarian tumour. In that case, the fat undergoes further changes, resulting usually in the production of crystals of CHOLESTEARINE (Fig. 35). This substance occurs as a normal

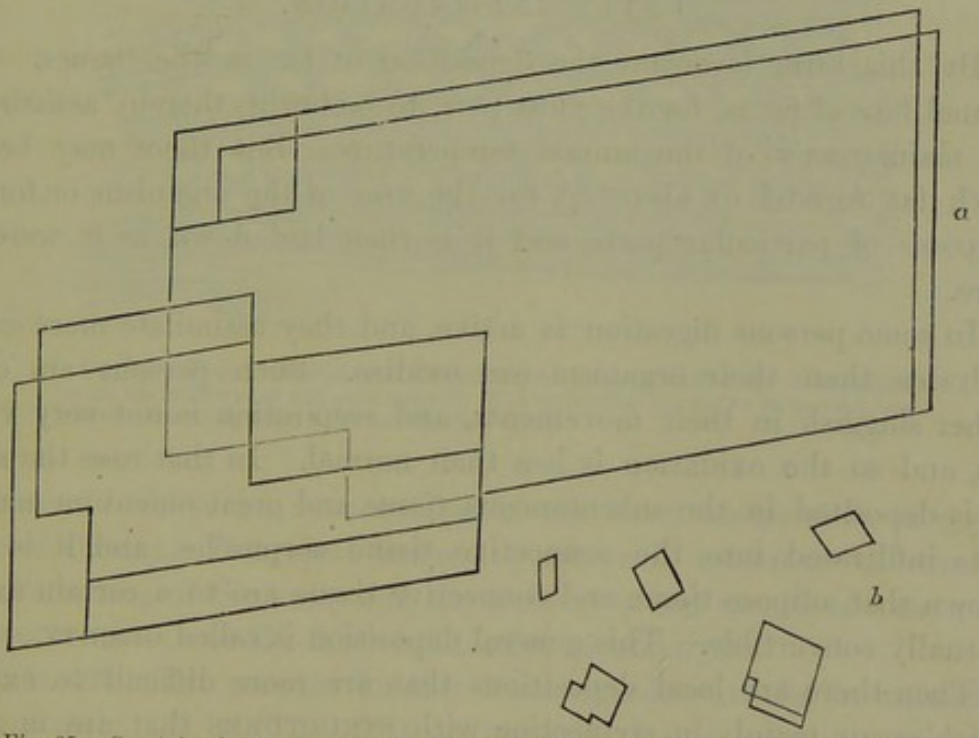


Fig. 35.—Crystals of cholestearine ; *a*, large ones from an old hydrocele ; *b*, from stagnant bile in gall-bladder. ×350.

constituent of the central nervous tissue and bile, in which latter it is dissolved. Its crystals are rhombic tables whose angles measure 79° 30′ and 100° 70′. On adding strong sulphuric acid to a crystal of cholestearine, letting it gradually run in and act on it, the crystal appears to melt from the edge inwards, and take on a fatty appearance, and by and by it gathers into a brown drop. On adding iodine and sulphuric acid to a crystal, there is at first a beautiful display of colours.

The changes mentioned above occur when there is abundant fluid in connection with the fatty debris, converting it into an emulsion, which either is absorbed or deposits crystals of cholestearine. But when the fluid is deficient, as when the vessels are few and the cells are heaped

together closely, in that case the fatty degeneration is often associated with necrosis, and there is a shrinking and drying-in of the structure, resulting in the formation of a cheesy-looking material. This process we have already considered under the designation caseous necrosis. The cheesy material used to be regarded as crude tubercle, and the metamorphosis was called TUBERCULIZATION. We have already seen that although caseous necrosis is far more frequent in connection with tuberculosis than any other condition, yet the name must not be monopolized by this process.

FATTY INFILTRATION.

By this term is meant the deposition of fat in the tissues. The normal fate of fat is, for the most part, to be burnt, thereby assisting in the maintenance of the animal temperature. But there may be too much fat formed or absorbed for the uses of the organism or for the purposes of particular parts, and it is then laid down, as it were, in store.

In some persons digestion is active, and they assimilate more carbohydrates than their organism can oxidize. Such persons are often rather sluggish in their movements, and respiration is not very vigorous, and so the oxidation is less than normal. In that case the spare fat is deposited in the subcutaneous tissue and great omentum mainly. It is infiltrated into the connective tissue corpuscles, and it is well known that adipose tissue and connective tissue are to a certain extent mutually convertible. This general deposition is called OBESITY.

Then there are local depositions that are more difficult to explain which occur mainly in connection with STRUCTURES that are in some way PUT OUT OF USE. A most typical example of this is afforded by MUSCLES which have become fixed at their two ends by stiffening of joints. The muscle can no longer produce any movement, and its fibres gradually atrophy as we have already seen. At the same time, in the connective tissue around the muscle and in that which supports it, there is a great infiltration of fat, so that adipose tissue appears between and around the fibres (see Fig. 36). Then, again, in pseudo-hypertrophic paralysis—a disease chiefly of children—there is a similar process. The muscular tissue atrophies, but there is at the same time an excessive transformation of the connective tissue into adipose tissue, so that the wasting of the muscle is more than counterbalanced by the excess of adipose tissue, and there is thus a pseudo-hypertrophy.

A similar fatty infiltration occurs in THE HEART. Normally, there is a certain amount of adipose tissue beneath the pericardium. But sometimes this becomes excessive in quantity and extends into the muscular substance, between the muscular fibres, so that the wall of the ventricle may be largely composed of adipose tissue. If this fatty infiltration were primary then we could understand how, in these cases, there should be great wasting of the proper muscular fibre, and there

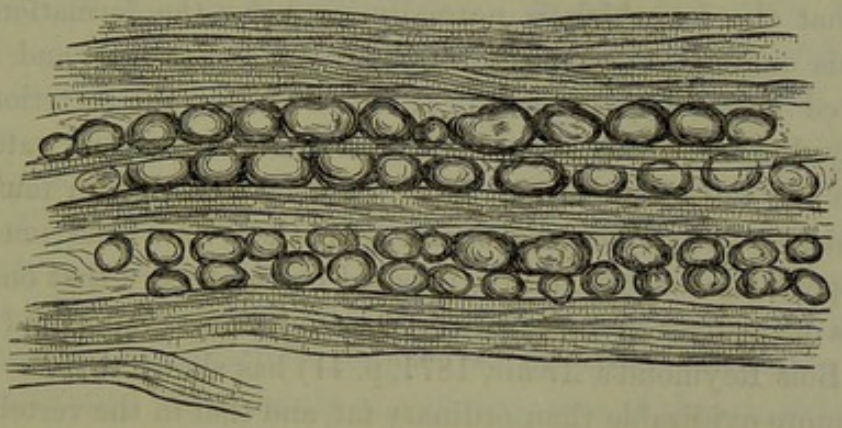


Fig. 36.—Fatty infiltration of muscle from a case of stiffening of the ankle by an epithelioma of the skin over it. The muscular fibres are narrowed, and adipose tissue appears between them. ×80.

are cases in which the over-loading of the heart seems to be part of a general obesity. But, more frequently, there is reason to believe that the weakening of the heart and the atrophy of the muscle are the primary occurrences and the fatty infiltration secondary.

It is difficult to account for this local deposition of fat in connection with muscle. It may be that as normally fat is largely oxidized in muscle, or largely produced there in connection with the active process of contraction, when the demand is gone it is laid down by the vessels in the neighbouring connective tissue.

Fat is often deposited in excessive quantity AROUND DISEASED AND USELESS GLANDS, especially the kidney. In hydronephrosis there is often an enormous increase of the fat which normally surrounds the kidney. This is also difficult to account for.

The INFILTRATION OF FAT INTO THE LIVER, which we meet with very frequently, is also difficult to explain. It is met with, in the first place, in persons addicted to the excessive use of alcohol, and in that case often goes along with an excess of fat in all the organs, probably due to the oxidation of the fat being interfered with by the alcohol. The fat, in

these cases, is often very fluid, and the organs have a greasy appearance and feeling. But, in the second place, fat is often found in large quantities in the liver in cases where, in the subcutaneous tissue or elsewhere, there is an actual deficiency of it. The fat in the liver is in the peripheral parts of the lobules, and from this it is to be inferred that it has been brought by the portal blood. This fatty infiltration occurs frequently in phthisis pulmonalis, and in other cachectic diseases. Its accumulation under these circumstances may, in part, be accounted for by supposing that the fat which is normally used for the formation of the fatty acids and the cholestearine of the bile is not so used and is therefore stored in the hepatic cells. It is known that the secretion of bile is greatly diminished in such cases, and that the bile is watery. In that case the fatty infiltration here would be like that in muscle, due to diminished activity of the organ. Another view, and one having some appearance of probability, is based on the theory that one of the functions of the liver is to prepare fat for oxidation. Naumann (Reichert and Du Bois Reymond's *Archiv*, 1871, p. 41) has shown that the liver fat is much more oxidizable than ordinary fat, and that in the vertebrata the size of the liver is in inverse proportion to the activity of the respiration, being largest in fishes and smallest in birds. It is therefore suggested that in phthisis and cachectic diseases the liver may produce an excess of easily oxidizable fat and store it up ready for use. Hence, perhaps, the utility of liver oils in cases of phthisis, etc.

We have seen that in fatty degeneration the fat appears in the form of fine granules or drops, and that as these increase they remain isolated. In fatty infiltration there are, of course, first fine fat drops, but as more fat is added the drops grow in size. In the case of the conversion of connective tissue into adipose tissue, there is a single fat drop in each cell, as in Fig. 36. In the case of fatty liver the fat drops are of various sizes (see Fig. 37), but, as a rule, much larger than in fatty degeneration. The size is by no means an absolute criterion, but it is an important practical indication. It is only in the liver that there can be much difficulty in distinguishing between fatty degeneration and fatty infiltration, and here the fact that

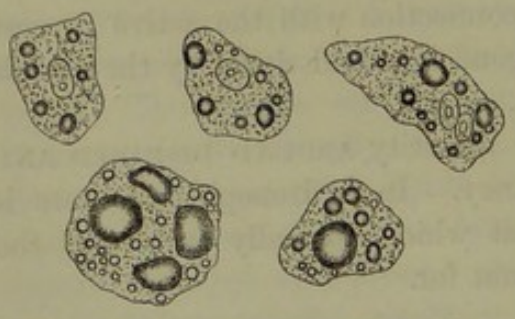


Fig. 37.—Fatty infiltration of the liver. Isolated hepatic cells with drops of fat of various sizes. ×350.

in the latter the fat is deposited at first in the cells at the peripheral parts of the lobules, and always continues more abundant there, is sufficiently distinctive.

PIGMENTARY INFILTRATION.

In studying HÆMORRHAGE we have already seen that a common result of the extravasation of blood is the pigmentation of the tissues around. This pigmentation may be brought about in various ways, and is of various degrees of permanence. In the first place the blood colouring matter may be dissolved out of the corpuscles and stain the tissues, this being an evanescent pigmentation. Then the dissolved colouring matter may be deposited in the solid form after a time. We may thus have crystals of hæmatin in the form of oblique rhombic pillars, or simply amorphous granules; the crystals occur mostly in large extravasations. Lastly, there is the pigmentation which results from the cells in the neighbourhood of the hæmorrhage taking up the red corpuscles and becoming pigmented by these. Probably much of the pigmentation which occurs as a consequence of chronic inflammation or passive hyperæmia is due to this last process, the hæmorrhage here being by diapedesis. Chronic catarrhs of the stomach and intestinal canal are often distinguishable after death by the slaty colour of the mucous membrane. In chronic passive hyperæmia of the lungs from heart disease there is a brown pigmentation, frequently called brown induration.

The pigmentation occurring IN TUMOURS, especially cancers and sarcomas, is often regarded as due to minute hæmorrhages, and there are many facts which appear at least to connect it with the blood-vessels. Gussenbauer (Virchow's *Archiv*, vol. lxiii., p. 322) asserts that in melanotic tumours there is a thrombosis in the smaller vessels, and that the blood-colouring matter is dissolved out, and is taken up by the cells of the tumours. It is to be remarked that in pigmented tumours there is not a homogeneous distribution of the pigment, but the majority of the cells are unpigmented, and there is often an arrangement suggestive of local foci of origin. It is to be presumed that in these tumours there is some peculiarity of the blood-vessels which allows either of ready extravasation or thrombosis. It is to be added, however, that it is denied by some that the pigment in tumours is derived from the blood pigment, chiefly on the ground that it does not contain iron.

Pigment is to be found in thrombi, and in the case of veins especially it may be deposited in crystals as well as in granules (see p. 31).

Pigmentation of THE LUNGS may be regarded as a normal condition, although it is acquired after birth. It is due to inhalation of particles of dust which are carried into the lung substance by amœboid cells, and partly remain in the connective tissue of the lung, and partly are carried to the bronchial glands. Where this pigmentation is excessive, as in the case of miners, we have a recognized morbid state designated Anthracosis. Other forms of pigmentation occur in the lungs from the inhalation of variously coloured stuffs by workers exposed to them.

ICTERUS is a yellow staining of the tissues with a colouring matter dissolved in the blood serum. This is usually the biliary colouring matter absorbed from the bile-ducts after its secretion. It implies an obstruction to the ducts in some part of their course. A similar staining may be a consequence of the destruction of red corpuscles, their colouring matter becoming dissolved in the blood—the so-called hæmatogenous icterus.

The BRONZE COLOURATION OF THE SKIN in Addison's disease is related to disease of the supra-renal capsules, in which there is a caseous condition, a local tuberculosis. The solar plexus of nerves is probably affected along with the capsules, but the exact pathology of the condition is not understood.

Lastly, a tissue may be unduly deep in colour simply from ATROPHY of the other constituents, and a concentration of the normal pigment. Thus when emaciation occurs, and the fat is absorbed from the subcutaneous tissue, this often assumes an unusually dark yellow or brown hue. An emaciated heart presents in its muscular substance a very dark colour from the diminution of the contractile substance and concentration of the pigment.

MUCOUS AND COLLOID DEGENERATION.

These two conditions present considerable similarity, and in individual cases it is often difficult to say which of them is actually present. They are characterized by the abnormal occurrence in the tissues of two chemical principles, which are albuminates, and doubtless arise by transformation of the normal tissue albumen. One of these substances is known as a definite chemical principle, and is named mucin; the other is not well known in its chemical relations, and is somewhat indefinitely named colloid material. Both have the peculiarity that in the presence of water they swell up and acquire a gelatinous consistence.

With very similar physical characters, and arising under somewhat similar circumstances, they are distinguished by their difference in chemical reaction. Mucin forms a somewhat membranous precipitate with acetic acid, and its solutions are also rendered turbid by alcohol and chromic acid. Colloid material is not obviously altered by these reagents.

A PHYSIOLOGICAL TYPE of mucous and colloid degeneration is afforded by the normal secretion of mucus. Here it is known that the epithelial cells, whether of the surface of the mucous membrane or in the proper glands, become converted into goblet cells, by the formation of mucus within them. The mucus is secreted by the rupture or disintegration of these cells, and the discharge of the material which has swelled them up.

In certain pathological conditions this secretion of mucus is exaggerated, notably in the catarrhs of mucous membranes. But this can hardly be regarded as a proper mucous degeneration.

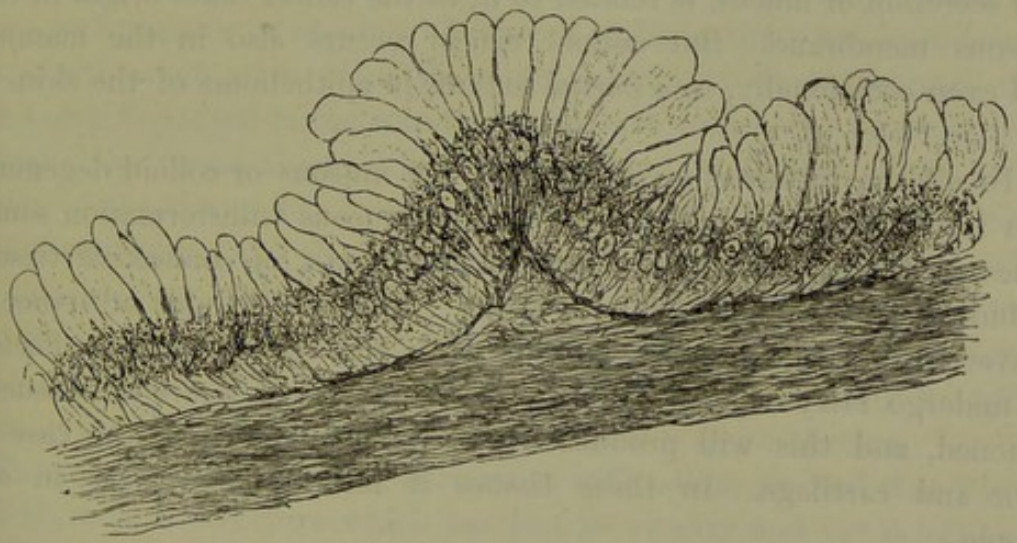


Fig. 38.—From internal surface of a colloid ovarian cyst. The lining epithelium is mostly in the form of goblet cells, the superficial parts having clear transparent contents. ×350.

In OVARIAN TUMOURS a process is often visible which closely resembles the secretion of mucus. We shall see afterwards that the larger number of ovarian tumours originate in a glandular formation, and in this gland tissue most characteristic goblet cells are often to be seen (see Fig. 38), the gelatinous contents of the cysts formed being obviously secreted in this way. But then, the gelatinous material does not usually give the reaction of mucin with acetic acid, and is clearly an albumen of a different kind, whose chemistry is not well known. Hence

this would be included under colloid degeneration, although in histological details resembling the mucous form.

Again, in the THYROID GLAND there are often, even normally, little gelatinous particles visible on dividing the gland, and in the commonest form of goitre (colloid goitre) there is a great increase of this clear gelatinous material. On microscopic examination it is clear that the gelatinous material arises by transformation of the epithelium lining the saccules which form the parenchyma of the gland. The cells swell up and become filled with clear gelatinous material; by the discharge of this or the disintegration of the cells the colloid contents of the saccules are formed. But this material has not the reactions of mucus.

In COLLOID CANCERS there is a similar transformation of the epithelium, so that the cellular masses are transformed into colloid masses, which fill the spaces in the stroma. This form of cancer is most frequent in the stomach and large intestine, and it may be thought that this colloid transformation, so closely resembling the normal secretion of mucus, is related to it, as the cancer takes origin in the mucous membrane. But colloid cancer occurs also in the mamma and even occasionally, to a partial extent, in epithelioma of the skin.

In all the instances given hitherto, the mucous or colloid degeneration has affected epithelial cells. But a mucous transformation sometimes occurs IN THE INTERCELLULAR SUBSTANCE of connective tissue, including bone, cartilage, adipose tissue. The intercellular substance is converted into a gelatinous material, while the cells remain unaffected or undergo fatty degeneration. When this change occurs the tissue is softened, and this will produce a very striking result in the case of bone and cartilage. In these tissues it mostly takes place in old people.

We shall see afterwards that there is a form of TUMOUR which is characterized by the fact that its tissue contains mucin in its intercellular substance. This is not a case of mucous degeneration, but sometimes a portion of a tumour of a different kind will acquire these characters, and then we may use this designation. It is mostly in fatty tumours and sarcomas that this occurs.

CALCAREOUS INFILTRATION.

This is a condition of very frequent occurrence, and therefore deserving of very careful attention. By the designation is meant the deposi-

tion of lime-salts in abnormal fashion in the tissues. The lime-salts are for the most part the same as those which normally take part in the structure of bone, namely phosphate and carbonate of calcium.

There is a certain proportion of the salts of lime existing normally in all the tissues and juices; these all leave an ash on burning, and lime-salts form part of this ash. But the lime-salts here are dissolved in the juices, or form combinations with the albumen, so that they do not appear on microscopic examination. In calcareous infiltration there is a deposition of the lime in the form of insoluble carbonate and phosphate, and there is also an accumulation of these insoluble salts, so that the ash on burning the tissues is greatly increased. There is a precipitation of the lime, and as lime-salts in solution are continually being brought in along with the fluids of the tissue, they are continually precipitated and thereby fixed.

In considering the circumstances which induce this precipitation, we encounter what Virchow has called METASTATIC CALCIFICATION. In some cases where there is rapid destruction of bone, as by multiple caries, or by cancer or sarcoma advancing on bone, there has been found after death calcification of portions of the lung or digestive canal, the lime being deposited in the connective tissue in such a way as sometimes to make the tissue almost like pumice stone. In several of the cases disease of the kidney has co-existed, and there may have been therefore some interference with the due excretion of the absorbed lime-salts. In any case we may presume that the deposit is related to excess of lime-salts in the blood and fluids. There must, however, have been some cause determining the locality of the deposition, in the lung in some cases, in the intestinal walls in others, but this is quite obscure.

Turning to other cases of calcareous infiltration, we find that wherever there is a structure which has lost its vitality and yet is left as a kind of DEAD AND FOREIGN BODY in the midst of the tissues, there is apt to be deposition of lime in and around such structure. It may be said that obsolete or obsolescent structures are liable to be impregnated with lime. It has already been stated that lime is present in all the fluids and tissues of the body, and in the fluids it is probably kept in solution by the presence of an excess of carbonic acid. In the case of a structure which is obsolete the fluids will stagnate, will lie about in it, and it is not remarkable that their lime, which is so readily precipitated from solutions, should deposit. As the fluid is renewed, more and more lime is deposited, and the structure may finally be converted into a stony mass.

The lime-salts are deposited in the first instance in the form of fine globular granules, either in the protoplasm of cells or in the intercellular substance. The structure is as if dusted with refracting granules, and the appearances in many respects resemble those of fatty degeneration. (Fig. 39*a*.) As the salts accumulate, the appearance of

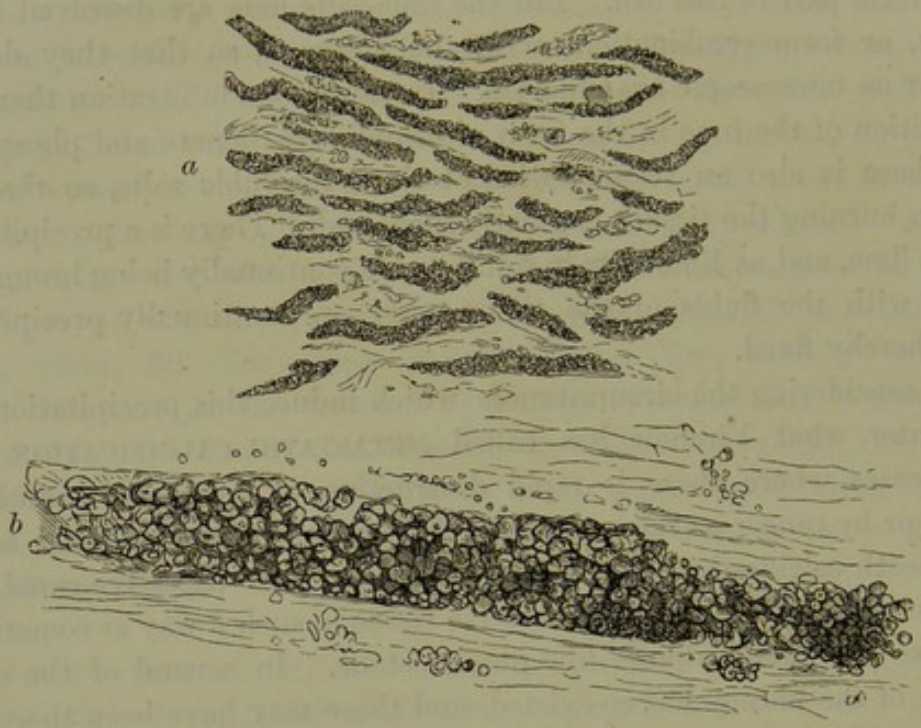


Fig. 39.—Calcareous degeneration in a tumour; *a*, cells of smooth muscle filled with lime granules; *b*, a blood-vessel converted into a solid rod. ×350.

granules is somewhat lost and a more continuous petrifaction results. (Fig. 39*b*.) The addition of a dilute mineral acid causes the salts to dissolve, and, as carbonates are nearly always present, solution occurs with evolution of gas.

Examples of this process are very numerous. A minute parasite, the trichina spiralis, occurs in the embryo form in the muscle of man and animals; it lies there quiescent, coiled up spirally and surrounded by a capsule. It is virtually a foreign body, and the capsule is by degrees impregnated with lime, assuming an opaque appearance at its poles (Fig. 40). If the embryo itself dies, it also may become impregnated with lime (see Fig. 40, lower part). Sometimes an extra-uterine fœtus dies and remains inside the abdomen as a foreign body. It becomes surrounded by adhesions and partially encapsuled. The capsule and superficial parts of the fœtus become through time encrusted with lime. Again, an inflammatory exudation in the pericardium may dry in and remain as a half-caseous material, which finally becomes impregnated

with lime, and something like a shell may form around the heart. In phthisis pulmonalis, if healing occurs, the contents of cavities and in-

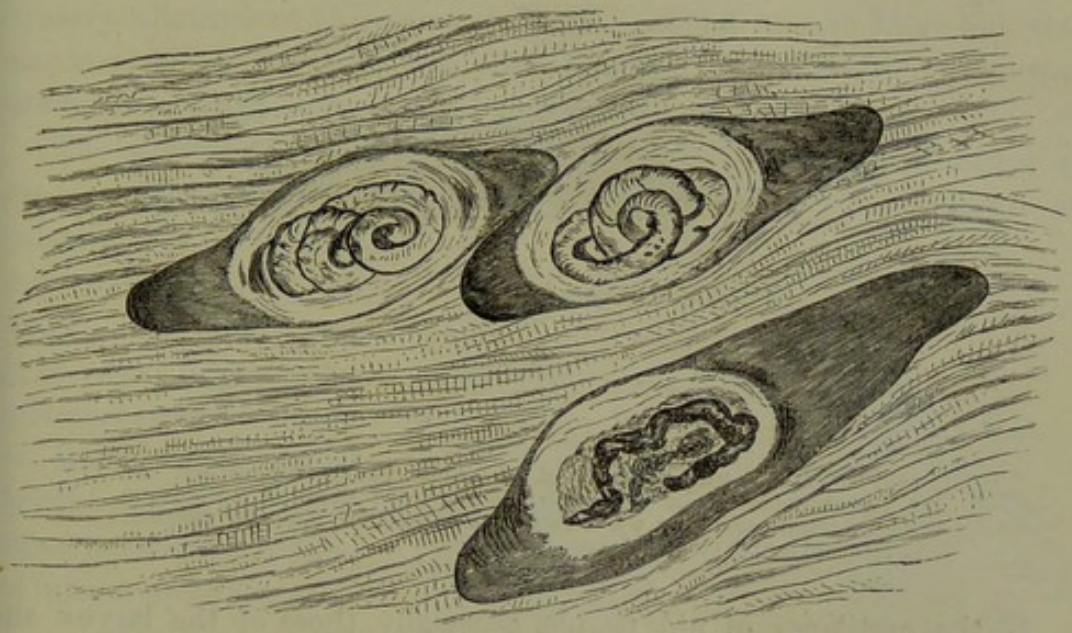


Fig. 40.—Trichina spiralis in muscle. The capsules infiltrated with lime, and in one case a dead worm shrivelled and impregnated with lime.

flammatory products may dry in and become surrounded by a capsule. Impregnation with lime results, leading to a pultaceous or mortary material, which may ultimately condense into a stony mass. These stony masses are sometimes coughed up if the lung afterwards breaks down, but it is very common to meet with them in the midst of cicatrices at the apices of the lungs after death. Again, in valvular disease of the heart, due to chronic endocarditis, the new-formed connective tissue, by its contraction, becomes hard and dry and virtually obsolete, and deposition of lime-salts occurs.

In regard to the frequent deposition of lime-salts IN THE MIDDLE COAT OF ARTERIES (Fig. 41) there seems to be little doubt that this is frequently associated with atheroma, which is a chronic inflammation of the internal coat, and we may suppose that the induration of the internal coat affects the neighbouring middle coat. This calcareous infiltration is peculiarly liable to occur in old persons, and we may believe that in them there is a defective vitality of the walls of the artery perhaps specially affecting the more active middle coat. But there are cases, and some of them not in very old persons, where there is a remarkably extensive calcareous impregnation of the middle coat, so that the arteries are largely converted into rigid tubes. In these cases we

may presume that, from some unknown cause, the middle coat is prematurely defective in vitality.

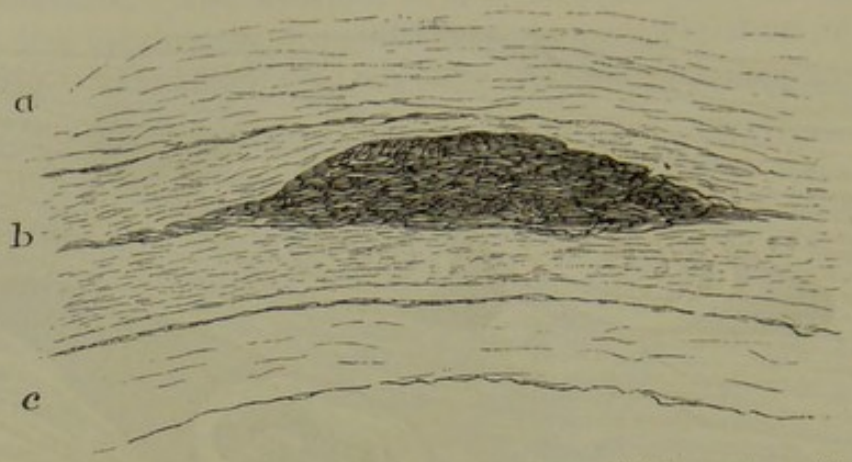


Fig. 41.—Calcareous infiltration of the middle coat (*b*) of an artery. At the tapering borders of the patch the elongated shape of the opaque structures indicates that the muscular fibre-cells are specially affected. The internal coat (*c*) is thickened. ×60.

In the cartilages of old people, especially those of the larynx and ribs, there is very commonly a deposition of lime salts. But, in this case, there is not simply a calcareous impregnation, rather a true ossification occurs, and the process may be regarded as virtually a physiological one, a late development of bone from cartilage.

AMYLOID DEGENERATION.

This name is applied to a condition in which the constituents of the tissues are converted into a substance whose chemical characters are different to those of any normal principle in the body. The degeneration is also called WAXY and LARDACEOUS from the physical characters of the substance produced. This may be called for convenience AMYLOID SUBSTANCE, and, as the name suggests, it was originally supposed to be allied to starch. It has really no chemical relation to starch, being a nitrogenous substance and a modified form of albumen. It resembles starch, however, in respect that it gives a colour reaction with iodine. When a solution of iodine in water * is poured on the surface of an organ which presents amyloid degeneration, then the amyloid substance takes on a mahogany-red colour. If, afterwards, a very dilute sulphuric

* A convenient solution is, Iodine, 10 grains; iodide of potassium, 20 grains; water, 4 ounces. For microscopic sections a solution half this strength is sufficient.

acid be added, the colour will sometimes assume a darker brown or bluish tint. More recently it has been found that amyloid substance presents a peculiar reaction with methyl violet, one of the aniline dyes. Watery solutions of this dye colour the normal tissues blue, but stain amyloid substance of a rose-pink colour. Other aniline dyes show differences of tint with amyloid substance.

The substance itself has a peculiar bright translucent glancing appearance (see Fig. 42), and, as the structures in which it occurs are enlarged, they are often remarkably prominent under the microscope. It is a very dense heavy material, and after death, at least, is somewhat brittle, so that the structures have often a kind of broken-up appearance.

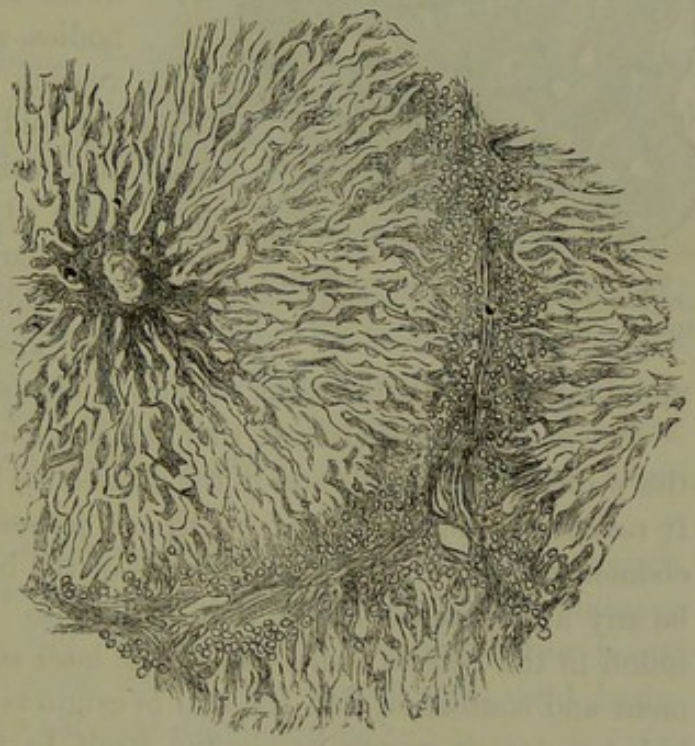


Fig. 42.—Advanced amyloid disease of the liver. The arrangement of the transparent amyloid material suggests its formation in the capillaries. The round bodies at the peripheral parts of lobules are fat drops, there being slight fatty infiltration. ×70. (THIERFELDER.)

AMYLOID DISEASE may affect any organ of the body, but it is particularly frequent in the spleen, liver, kidneys, intestine, and lymphatic glands.

In all these organs it BEGINS IN THE CONNECTIVE TISSUE or the WALLS OF THE BLOOD-VESSELS, more especially the walls of the capillaries and smaller arteries. As the disease is a progressive one and the amyloid substance accumulates in large quantity, it is important to observe the condition in the very earliest stages. If a section of the liver be made at a time when the disease is not far advanced, and the section, after staining with iodine and sulphuric acid, or with methyl violet, be examined under the microscope, it will be seen that, besides the smaller arteries, the capillaries are the seat of degeneration (see Fig. 43). Their walls are swollen and translucent and the calibre encroached upon. At the same time the hepatic cells are compressed and are undergoing atrophy. In advanced stages, on the other hand, the whole

tissue of the liver seems to be replaced by the amyloid substance, and it is difficult to say in what structures the degeneration has originated, but even here there are often, as in Fig. 42, indications of its origin in the capillaries. In the spleen, as we shall see afterwards, there are two forms of amyloid disease, and in one form it seems to begin in the reticulum of the Malpighian bodies, methyl violet or iodine revealing a fine network having an amyloid reaction in these bodies in the earliest stage. In the other form it affects the walls of the vascular sinuses of the pulp. In the kidney it is chiefly the vessels that are affected, but the basement membrane of the uriniferous tubules is also sometimes involved.

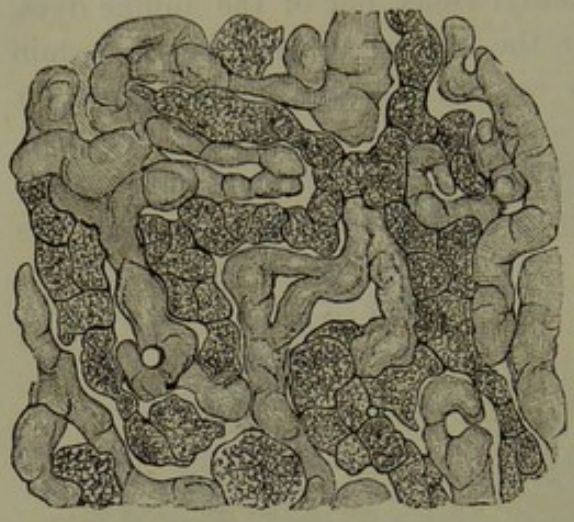


Fig. 43.—Amyloid disease of liver in early stage. The walls of the capillaries swollen and translucent. ×350.

It would seem, therefore, that the amyloid substance first appears in the walls of the vessels and in the connective tissue in these three organs. It remains to be considered whether it passes beyond these to the other elements of the organs. In the case of the liver there does not seem to be any undoubted evidence that it does so. In the earlier stages it is found in the vessels alone, and in the later stages there is such enlargement and contortion that the seat of origin is somewhat obscure. In the kidney, also, it seems to confine itself to the vessels and connective tissue of the organ. In the spleen it does not, according to the observations of the author, confine itself to the vessels and connective tissue proper. Even in very early stages he has generally found that here and there in the sago spleen the round cells of the lymphoid follicles are affected. These cells, from what has been said on a previous occasion, may be regarded, however, as belonging to the connective tissue. In the lymphatic glands, again, it is the blood-vessels and reticulum that are affected. In the intestine it is the capillaries and arteries, and to a less extent the muscular fibre cells.

From this it will appear that the view formerly held, according to which the disease might attack the epithelial cells of such organs as the liver, is erroneous, and that the degeneration is confined to the structures constituting the supporting frame-work of the tissues, including the vessels.

We have now to consider the EFFECTS OF AMYLOID DEGENERATION. We have referred to the brittleness of the amyloid substance, but it is not to be inferred that this exists to any considerable extent during life, otherwise we should have frequent hæmorrhages as a result of amyloid disease. Hæmorrhages rarely occur, and so we infer that the substance is tolerably elastic during life. In examining amyloid organs after death, especially such organs as the intestine, great care should be taken in handling them lest destruction of the amyloid structures should take place.

It is clear from symptoms observed during life that the amyloid substance is very pervious to fluids, the prominent symptom of amyloid disease in the bowels being diarrhœa, and in the kidney excessive discharge of watery urine.

It has already been said that the calibre of vessels is reduced when amyloid disease occurs in their walls. This will cause anæmia in the structures supplied; and atrophy, sometimes with fatty degeneration, is frequently the result. This we see in the kidney and in the liver, the atrophy of the proper secreting substance of the liver being, however, to a great extent, the direct result of pressure by the swollen capillaries.

The amyloid structures are greatly increased in bulk and weight and this tells on the organ as a whole. The liver, spleen, and kidneys are often greatly enlarged, and they present a peculiar dense translucent appearance which has given rise to the names waxy and lardaceous disease often applied to amyloid degeneration.

Besides the generally diffused amyloid disease occurring in a number of organs, and present in every part of the individual organs affected, we sometimes meet with a LOCALIZED AMYLOID DEGENERATION. This mostly occurs in new-formed inflammatory tissue and cicatrices, especially when of syphilitic origin, and also in tumours. As yet this local amyloid degeneration has only been observed in pathological structures such as those mentioned. It has been seen in syphilitic cicatrices in the liver, in the tongue, and larynx, in degenerating cartilage, etc., and in some cases the amyloid piece of tissue is of considerable size, and as it differs in its hard translucent character from the tissues around, it may itself look like a tumour.

We may now consider THE NATURE OF THE PROCESS which has been described. Looking to the history of the cases in which it occurs

it is clear that it is to be referred primarily to an alteration in the blood, probably an impoverishment of it in albumen. The disease is not an independent one, but comes on in certain cachectic states due to chronic tuberculosis, syphilis, diseases of bone involving prolonged suppuration, chronic dysentery, chronic albuminuria, etc.

It is more difficult to determine the nature of the connection between the vice in the blood and the disease in the tissues. By some it is supposed that the amyloid substance arises in the blood by modification of the albumen and is then infiltrated into the structures. But this view cannot be accepted, for various reasons. In the first place the substance is eminently insoluble, and it is difficult to understand how it can be carried; besides this it does not displace the normal structures simply, but replaces them, these structures being converted into the amyloid substance. It is more consistent to suppose that the tissues are reduced in vitality by the altered condition of the blood, and that the albumen received enters into combination with the protoplasm in such a way as to produce this peculiar substance. The process may perhaps be compared to the coagulation of the tissues, which, as we have seen, sometimes occurs when they undergo necrosis, the tissues entering apparently into a chemical union with the fibrinogen in the fluid exuded from the blood-vessels, so as to form fibrine or some substance allied to it. Amyloid substance has been often regarded as akin to fibrine, and fibrinous casts in the tubules of the kidney are sometimes converted into amyloid substance. The existence of localized amyloid disease is strongly confirmatory of some such view as this. Here abnormal structures enter into this peculiar chemical combination with the albumen of the blood, while normal structures do not. In this connection also, the fact that amyloid disease affects the connective structures of the body is not to be forgotten. It is as if the chemical basis of these structures had a special relation to the amyloid substance. Amyloid disease is therefore essentially a degeneration, although, in order to the formation of the amyloid substance, it is necessary to have added to the tissue material from without, and this adds greatly to the bulk and weight of the structures.

We have still to refer to bodies occasionally met with, and designated AMYLOID CONCRETIONS or CORPORA AMYLACEA. In old extravasations of blood we sometimes meet with round or oval stratified bodies of small size (see Fig. 44*b*), which give a typical amyloid reaction. Sometimes they contain in their central parts a foreign body, such as a

blood crystal. Again in the prostate gland (*a*) we meet with concretions of considerable size, it may be visible, as brown granules, to the naked eye, with all the characters of stratified amyloid concretions. They are also met with in the tissues of the central nervous system (*c*), they are present in the normal brain, especially in the ependyma of the ventricles, but in cases of sclerosis they may be present in enormous numbers.

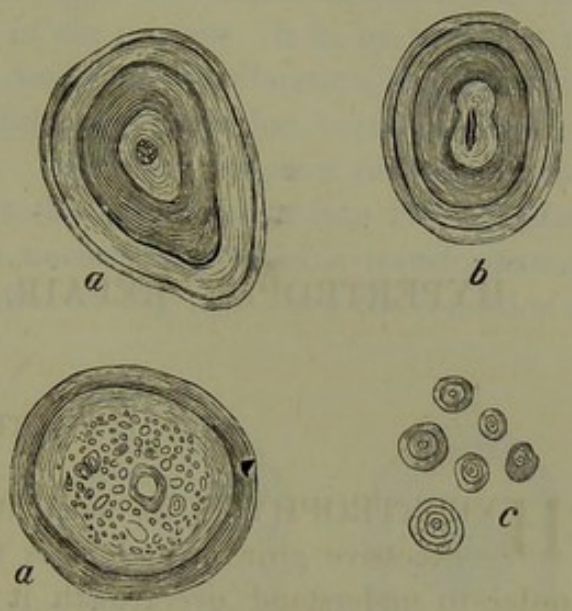


Fig. 44.—Corpora amylacea: *a*, from the prostate; *b*, from a hæmorrhagic infarction of the lung; *c*, from the spinal cord. ×400. (Ziegler.)

The significance of these amyloid bodies is not usually very great in a directly practical point of view, but their presence under these various conditions seems to prove that various albuminous substances may undergo conversion into the so-called amyloid substance.

HYPERTROPHY, REPAIR, AND REGENERATION.

I. HYPERTROPHY.

HYPERTROPHY, in its most literal sense, means overgrowth, or excessive growth, and it is so that we shall use it here. In order to understand overgrowth it will be necessary to make some observations on the characteristics of normal growth.

In the NORMAL GROWTH of the body each tissue has the power of reproduction up to a certain point. By some hidden power the tissue grows and moulds itself into particular anatomical forms, and ceases growing when it has attained the proportions necessary for its function in the organism. We do not know what this power is, but we can say that it is inherited by the germ from its parents, and that in the variations which are presented in different individuals heredity plays a very important part.

In order to this growth the new-formation of blood-vessels is necessary, but here, as in pathological conditions, the formation of vessels is secondary, and takes place merely according to the needs of the organism. The amount of blood supplied and its distribution strictly follow the necessities of the growing tissues, and the vascular system shows a wonderful power of adaptation to the requirements of the tissues. It is true, as we shall see afterwards, that an excessive supply of blood may lead to increased growth, but such an excessive supply of blood never occurs normally, is an accident, and as such may lead to morbid or excessive growth.

When tissues cease to grow, it is not that the formative power inherent in them has ceased to exist, but simply that, being subordinate to the general law of the organism they have attained the full size requisite for their intended uses. Should occasion occur for their

renewed growth, then it will very often happen that a fresh start will be made.

Looking to the details of normal growth, we find that it is the cells which are the essential factors in the process. It is by DIVISION OF THE CELLS, a process frequently designated proliferation, that growth is ultimately effected. Much careful observation has been bestowed on the process of division of cells. There are frequent indications that first the nucleus and afterwards the cell separate into two. Before the actual division begins the nucleus undergoes a transformation, the details of which may be studied in Fig. 45. In *a* the condition of

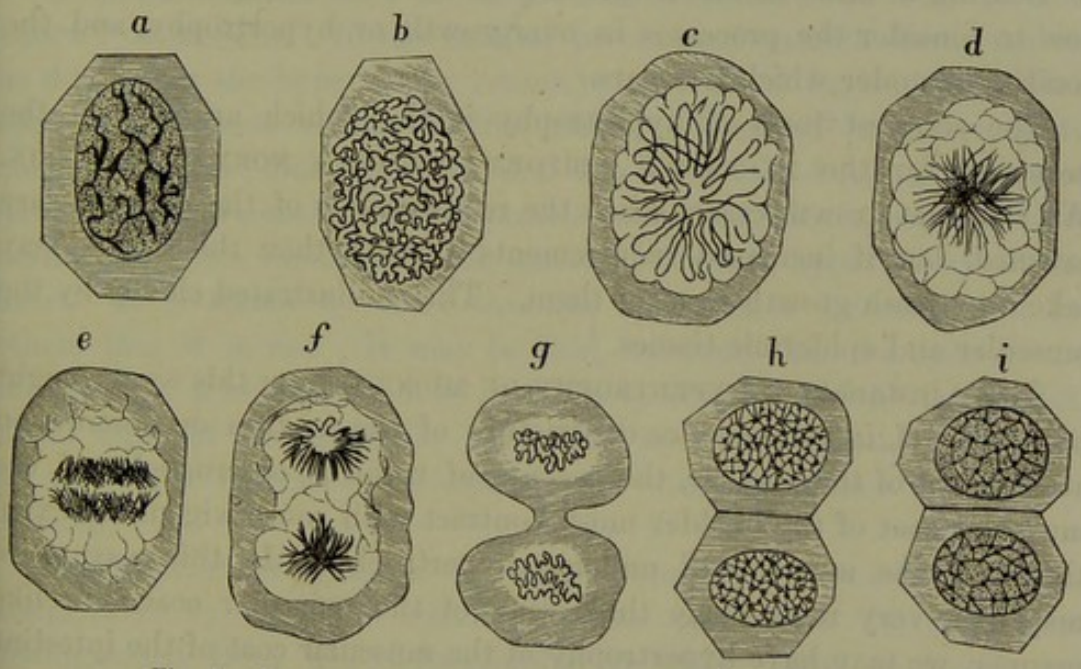


Fig. 45.—Division of cells. Explanation in text. (After FLEMMING.)

an epithelial cell in its normal quiescent state is shown. By particular methods of staining it can be shown that the nucleus contains a fine network of fibres, but here the substance of the nucleus as well as the fibres is stained. In *b* the condition preliminary to division is shown. The nucleus now contains a collection of convoluted tubes, and those alone are stained while the substance between does not take on the colour. These fibres are apparently contractile and vary their position somewhat, but gradually tend to assume a radiating arrangement as in *c* and *d*. There now comes a separation in the middle, as at *e*, and the two sets of fibres retreat from one another towards the poles of the cells as in *f*. The division of the nucleus is thus effected, and that of the cell follows as in *g*. Subsequently the irregular bundle of fibres in each new cell

assumes the shape of the regular nucleus and gets surrounded by a membrane. The fibres also give place to a fine network as in the original cell, and the substance of the nucleus between the fibres again takes on the staining as in *i*.

This process of division has been observed in the fixed cells of many tissues, and it is probably the only one which occurs in the normal process of growth. In white blood corpuscles, and probably also in the embryonic cells a more direct division of the nuclei appears to occur, but the details of that process are not very clear.

Bearing in mind the facts mentioned as to normal growth we have now to consider the processes in overgrowth or hypertrophy, and the conditions under which it occurs.

The simplest form of hypertrophy is that which arises from the necessity for the EXCESSIVE PERFORMANCE OF A NORMAL FUNCTION. We saw that growth ceases when the requirements of the organism are satisfied, but if increased requirements develop, then the tissues may take on a fresh growth to meet them. This is illustrated chiefly by the muscular and epidermic tissues.

Many instances of HYPERTROPHY OF MUSCLE, from this cause, might be cited. If, in consequence of stricture of the urethra or obstruction at the neck of the bladder, the passage of urine is obstructed, and the muscular coat of the bladder must contract with more vigour to expel the urine, the muscle will undergo hypertrophy. In this way there may be a very remarkable thickening of the muscular coat. In like manner, we may have hypertrophy of the muscular coat of the intestine in connection with stricture of the rectum or colon. The muscular tissue of the heart also undergoes an exactly similar hypertrophy when, in order to expel the blood from its cavities, more forcible contractions are requisite. We know also that the voluntary muscles hypertrophy when they are repeatedly exercised in a forcible way.

In all these cases of hypertrophy of muscle it is usually said that frequent exercise is the cause, but this is hardly a full description of the circumstances. The exercise must not only be frequent, but the work to be done must require an UNUSUALLY FORCIBLE EXERTION. In the cases already cited it will be seen that the essential condition is the necessity for additional power, usually to expel the contents of a cavity through a narrowed orifice. The heart does not hypertrophy because its muscle undergoes frequent exercise, but only when additional force is required. It is so also in the case of voluntary muscles. Mere

agility and rapidity of movement does not cause hypertrophy of muscle, whereas repeated severe exertion calls it forth. The muscles of the hand and arm do not hypertrophy in persons who use them frequently in writing, but they do in artizans who use great force in their occupations. It may be added that a muscular action which is ordinarily performed with moderate force may, from abnormal conditions, come to be performed frequently with excessive force, and so lead to hypertrophy. For example, the urinary bladder may be induced to contract frequently and with exaggerated force, although there is no obstruction, and this may induce hypertrophy.

A question arises here as to the FINER DETAILS OF THE HYPERTROPHY OF MUSCLE. In the case of involuntary muscle there can be no doubt that the hypertrophy occurs by division of the muscular fibre cells by a process similar to that already described in referring to normal growth. But some question has been raised as to the exact nature of the process in striated muscle, and careful measurements have been made of the diameter of the muscular fibres in hypertrophy of the heart. It is stated by some that the diameter is increased and by others that it is not. It may be said, however, that the increase in thickness, if it occurs, is not so great as to account for the large additional bulk of the muscular substance as a whole, and that there is, as well, a numerical increase in the muscular fibres effected by division.

Enlargement of a tissue by such numerical increase has been designated by Virchow HYPERPLASIA, and this is sometimes distinguished from true hypertrophy in which there is merely an enlargement of the elements of the tissue. This distinction, however, cannot be rigidly carried out, and the term hyperplasia will only be used here in order to indicate that the hypertrophy is by proliferation.

The EPIDERMIS is the other tissue which frequently shows hypertrophy when the necessities of the organism call for it. The function of the epidermis is chiefly to protect the true skin from injury by friction against external objects, and, in its primary formation in the fœtus, the epidermis is thicker or thinner according as the parts of the skin are liable after birth to be exposed to greater or lesser amounts of friction. But, if afterwards, certain portions of the skin are frequently exposed to friction, then an additional growth will occur in the epidermis, a hypertrophy. We have abundant instances of this in the

HORNY HANDS of workmen. The thickening of the epidermis which results in the so-called CORNS is another instance of hypertrophy, in order to protect a portion of the sensitive skin from undue friction or pressure.

In regard to these thickenings it is to be pointed out that they only occur when the friction or PRESSURE is not constant, but recurs AT FREQUENT INTERVALS. A constant pressure, as by a splint pressing on a part, causes atrophy, whereas a frequently repeated pressure results in hypertrophy, apparently by allowing the structures to recover and afford time for increased nutrition. The same law applies to tissues in the interior of the body. When exposed to constant pressure they atrophy; when the pressure is intermittent they hypertrophy. It is here to be noted, however, that pressure from within (as by tumours, aneurisms, etc.) is usually constant, while that from without is mostly intermittent. Hence the original statement of John Hunter is justified, that pressure from without produces thickening, while that from within causes atrophy, although it is not to be taken without reservation.

The hypertrophy of the epidermis in these cases is undoubtedly effected by division of the cells; it is a hyperplasia, and the process is similar to that already described.

HYPERTROPHY FROM INCREASED BLOOD-SUPPLY.—In what has been already stated we have not exhausted the subject of hypertrophy, and, in order to appreciate what follows, it is necessary to refer again to normal growth. It was observed above that in ordinary growth of tissue the blood-vessels strictly follow the growing tissue, and are formed according to its needs. But if, from some accidental circumstance or by artificial interference, the blood supply be greatly increased, then excessive growth may result. If the spur of the cock be removed from the leg and successfully transplanted into the comb, it will grow with excessive vigour, forming a prominent horn-like structure. Here the excessive supply of blood, the comb having a much more active circulation than the leg, induces an excessive growth of the epidermis forming the spur.

In human pathology we have numerous instances of hypertrophy analogous to this. Increased activity of the circulation will often lead to hypertrophies. We see it IN THE NEIGHBOURHOOD OF INFLAMMATIONS. We have already seen that determination of blood exists outside the immediately inflamed area, and if this is prolonged it may lead to

overgrowth of the tissues. In this way we may account for the excessive growth of hair sometimes seen in the neighbourhood of ulcers, near diseased joints, and at the ends of stumps which have remained long inflamed.

A very striking instance of hypertrophy of this kind is sometimes afforded IN BONES. In the neighbourhood of inflamed joints the surface of the bones is often nodulated, and the bones greatly thickened by new-formation from the periosteum. In cases of periostitis, the new-formation of bone is perhaps more strictly to be regarded as a part of the inflammatory process, as we shall see afterwards. There are some curious instances of limited necrosis of bone occurring during the period of growth in which the bone, as a whole, has grown larger than the other. If a boy has a necrosis of the femur, the whole bone is probably more richly supplied with blood, and the normal growth is accelerated. The necrosis may be recovered from, and the person is left with a permanently elongated femur which may be as much as two inches longer than the other, and may lead to considerable lameness. The tibia is differently situated to the femur. Its two extremities are tied to the ends of the fibula by firm ligaments, and so the bone cannot elongate. If overgrowth occurs the bone must curve so as to accommodate itself. An example of this is shown in the accompanying Fig. 46, from a preparation in St. Bartholomew's museum (quoted by Paget), in which the bone, measured over its curve, was two inches longer than the healthy one.

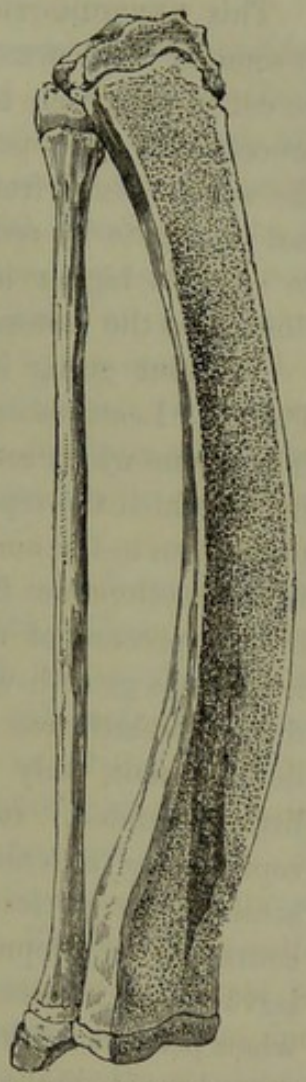


Fig. 46.—Elongation and curvature of tibia, the result of necrosis during period of growth. (PAGET.)

II. THE REPAIR OF INJURIES AND RESTORATION OF LOST PARTS.

The term REGENERATION is applied to the restoration of portions of the body which have been lost by injury or disease. The regeneration of a part is to be carefully distinguished from mere growth. A tissue may be able under suitable stimulation to reproduce its elements, and increase in size; but for the replacement of a lost part, if at all consider-

able, there must be, virtually, a renewal of the process of development.

This REPRODUCTION OF LOST PARTS in their entirety occurs readily in some of the LOWEST FORMS OF ANIMALS. In the hydra, if the creature be cut in two, each half will develop into a complete animal, and the process may be repeated indefinitely. This power of reproduction of the whole animal from a part seems confined to those creatures which can propagate by spontaneous fission or gemmation. When we come to animals higher in the scale the power of reproduction seems to be limited to the restoration of lost limbs, antennæ, etc.

Without going into details, which will be found by reference to Paget's "Lectures on Surgical Pathology," it may be said that there are indications which seem to show that there is some kind of LAW according to which the reparative power in each perfect species is in inverse proportion to the amount of change which the animal has passed through in its development from the embryonic to the perfect state. It is as if, in the process of development, the formative power as distinguished from mere growth were gradually exhausted, and the process of reproduction, which we have seen to be, as it were, a renewal of that of development, only occurs when this power has been comparatively little expended. It appears, for instance, that in insects the power of reproducing antennæ or limbs is limited to those species which have attained the perfect state through a comparatively simple and direct course of development. It is consistent with this view that in the larval state insects show a much greater power of reproduction than when perfect. The larva of one of the higher insects will be able to reproduce its limbs, while the perfect insect is not.

In man, and in the vertebrata in general, the long course of development seems largely to exhaust the reproductive power of the body, and, in the adult state at least, the power of restoration of lost parts is very small, and the processes concerned are almost as much related to growth of tissue as to development. In the embryonic state it is probable that the power of restoring lost parts is much greater than in the adult. Some children are born with a short arm at the extremity of which are imperfectly developed fingers; it is probable that in these cases amputation of the arm has occurred in utero, and an attempt at restoration has followed.

In the adult it may be said that restoration of lost structures is almost confined to the blood and the epithelial and connective tissues. Along with the connective tissues we have, of course, blood-vessels

which are readily reproduced, and we may also, to a limited extent, include nerve fibres, which, as we shall see afterwards, are sometimes restored.

While, therefore, the absolute restoration of complete and considerable portions of the body is scarcely possible in man, yet the body is by no means unprovided with powers by which INJURIES ARE REPAIRED and loss of structures is made good. It may be said that the higher and more complex animals are endowed with greater ability to protect themselves from injury, and that their tissues possess the necessary powers of restoration in the case of those injuries to which they are specially liable. In the various processes here to be considered, it will be seen that what may be called the definite intention to attain a certain result which is shown in the process of development, is distinctly visible, and that the tissues have a remarkable power of meeting adverse conditions.

HEALING OF WOUNDS.—The power of repair is well seen in the various processes concerned in the healing of wounds. There are some wounds which heal by a process fitly designated IMMEDIATE UNION. That is to say, the surfaces are brought together and coalesce without any new-formed material being produced to serve as a bond of union. This occurs mostly in clean-cut wounds, which, shortly after their infliction, are closed so as to bring the cut surfaces into close contact. It is necessary for this process that all inflammation be avoided either at the time of infliction of the wound or afterwards. The wound should therefore be clean cut and made with a sharp instrument. We are to think of the living tissues not as mere mechanical pieces of texture, but as possessed, by virtue of their vitality, of wonderful powers of adaptability to circumstances. When two living surfaces are brought into contact and all disturbing conditions are averted, then the blood-vessels will form communications, the nerves will by and by unite and become continuous, and the connective tissue coalesce. In this way it frequently happens that a wound in the skin, or even in muscle, unites, and no trace of a bond of union or even of the line of union can be found after a few days. The epidermis probably does not unite so directly, and the wound is covered by new-formed epidermis.

In union by PRIMARY ADHESION we have a process of a more complicated kind. In it inflammation plays a part. When a wound is inflicted the mere mechanical injury, or exposure afterwards, frequently leads to a trivial but acute inflammation, resulting, as we have seen, in the coating of the cut surface with a fibrinous exudation, the so-called

glaze. If two surfaces thus coated with fibrine be brought in contact they unite, the fibrine acting as a glue or cement. But the fibrine does not form a permanent bond of union, and if no attempt is made to effect union by other methods, then the wound will subsequently gape by the breaking down of the fibrine. In order to effect a permanent union we must have formative cells produced, such as we saw, when studying inflammation, to be necessary for the formation of connective tissue out of granulation tissue, and we must have a similar new-formation of blood-vessels. The new-formation of a uniting tissue here is very trivial in amount; there is no production of proper granulation tissue, but merely a limited production of formative cells which replace the thin layer of fibrine, and a budding of the blood-vessels till communications are formed between the two surfaces. This whole process may occupy only a day or two, and the permanent new-formed tissue forming the cicatrix is usually very small in amount. This form of union is sometimes spoken of as UNION BY THE FIRST INTENTION, but that term is also applied sometimes, but not correctly, to immediate union, and so it is, perhaps, better to use the term primary adhesion for this form.

In studying inflammation we have already considered the method of UNION BY THE SECOND INTENTION which occurs when two granulating surfaces come in contact.

It is necessary now to refer more particularly to the processes of REGENERATION as manifested in the individual tissues of the body.

In the first place we may regard the BLOOD as a tissue, and we have already seen that after a severe hæmorrhage its constituents are gradually regenerated, the fluid part most quickly, the white corpuscles comparatively soon, and the red corpuscles somewhat slowly.

The EPIDERMIS and EPITHELIUM of the surface of the skin and mucous membranes are restored with considerable rapidity. In the case of the skin and mucous membranes there is normally a continuous shedding of the surface epithelium, and a new-formation in the deeper layers to replace that which is lost, a kind of physiological regeneration therefore. When, by accident or otherwise, a superficial portion of epithelium is shed before its time, it will be replaced by the normal growth of the deeper layers, probably accelerated by the requirements of the body. When the whole thickness of the epithelium is destroyed the gap is by degrees filled by the proliferation of the epithelium at the edges of the wound, as we have already seen in the case of the cicatriza-

tion of a granulating wound. According to the observations of Klebs the new-formed epithelium acquires a slight power of amœboid movement so that it can proceed to the spot which it is to occupy.

The proliferation of the epithelium proceeds by a process similar to that already described in considering the normal division of cells. In the accompanying illustration (Fig. 47) from a paper by Eberth (Virchow's *Archiv*, 67) the fibrous transformation of the nucleus and the other changes, as seen in the cornea of the rabbit, some days after a portion of the epithelium had been removed, are shown. In the normal cornea there are traces of a similar process by which, we may presume, the physiological regeneration occurs.

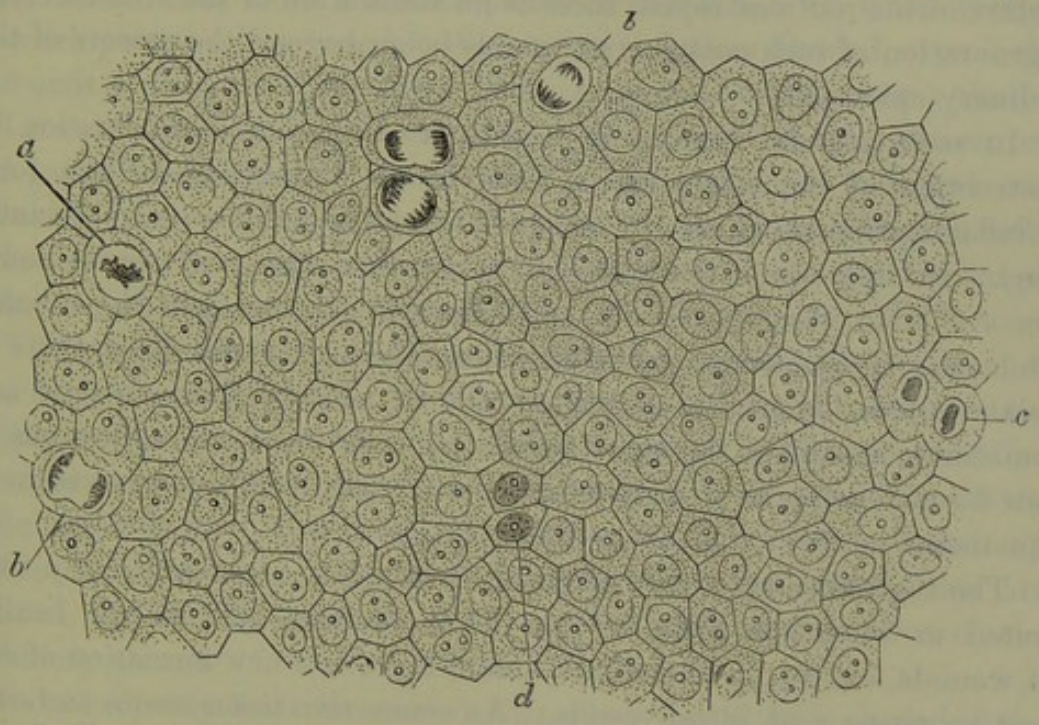


Fig. 47.—Regeneration of epithelium in cornea of a rabbit. (*a*) Fibrous transformation of nucleus. (*b*) Partial separation of the fibres and hour-glass change of nucleus. (*c*) Complete division of nucleus. (*d*) Complete division of cell. (EBERTH.)

It is here of interest to observe that the epidermic cells may be transported from their original seat and survive and proliferate on the surface of a wound, even in another individual. It is well known that advantage is taken of this fact in the process of grafting which surgeons resort to in order to accomplish the cicatrization of large wounds. The whole thickness of the skin or mucous membrane may be transplanted from one place to another, or even from a different person; or the skin may be made to occupy the place of the mucous membrane or *vice versa*. When the skin or mucous membrane is thus made to occupy a different position with different relations and duties, it by and by conforms

itself to its new position and the epithelium acquires a structure like that in its neighbourhood.

In the case of the hairs and nails we have normally a process of desquamation and regeneration similar to that of the surface epidermis. If a hair be prematurely extracted or a nail torn off, it is restored by a strictly normal process. But if the hair follicle be removed or the matrix of the nail destroyed, there is no restoration of the structure, the regeneration of such complex structures being beyond the powers of the ordinary epidermis.

In some glands there is in health or disease a desquamation or destruction of the epithelium. Then in the kidneys there is a form of inflammation in which the epithelium of the tubules is abundantly shed. In this case it is restored by a new-formation, and we are sometimes able to observe the old epithelium in the lumen of the tubules, while the small young epithelium lines them. In the liver there is great destruction of the secreting cells in acute yellow atrophy, and sometimes alongside the remains of the cells there are collections of new-formed cells, as if an attempt were being made at renovation of the tissue.

The regeneration of CONNECTIVE TISSUE has been sufficiently illustrated in what has gone before. It is obvious that in the healing of wounds, except by immediate union, there is a new-formation of connective tissue and blood-vessels. As connective tissue seems to be the simplest form of tissue, it is sometimes used to fill up gaps where more complex tissues have been lost. Thus a wound in a muscle is not restored by the formation of muscular but of connective tissue, and so is it with wounds of the liver, spleen, kidneys, etc.

The regeneration of BONE is frequently exemplified in the repair of fractures. In the various processes observable here we may see conditions analogous to those in healing by primary adhesion and by the second intention. In cases where the broken ends are kept closely together and at rest there may be very little inflammation, and the permanent uniting medium may be produced by the immediately neighbouring tissue. As we shall see afterwards, although the periosteum usually supplies the new bone, yet it is not necessary to its formation, but the bone itself, perhaps rather the tissue occupying the Haversian canals, is capable, under certain conditions, of producing new bone. In other cases there is more considerable inflammation, it may be with suppuration, and granulation tissue is produced. This granulation tissue, arising largely from the periosteum, develops according to circumstances

bone, cartilage or connective tissue, forming the callus and ultimately supplying the permanent bond of union between the broken ends.

It has recently been shown by the observations of Dr. Macewen of Glasgow that BONE MAY BE TRANSPLANTED. Pieces of bone have been taken from a person, and used to fill up a gap in a bone, and they have both lived and grown larger in their new position.

NERVE-FIBRES show a certain power of new-formation when divided or when portions are excised. When a nerve is thus divided, even if the two ends are separated for some distance, there is often, after a time, a full re-establishment of the conduction. It appears that from the central end pale fibres grow out. These pass to the peripheral end, and constitute the axis cylinders, which afterwards acquire medullary sheaths and so become complete nerve-fibres. In this way a considerable length of nerve may apparently be restored.

There is another form of regeneration sometimes described, but it is of a more doubtful nature. When a nerve is divided, the fibres in the peripheral portion, from its cut end downwards to its ultimate distribution, show a peculiar change, consisting mainly in degeneration of the medullary sheath. It is doubtful whether the axis cylinder takes any part in this process. After the cut ends join, the nerve-fibres are restored, and this by a process which may be called regeneration of the medullary sheath.

It has already been mentioned that when a MUSCLE is wounded the gap is filled by connective tissue; there is no proper regeneration. But there may be loss of the contractile substance by degeneration, as in fatty degeneration of the heart. When such a process is intense, it seems impossible that the muscular fibres can be restored, and as the heart often recovers there must be a regeneration of the contractile substance. But in this case there is not a destruction of the muscular nuclei, and therefore not a regeneration of the muscular cell as a whole. In the case of unstriped muscle there is probably also an occasional degeneration and renewal of the contractile cells.

INFECTIVE TUMOURS (GRANULATION TISSUE TUMOURS).

THIS class of tumours is taken up here chiefly because they show in their structure and general relations considerable analogies to inflammation on the one hand and tumours proper on the other. As indicated in a previous part, the expression infective means that the disease is 'spreading,' that it depends on some virus which propagates itself, and tends to reproduce the same kind of lesion outside its original seat. In two forms of disease included here, the exact nature of the virus has been made out, namely, in tuberculosis and leprosy; and in both it is found to be a micro-organism in the form of a short rod-shaped bacillus. It may perhaps be legitimately inferred that in all the rest specific organisms are the infective agents. It may be added that several of these forms of disease are not only infective but infectious, communicable, that is to say, from person to person; some are capable of being inoculated into animals.

The virus acts as an irritant, and the resulting lesions present strong analogies to inflammations. It is not to be inferred that the micro-organisms, where they are concerned, themselves irritate the tissues; it is more probable that the irritation is due to chemical products resulting from their vital processes. The resulting lesions are in some cases indistinguishable from those of inflammation, and we shall see afterwards that we have to speak of syphilitic and tubercular inflammations. But the virus also takes usually a more local habitation, and concentrating its action on particular points, it gives rise to numerous lesions, having more or less the character of tumours. Even the tumours present great analogies to inflammation in their structure. They are formed of granulation tissue, and are often called GRANULATION TISSUE TUMOURS or granulomas.

But the tissue of the tumours presents certain differences from ordinary granulation tissue chiefly in its tendencies. The granulation cells tend to undergo fatty degeneration, and so the tissue may become caseous or break down. At the same time there is the more normal tendency to undergo development into connective tissue, and this may go on in an imperfect way alongside the other change. Hence the tumours frequently present great varieties in structure, and it is sometimes difficult fully to unravel their relations.

SYPHILIS.

In this section we have to consider the general relations of this disease. In what has gone before some of the grounds have been indicated for stating that A VIRUS is concerned in its production. In addition the following may be mentioned; it is well known that the discharges from a syphilitic person are contagious; and it is also generally believed that in the secondary stage the blood, and even the milk, are infectious. In this connection it is to be remembered that an attack of syphilis generally confers immunity against a further attack, the analogy with the specific fevers being suggested by this.

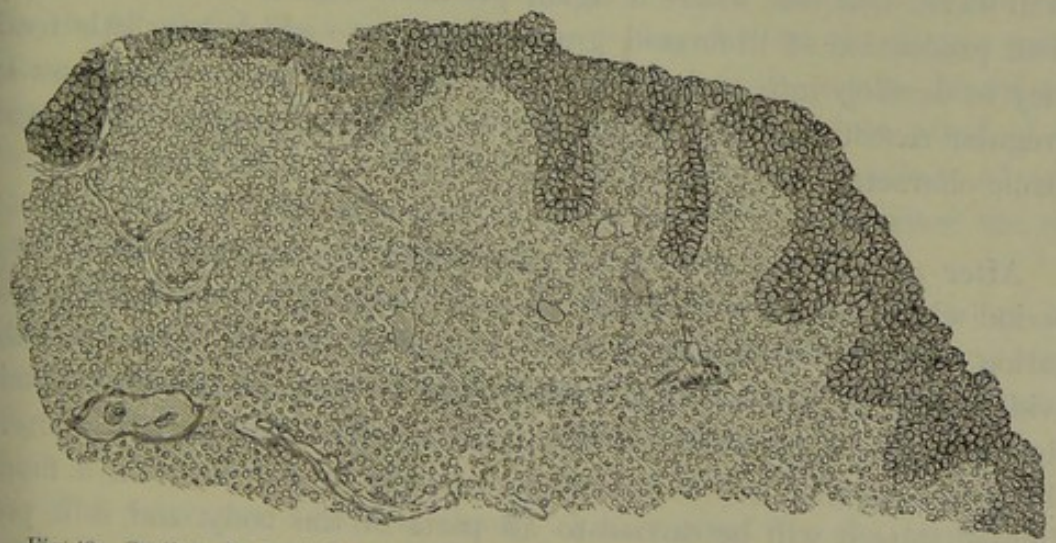


Fig. 48.—Section of a hard chancre at its marginal part. The granulation tissue occupies the skin under the epidermis, gradually replacing the latter. ×75.

A virus is the cause of the disease, and as a general rule it is usually applied to some part of the organs of generation. It may be applied, however, to some other part, as to the finger (in the case of a surgeon examining a part), to the lip (as in the case from which Fig. 48 is taken), to the eyelids or other external part. The result is the INDURATED or

PRIMARY CHANCRE. This consists of a raised hard structure generally with an ulcerated surface. Examined microscopically, it is found that the epidermal covering of the skin is not necessarily lost, but that beneath it, and in the central part, it may be to some extent replacing it, there is an enormous formation of granulation tissue (Fig. 48). The true skin is entirely replaced by this granulation tissue, and instead of it there is a bulky mass of round cells. This structure may be regarded as inflammatory, but it may also be regarded as a kind of tumour, and may be taken as the type of the syphilitic tumour. In its less common seats it may very closely resemble another form of tumour. Thus a chancre of the lip may be mistaken for an epithelioma, and be excised under that impression. This actually occurred in the case from which Fig. 48 was taken. The tissue, although like in structure to granulations, does not, like them, readily form connective tissue, but remains long in the same rudimentary condition, and when it disappears leaves comparatively little of a cicatrix. On the other hand it sometimes becomes caseous, but this does not so readily occur here as in some other localities.

The virus is carried from the indurated chancre by the lymphatics, and in the first place lodges and is caught in the neighbouring LYMPHATIC GLANDS, where it again produces similar results, namely a great production of ill-formed granulation tissue which has little tendency to develop into proper connective tissue, but readily undergoes an irregular caseous metamorphosis, and occasionally takes on the phagedænic character.

After an interval the virus PASSES INTO THE BLOOD. There is a period which may be regarded as a period of incubation, or self-propagation of the virus between its first introduction into the system and the evidences of its presence in the blood—the virus seems to take a certain time to reproduce itself in quantity, and it generally does so chiefly in the lymphatic glands. When an agent exists in the blood in a finely divided state it will be carried to all parts of the body, and if it produces lesions they will probably be symmetrical, as the corresponding parts in each lateral half of the body are for the most part in similar circumstances, and are similarly affected by any agent acting equally on them. The existence of symmetrical lesions is presumptive evidence that a disease is due to something in the blood. In the secondary stage of syphilis then we have the virus in the blood, and the result is symmetrical lesions of the skin, mucous membranes, bones, etc.

These secondary lesions are inflammatory in character, and have generally a resemblance to ordinary inflammations. They are most frequent in the skin, and so we have the syphilitic roseola, eczema, etc., but other parts may be affected, and we have syphilitic periostitis, pharyngitis, etc. It is a question to what extent inflammations occur in internal organs in this stage, but according to Hutchinson they are more frequent than is generally supposed, but are rarely seen because persons seldom die in the secondary stage.

The secondary stage has been aptly compared with the eruptive stage of specific fevers, it is like a fever long drawn out. There is in both cases a virus in the blood, and in syphilis, as well as in the acute fevers, there is generally elevation of temperature. The analogy between the rash of secondary syphilis and those of measles, scarlet fever, small-pox, etc., is also suggestive, the skin affections in both classes of cases being inflammatory.

During this stage then the virus is active in the blood, and it is generally held that the blood and secretions are contagious. The person is also in the position of transmitting the disease to his offspring, the virus apparently passing into the germ and sperm cells. Just as in the specific fevers, the virus dies out of the blood spontaneously, and the various secondary lesions disappear. When the virus is no longer in the blood this fluid will cease to be contagious and the disease will no longer be transmissible to the offspring. But it is not to be inferred that the disappearance of the secondary lesions is absolute proof of the virus having died out of the blood, and it would not be safe to advise a patient that he could safely marry till at least two years after the subsidence of all secondary symptoms.

In this secondary stage it is not common to meet with tumours like the indurated chancre. They are characteristic rather of the next stage, and when they do occur in this stage they are small and accompanied by more pronounced inflammatory manifestations.

The TERTIARY STAGE is chiefly characterized by the formation of tumours to which the name GUMMATA is applied. They are composed similarly to the indurated chancre, namely of granulation tissue in the first instance, but in them this tissue has a much greater tendency to undergo caseous necrosis, although the transformation into connective tissue also occurs. Hence it happens that the gumma of the tertiary stage is very commonly more or less caseous in certain of its parts.

To the naked eye the tumour is a whitish or greyish body, commonly

with a yellow caseous appearance in its central parts, or irregularly distributed. It varies in size, sometimes as small as a millet seed, in which case it is usually multiple, but it is usually much larger, and may attain the size of an apple. The tumour is not generally sharply defined from neighbouring structures, but its periphery merges in a firm connective tissue which usually extends outwards into neighbouring structures, so that the tumour appears planted in the midst of a cicatricial mass.

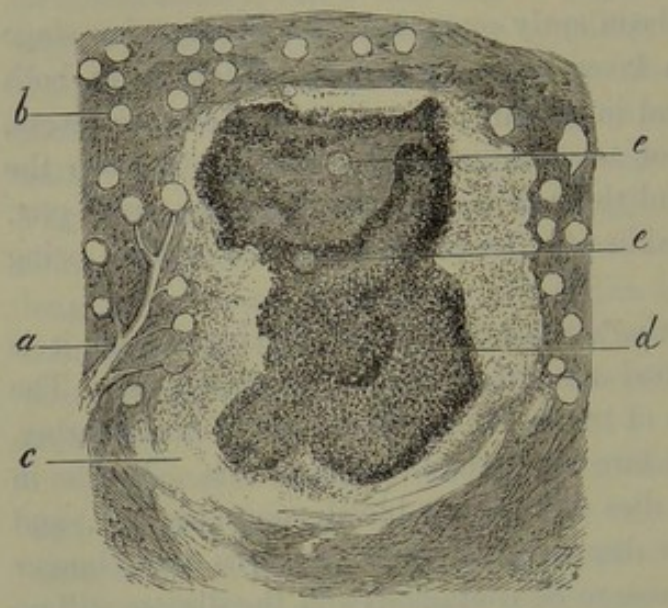


Fig. 49.—Gumma of Kidney. The opaque central part (*d*) is caseous ; around this there is fibrous and granulation tissue (*c*). ×20. (Cornil and Ranvier.)

Under the microscope the tumour will be found, as in Figs. 49 and 50, to replace a certain portion of the normal tissue. The central caseous part will be opaque as in *c*, Fig. 50. Externally there is more transparent tissue (*b*), while around and in neighbouring parts of the organ there is new-formed connective tissue, as at *d* in the figure.

In Fig. 51 the appearances seen under a higher power are shown, the parts taken being from *b* and *c* in Fig. 50. It is seen that the peripheral portions (Fig. 51 *a*) of the tumour present innumerable round cells mixed with fibrous tissue, which latter is often very pronounced. The caseous parts are opaque and present fine fat granules with shrunken cells and nuclei (Fig. 51 *b*).

The tumours are met with in almost all the tissues of the body, skin, mucous membranes, subcutaneous tissue, in the substance of muscles (as in the tongue), periosteum, liver, dura mater, soft membranes of the brain, cerebral nerves, etc. The name gumma does not express their usual consistence, and is stated to have been first applied to the periosteal form.

The caseous metamorphosis leads to various results, according to the situation and circumstances of the gumma. If the tumours have a superficial situation, then ULCERATION results, and we have a deep excavated ulcer with swollen infiltrated walls, consisting of tissue like that of the gumma, and with the same tendency to degeneration, so that the

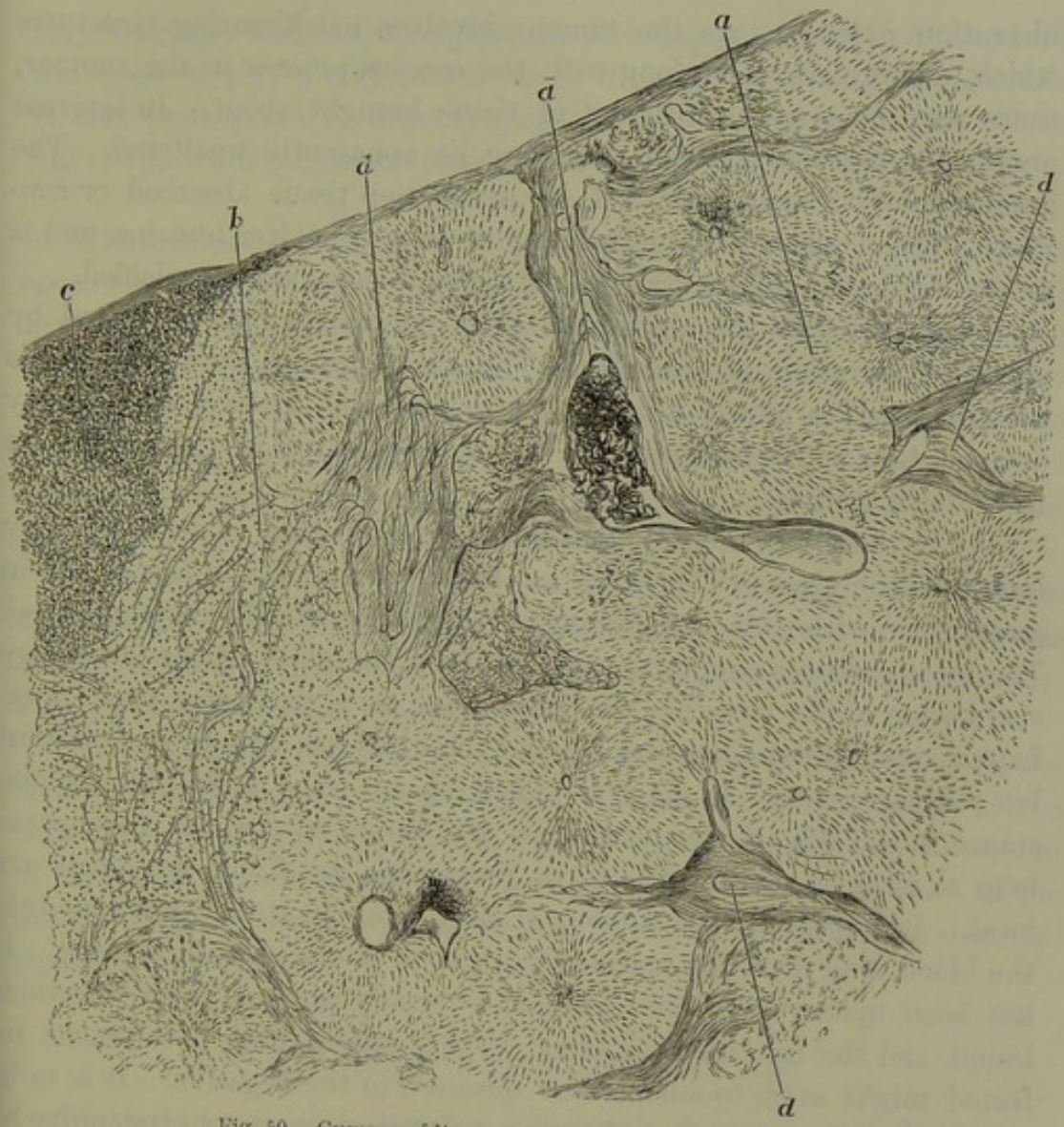


Fig. 50.—Gumma of liver. Explanation in text. ×16.

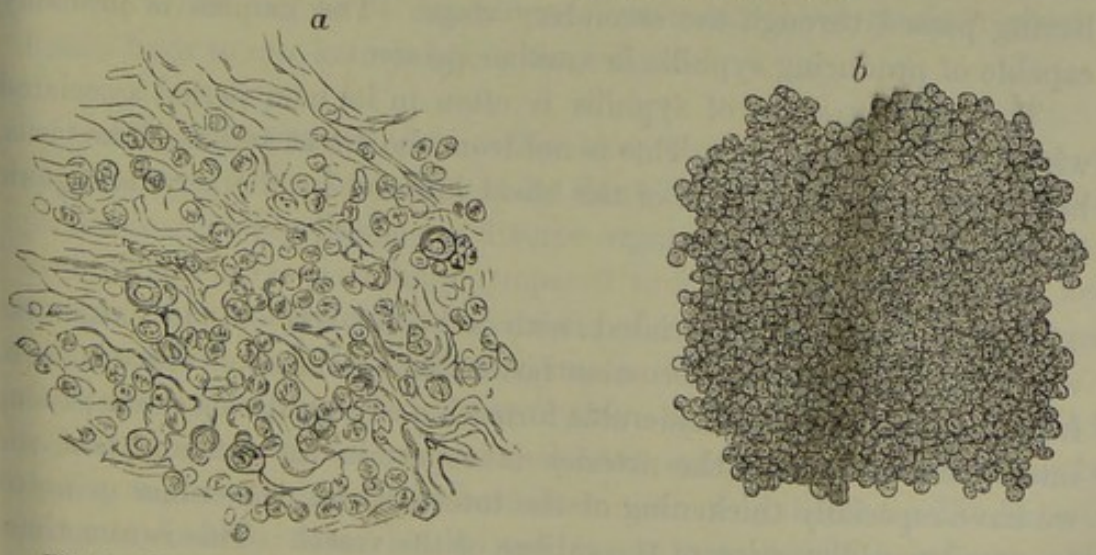


Fig. 51.—From gumma of liver, same section as Fig. 50; *a*, taken from recent part (*b*, in other figure); *b*, from caseous (*c*) ×350.

ulceration extends. As the tumour involves neighbouring structures which undergo necrosis along with the caseous process in the tumour, there may be great destruction of tissue brought about. In internal organs the caseous material may long lie apparently unaltered. The gumma may be virtually healed, its granulation tissue absorbed or converted into connective tissue, while the caseous matter remains, and is finally left in the midst of a cicatrix where it may become calcified.

It appears that the absorption of a gumma may be promoted by the administration of remedies. The exact process by which this is brought about is hardly known, but there seems to be a simple fatty degeneration with absorption, in the way indicated in the section on fatty degeneration.

We have still to inquire what may be the relation of these tertiary lesions to the virus. The virus no longer exists in the blood, and in accordance with this the lesions are characteristically unsymmetrical. The most probable supposition is that, after the close of the secondary stage some of the virus has remained lying in a particular part. Perhaps a small gumma has formed, and the virus has lain in it quiescent but still surviving. It may be waked up by some accidental circumstance in the life of the patient, at any period afterwards, perhaps as long as twenty years. The virus propagates itself, but its effects are local. It may produce a tumour of large size, but it does not pass into the blood, and does not produce the lesions of the secondary stage. It has been matter of dispute whether a tertiary gumma is an infectious lesion, and the fact that the blood of the patient does not become infected might seem to answer the question in the negative. It is to be remembered, however, that the person already possesses an immunity by having passed through the secondary stage. The gumma is probably capable of producing syphilis in another person.

The tertiary stage of syphilis is often in its later period associated with AMYLOID DISEASE. This is not from the direct action of the virus, but is due to the condition of the blood induced by the serious organic lesions.

Syphilis is often associated with a CONDITION OF THE ARTERIES which will come up for discussion farther on. Wherever there is, as so frequently happens, a considerable formation of granulation tissue passing into connective tissue, the arteries take part in the inflammation, and we have especially thickening of the internal coat, sometimes going on to complete obliteration of the calibre of the vessel. This is sometimes

very strikingly seen in the neighbourhood of gummata, and by diminishing the blood supply, it may contribute to the degeneration of the gumma. It also predisposes to degenerations in parts around, as where softening of the brain occurs in connection with gummata.

HEREDITARY SYPHILIS.—We have already seen that syphilis, in the secondary stage at least, may be transmitted to the offspring. In the acute period the children often die in utero, or they sicken soon after birth and die within a few weeks. But it often happens that the children do not show any evidence of syphilis for months or years. In this way we may distinguish cases of congenital syphilis from cases of simple hereditary syphilis, the former being born with syphilitic lesions, the latter only acquiring them afterwards.

In CONGENITAL SYPHILIS the most constant and unequivocal lesion is the affection of the bones, which will be considered afterwards. In this condition there is the formation of a kind of gummatous tissue apparently, with inflammatory conditions.

In the simple hereditary cases the lesions are, like those of the secondary stage, mainly inflammatory. There are inflammations of the skin, mucous membranes, cornea, etc. The characteristic malformation of the teeth which Hutchinson has pointed out seems related to the inflammation of the mucous membrane of the gums during the development of the teeth.

TUBERCLE AND TUBERCULOSIS.

We enter here on a somewhat debateable department of Pathology, but the investigations of experimental pathology have recently given a firmer basis to our knowledge of the subject.

GENERAL TUBERCULOSIS.—We have already seen in the case of syphilis that in the secondary stage there is a virus in the blood which produces secondary lesions in diverse organs. This secondary stage of syphilis has been sometimes compared to a long drawn-out fever, and we saw that the symmetrical character of the lesions was to be regarded as presumptive evidence that the virus is in the blood.

Now in ACUTE MILIARY TUBERCULOSIS we have a condition in which lesions appear in diverse organs and occur symmetrically, and it may be well to begin our study of tuberculosis with this disease. We have in it an undoubted tuberculosis, and the principles which we are able

to establish in regard to this disease will afford us a criterion by which we may judge of the nature of other processes more doubtfully or less purely tubercular. The disease much more closely resembles an acute fever than secondary syphilis does, and is often mistaken for typhoid fever. In the course of a few weeks there spring up in the lungs, kidneys, liver, lymphatic glands, and frequently also in the soft membranes of the brain, substance of the heart, spleen, and elsewhere, a multitude of small lesions whose structure will be described presently. In the case of bilateral organs, such as the kidneys, the little lesions are scattered through both, and are present in all parts of each organ. Looking at a case of acute miliary tuberculosis, the conclusion can hardly be avoided that there is here a virus which has been circulating in the blood and sown wherever the blood has reached, although producing its effects only in organs affording a fitting nidus for it.

It may be well here at the outset to inquire what is the STRUCTURE of these multitudinous lesions, each of which is a MILIARY TUBERCLE. They present certain differences in their various situations, but there are certain points of agreement in all. If we take a very recent case

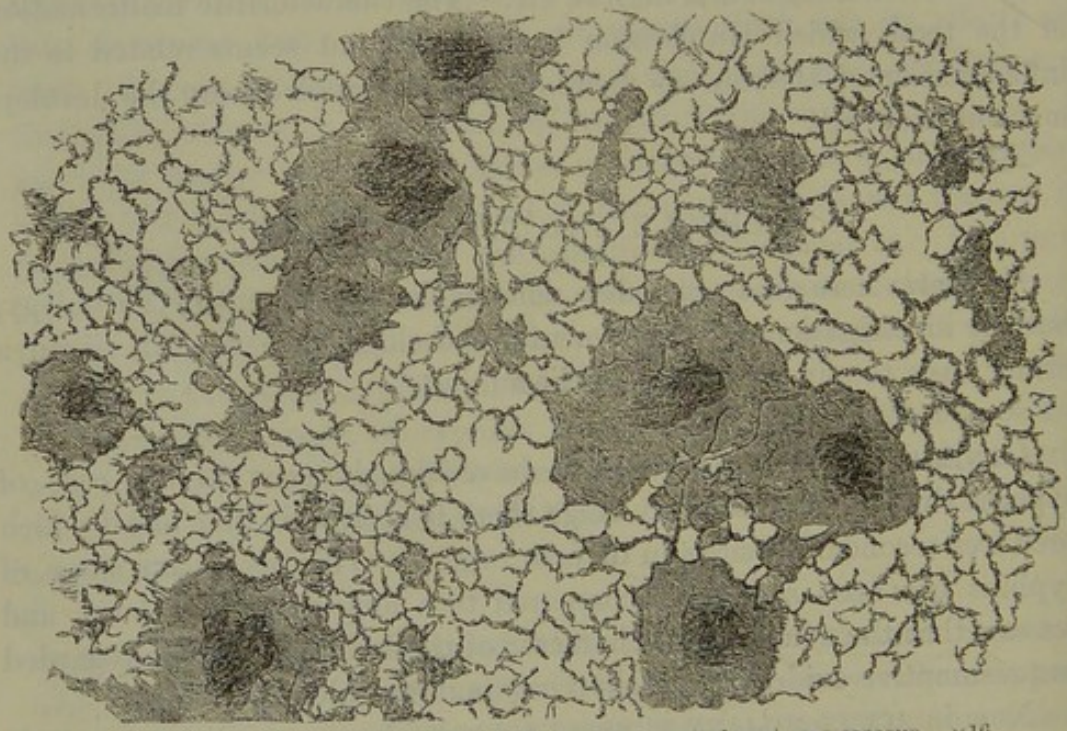


Fig. 52.– Miliary tubercles in lung. The opaque central parts are caseous. ×16.

and examine the lung, we shall find an immense number of minute nearly globular bodies (Fig. 52), occupying the stroma of the lung, and

very often either involving a blood-vessel or immediately bordering on one. These bodies are the tubercles, and whether in the lung or elsewhere they present a structure which is virtually identical in every part. Fig. 53 shows a very small tubercle from a lymphatic gland, con-



Fig. 53.—Tubercle in a bronchial gland. ×350.

siderably magnified. It is seen to be a defined roundish body, presenting at its peripheral parts numbers of round cells like leucocytes; nearer the centre rather larger cells, like the formative cells of granulation tissue, and often called epithelioid cells; and in its more central parts one or more gigantic cells having numerous nuclei, the so-called giant-cells. These various structures are not to be distinguished in every one of the tubercles, as it depends on the section whether their central parts are shown, and, besides, they are liable to degeneration, which obscures their structure.

We can hardly avoid calling these little bodies tumours, and to bodies of this kind we shall confine the name tubercles; these are miliary tubercles.

Their relation to the blood-vessels is often very well seen if the soft membranes of the brain are involved. In the adventitia of the fine arteries of the pia mater, there will be found aggregations of cells, form-

ing sometimes, as in Fig. 54, a prominence on the wall, or, if the vessel be small, a spindle-shaped sheath around it.

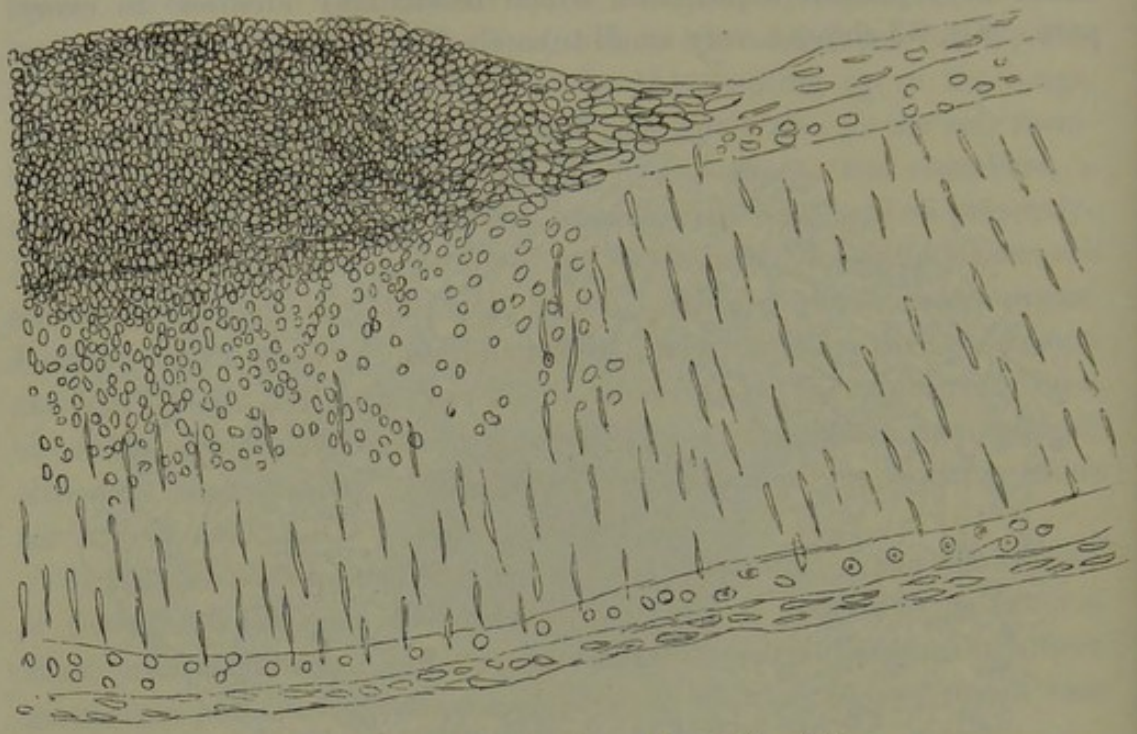


Fig. 54.—Tubercle on artery of pia mater. ×300.

The cells constituting the tubercles are prone to undergo CASEOUS NECROSIS so that, as in Fig. 52, the central parts are often markedly opaque, and the structure completely obscured. The giant-cells are often dotted with fine fat granules, and fatty degeneration frequently overtakes the greater part of the tubercle. It should be added that very frequently what appears to the naked eye to be a single tubercle often turns out, under the microscope, to be a group of two or more, and even when completely coalesced this may still be indicated by the caseous metamorphosis having two or more distinct centres joined at the periphery. The tubercles contain no blood-vessels, and this may partly explain their proneness to caseous metamorphosis.

We have hitherto referred only to the caseous change which tubercles undergo, but it has to be added that they are liable also to a change which may be called FIBROUS TRANSFORMATION. We have already seen that tubercles contain the elements of inflammatory new-formation, in their details having all the ultimate constituents of granulation tissue, except the blood-vessels. They may, like this tissue, present a tendency to organization, and be converted into masses of hard, solid, connective tissue. It is noteworthy that when this occurs the inflammatory products

around commonly undergo similar changes, making, as a rule, common cause with the tubercles whether the change be caseous or fibrous. This form is less common than the caseous, and its occurrence is probably determined by peculiarities of the constitution or circumstances of the individual.

Connection of Tuberculosis and Inflammation.—In the above remarks the structure of the typical tubercle has been described, but it is not common to meet with tubercles entirely free from inflammatory complication, although cases of acute miliary tuberculosis do occur in children in which the tubercles are virtually pure. In the great majority of cases, however, there are evidences of inflammation around them. In the case of the lung, for instance, the alveoli immediately bordering on the tubercle are filled with large cells, the products of catarrhal inflammation, and the walls of the alveoli are infiltrated with round cells. These inflammatory products frequently make the tubercles appear to the naked eye much larger than they really are—the tubercle and inflamed lung tissue making a common mass. Throughout the lung also, and away from the immediate vicinity of the tubercles, there are often evidences of inflammation in the form of serous exudation and catarrhal cells in the alveoli. In the pia mater the inflammatory products are so abundant that they give their character to the disease called tubercular meningitis, and by their presence obscure the actual tubercles, which are often difficult to see.

The inflammations which are of nearly constant occurrence in connection with tubercles may be accounted for in various ways. They may be due directly to the action of the virus, or to an irritation springing from the mere presence of the tubercles acting as foreign bodies. Looking to the case of syphilis where we have the virus producing both inflammations and gummata, the presumption is that both tubercles and inflammation are to be traced to the virus. The tubercles themselves, in their structure, present, as we have seen, close analogies to inflammatory products, and to syphilitic gummata. We have the same round and epithelioid cells. And even the giant cells are met with in luxuriant granulations. The new-formed cells in tubercles again are prone to degeneration just as those in gummata. The tubercles differ from gummata in their small size, a single tubercle being, as a rule, just visible to the naked eye; and in the regularity of their structure, which, with great uniformity, agrees with the description given above. It is interesting that in both these diseases there is such a tendency to inflammatory formations, and to the production of

tumours, which in their structure show such analogies to inflammation.

Local Tuberculosis.—We have seen that in acute miliary tuberculosis there is something analogous to the secondary stage of syphilis in which a virus exists in the blood, and we have now to inquire whether there is anything analogous to the tertiary stage in which the virus is localized, and the lesions are unsymmetrical. Doubtless tubercles, like gummata, may become obsolete, and possibly the virus may wear itself out, but it is not known that any patient has ever survived a general miliary tuberculosis, so that we have here nothing strictly analogous to the tertiary stage.

But we have such a thing as a Local Tuberculosis, an unsymmetrical tubercular lesion. Many instances of this may be adduced, and in all of them there are evidences to be found of similar characters to those seen in acute general tuberculosis. The existence of a virus is indicated by the infective character of the lesions, that is to say, the tendency, when the disease has manifested itself in a part, to propagate itself in the neighbourhood; as if there were a virus, which, reproducing itself in the original centre, was carried outwards and gave rise to similar lesions around. Again, in these local manifestations the tuberculosis is accompanied by inflammation, and here, also, the tubercles as well as the inflammatory products tend to undergo changes the chief of which is caseous necrosis.

As an example of this we may take tuberculosis of serous cavities, such as the peritoneum or pericardium. If the tubercular virus gets into the peritoneum it is carried up and down in it, and the result is the production of tubercles in every region of the cavity. The tuberculosis is accompanied by inflammation, so that tuberculosis of the peritoneum is known under the name of tubercular peritonitis. The peritoneum, being a lymphatic sac, is directly related, as we shall see in connection with the spread of cancerous tumours, to the lymphatics in the diaphragm, and through the diaphragm with the pleural cavity, which is another lymphatic sac. The virus appears to be carried through the diaphragm in many cases of tuberculosis of the peritoneum, and produces an eruption of tubercles in the lower part of the pleural cavity.

Take, again, local tuberculosis of the kidney, forming the disease sometimes called renal phthisis. When this disease is fully developed there are, usually in one kidney, irregular cavities lined with ragged ulcers, and these cavities often replace the greater part of the kidney

tissue. In this disease the course of events seems to be this: tubercles are formed at the apices of the pyramids of the kidney where they project into the calices, or else in the mucous membrane of the pelvis itself. These tubercles in the usual way undergo caseous necrosis, and, being on a surface, they break down and form TUBERCULAR ULCERS. Meanwhile the virus has extended deeper into the kidney tissue, and a fresh crop of tubercles has arisen beyond the ulcer. These tubercles in succession undergo caseous necrosis and break down, and at the same time fresh crops are formed, so that a progressive destruction of the



Fig. 55.—Tubercular ulcer of intestine. The rounded form of the tubercles around the ulcer (*a*) is seen, some of them breaking up the muscular coat (*b*); one (*d*) outside this coat, and beneath the peritoneum. × 16.

kidney tissue results. (A similar process of ulceration is indicated in the accompanying illustration (Fig. 55) of a tubercular ulcer of the intestine.) But the virus is not only carried inwards into the kidney tissue, but also downward into the pelvis of the kidney, and down the ureter. As it is borne along it seems to lodge on these surfaces, and produce similar changes—tubercular ulceration of the pelvis of the kidney, of the ureter, of the bladder, and sometimes also of the vesiculæ seminales or vasa deferentia. From the bladder the ulceration may extend to the ureter of the opposite side, but usually it confines itself to the portion close to the vesical opening, hardly ascending against the current of the urine.

In the case of renal phthisis we see how the caseous necrosis leads

to tubercular ulceration, the caseous material being removed, and leaving an ulcerated surface, and this case may be taken as typical of that process. But sometimes in the ureter the caseous material is not carried away, but remains as a dense consistent layer, lining the tube, it may be, in its entire length. There are cases again in which a local tuberculosis occurring in the midst of an organ leads to a considerable accumulation of caseous material.

A typical instance of this is presented by the SCROFULOUS TUBERCLE OF THE BRAIN. In the brain substance of children we sometimes meet with a considerable tumour composed of dense caseous material, surrounded by a zone of grey transparent tissue. The course of events has been, that a group of tubercles has first formed, let us say from the virus having lodged here. These have undergone caseous metamorphosis while a fresh crop has been produced at their periphery. And so as time elapses there is ever fresh new-formation of tubercles and their death and degeneration. In this way a caseous mass is formed of the remains of myriads of dead tubercles. The grey transparent zone at the periphery is composed of tubercles not yet degenerated, mixed with inflammatory products. The existence of a virus is here shown by the tendency to extend by the successive formation of crops of fresh tubercles.

ARTIFICIAL PRODUCTION OF TUBERCULOSIS.—In what has gone before it has been shown that in acute general tuberculosis there is a virus in the blood producing multitudinous tubercles in various organs. It has also appeared that in cases of local tuberculosis there is a virus producing tubercles by a process which may be called infective, inasmuch as the influence passes out from a centre and infects the neighbouring tissues. We have now to inquire whether the virus can be conveyed from one animal to another by inoculation.

Numerous experimenters since the time of Villemin have shown that in certain animals, especially guinea-pigs, it is possible to produce a GENERAL TUBERCULOSIS BY INOCULATION with certain products from the body of man. When pieces of a caseous tubercle or scrofulous lymphatic gland are inoculated under the skin or into the abdominal cavity of a guinea-pig, then the animal in six to ten weeks dies of general tuberculosis. Tubercles are found in the peritoneum, pleura, kidneys, liver, spleen, bone-marrow, etc. By the introduction of the material a virus has been introduced which gives rise to the regular tubercular manifestations.

A LOCAL TUBERCULOSIS may also be produced by inoculation. In Cohnheim's experiments, for instance, a piece of caseous material is introduced by an incision through the cornea into the anterior chamber of the eye of a rabbit or guinea-pig. If the substance has been so fresh as to contain none of the products of decomposition, the irritation produced by its introduction soon passes away, and the inoculated substance gets smaller and smaller and may even, after a time, disappear. For a time the eye appears quite clear and intact. Then suddenly there appears in the iris a larger or smaller number of fine gray nodules, which, just as in man, attain a certain size and then become caseous. In rabbits this eruption of tubercles generally occurs twenty-one days after inoculation, in guinea-pigs it is usually a week earlier, although even in rabbits it may take place in fourteen days. The tuberculosis may confine itself to the eye or it may extend to other organs.

It is specially interesting that in this case the virus has apparently a period of incubation of fourteen or twenty-one days, in this respect conforming to the viruses of other forms of disease.

Experiments have also been made in which animals have INSPIRED AIR containing the sputa of tubercular patients, with the result of inducing tuberculosis of the lungs and bronchial glands. Again, animals have been fed with tubercular matter, and have contracted tuberculosis of the intestines and mesenteric glands, and so on. These experiments prove undoubtedly that tubercular material contains a virus which is capable of transmission to other living animals just as the syphilitic virus is.

NATURE OF THE TUBERCULAR VIRUS.—But now the question arises, Is this a specific virus only produced by itself, or may it arise in the body from other products? Opinions diverge on this point. Villemin, whose experiments are the earliest bearing on this subject, and Klebs have strongly expressed the view that the tubercular virus is specific, and can only be produced by self-propagation. On the other hand, it is held by many that caseous material, whether the result of the degeneration of tubercular products or of those of simple inflammations, is capable of producing tuberculosis. In fact, in the experiments in which tubercular material is inoculated, these observers assert that it first produces a local inflammation, and that the finely divided material which results from the drying in of the inflammatory products is the cause of the tubercular eruption. In this connection it may be mentioned that acute miliary tuberculosis in man

is often supposed to take its origin in some local mass of caseous material, and that local tuberculosis, say of the lung, is frequently, by such authors, referred to the products of caseous necrosis in the inflammatory exudation of a simple catarrhal pneumonia.

This matter we may now regard as finally set at rest by the recent discoveries of Koch, already confirmed by several others, that the virus of tuberculosis is essentially connected with a particular form of micro-organism, a bacillus. These observations, establishing as they do the parasitic nature of tuberculosis, completely corroborate and carry to their due conclusion the views expressed in the preceding pages. By a particular method of observation, Koch has succeeded in demonstrating the existence of a special bacterium (bacillus) in tubercles, whether occurring spontaneously in man and animals or induced by inoculation.

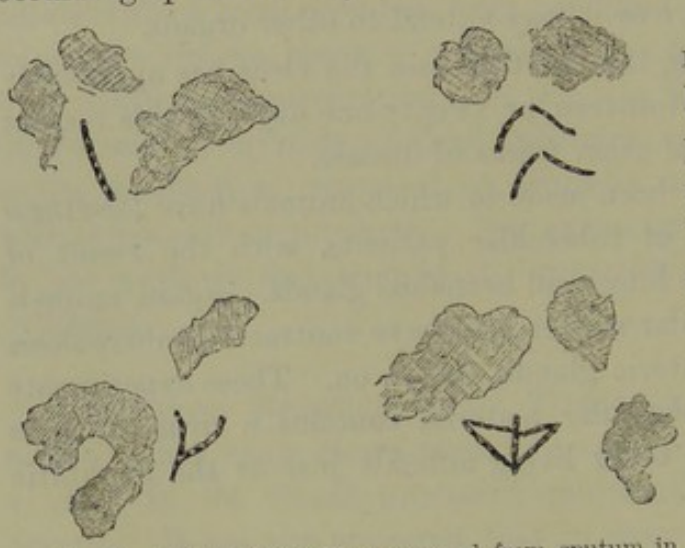


Fig. 56.—Tubercular bacillus prepared from sputum in phthisis pulmonalis. ×1500.

The bacilli are short rods, a quarter or half the length of a red blood corpuscle (see Fig. 56), but occasionally a little longer. They are often in considerable aggregates, especially where the tubercular process is advancing, and they frequently exist inside the giant-cells. In many cases the rods contain spores, generally two to four in each bacillus.

These organisms have been found in the following diseases—General miliary tuberculosis, phthisis pulmonalis, scrofulous tubercle of the brain, tuberculosis of the intestine, scrofulous disease of lymphatic glands, scrofulous synovitis. They have been found also, uniformly, in bovine tuberculosis, in the spontaneous tuberculosis of guinea pigs, rabbits, and monkeys. They are also present in the tubercles produced by inoculation in animals.

But the bacillus has not only been discovered, it has been cultivated outside the body. It grows in blood-serum, but very slowly, and only when the temperature is between 30° and 41° C. The organism has been cultivated through many generations, and from various forms of tuberculosis, and at the end it has been found to retain all its virulence. When introduced it takes about a week or ten days to produce

any manifest change, but it ultimately gives rise to a regular tuberculosis in the internal organs.

These observations, then, distinctly prove that tuberculosis is a specific infective disease. Considering that the bacillus is present abundantly in the sputum of phthisis, and gets dispersed everywhere from that, there is no difficulty in understanding how the organism gets into the body. It is clear, however, that in order to its development there must be some existing condition of the body predisposing. It has already been mentioned that the bacillus is of slow growth, and when it is carried into the healthy tissues it probably gets eliminated before it undergoes considerable increase. In the case of weakly persons, however, the tissues may be less able to resist its inroads, and as different persons are variously constituted the locality of the development will vary. The lungs, however, are obviously the favourite seat of attack, and the organism is doubtless inhaled.

According to the views already advanced, the relations of the tubercular process and the area covered by it are somewhat more extended than many have hitherto acknowledged. Not only such definite tubercular conditions as the scrofulous tubercle of the brain, but also pulmonary phthisis, scrofulous disease of the glands, etc., are essentially tubercular in their nature. The virus is present in all such products, and they are capable of producing tuberculosis by inoculation. The domain of tuberculosis therefore covers that of SCROFULA.

It is here proper to state that histological investigation seems to confirm this latter view. SCROFULOUS DISEASE of the lymphatic glands is not a simple inflammatory swelling of them, but tubercles of typical structure are to be found in them from the earliest period, and the process is as much a tubercular one as the local tuberculosis of the brain. It is the same with phthisis pulmonalis. There are undoubted inflammatory phenomena here, but tubercles are found as well, and although it may be said that the tubercular formation is secondary to the degeneration of the inflammatory products, the constancy with which tubercles are to be found in the earliest periods rather contradicts this view.

The so-called scrofulous diseases are characterized by a rich new-formation of cells, apparently inflammatory, in the midst of which tubercles are to be found. Both tubercles and inflammatory products are prone to undergo caseous necrosis. Here the former question comes up as to the relation of the inflammatory products to the specific tubercles. Looking to the fact that these products undergo precisely

the same changes as the tubercles it seems reasonable to infer that they are both due to the action of the same virus. This is only consistent with what we have seen in the case of syphilis where the same virus produces both the inflammatory manifestations and the gummata.

Source of the Tubercular Virus.—There are still some questions to be answered after all that has been stated above. If in acute miliary tuberculosis we have a virus in the blood, whence does it come? If in local tuberculosis there is a virus, what is its source, and how does it reach its local habitation?

It has been stated that in acute miliary tuberculosis the virus is present in the blood, but this does not quite explain the whole. The virus is often present in the blood without producing this general tuberculosis. For instance, in phthisis pulmonalis there are often a few tubercles in the liver and kidneys, and the virus must have reached these organs by the blood. Then in local tuberculosis it is difficult to understand how the virus can have reached such organs as the kidneys or the joints except by the blood. We have already seen that the tubercular bacillus is slow of growth, and does not multiply with great rapidity, and the probability is that before acute miliary tuberculosis can be produced there must be a large accumulation of it in the blood.

It is often stated that in acute general tuberculosis the source of the virus is to be found in some old caseous mass in the body, such as a scrofulous tubercle of the brain or a caseous gland. But the disease not infrequently occurs without any such caseous focus being discovered, and even when a caseous mass exists it is not clear how the virus is produced in such quantity as we are led to infer. In some cases tuberculosis of the thoracic duct, and in others of the branches of the pulmonary artery, has been found in acute miliary tuberculosis, and in these we have a sufficient source of virus in immediate connection with the blood. It may be that careful examination will reveal such sources of supply in most cases of this disease, but meanwhile we must wait. It is even possible that the virus may sometimes be introduced in a peculiarly virulent form. As Virchow long ago pointed out, epidemics of general tuberculosis occur, and the explanation may be found in this.

In regard to local tuberculosis it is to be presumed that the virus is introduced in small quantity, and in order to its propagation two things are necessary. In the first place the virus must be allowed to tarry in the part, and in the second place it must find a fitting nidus. It seems as if the normal tissues had the power of destroying small quantities of

the virus. But if the tissues are defective in vitality, and especially if along with that the blood stagnates in them, then we may have the virus, if introduced, propagating itself and producing tuberculosis.

The source of the virus is not far to seek. If phthisis pulmonalis is a tubercular disease, and if, as Koch and Ehrlich have shown, the sputum of such patients contains myriads of the specific bacillus, then the air of towns must contain it in abundance, and everyone must inhale it. But it is only persons who have natural or acquired weaknesses that become the subjects of local tuberculosis.

But the virus may be introduced by the food as well as the air, and in this connection it is important to note that the bacillus of bovine tuberculosis appears to be identical with that of human tuberculosis. There is reason to believe that the milk of tubercular cows contains the virus, which may thus find access to man.

The virus then having been introduced by the air or in the food may lodge in the lungs or intestine, and, in persons predisposed, may develop tubercular disease at the seat of its entrance. But if the place of entrance does not afford a fitting nidus, the virus may be carried beyond. It will most readily be carried by the lymphatics to the nearest lymphatic glands, and may thence pass into the blood. In children it seems as if the virus were peculiarly liable to lodge in the mesenteric glands after being taken in by the food.

Again, the virus may get into the blood, but it does not develop unless it finds some part of the body fit for its reproduction. In many cases of scrofulous and tubercular disease, there has been, previous to their development, some injury or disease of the particular part in which they have occurred. For instance, in scrofulous synovitis, there is very commonly some history of an injury as the starting point of the disease, which is really a local tuberculosis of the joint.

BOVINE TUBERCULOSIS.

This disease, perhaps better known by its German name of Perlsucht, is rather common among cattle. It is a general disease manifesting itself in a variety of organs like our own general tuberculosis, but running a much slower course. It is an infective disease, and has been communicated to the calf, lamb, goat, pig, and rabbit, by feeding these animals with milk from an affected cow, or with the actual pearl nodules. Like tuberculosis, it is due to a virus, which, as we have seen,

is the same bacillus as that of ordinary tuberculosis; it is generally believed to be hereditary.

The disease in the cow is characterized, like general tuberculosis, by the formation of numerous isolated or conglomerated nodules. They occur chiefly on the serous membranes, in the lymphatic glands, and in the lungs. The nodules on the serous membranes are the most obvious and characteristic, and it is they which have given the disease its commonest name, Perlsucht or pearl disease. In the pleura and peritoneum appear vascular villous outgrowths in which the nodules ultimately develop (Fig. 57). These nodules are of various dimensions, mostly

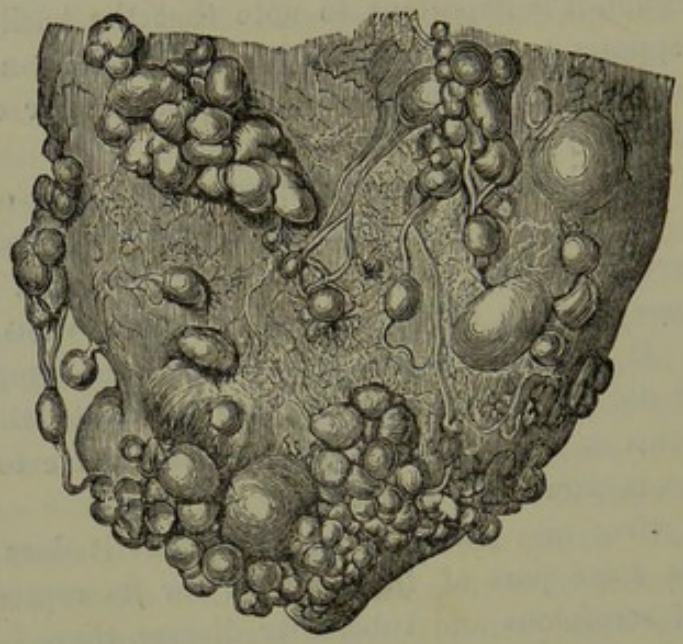


Fig. 57.—A piece of lung in bovine tuberculosis. On surface of lung many rounded tumours are seen, some pendulous. (VIRCHOW.)

about the size of lentils, either sessile or stalked, and very often in the form of flat oval bodies crowded together on the surface like duckweed in a pool of water. They are liable to become caseous or ultimately cretaceous. The lymphatic glands are simultaneously affected, especially the thoracic and abdominal ones, and they often grow to enormous dimensions, from the formation of nodules in them. They also are liable to caseous necrosis or calcareous deposition. The lungs rarely escape infection, and the nodules here frequently coalesce so as to form somewhat large masses, which are most abundant towards the surface. These masses are often surrounded by distinct capsules, and if softening, which is of common occurrence, supervenes, we have cavities lined with a distinct connective-tissue membrane. Such cavities

are regarded by very high authorities, and especially by Virchow, as due to dilatation of the bronchi by accumulated secretion. Besides in these organs, nodules may occur in the liver, intestine, joints, bones, genito-urinary organs, and udder, and in these situations they present similar characters to those already referred to.

In its essential or minute structure the pearl nodule differs little, if at all, from the tubercular nodule of the human subject. It is made up of a congeries of minute bodies which may be called tubercles, consisting of rounded aggregations of cells, the most characteristic of which are the giant cells, which are here even more abundant than in ordinary tubercles. It is therefore in its general features, and in the peculiar arrangement of its nodules, that this disease differs from tuberculosis in man.

It has been indicated above that the virus of bovine tuberculosis, being the same as that in human tuberculosis, may produce the latter when introduced into the body of man. According to Creighton, the resulting lesions often resemble those of bovine tuberculosis rather than those of the human form.

LUPUS.

This is a disease of the skin, usually of the face, and occasionally of neighbouring portions of the mucous membrane. It is characterized by the formation of rounded prominences, generally of a brownish colour, on the surface of which there is often desquamation of the epidermis.

On microscopic examination of the rounded prominences (which are sometimes called tubercles, in the macroscopic sense) they are found to consist essentially of granulation tissue. The cutis vera has been replaced by an abundantly cellular tissue, the cells mainly like leucocytes, but also epithelioid, and even giant-cells. The infiltration of the skin also is not homogeneous, but often in distinct nodular aggregations resembling tubercles.

As in the other forms of infective tumour, the cells here present a tendency to degeneration. It sometimes happens that the granulation tissue is partially absorbed, and partially developed into connective tissue, so that a cicatrix results, but it is a cicatrix without previous ulceration (lupus non-exedens). In other cases the epidermis over the prominences gives way and an ulcer forms, the granulation tissue breaking down so as to cause a deep loss of substance. The mode of

formation of these ulcers is like that of the syphilitic ulcer from the gumma, or the tubercular ulcer, and, like them, they tend to enlarge by successive new-formation of lupus tissue at the periphery, and its destruction. In this way there may be extensive loss of substance of the skin (lupus exedens). There may be a partial healing of the ulcers at one part, and advance at another, so that considerable deformities result.

As the disease is an infective one we may presume that it depends on a virus, but the nature of the virus is obscure. There are some cases in which the syphilitic virus seems to be the cause (syphilitic lupus), but these are a very small minority. It is believed by some that we have here a local tuberculosis of the skin, and it is possible that this view may turn out to be correct. There is, however, this objection to it, that it does not appear that the lymphatic glands in connection with the lupus become the seat of scrofulous disease.

LEPROSY.

This disease is also called Elephantiasis Græcorum. It was at one time spread all over Europe, but is now confined to Iceland, some parts of Norway and Russia, and the coast of the Mediterranean.



Fig. 58.—Leprosy. The face shows nodular swellings, especially on nose, eyebrows, lips, chin, and ears. Patient had also a large ulcer on right leg, and a small one on left. (Virchow.)

The disease occurs in two forms which are designated lepra tuberculosa and lepra anæsthetica. In the first the new-formation has its seat in the skin or mucous membrane; in the second it is the nerves which are affected.

When it attacks the skin, it is mostly the face and hands which are affected, and the legs if they are exposed to the weather. There appear larger or smaller swellings, at first red or bluish in colour, which become firmer and harder. These tubercles may reach the size of a hazel nut or a walnut. They consist of granulation tissue in which

cells of the size of leucocytes are most abundant. As in other granulation tumours, we often have ulceration, or, as in the case of lupus, there may be cicatrization without ulceration. By the formation of the swellings and cicatrization, great deformities frequently result, so that the patients have often a peculiarly hideous appearance, the face being knobbed and gnarled. (Figure 58.)

In the anæsthetic form the nerve stems become the seat of granulation tissue, forming spindle-shaped swellings, sometimes of considerable length. The granulation tissue here is in the interstitial connective tissue, so that the nerve fibres are separated and compressed. In the anæsthetic parts it is not uncommon to find gangrene occurring, so that fingers or toes drop off.

In leprosy there are sometimes tumours formed in internal organs, but this is very rare.

By the researches of Hansen and Neisser, it has been shown that leprosy is related to a micro-organism, which closely resembles the tubercular bacillus. The bacilli are always to be found in the granulation tissue forming the tumours. Their source, however, is not so clear. They are not acquired by contagion, and experiment has hitherto failed to produce the disease by inoculation, although the possibility of inoculability is not to be denied. The fact that leprosy occurs at the present day only among fish-eating people may perhaps indicate that the organism has its origin in the decomposition of fish, and persons in a low state of health eating decomposing fish are liable to be affected by it.

GLANDERS AND FARCY.

This is a single disease, although the names to some extent are applied separately. It affects chiefly horses, and is called glanders when it has its chief seat in the nasal mucous membrane, and farcy when the skin is chiefly affected. It is eminently contagious, and communicated from animal to animal by inoculation. Occurring chiefly among horses and similar animals, it is met with also in some of the domestic animals, and is not infrequently communicated to man, especially to persons who work about horses.

The disease in horses manifests itself first in the formation of swellings of the mucous membrane or skin, consisting of granulation tissue. The nasal mucous membrane is generally first attacked, and there is either a diffuse infiltration of it or else a more localized series of swellings like those of lupus. From this seat the disease spreads to neigh-

bouring lymphatic glands, also along the mucous membrane to the lungs and intestinal tract.

The granulation tissue here, even more than in the other infective tumours, tends to break down, so that, as a rule, ulcers soon form, which present a great tendency to spread. These ulcers arise by what is virtually a suppurative process, and if the tumours are situated deep in the skin or mucous membrane there may be actual abscesses, which, by bursting, form ulcers. If the ulcers heal, cicatrices are formed in the usual way.

The manifestations in internal parts are largely inflammatory in character. The lymphatic glands of the neck are the seat of inflammatory swelling. In the lungs there are nodules either consisting of granulation tissue with caseous central parts, or more distinctly pneumonic. There are also in the mucous membrane of the intestinal canal nodules which are sometimes more solid, at other times breaking down into pus.

It is to be added that the above description applies to the acute cases, which are the commoner, but that the disease is sometimes chronic in its course. Chronic cases have usually the nodules in the skin, and there are secondary tumours in the muscles, etc.

In man, glanders is usually an acute, rapidly fatal disease. There are nodules and ulcers in the mucous membranes and the skin, and frequently phlegmonous inflammation of the skin with abscesses among the muscles, etc. In fact, in man the disease takes the inflammatory character more distinctly than in the horse. We may have in man also nodules, ulcers, and abscesses in internal organs.

It is clear that we have in this disease a virulent agent, but the nature of it is unknown.

TUMOURS OR MORBID GROWTHS.

DEFINITION.—A tumour means literally a swelling, and formerly any swelling was called a tumour. Tumor, for example, is often named as one of the cardinal signs of inflammation, and it is still customary to speak of the inflammatory tumour. But now-a-days the use of the word has become limited; it is applied to a class of new-formations of which it is difficult to give a strict definition.

It may be said that tumours are pieces of tissue which have a life and growth of their own irrespective of the needs of the organism, and of the general local conditions around them. The structure of a tumour does not differ in any essential particular from that of normal tissues; in its elements it is wholly analogous to what may be found in the physiological tissues. It is nourished by the same blood, its blood-vessels being continuous with those of surrounding parts, its nerves are connected with neighbouring nerve-stems, and its tissue, if not always similar to that near it, is frequently identical. But it grows independently and without apparent object. Thus a fatty tumour goes on increasing in size irrespective of the adipose tissue in which it has its seat, and the person may be reduced to the greatest emaciation, most of the ordinary fat being absorbed, while little or no impression is made upon the fatty tumour.

It may here be said that tumours usually arise in the midst of tissues of their own nature, and when they do so, they may be called HOMOLOGOUS. But they not infrequently arise in the midst of tissue of a different kind, a tumour composed of muscular tissue, for instance, in the kidney, and they are then called HETEROLOGOUS. These words were at one time used to express the distinction, that in the one case the tissue corresponds to the tissue of the body and in the other is different from the tissue of the body. But as the tissues of tumours correspond

in their structure to the physiological tissues, there is no such thing as heterology in this sense.

Origin and Development of Tumours.—In the definition given of tumours we have seen that they are composed of tissue which follows in its structure the normal tissues, but grows without reference to the needs of the organism. We have here to enquire how this piece of abnormally growing tissue takes origin.

For the most part it may be asserted that it arises in tissue of its own nature, and that it grows by a process perfectly analogous to that of its own kind of tissue. Even in the case of heterologous tumours this is, at the outset, true. A muscular tumour, whatever its seat, must have had embryonic muscle as its primordial basis, and it grows by a process analogous to the growth of muscle. But most tumours in their primary position are strictly homologous, and their tissue presumably has its origin along with that of the tissue in which they have their seat. A fatty tumour has its seat among the adipose tissue, and is at the first a piece of fat indistinguishable from that which surrounds it. We have to enquire how it is that this particular piece of adipose tissue has taken upon itself this peculiar and unusual development.

An explanation has been recently suggested by Cohnheim, and enforced by cogent arguments and ingenious experiments performed by him and his pupils. Let it be supposed that the primordial tumour is a piece of tissue left over as it were from the embryonic state, and retaining unabated much of the embryonic power of growth and development, and much of the special phenomena of tumours will be explained.

In the normal growth of the body the various tissues go on reproducing themselves up to a certain point, but they stop short when they have produced the proper amount of tissue for the needs of the organism. The finer details of this process are largely governed by heredity, but it is clear that there is a law in the organism regulating the growth of the tissues in relation to each other and to the organism as a whole. It may be presumed that the embryonic basis of each tissue starts with a great power of new-formation, but this power is strictly under command of the organism as a whole.

But if a piece of embryonic tissue be taken out of its normal relations and placed in a position favourable to its further growth, then it may perhaps grow on irrespective of the needs of the organism, and develop something in the nature of a tumour. We have already referred to a

case in which a process like this occurs. When the spur of a cock is transplanted to the comb, it grows rapidly, and by and by forms a prominent tumour. Here is a piece of tissue removed from its proper relations into a position more favourable for its growth in respect to blood supply, and it grows with a very special vigour. Again, Leopold has found that it is possible to transplant cartilage from a living animal into the anterior chamber of the eye, where it acquires vascular connections with the iris. If fœtal cartilage be used, it grows in its new position and may form a distinct tumour of some size, but if it be cartilage from an animal after birth it does not show the same vigour. It appears also that the earlier the period of development of the embryo from which the cartilage is taken, the more likely is there to be a vigorous growth in the new position.

These facts would indicate that the normal tissues may under unusual circumstances, when they are disconnected from their normal relations, assume an independent growth, and the tissues of the embryo are more capable of this independent growth than those of the fully developed animal.

But there are some facts in the pathology of tumours themselves which indicate that in some cases, at least, they take origin in pieces of tissue left over, as it were, from the embryo. There are tumours which arise, as it is said, by inclusion. A very striking instance of this is the so-called sacral teratoma. In these tumours almost all the tissues of the body may be present, and sometimes there are parts as of a fœtus. There seems no doubt that in this case, at an early period, a whole embryo has been included inside the fœtus, and the person is born with an embryo included in his tissues. The various embryonic tissues grow in their abnormal position not altogether indiscriminately.

Again, tumours of striped muscle have been found in the kidneys and other parts of the urino-genital system. The explanation of this seems to be that the Wolffian body from which the kidneys are developed is, in the embryo, close to the corneous and vertebral layers, and portions of these being included in the Wolffian body, in the embryonic state, they may afterwards develop into tumours.

Again, it is not uncommon to find tumours developing in after-life from congenital moles or soft warts. These little outgrowths present throughout life a somewhat rudimentary structure, but they lie quiescent for many years, till suddenly, it may be, they present an extraordinary power of growth and develop tumours.

It may then perhaps be presumed that in the case of many tumours

they take origin in pieces of tissue left over from the embryo, and retaining largely their power of growth.

But this does not apply to all tumours, and especially it does not apply to cancers. We shall afterwards see that these tumours do not grow from a single piece of tissue, but that in a considerable and extending area, the existing epithelial structures take on an unusual growth. At the marginal parts of an epithelioma of the tongue, for instance, it can nearly always be seen how the normal epithelium is extending and penetrating inwards ; and again, a cancer of the kidney appears to arise and advance by transformation of the existing tissue of the organ. It appears, therefore, that in this case the tumour arises from the existing normal structures, and that we must look for some abnormal impulse inducing it to grow outrageously.

In the case of cancers and sarcomas the abnormal impulse is not infrequently related in some way to a traumatic cause. Many tumours are referred by patients to injuries received, although there must be some local peculiarity before a simple injury can produce such effects.

Growth and Extension of Tumours. — For the most part, tumours enlarge by a new-formation of tissue within themselves, just as the normal tissues increase during the period of growth. The tissue of the tumour is sometimes continuous with that of surrounding parts, sometimes it is separated by a capsule composed of connective tissue ; sometimes it begins by being continuous and afterwards gets separated. In any case the ordinary tumour simply grows by new-formation of its own tissue. It often produces effects on neighbouring parts, by pressure especially, but apart from these merely mechanical effects, it does not prejudice neighbouring structures. Tumours possessing these characters are usually called simple or innocent growths.

But then there are tumours of which this is not true. They have a tendency to grow into and infiltrate neighbouring tissues, presenting characters of what may be designated local malignancy. This is peculiarly the case with sarcomas and cancers. In the case of sarcomas the tumour seems to penetrate into and develop, as it were, on the mould of the existing tissue—apparently very much in the style that a thrombus or a piece of catgut in the tissue is replaced by granulation-tissue which moulds itself on it. For instance a sarcoma may penetrate through a blood-vessel, replacing and taking the shape of a thrombus in the vessel. In the case of cancers, on the other hand, their tissue, which

is epithelial in character, penetrates among the tissues, largely destroying them and producing inflammatory disturbances.

There is another peculiarity which certain tumours show, and particularly the sarcomas and cancers, namely METASTASIS or GENERALIZATION which is another feature of malignancy. In the case of these tumours, secondary growths spring up in parts removed from the primary tumour. Doubtless something is carried from the original tumour to the remote part, and we have to inquire by what path this is carried, or what may be the nature of the material. In the case of cancers the epithelial processes penetrating into the tissues readily find their way into the lymphatic spaces. Around a cancer there are often indications under the microscope that the lymphatics are filled with epithelial masses. From these growths in the lymphatic spaces material may be carried off to distant parts of the lymphatic system and cause secondary tumours to form there. Thus, a cancerous tumour sometimes penetrates into the peritoneal cavity, which, of course, is a lymph sac, and secondary tumours are sown up and down the peritoneum. The lymph sac of the peritoneum communicates with that of the pleura by lymphatic channels which pass through the diaphragm, and it is quite common to find the cancerous growth extending into these channels, and through them into the pleura, producing secondary tumours there. In other cases the secondary tumours spring up in the lymphatic glands, and it is always those to which the lymphatics around the tumour pass that are first involved, something passing off from the epithelial processes in the lymph spaces and being conveyed to the lymphatic glands.

While this is the course in cancers, we find that in sarcomas if metastasis occurs it is by the tumour penetrating through the walls of blood-vessels. The material from the tumour is therefore carried by the blood, and as it is mostly the thin-walled veins which are thus opened into, the metastasis is usually in this case to the lungs.

As to the nature of the material which passes from the tumour, it must be either something dissolved in the juices, or else solid particles of some kind. Looking to a secondary cancerous infection of the peritoneum, we can hardly escape the conclusion that it is a finely divided solid. The secondary tumours are not regularly distributed over the peritoneal surface, but occur here and there or in groups, just as if solid particles had been carried and produced their effects where they got leave to lie. Then also it must be solid particles which are arrested by the lymphatic glands and give rise to the secondary tumours there,

as it were by embolism. The probability is that the actual cells of the tumour are carried off and deposited at a distance. Perhaps it is not the fully developed cells but small rudimentary ones.

In this connection it is important to note that the secondary tumour for the most part exactly reproduces the tissue of the original one, even to the smallest details, and it is natural under these circumstances to believe that pieces of the original tumour are actually transported.

It has already been stated that sarcomas and cancers are the tumours which regularly present a malignant tendency, but on rare occasions other tumours also do so. CARTILAGINOUS TUMOURS are not infrequently MALIGNANT. Next to them mucous tissue tumours most frequently become malignant, but even fibrous tumours have been observed to do so, and lately Cohnheim has recorded a case of colloid goitre in which secondary tumours occurred. So that malignancy is not confined to sarcomas and cancers. On the other hand tumours having the structure of sarcomas may remain local to the end.

It has been usual to believe that this malignancy is dependent on peculiarities of the tumour itself. And when a simple tumour, as sometimes happens, assumes malignant characters, it usually assumes the structure of a sarcoma or cancer. Lately Cohnheim has started another theory, according to which the peculiarity is not in the tumour but in the normal tissues. In the case of a simple tumour the normal tissues are able to prevent its tissue from penetrating into them, but in the case of malignant tumours the tissues have become weakened and are unable to form a barrier to their extension. When a simple tumour becomes sarcomatous, it is because the tissues around have assumed a peculiar weakness. When pieces of a tumour are transported to a distance, a struggle, as it were, occurs between the tendency of the tissue of the tumour to grow, and that of the normal tissues to prevent its growth. In the case of a simple tumour the tissues assume the upper hand, and cause the absorption of the tumour-tissue. In the case of malignant tumours, however, the tissues are too weak to accomplish this, and the secondary tumour develops. This theory is too strained, and all the facts are much better explained by supposing a special power of growth in the tumour. When a secondary infection of the peritoneum is examined, it is difficult to believe that there is anything but a peculiarly active agent and not any speciality in the peritoneal tissue.

We have still to consider certain SECONDARY CHANGES to which tumours are liable. They are exposed to the same pathological pro-

cesses as normal tissues, and in a higher degree. Thus we meet with fatty degeneration, which is common, especially in quickly growing tumours; calcareous infiltration in structures which are obsolete; hæmorrhages, principally in superficial rapidly growing tumours, when the blood-vessels are ill-formed; and necrosis mostly in tumours near the surface and thus exposed to mechanical irritation, the consequences of such necrosis being ulceration with, it may be, suppuration, hæmorrhage, decomposition.

Conditions like those last named will seriously affect the organism as a whole, and they will occur most frequently in the case of malignant tumours, which grow quickly, and rapidly come to the surface. Malignant tumours also affect the organism as a whole by the readiness with which they extend to or produce secondary tumours in important organs, and secondary cancers frequently also induce inflammations as in the case of the peritoneum or pleura.

It is clear therefore that malignant tumours, especially by bleeding, by ulcerating and sloughing, by invading important parts, by producing inflammations, etc., have a tendency to deteriorate the system, producing anæmia and general weakness. If growing quickly they also tend to emaciate by using up the nutritive material of the body. A simple tumour, if it happens to be at the surface and exposed to mechanical violence, may also ulcerate and produce serious constitutional results, but it will be mainly in the case of malignant tumours that these results will follow. To these conditions of the body as a whole the name CACHEXIA is often given. Sometimes also the term DYSCRASIA or DIATHESIS is used with the meaning that there is some peculiar condition of the system preceding and inducing the formation of malignant tumours, but of this there is no evidence, and the changes in the general condition are always secondary.

CLASSIFICATION.

In considering the individual forms of tumours the simplest possible method of classification will be adopted. In a work professedly on pathology it will be admitted that the structure of a tumour is the essential basis of classification and nomenclature, and in what follows terms will be used in what may be called their anatomical sense. It may be clinically convenient to designate tumours which present malignant properties as cancers, but it will not do here to group together in one class tumours of totally different structure.

The various tumours will be divided into three groups. In the first will be included tumours whose tissue reproduces a single simple physiological tissue, such as adipose tissue, connective tissue, bone. In the second group are tumours into whose structure more than one simple tissue enters, such as tumours consisting of such complex structures as papillæ, or even made up of a systematic formation of bone, skin, etc. In the last group we have tumours which are mainly composed of cells, or in which cells predominate. The individual cells are not different from those of the normal tissues, but there is an enormous new-formation of them, with little tendency in them to develop into a proper physiological tissue. The first group may be called simple-tissue tumours, the second compound-tissue tumours, and the third cellular tumours. This classification, it may be remarked, is only used for convenience, and does not lay claim to logical consistency.

A very great advance has been made in our knowledge of tumours by the publication of Virchow's classical work, *Die krankhaften Geschwülste*. From this work many of the following illustrations are borrowed by the kindness of the author.

A.—SIMPLE-TISSUE TUMOURS.

1.—THE CONNECTIVE-TISSUE TUMOUR OR FIBROMA.

WE have already abundantly seen that connective tissue is frequently produced in inflammations, and it is not surprising to find that one class of connective-tissue tumour lies on the borderland of inflammations and tumours.

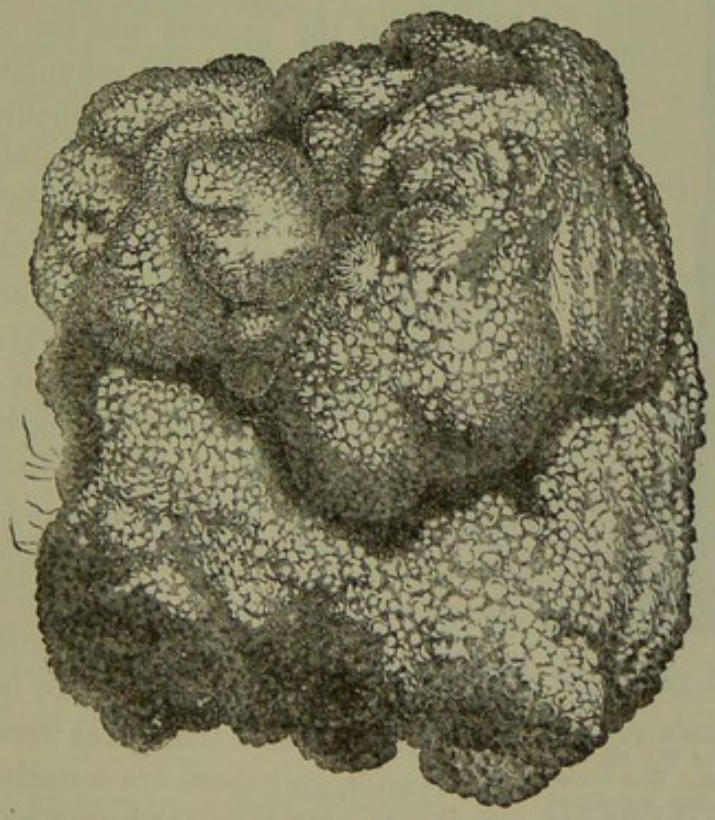


Fig. 59.—Elephantiasis verrucosa from labia majora. A tumour the size of a child's head, with a small base. The surface is lobulated, and each lobule presents warty projections, some fine and delicate, others thick and knobbed. The epidermis is everywhere somewhat thick. The internal parts are composed of thick, interlacing connective tissue, which is œdematous. (Virchow.)

Elephantiasis arabum (E. græcorum is leprosy) is a localized

thickening of the skin, beginning in attacks resembling erysipelas, at first passing off and then recurring. There is finally a permanently progressive and apparently unaccountable new-formation of connective-tissue, and so the characters of a tumour are assumed. The tissue produced is a loose succulent connective tissue, like that of the skin but containing more cells, and so more like inflammatory tissue. The epidermis is also thickened, so that the whole partakes of the character of an exaggerated hypertrophy of the skin (Fig 59). The new-formation may extend inwards to the fasciæ, the intermuscular tissue, and even to the periosteum, inducing thickening of the bones (Fig. 60.)



Fig. 60.—Hyperostosis and synostosis of the bones of the leg and foot in elephantiasis. The bones present everywhere flat or pointed projections. At +-+ the tibia and fibula are united, as they are also above the ankle-joint. The astragalus and os calcis are also united. (Virchow.)

The conditions here present considerable analogies with those in the infective tumours. There is in both a spreading new-formation of tissue like that produced in inflammation, although in the present case the tissue does not remain so long in the granulation stage. To one of those forms of tumours, namely leprosy, there is the further resemblance, that elephantiasis is endemic in certain localities. All these facts may be held as pointing to the inference that this disease is due to a virus of a similar nature to that of leprosy. The resemblance in pathology of the two diseases is further indicated by both having been designated by the same name, the disease under consideration being E. arabum, and leprosy E. græcorum. The disease is frequently regarded as taking origin in obstruction of the lymphatics. This view is supported by the fact that the new-formed tissue is generally very succulent, as if the spaces were overfilled with lymph, and there are sometimes dilated lymphatics visible in the hypertrophied skin. The obstruction produced by filaria sanguinis (see section on Parasites) in the lymphatic glands has been assigned as the cause, as well as mere simple indurations of the glands.

The commonest seat of elephantiasis is the leg, and here alone is the name properly applicable; but it is also very frequent in the external generative organs. It occurs also not infrequently in a localized piece of skin, especially in the scrotum or labia pudendi, where a prominent outgrowth is the result. This may assume very large dimensions, becoming by and by pendulous. To such tumours Paget gives the name CUTANEOUS OUTGROWTHS, and they sometimes grow to enormous size, hanging down from the genital organs as far as the knee. The surface of the skin in these tumours, as well as in the more simple cases of elephantiasis, has a rough tuberculated appearance, and sometimes a highly warty aspect, as in Fig. 59.

Smaller tumours of similar structure sometimes occur in large numbers, and to these the name MOLLUSCUM FIBROSUM, or fibroma molluscum, or even elephantiasis mollusca is given. There are cases of elephantiasis having a certain resemblance to molluscum, inasmuch as there are multiple tumours outside the main one, and the growth seems to be increasing by the coalescence of these. These tumours at the margins are sometimes related to the sebaceous glands, and appear to be formed around them. In the proper molluscum, however, we have multiple isolated tumours beginning as little growths of connective tissue in diverse regions of the skin, by and by growing out and becoming pendulous. Thus we may have hundreds of more or less pendulous tumours in various parts of the body. This purely fibrous molluscum must be carefully distinguished from molluscum contagiosum, a totally different disease, which will be considered in the section on Diseases of the Skin.

In all the forms hitherto described the tumours have been continuous with the skin. Tumours are sometimes met with, however, composed of a similar soft connective tissue, but enclosed in a capsule, so that they are separable from the skin. To these Paget gives the name FIBRO-CELLULAR TUMOURS, and they are met with chiefly in the same regions (namely the external organs of generation) as the fibro-cellular or cutaneous outgrowths with which they may be combined, the skin over the tumours being greatly thickened.

HARD FIBROMAS or true Fibromas are exceedingly dense tumours composed of firm connective tissue tightly interlaced and resembling tendon in its structure. On section they show a brilliant white surface and often a concentric arrangement of the connective-tissue bundles. We do not include here the uterine fibromas, which are really muscular

tumours, and will be described as such. Fibromas are frequent in connection with periosteum and bone, especially on the jaws. Growing from the periosteum they are sometimes intimately connected with the bone which may be as if buried in the tumour. Sometimes the fibroma originates inside a bone. Fibromas also occur on fascias and membranes, as the dura mater, also rarely in the subcutaneous tissue and on nerve stems. Just as dense connective tissue formed in chronic inflammation may become calcified, so may dense fibromas be partially infiltrated with lime salts.

2.—THE FATTY TUMOUR OR LIPOMA.

This form of tumour consists of adipose tissue exactly like that of the body, as for instance the subcutaneous adipose tissue. Adipose tissue contains bands of fibrous connective tissue which carry the vessels and nerves, and so do lipomas, but in different tumours this is variously abundant, the hardness or softness of the tumour depending on this. If there is little connective tissue the tumour will be soft, and may even feel fluctuant. If there is much it will be hard, and we may even have an approach to the fibrous tumour, the fibro-lipoma. The fibrous character may be increased by irritation, as where a tumour is exposed to friction, producing a kind of productive inflammation in the tumour.

Fatty tumours are mostly surrounded by a distinct capsule, but sometimes they are continuous with the surrounding fat. Thus the fat around the mamma may undergo such an enlargement as to warrant the name of tumour (Lipoma capsulare). Billroth mentions a lipoma which had grown in between the muscles of the thigh in such a way as that it could not be removed completely. Lipomas which are not definitely circumscribed may be called DIFFUSE LIPOMAS.

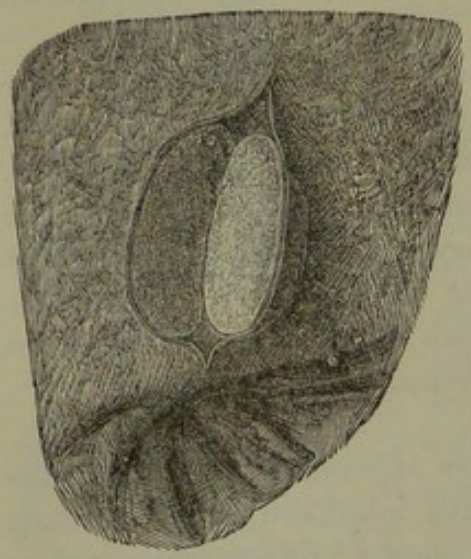


Fig. 61.—Lipoma in the wall of the stomach. It was the size of a hazel-nut, situated near the pylorus in the submucous tissue. Natural size. (VIRCHOW.)

Lipomas are of common occurrence. Their most frequent seat is under the skin, especially of the trunk. They are rare under mucous membranes, as that of the stomach (Figure 61), where

there is normally a small quantity of fat corresponding with the subcutaneous fat. They are occasionally met with in connection with serous and synovial membranes, in the appendices epiploicæ of the intestines or the synovial fringes. Very rarely they occur where fat is not present normally, as in the kidneys, brain, etc. The author met with a case in which an elongated piece of fat lay on the upper surface of the corpus callosum. Lipomas are for the most part single, rarely multiple.

Fatty tumours sometimes become PENDULOUS. Those in the appendices epiploicæ (figure 62) are so from the first, and the neck of the

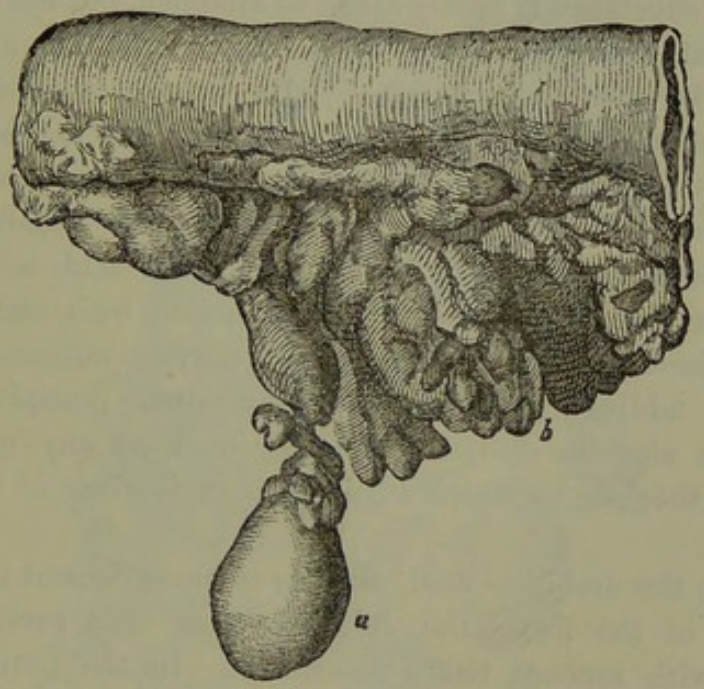


Fig. 62.—Pendulous lipoma of appendices epiploicæ of colon. A pedunculated tumour (*a*) projects from the general mass of subserous adipose tissue (*b*). It is twisted twice on its axis, and the peduncle is very thin. (VIRCHOW.)

polypoid tumour may get severed, the tumour becoming a loose body in the peritoneum; it is similar with the lipomas of the synovial fringes. But subcutaneous lipomas may become pendulous and polypoid, and may grow to great dimensions in this form. There is apt to be ulceration of the surface of such tumours, and even hæmorrhage. Besides these changes we have the occasional induration already mentioned, and sometimes calcareous infiltration follows. Softening with the formation of a cyst inside the tumour is a rare occurrence.

3.—THE MUCOUS-TISSUE TUMOUR OR MYXOMA.

This form of tumour is composed of MUCOUS TISSUE, and as this is not one of the physiological tissues of the adult, it will be proper to refer more specially to its characters. The blood-vessels of the umbilical cord are padded and protected from pressure by a gelatinous substance called Wharton's jelly. Under the microscope, this consists of variously shaped cells separated by a clear transparent intercellular substance. The intercellular substance is of gelatinous consistence, and owes this character to the fact that it consists of a watery solution of mucin. This substance is nearly allied to albumen, but has the physical characters that, when present in even small quantity in a solution, it gives it a sticky gelatinous character. Its chemical reactions also differ from those of albumen, in respect that though like it precipitated by alcohol, the precipitate is redissolved by water. Also, acetic acid and other organic acids precipitate mucin, but not usually albumen. The precipitate of mucin by alcohol or acetic acid is more membranous than that of albumen. The reaction with acetic acid can be readily brought out in Wharton's jelly, a microscopic section showing, on adding acetic acid, a reticulated precipitate. These reactions can also be studied in the mucus from any mucous membrane, or in the bile in which mucin is normally one of the dissolved constituents.

Besides in the umbilical cord, mucous tissue is present in the villi of the chorion of the fœtus, the villi consisting of a covering layer of epithelium with mucous tissue internally. In the fœtus, it is also present in early stages in the subcutaneous tissue where it has the place of the subcutaneous adipose tissue, being, in fact, related to fat very much as the temporary cartilage is to bone. Some remains of this tissue may be met with in the adult. Thus, the vitreous humour of the eye is really composed of soft mucous tissue, and traces of it have been found in places where normally adipose tissue exists, as under the pericardium, at the hilus of the kidney, subcutaneously and in the medulla of bone. It appears that in these positions there is sometimes a partial recurrence to the fœtal condition. The connective substance of the brain, the neuroglia, is allied to mucous tissue, and seems to present a proneness to return to that form.

Of MUCOUS-TISSUE TUMOURS a very interesting form is the HYDATID MOLE. Here the mucous tissue of the villi of the chorion undergoes

great increase, and the result is the transformation of the villi into congeries of oval, cyst-like bodies which hang like grapes on a stalk, and often hang one on the other (Fig. 63). Thus a bulky mass often results, consisting of an enormous multitude of these berry-like cysts. If the change has begun early in fœtal life, then the whole chorion is

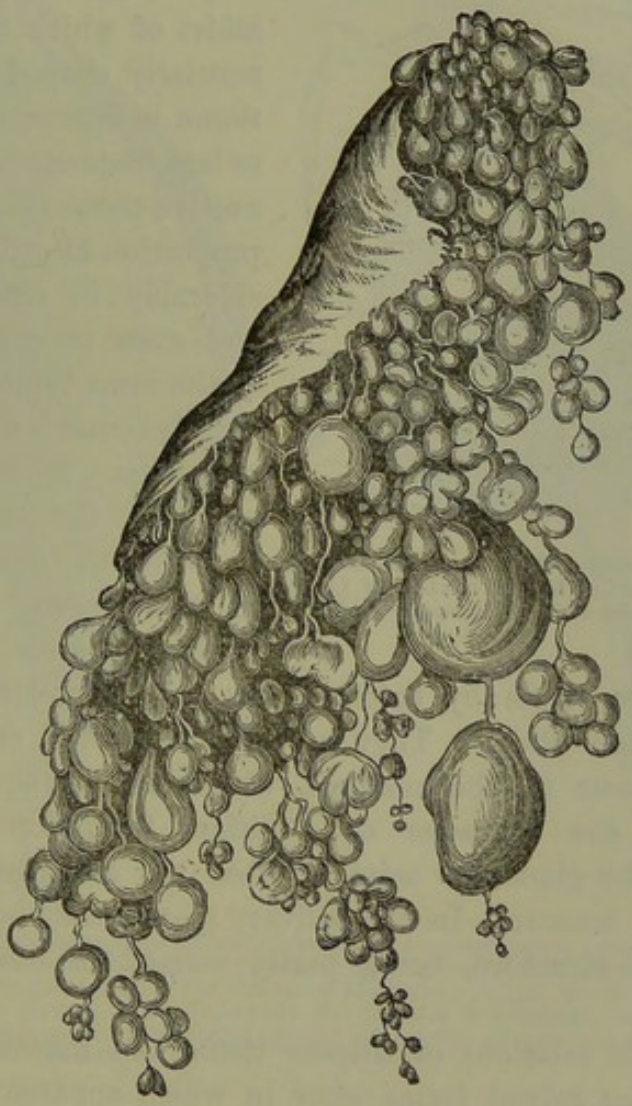


Fig. 63.—Portion of a hydatid mole showing the berry-like masses. Natural size. (VIRCHOW.)

thus converted; if later, when the villi have become confined to the placental surface, then only one surface is affected. The dead and blighted fœtus will be found inside the mass, generally in an early stage of development, but sometimes more advanced.

Proper MUCOUS-TISSUE TUMOURS are met with principally in the subcutaneous tissue, where they may be regarded as perhaps due to a

piece of embryonic tissue left over when the mucous tissue was converted into adipose, in this respect resembling the chondromas of bone. They form rounded or oval tumours generally soft, sometimes almost fluctuant in consistence and gelatinous in appearance. Examined under the microscope we have a very translucent tissue in the midst of which there are irregularly shaped cells. The tissue is intersected by more or less frequent bands of connective tissue (Fig. 64). The proportion of cells varies considerably in different cases, and even in different parts of the same tumour.

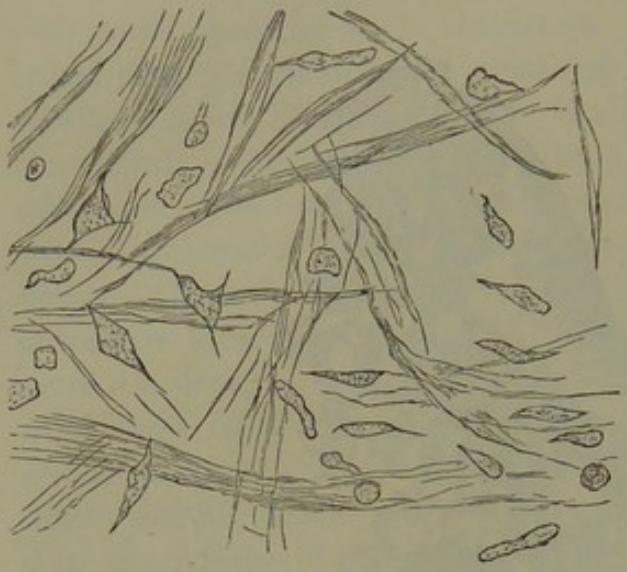


Fig. 64.—Microscopic section of a myxoma of the subcutaneous tissue. Isolated cells and strands of fibres are shown. Between them a clear gelatinous material was present. × 350.

Myxomas are also of somewhat frequent occurrence in the brain as compared with other tumours in this organ. Here they sometimes grow to considerable size, and are liable by softening to take the form of cysts filled with a mucous fluid. They are also met with on peripheral nerves. They occur in the mamma, where not infrequently they appear to have the character of a diffuse formation of mucous tissue between the glandular acini, so that the gland as a whole is converted into a tumour. In the salivary glands they occur, but are usually of mixed structure, being partly formed of other kinds of tissues.

Considering the relations of adipose tissue and mucous tissue it is not remarkable that mixed forms occur in which apparently a partial conversion of the myxoma into a lipoma is in progress, or conversely a metamorphosis of the lipoma. Then also the myxomas vary very greatly in the proportion of cells, the very cellular ones being called medullary myxomas, and frequently graduating into sarcomas. In fact, with pathologists who take the embryonic nature of the tissue as the criterion of sarcomas, the fact that mucous tissue is the embryonic precursor of adipose tissue induces them to class this form of tumour among the sarcomas. Consistently with these facts there are some myxomas which show malignant characters, either local or general.

In a case recorded by Virchow (Fig. 65) there were tumours on the nerves and in the dura mater of the cord and brain.

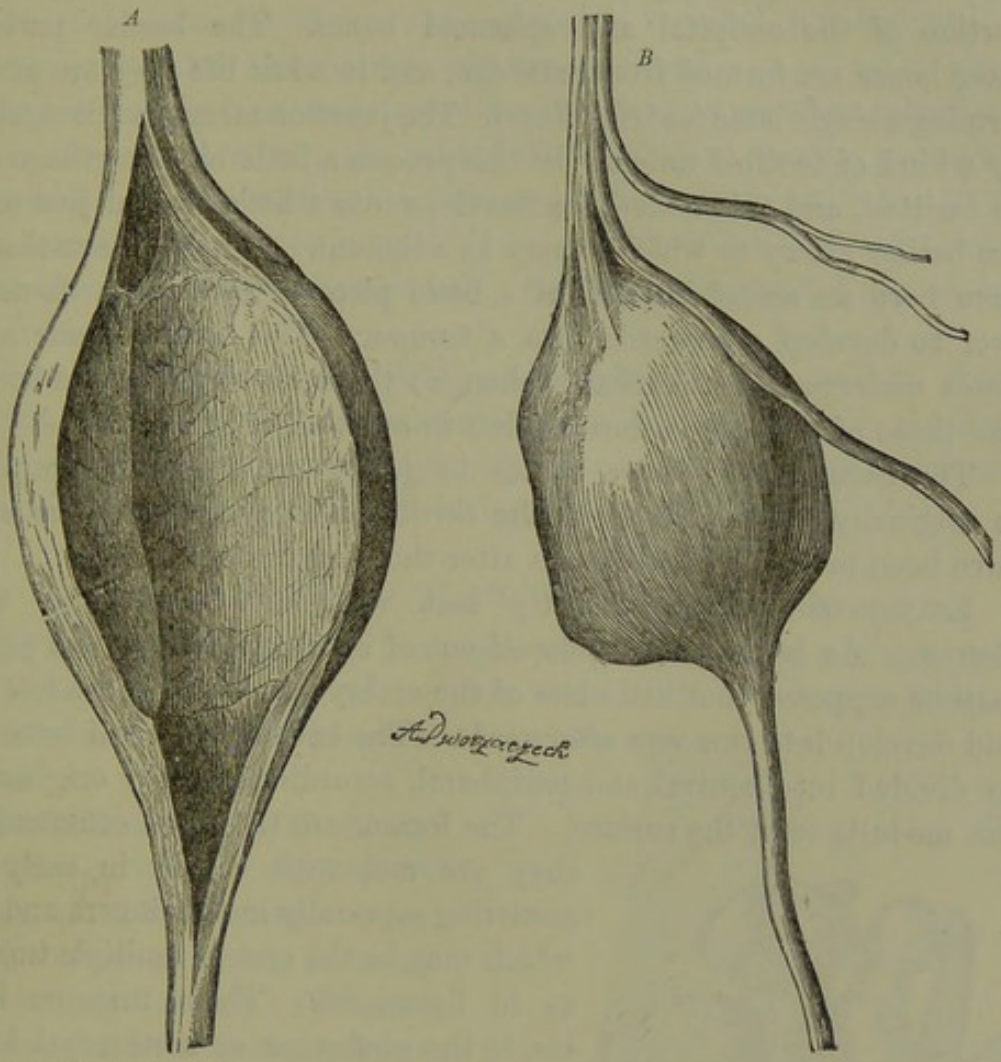


Fig. 65.—Malignant myxoma lipomatodes of the long saphenous nerve. *A*, Section. *B*, External appearance. The tumour measured 2¼ × 1¾ inches. At *A*, the nerve fibres are seen to be for the most part on the outside of the tumour, which, however, was completely covered by the neurilemma. Internally the tumour is lobulated, and it presented a gelatinous appearance, but somewhat opaque. A similar tumour was seated on the short saphenous nerve. (VIRCHOW.)

4.—THE CARTILAGINOUS TUMOUR OR CHONDROMA.

This tumour is composed of cartilaginous tissue. The cartilage may be hyaline or fibrous, generally the latter. The tumour is also intersected with fibrous bands which carry blood-vessels that nourish the tissue. If a cartilaginous tumour grows in connection with and out from cartilage it is called an ECCHONDROSIS, but if, as in the majority of cases, it grows in connection with other tissues, then it is called an ENCHONDROMA. The term chondroma of course includes both.

The ecchondroses are usually small unimportant outgrowths chiefly of the cartilages of the larynx and trachea and ribs. Virchow has described an interesting form of so-called ecchondrosis at the basilar portion of the occipital and sphenoid bones. The basilar parts of these bones are formed from cartilage, and in adult life they are united, forming a single bone (os tribasilare). The junction takes place irregularly by a kind of toothed union. In this process a little bit of cartilage may be omitted, and this sometimes develops into a little tumour just under the basilar artery to which it may be adherent. It will be seen that we have here an actual instance of a little piece of embryonic tissue left over to develop afterwards into a tumour. This little tumour sometimes undergoes a remarkable change; the cells swell up and become like those of the chorda dorsalis, but in other cases it ossifies.

The cartilaginous loose bodies in joints are sometimes regarded as originally outgrowths from the cartilages or synovial fringes which have been broken off and grown after their separation.

ENCHONDROMAS are mostly met with IN CONNECTION WITH BONES. As bones are developed out of cartilage for the most part, it may be supposed that little bits of the embryonic cartilage are left over and develop into tumours afterwards. The enchondromas of bone may be divided into central and peripheral, according as they originate in the medulla or at the surface. The former are the more common, and they are met with chiefly in early life, occurring especially in the fingers and toes, which may be the seat of multiple tumours as in figure 66. These tumours begin inside the phalanges or metacarpal bones, or, less frequently, the analogous bones of the foot. Growing inside the bones they may be for a time unperceived, but afterwards swell up the bones and may even burst through the external shell. These tumours often show a local malignancy, growing by the formation of new nodules in the tissue around. The peripheral chondromas are met with most frequently on the femur and pelvis, and most rarely on the bones of the face and skull.

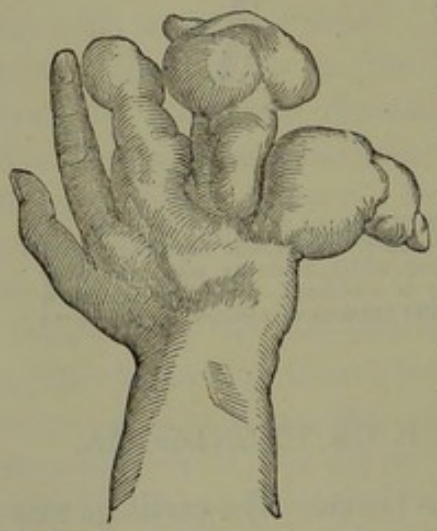


Fig. 66.—Multiple internal enchondromata of fingers. (CORNIL and RANVIER.)

In soft parts chondromas are found occasionally, but are commonly mixed with fibrous, mucous, glandular, sarcomatous, or cancerous tissue.

They are particularly frequent in glands, as the testes, ovaries, mammæ, or salivary glands. In these situations they are occasionally found to follow chronic irritations.

In their form chondromas are generally rounded tumours and distinctly encapsuled, but if large they are lobulated.

It has already been said that the enchondromas are often mixed with other tissue, and it is to be added that secondary changes are not infrequent. They sometimes soften, and this is frequently due to partial transformation into mucous tissue. This is particularly the case with the glandular enchondromas. On the other hand, those of bone are liable to ossify.

Lastly, chondromas are liable, as has already been said, to show a certain malignancy, forming secondary tumours, especially in the lungs. This is connected with the frequently mixed character of these tumours and their association especially with sarcomas and cancers.

5.—THE BONY TUMOUR OR OSTEOMA.

In this class are included tumours composed of bone, not mere new-formations due to inflammation, nor tumours in which bone exists as a subordinate element with other tissue.

The immense majority of bony tumours grow from bone, and are hence called EXOSTOSES. In regard to their structure, some are like spongy bone with the interstices filled with ordinary bone-marrow, and some are composed of dense bone such as forms the shaft of a long bone, and are called ivory exostoses. There are even tumours which originate in the teeth. When these are composed of cement, they are called dental osteomas, but when formed of dentine, odontomas. Several forms are to be distinguished.

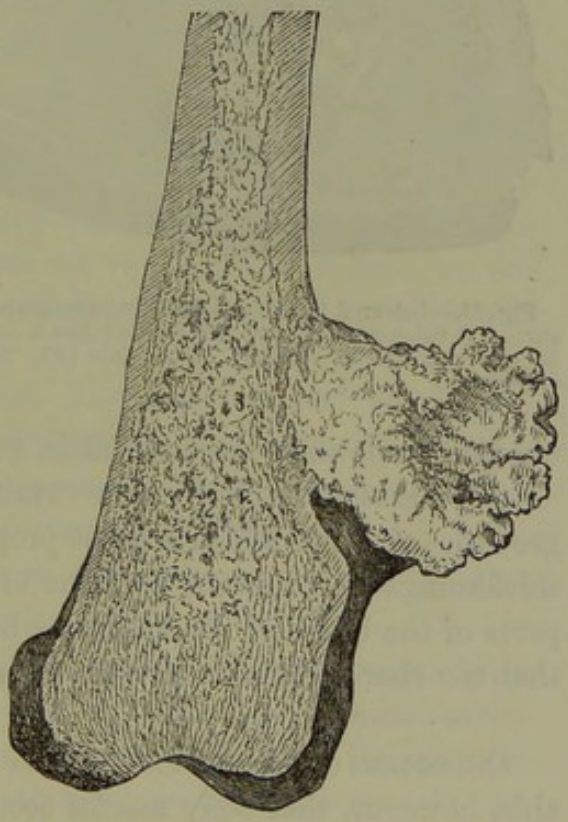


Fig. 67.—Cartilaginous spongy exostosis of femur. (VIRCHOW.)

(1.) THE SPONGY EXOSTOSIS, or the exostosis cartilaginea (Fig. 67). These tumours occur mostly at

the epiphyses of the long bones, and are derived primarily from the epiphyseal cartilage. They grow during childhood, and, just as the cartilage from which they originate ossifies, so do they, and the bony tumour formed is directly continuous with the bone beneath. The tumour begins as a small outgrowth, and so the first bone formed is a narrow piece. The cartilage as it goes on growing enlarges in every direction, and so overhangs its base, the tumour thus becoming larger as it grows outward, and consequently pedunculated. The tumour consists of spongy bone with a thin layer of cartilage on its surface. It is enough to snip through the base in order to remove the tumour.

(2.) THE IVORY EXOSTOSIS is mostly met with on the bones of the head, but also on the pelvis, scapula, great toe, etc. The tumours are usually rounded in form, and may be tuberculated on the surface. In their favourite seat on the head they may grow from the external table and project externally, or from the internal table and project internally (as in Fig. 68), in which case they may produce irritation of the brain substance beneath. It sometimes happens that an ivory exostosis grows from corresponding parts of both external and internal tables. These tumours are sometimes multiple, as in Figure 69.

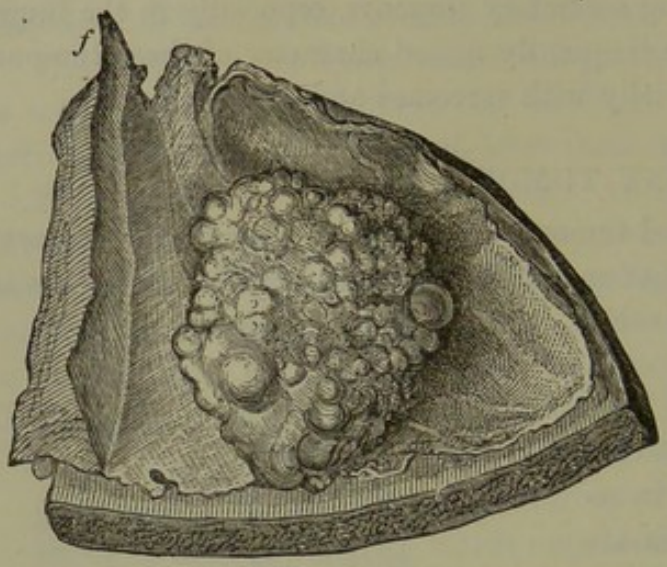


Fig. 68.—Internal ivory exostosis of the frontal bone. The surface is tuberculated, and the tumour has a narrow base. It was situated to the left of the falx (*f*). Natural size. (VIRCHOW.)

(3.) HYPEROSTOSIS AND PERIOSTOSIS are names applied to growths of bone which are not properly tumours. They are localized thickenings of bones or portions of bones. This growth of particular parts of the bones of the head may become so independent in its manner that the characters of a tumour are simulated.

OSTEOMAS OF OTHER PARTS than bones are rather rare. It is remarkable, however, that bony masses occur sometimes in the central nervous system. They are met with in the arachnoid, where they used to be regarded as evidences of chronic irritation, and are hardly tumours.

Actual tumours occur in the dura mater, and even in the brain substance. They are also met with in the eyeball, in the lungs, and, as little bony granules, in the skin.

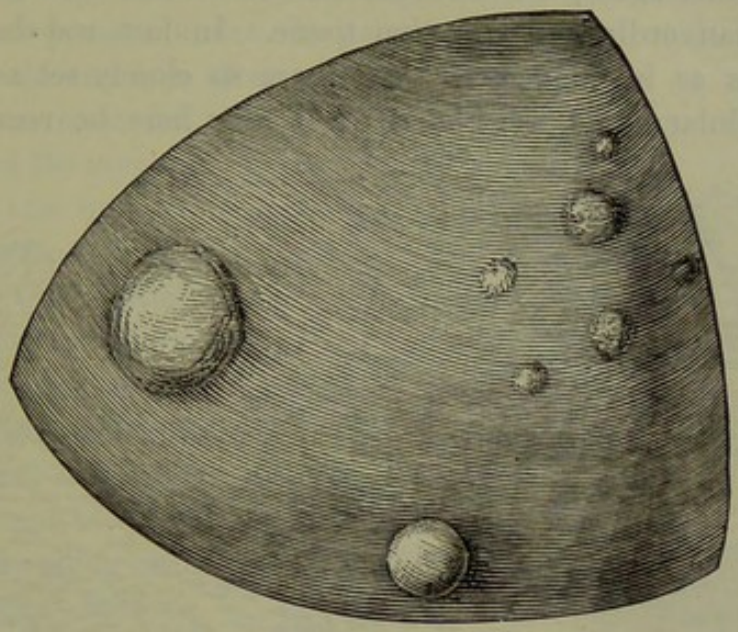


Fig. 69.—Multiple exostoses of the frontal bone. Natural size. (VIRCHOW.)

6.—THE MUSCULAR-TISSUE TUMOUR OR MYOMA.

These are tumours in which muscular tissue is the essential constituent, but just as all muscles have supporting connective tissue so have these, some more, some less. As there are two kinds of muscle, so are there two forms of muscular tumour, those composed of striated, and those of smooth muscle.

The MYOMA STRIO-CELLULARE OR LABDO-MYOMA is very rare. Tumours of this structure have been observed in the heart, where they are congenital. They have also been seen in the kidneys, ovaries, and testicles, where the tissue consists usually of spindle-shaped cells, which are transversely striated, and so the tumours are often called myo-sarcomas on account of their cellular character.

The SMOOTH-CELLED MYOMA (M. lævi-cellulare or leiomyoma) is an exceedingly common form of tumour, and is met with in almost every part where smooth muscle exists normally. According to the amount and density of the interstitial connective tissue is the consistence of the myoma—it may be very dense and warrant the name fibro-myoma, or it may be so hard as to resemble cartilage.

Myomas are often described as fibrous tumours, and in appearance

they justify this designation. To the naked eye they appear fibrous on section, and even under the microscope they appear to be formed of fibres. On adding acetic acid to a microscopic section, or staining with carmine or other agent, the fibres are seen to be much more abundantly nucleated than ordinary connective tissue. In fact, rod-shaped nuclei (not spindles as in connective tissue) are so closely set as at once to suggest a cellular tissue (see Fig. 70). It may here be remarked that

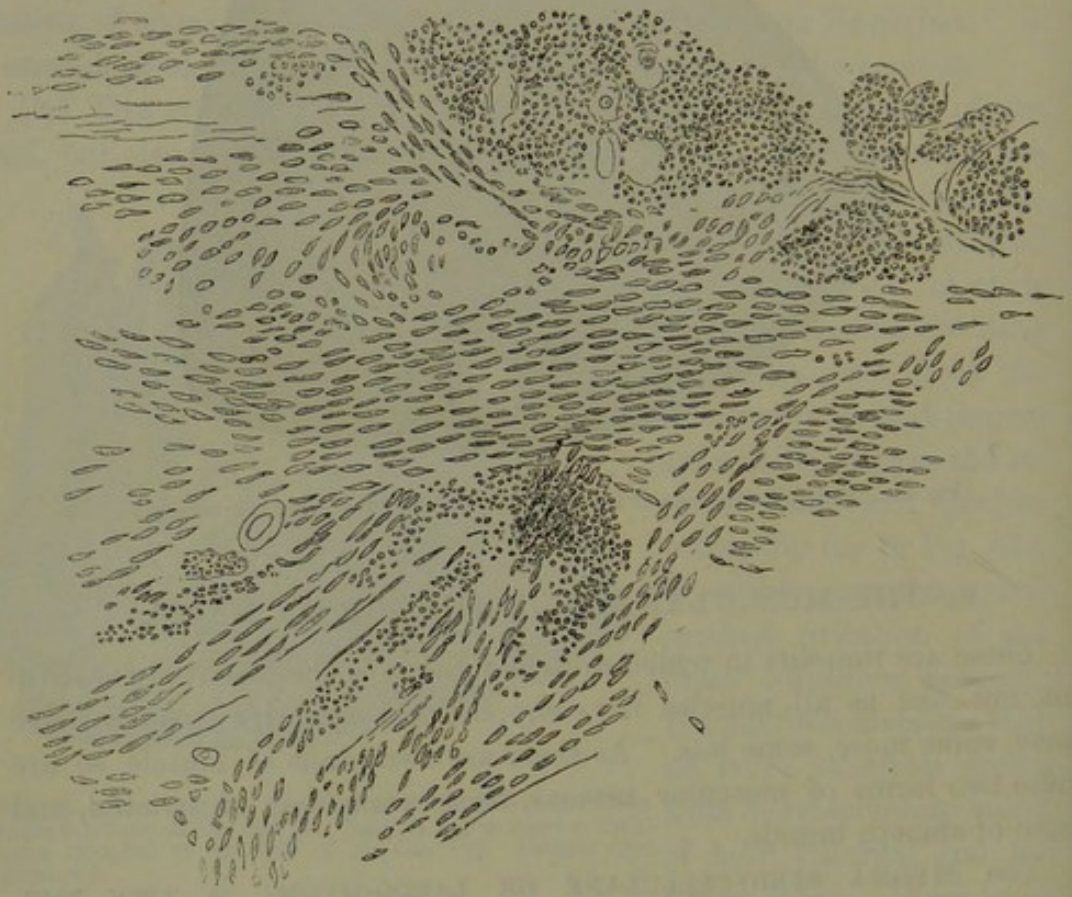


Fig. 70.—Section of a myoma of the uterus stained with carmine. The muscular nucle are seen in longitudinal and transverse section. × 350.

in the unimpregnated uterus there is the same difficulty in distinguishing the individual spindle-cells. In both cases, however, the cells may be isolated by macerating the tissue for twenty-four hours in a 20 per cent. solution of nitric acid, or for twenty to thirty minutes in a 34 per cent. solution of caustic potash. This makes the tissue rotten, and separates the cells, which are recognized as spindles (as in Fig. 71).

Myomas always arise where muscle already exists, and as smooth muscle is most frequent in the walls of mucous canals and cavities, it is there that they usually originate. The tumour may be continuous

with the muscular wall, forming an outgrowth from it, or it may be distinctly isolated and encapsuled. It may remain in the substance of the muscular wall (intraparietal or intramural), or it may slip inwards so as to bulge under the mucous membrane (submucous), or it may pass outward and present under the serous coat (subserous). In the two latter cases the tumours often become polypoid.

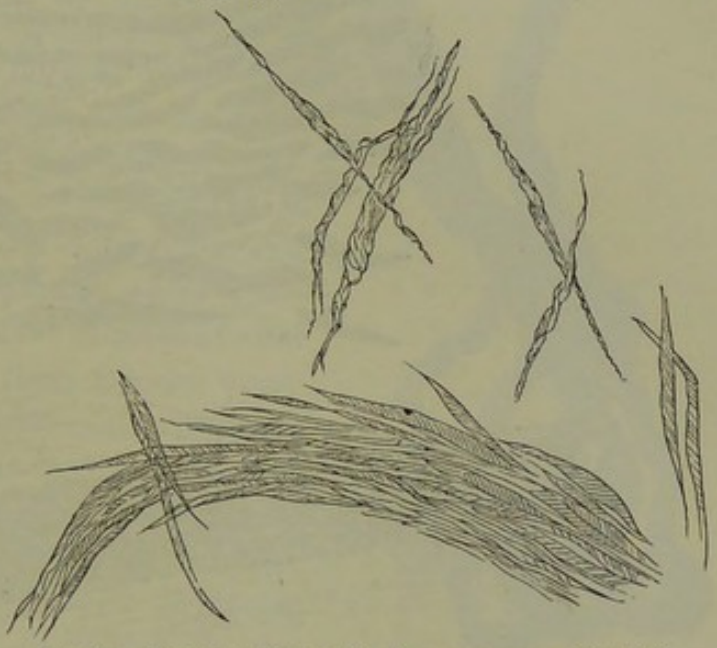


Fig. 71.—Muscular fibre cells from a myoma isolated by steeping in nitric acid. × 350.

By far the most frequent seat of the myoma is the FEMALE ORGANS OF GENERATION, most frequently the uterus, but also the ligaments and ovaries. The so-called uterine fibroids are myomas, and the most important of these are the submucous which so frequently become polypoid, and give rise to hæmorrhage, sloughing, etc. In the PROSTATE the hypertrophy frequently met with in old men is really from the formation of a muscular tumour, and the third lobe which forms a prominent bulging projection at the neck of the bladder is an outgrowth from the muscle of the prostate. Sometimes there are even isolated muscular tumours in the midst of the prostate. This form of tumour is to be distinguished from the glandular tumour, which is a much rarer form of hypertrophy and occurs mostly in young men. Myomas of the STOMACH and INTESTINE are infrequent, and are usually submucous. They have also been seen in the urinary bladder, Lastly, they are rarely met with in the SKIN, one or two cases in connection with the nipple and the scrotum have been observed.

The myoma is of SLOW GROWTH, but many go on as long as 30 or 40 years, and many reach a very great weight, as much as 60 lbs. RETROGRADE CHANGES may occur, such as fatty degeneration, resulting in shrinking or the formation of cysts. If induration occurs from formation of hard connective tissue, this may calcify, leaving the muscular tissue in the spaces between the calcified trabeculæ. In some cases, from derangements of the circulation in large tumours, we may have an

actual necrosis of a portion of the muscular substance, resulting sometimes in absorption and the formation of a cyst. In other cases, the dead structures become calcified as in Fig. 72, where muscular elements, connective tissue, and walls of blood-vessels were all found

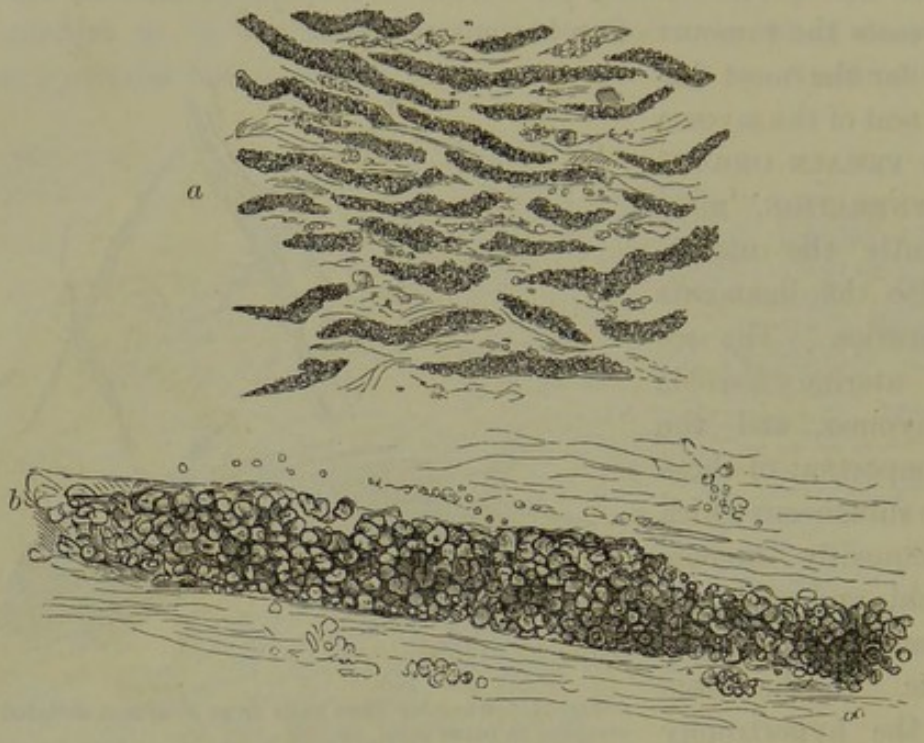


Fig. 72.—From a myoma, a portion of which had become calcified. *a*, muscular fibre cells impregnated with lime salts; *b*, a blood-vessel with wall incrusted. ×350.

impregnated with lime. As the myomas so readily become polypoid, they are liable to be insufficiently nourished, as the neck gets thinner; sloughing may even occur, especially if they present on a mucous surface, and are exposed to injury. Such tumours are also liable to bleed, especially as the vessels in them sometimes undergo great dilatation.

7.—THE NERVOUS-TISSUE TUMOUR OR NEUROMA.

By the name neuroma is often understood a tumour which grows on a nerve stem, and this use of it may be convenient for surgical purposes. Here we have to consider tumours according to their structure, and if a fatty, mucous, or fibrous tumour grows on a nerve, it is to be embraced in its own class. Tumours on nerves, but not of nervous structure, are designated FALSE NEUROMAS.

But there are tumours composed essentially of nervous tissue. As there are two kinds of nerve tissue, the central or ganglionic and the

fibrous or fascicular, it might be expected that we should have two kinds of neuromas. But practically we have no such thing as a tumour composed of ganglionic nerve tissue, although central nervous tissue does occasionally enter into the composition of a teratoma.

The TRUE NEUROMA is composed of nerve fibres, which may be either medullated, as in the ordinary cerebro-spinal nerve, or non-medullated. One of the most striking forms is the so-called amputation neuroma (Fig. 73). Sometimes after amputations the cut ends of the nerves produce little knots or knobs which have a hard consistence and to the naked eye look fibrous. Under the microscope medullated nerve fibres are found running in bundles, but there are also many fine fibres which are probably non-medullated nerve fibres. It is in this case as if the cut end of the nerve had made an attempt at regeneration of the lost portion. Allied to this form is the traumatic neuroma, occurring as the result of injury in the course of a nerve.

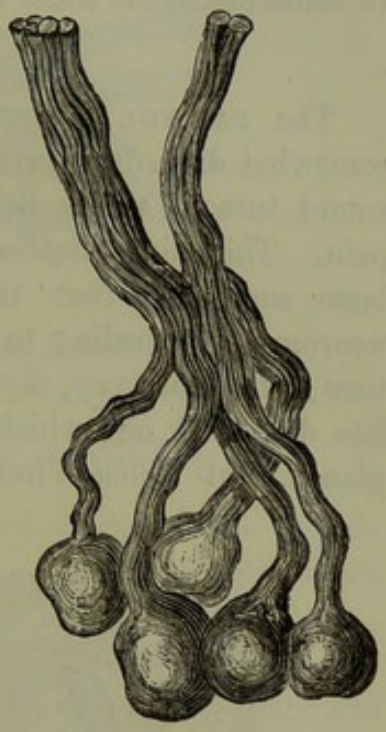


Fig. 73.—Amputation-neuroma. The nerves end in knobbed extremities. The case was one of amputation in the upper arm. Two-thirds of the natural size. (VIRCHOW.)

But neuromas occur in the course of nerves spontaneously, and they are often multiple, forming oval swellings, hard and fibrous in appearance. They contain much fibrous tissue, in the midst

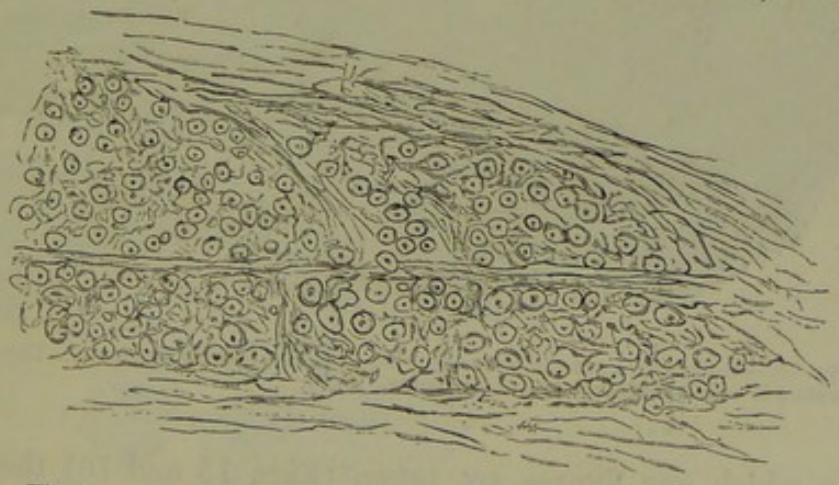


Fig. 74.—Transverse section of a neuroma. The medullated nerve fibres are shown, the appearance being much like that of the section of a nerve. × 80.

of which there are medullated nerve fibres (see Fig. 74) recognizable in

the fresh state by the double contour, especially when the connective tissue has been rendered transparent by acetic acid or liquor potassæ. But usually in addition to these medullated fibres, there are fine nucleated fibres which Virchow regards as non-medullated nerve fibres. In some neuromas these are very abundant.

The PAINFUL SUBCUTANEOUS TUMOUR, or Wood's tumour, is a somewhat difficult growth to classify. It occurs in the form of a small round tumour under the skin, and is commonly the seat of intense pain. The pain indicates some connection with the nerves, and it has been suggested that the tumour may even be a non-medullated neuroma. According to Virchow there are tumours of various structure in this category, myomas, angiomas, neuromas. Recently Hoggan has described one which he believes to be an adenoma of the sweat-glands, but which Virchow rather takes to be an angioma. In the



Fig. 75.—Section of a painful subcutaneous tumour (Wood's tumour). The appearance is somewhat like that of a myoma. × 80.

case from which our figures are taken (Figs. 75 and 76) the tumour consisted of a dense interlacing network of fibres, very suggestive of the appearance of a myoma (Fig. 74). On macerating portions in nitric acid the tissue broke up into large spindle cells, as shown in Fig. 75.

This tumour is probably a myoma of the skin, and several others examined by the author had a similar structure.

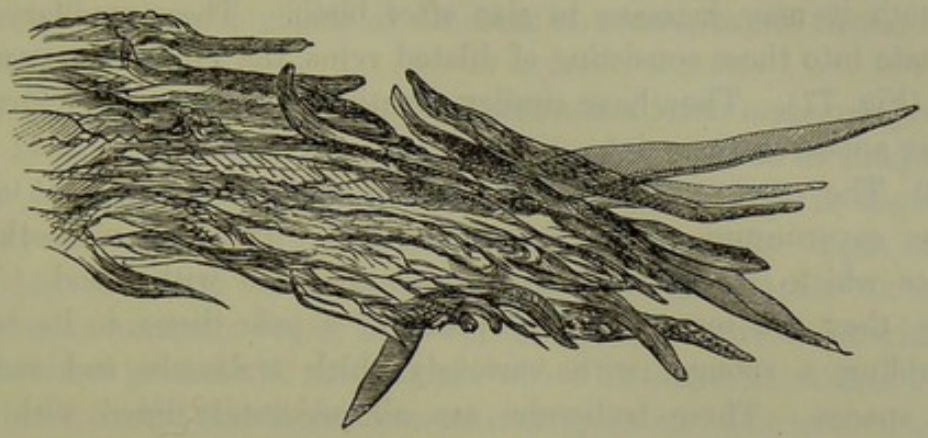


Fig. 76.—From same tumour as Fig. 75, after maceration in nitric acid. Large spindles are isolated, probably smooth muscle cells. × 350.

8.—THE VASCULAR TUMOUR OR ANGIOMA.

We have here a tumour composed of blood or lymphatic vessels. Several forms are distinguished according to the kind of vessels which form the tumour.

The commonest form is (1) the PLEXIFORM or CAPILLARY ANGIOMA. This includes most of the vascular nævi, and consists of capillary and

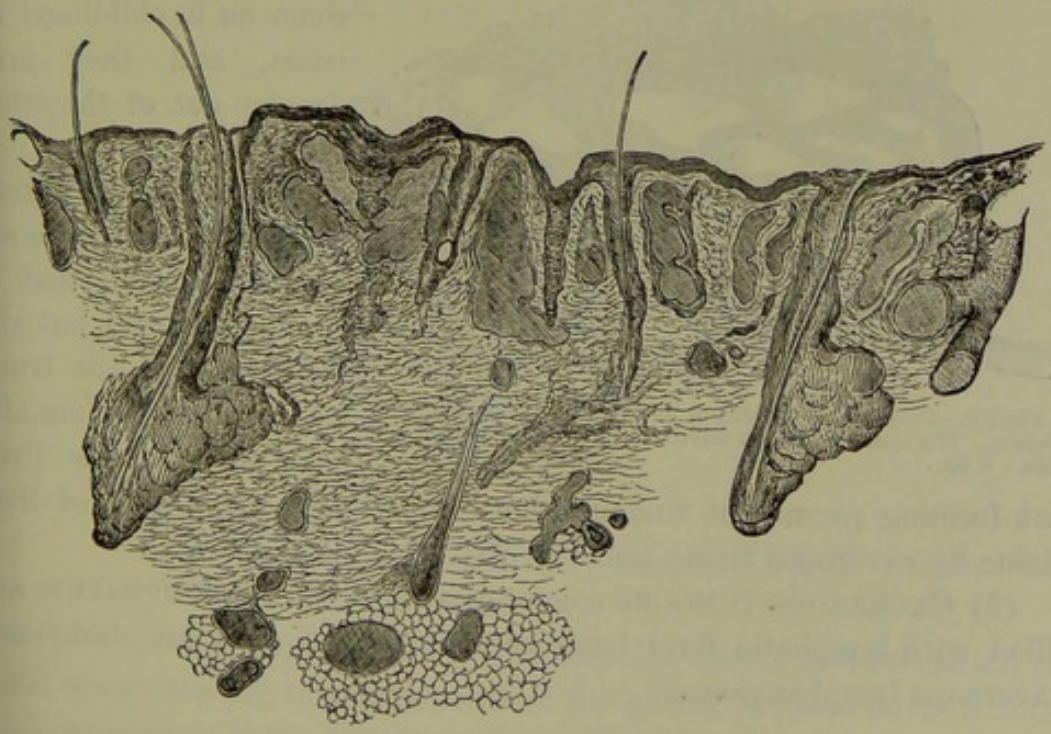


Fig. 77.—Section of skin in a case of diffuse venous nævus. The large sinuses (shaded are) seen to lie superficially between the hair-follicles and glands. (VIRCHOW.)

intermediate vessels forming a rich plexus. It is mostly a growth of

the skin, and may be very small or cover a large area, forming a flat soft surface of dark or bright hue. It is nearly always congenital, although it may increase in size after birth. These capillary naevi graduate into those consisting of dilated veins, the VENOUS or VARICOSE nævi (Fig. 77). They have similar situations to the capillary form and similar appearances.

(2) The CAVERNOUS ANGIOMA consists of tissue like that of the corpus cavernosum of the penis or clitoris, namely a network with meshes which communicate freely and are filled with blood. When empty they are seen to be composed of a pale tissue, in its texture resembling a sponge, with variously thick trabeculæ and variously wide spaces. These trabeculæ are all accurately lined with endothelium, and consist of connective tissue with some muscular fibre-cells in them. These tumours are erectile and sometimes pulsatile. Sometimes the tumour merges into the neighbouring vessels without distinct boundary, but sometimes it has a distinct connective tissue capsule, which, however, appears to be a secondary formation. Sometimes also they are indurated in the centre, and the induration may gradually lead to the obliteration of the spaces and the destruction of the tumour. These tumours are not so usually congenital as the former kind, but they come on in childhood at latest, and they may develop out of the other form.



Fig. 78.—Cavernous angioma of liver. The fibrous septa are shown. The spaces between were occupied with blood during life. × 90.

The skin is a frequent seat of the cavernous angioma, especially that of the face or head, but also sometimes of the trunk or limbs. They are also met with in the liver, not forming prominent tumours, but simply replacing a piece of liver tissue by cavernous tissue (see Fig. 78).

(3) CAVERNOUS TUMOURS communicating with the LYMPHATICS and filled with lymphatic fluid have been described, and are designated cavernous lymphangiomas.

9.—THE GLANDULAR TUMOUR OR ADENOMA.

As there are many glands of different structure, so are there various forms of adenoma.

(1) The MAMMARY GLANDULAR TUMOUR is a form concerning which there is some difference of opinion. Glandular tissue is frequently present in sarcoma of the mamma, and this is expressed in the name adenoid sarcoma. Again, cancers of the mamma take origin in the glandular tissue, and it may sometimes be doubtful whether we have a cancer or an adenoma before us. But besides these, we meet with distinct isolated growths in the mamma whose tissue imitates that of the gland itself, except that there are no excretory ducts. The tumour occurs in, or over, or under the gland, sometimes as if it were a supernumerary breast. It is markedly lobed and varies in consistence according to the predominance of gland tissue or connective tissue. Under the microscope we find lobes, consisting of groups of acini or terminal gland structures lined with glandular epithelium (Fig. 79).

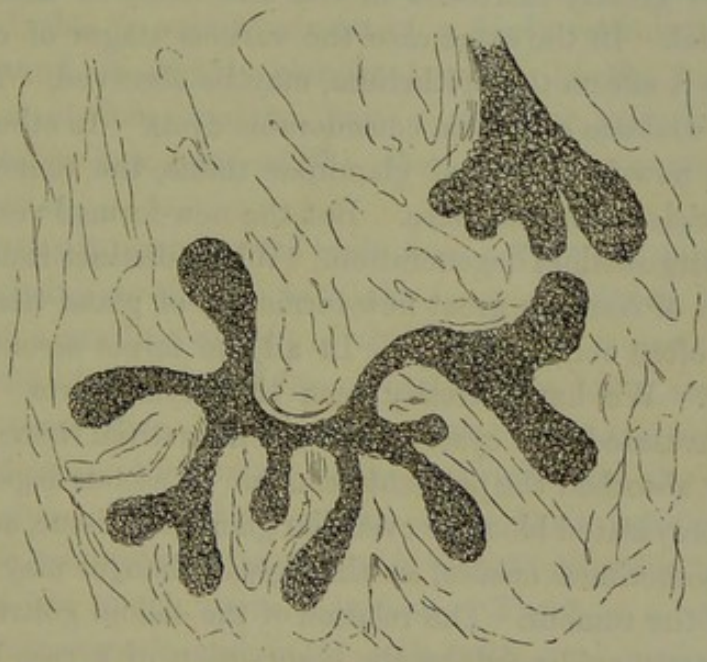


Fig. 79.—Adenoma of mamma. Glandular structures are seen in the midst of fibrous tissue, but without proper ducts. × 90.

(2) In the PROSTATE gland we occasionally have a new-formation of gland tissue, leading to enlargement of the gland, but this forms a very small proportion of the hypertrophies of the prostate.

(3) MUCOUS POLYPI are very frequent forms of tumour, and are mostly composed of hypertrophied mucous glands. They form pendul-

ous tumours, generally on mucous membranes which have been the seat of chronic inflammation. There are some polypi of mucous membranes which do not consist of gland tissue, especially those of the ear and of the female urethra (the urethral caruncles). Elsewhere, as in the nose, rectum, stomach, uterus, they are usually composed of masses of mucous gland tissue covered with epithelium of the kind existing in the mucous membrane where they grow, cylindrical in the stomach and rectum, ciliated in the nose. Very frequently from closure of their ducts, the mucous glands develop cysts. These polypi may generally be regarded as evidences of chronic catarrh of the mucous membrane in which they are found.

(4) The THYROID ADENOMAS form a large proportion of the GOITRES or BRONCHOCELES. The thyroid gland consists of vesicles lined with epithelium, these vesicles being grouped into lobules. A goitre may consist in a simple enlargement of the whole gland, or of a single lobe of it, or it may be due to the formation of isolated tumours consisting of gland tissue. In the case of apparent simple enlargement the vesicles may be found greatly increased in size and many of them filled with colloid material. In the same case the various stages of colloid metamorphosis, as it affects the epithelium, may be observed. These colloid vesicles may coalesce and form considerable cysts. In other cases there is a distinct new-formation of glandular tissue, the tumour consisting largely of vesicles of normal size. But the new-formed vesicles are also prone to undergo colloid degeneration. Where distinct isolated tumours exist, there is of course a great new-formation of gland tissue, and here also there is often colloid change. In all the forms secondary changes are frequent. We have already seen that cysts form. Then blood may be extravasated into cysts or into the interstitial tissue, and though subsequently absorbed the pigment remains. Caseous degeneration may affect the extravasated blood or even the glandular tissue, and calcareous infiltration sometimes ensues, so that great changes may occur in the characters of the tumour. The relation of the colloid goitres to tumours is very distinctly evidenced by the observation of a case by Cohnheim in which secondary tumours developed by metastasis, the tumours occurring in the lungs, lymphatic glands, and elsewhere having the structure of the thyroid with colloid degeneration.

(5) ADENOMAS are of occasional occurrence IN THE LIVER, consisting of liver tissue. There may be a single tumour or many, and the tumours may be distinctly encapsuled or not. They consist of liver-tissue arranged in lobules, but the hepatic cells are larger than normal,

and contain more nuclei. They usually show fatty metamorphosis. Similar multiple adenomas of the liver are of frequent occurrence in dogs. In addition to this form, we shall see in the section devoted to diseases of the liver that a form occurs sometimes designated adenoma, in which the tissue follows the type of tubular glands rather than that of the liver.

Among the adenomas we might include tumours of lymphatic gland tissue, but these will be more conveniently considered afterwards under the lymphomas.

10.—THE GLIOMA.

This is a tumour with the structure of the connective tissue of the central nervous system, the neuroglia. In examining a section of the brain substance, it is difficult to tell what is really nervous structure, and what the supporting connective substance, but when we examine the surfaces of the ventricles we find that the ganglion cells and nerve fibres fall away, and just at the surface or ependyma we have what is presumably a purely connective substance. When hardened sections are examined, this is seen to consist of a finely reticulated network of fibres and round or slightly elongated cells. In the fresh state the fibres are not obvious, and we have a granular material. This connective substance has some of the characters of mucous tissue, and seems allied to it.

The glioma as it occurs in the brain does not usually form an isolated tumour, but, being continuous with the brain substance, has more the appearance of a swelling of part of the brain. It is seen also that the different shades of colour of different parts of the brain are lost when a glioma takes their place. Gliomas sometimes occur as small granular or warty projections on the surface of the ventricles, but the more important ones involve considerable portions of the brain substance.

Under the microscope the glioma is seen to resemble the neuroglia, but the cells are much more abundant There is a well-developed fine or coarse net-work and in it cells with oval nuclei. The cells present considerable variety in size. Gliomas being soft and somewhat cellular tumours, are liable to secondary changes. Hæmorrhage not infrequently occurs, and the blood causing pressure around, the case may end like one of hæmorrhagic apoplexy. The tumour may also undergo fatty or caseous metamorphosis, and if a limited hæmorrhage has occurred the clot may change in a similar way. In this manner a tumour which had originally the appearance of brain substance may change considerably.

Gliomas occur also in the retina, forming soft tumours which fill up the eyeball. The true glioma is an innocent tumour, but sometimes it assumes a sarcomatous character and malignancy is developed.

11.—THE BRAIN SAND TUMOUR OR PSAMMOMA.

The pineal gland contains calcareous particles like grains of sand, and tumours are met with in which similar particles are present. It is necessary, of course, to distinguish these from tumours in which simply a secondary calcareous infiltration has occurred. The psammoma is composed of soft connective tissue in the midst of which there are calcareous masses in the form of irregular globes, rods or spines. (See Fig. 80.) The commonest form is the globe, which has rounded projections on its surface like a berry. The origin and significance of these masses is obscure. The tumours are met with in the pineal gland and choroid plexus—usually small. They also occur in the dura mater, where they form half globular tumours sometimes as large as a cherry and either smooth or irregular on the surface.



Fig. 80.—From a psammoma of the dura mater. Dark calcareous rods and masses are seen in a fibrous tissue. × 90.

B.—COMPOUND-TISSUE TUMOURS.

1.—THE CYSTIC TUMOUR OR CYSTOMA.

A cyst is a cavity having well-defined walls and containing material which is more or less fluid. Some cysts are formed simply by the transformation of existing structures, and it is clear that according to our definition of tumours these do not come under that designation, as they are not pieces of tissue which grow independently without regard

to the needs of the organism. There are other cysts, however, which do owe their origin to the independent new-formation of tissue, and therefore deserve the name of tumours. The two forms are so similar in appearance that it would be inconvenient to separate them rigidly, and without aiming at logical accuracy we shall here consider the cysts as a whole. If necessary the name Cystoma may be reserved for strictly cystic tumours.

MODE OF FORMATION OF CYSTS. As already indicated cysts vary greatly in regard to their mode of origin. Some of them arise out of a pre-existing cavity, very often by accumulation in it, in the first place, of its normal contents. Thus a gland will become a cyst by its duct becoming obstructed. Cysts arising thus are often designated RETENTION CYSTS. But other cysts arise simply by softening of existing tissue, the softened material being absorbed and fluid taking its place. This, as we have seen, often occurs in the brain, resulting in the APOPLECTIC CYST. Again, we may have cysts arising by a distinct new-formation; a preliminary tissue is formed, generally something like that of a gland, and this is afterwards transformed into a cyst somewhat in the fashion of the retention cyst. Instead of following out these modes of formation it will be more convenient to give some examples of cysts, and their mode of origin will come up for discussion as each is considered.

CYSTS OF THE SKIN appear to arise in many cases from sebaceous glands. The duct becomes obstructed by inspissated secretion or adhesion of its walls, and the sebaceous material accumulates behind. Such a cyst may attain some size, and contains mainly fat, cholestearine, and epidermic scales. From the nature of their contents such cysts are often designated ATHEROMATOUS. Their wall consists of connective tissue with a lining of epidermis, which may present papillary projections. They occur mostly on the head and face, and are often called wens. Besides these we sometimes meet with more complex cysts in the skin, and these are congenital in their origin, probably arising by inclusion of a piece of embryonic skin. Their walls are like the skin, containing hairs with hair-follicles and sebaceous glands, and sometimes even sweat glands. These are called DERMOID CYSTS, and they contain a less grumous material than the former ones, their contents consisting of cholestearine and epidermis often with loose hairs.

MUCOUS CYSTS, or cysts with mucous contents, arise in situations where mucous glands are present, their chief sites being the nostrils and communicating cavities, the upper surface of the epiglottis, the larynx, the œsophagus, and in connection with the glands of Cowper and

Bartolini. Of these a very typical form is the Ranula, whose origin and mode of formation has been carefully studied by Recklinghausen.

It has long been taught that these cysts arise by obstruction of ducts and accumulation of the contents behind them, but this scarcely explains the continuous enlargement of the cysts after they have been formed. It might be supposed that the epithelium lining the cysts would secrete mucus and so add to the contents, but there is the objection to this that the epithelium loses its glandular character, and there are no goblet cells to be found in it. The real state of matters appears to be that the cyst forms, not out of the gland, but from its duct, and, the gland persisting, its secretion is thrown into the cyst. This is shown in Fig. 81, copied from Recklinghausen's paper. It would thus appear that the persistence of the gland is an essential element in the formation of the cyst. In the enlargement of the cyst the power which mucin has of swelling up and absorbing water is of some consequence. A small amount of mucin formed by the gland and discharged into the cyst will swell up and add considerably to its contents. Before a regular cyst forms, the orifice of the duct is obstructed, usually by an inflammation around it. But on account of the peculiarity of mucin just noticed, a small temporary cyst may form without any considerable obstruction of the duct. If a quantity of mucin is discharged into the duct it may swell so much as to be unable at once to escape from the orifice and so form a small cyst, which afterwards discharges. In this way cysts often form in the mucous membrane of the mouth.

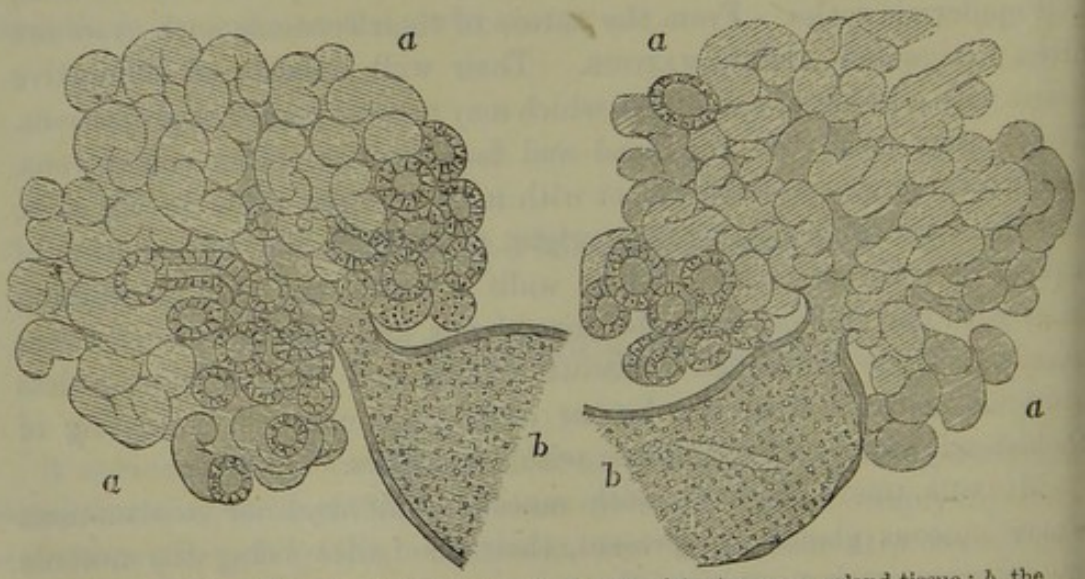


Fig. 81.—Formation of mucous cysts; *a*, the persistent mucous gland tissue; *b*, the dilated duct. × 300. (Recklinghausen.)

It has already been noted that cysts arise in mucous polypi, and

they have a similar mode of formation to that just described. The obstruction of the orifices is here the more likely, as the polypus itself usually originates in connection with a chronic inflammation of the mucous membrane.

Cysts of the THYROID GLAND have been already referred to as

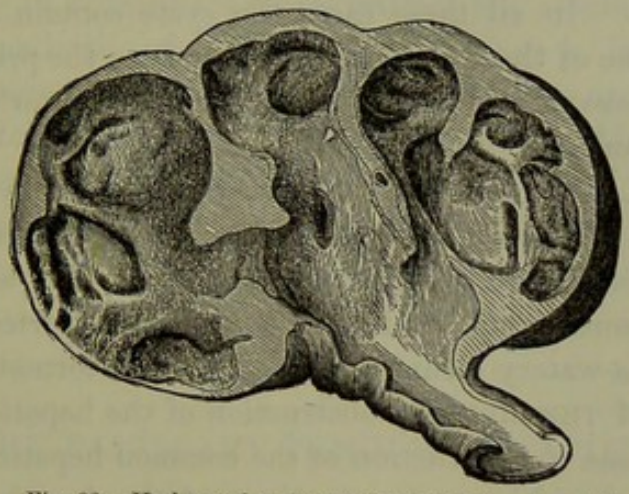


Fig. 82.—Hydronephrosis with granular atrophy of the kidney. The other kidney showed a marked compensatory hypertrophy. (VIRCHOW.)

taking origin in the vesicles of the gland, but they may also have origin in softening of the tissue of the gland. Sometimes one or more cysts attain very large dimensions in the thyroid.

In THE KIDNEY we have frequent cysts, most of which arise by obstruction, and are to be classed as retention cysts. By obstruction of the ureter the condition of hydronephrosis is brought about, in which the whole kidney goes to form a cyst (Fig. 82). Obstruction of the uriniferous tubules by tube-casts, or more commonly by the contraction of new-formed connective tissue, produces cysts in the kidney substance which may be of microscopic size, or large enough to be seen by the naked eye. These cysts are multiple. We sometimes meet with a single cyst of large size, with a definite lining membrane, and obviously of old date. Such cysts

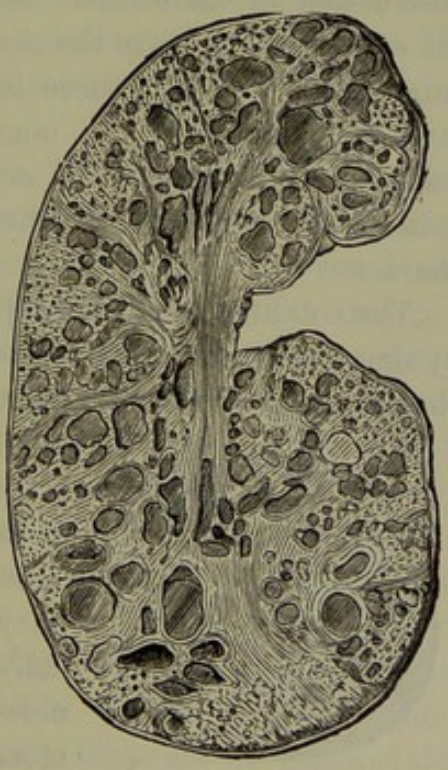


Fig. 83.—Congenital cystic kidney from a new-born child. Each kidney measured 5½ ins. long, 4 ins. broad, and 3½ ins. thick. The entire kidney tissue was replaced by cysts. (VIRCHOW.)

are probably congenital, and owe their origin to fœtal closure of one or more tubuli uriniferi. Again, the whole kidney may be converted into a congeries of cysts large and small, filled with serous or bloody fluid, the outline of the organ being greatly enlarged (Fig. 83). These also are congenital in their origin, and probably arise by fœtal closure of the tubuli uriniferi. In all these cases the cysts contain a serous fluid, although, in some of them at least, urine has been the primary contents; after a time, however, the urinary constituents are absorbed, and serous fluid alone remains.

The GALL BLADDER may be converted into a cyst by obstruction of its duct. It is the secretion of the mucous glands—a mucous material —which accumulates and produces the distention, ; but after a time this gives way to a serous fluid, and the bladder is converted into a large thin sac full of a watery serum. There may be a formation of cysts in the substance of THE LIVER by obstruction of the hepatic ducts in their finer ramifications. Obstruction of the common hepatic duct produces a distention of the ultimate terminations of the duct, but not a proper cystic formation.

The VERMIFORM APPENDAGE is sometimes converted into a cyst by obstruction of its orifice. At first mucus accumulates, and even when the cyst is of large size the contents may remain of a gelatinous consistence. But here also there is a tendency to simplification of the wall, involving atrophy of the mucous glands, so that there results a thin-walled cyst, consisting of connective tissue with merely a lining of epithelium, and the contents generally cease to have the mucous character.

The OVARIES are very frequently the seat of cysts. They may arise by simple accumulation of serous fluid in the Graafian vesicles, a dropsy of these (Fig. 84), but in the great majority of cases a definite new-formation precedes the cystic development. This consists in the production of tubular or gland-like structures out of which cysts develop apparently by closure of their orifices. In this way multitudes of cysts are formed, and as this tissue is continually being produced there is a progressive new-formation of cysts. Very often one or more cysts become predominant, and they enlarge by coalescence of others, but there is always evidence in the walls of the cysts that new-formation is progressing. These cysts contain originally a mucous



Fig. 84.—Dropsy of Graafian vesicles in ovary of a girl ten years of age. (VIRCHOW.)

or colloid material, which may be variously modified by fatty changes, hæmorrhage, and inflammation. Similar cysts are occasionally, though very rarely, met with in the testicle.

The ovaries are also the seat of cysts which will be referred to afterwards as teratomas.

Cysts occur IN TUMOURS, and are particularly common in mammary tumours, especially the adenoid sarcomas. There is, in fact, a form of sarcoma designated cysto-sarcoma. The cysts here appear to originate from the glandular structures. The glandular acini dilate, much in the manner of retention cysts. When the cyst has formed, the sarcomatous tissue, apparently growing in the direction of least resistance, very often grows into the cyst, and may even fill it up with an intracystic growth.

2.—THE PAPILLARY TUMOUR OR PAPILLOMA.

By this name is meant a tumour composed of a congeries of exaggerated papillæ like those of the skin, or like the villi of mucous membranes. A papilla or villus consists of a basis of connective tissue in which there is a loop of capillary blood-vessel, and a covering of epithelium. The epithelium is like that of the surface concerned, and may be stratified or in a single layer.

Their commonest situation is the skin, where they form the WART, which is an overgrowth of a group of existing papillæ covered with hard epidermis. At the surface of the wart the papillæ may be covered over with a continuous layer of epidermis, or the individual papillæ may project independently. The HORN is also formed on the basis of a group of papillæ, but the hard horny epidermis is greatly developed, and forms a consistent outgrowth of considerable dimensions. The CONDYLOMA is a syphilitic outgrowth due to exaggeration of the papillæ, with very soft epidermis. These occur near the genital organs mostly.

On MUCOUS MEMBRANES papillomas may be gathered into a local tumour, or cover a considerable surface, giving it a shaggy villous appearance. In the LARYNX (Fig. 85) they often form localized prominent tumours, especially on the vocal cords. They are not uncommon in the rectum. In the URINARY BLADDER they are of considerable importance on account of their tendency to hæmorrhage. In this situation they may form distinct tumours with long branched papillæ, or there may be a large surface which is simply villous in appearance.

The papillæ are covered with delicate epithelium, and are liable to severe and frequent hæmorrhage.

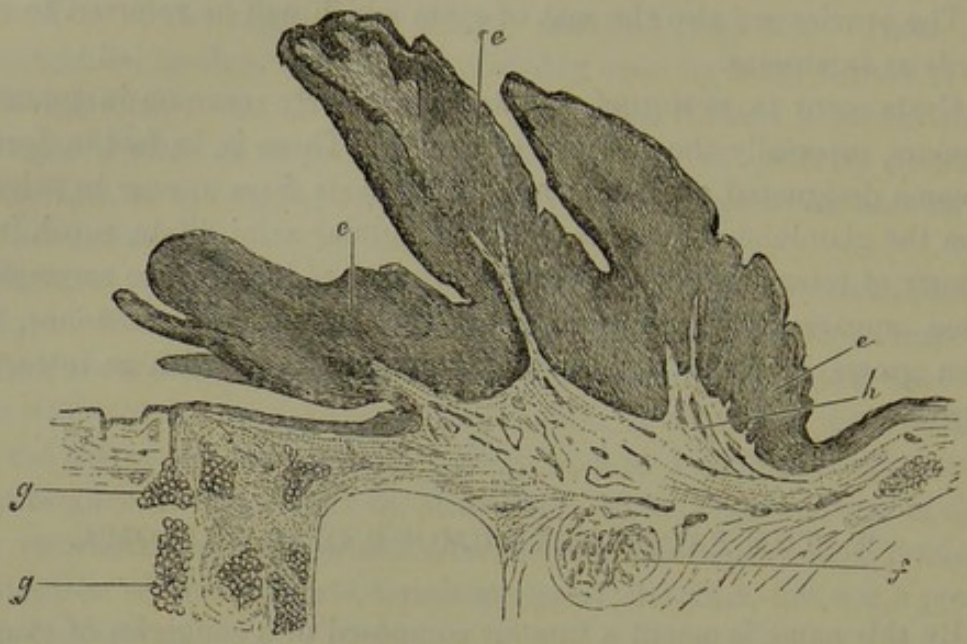


Fig. 85.—Papilloma of larynx: *e*, epithelium; *h*, connective tissue; *g*, mucous glands; *f*, an atrophied gland. × 20. (Cornil and Ranvier.)

The PACCHIONIAN BODIES of the encephalon are really papillary formations, and Dr. Cleland has described large tumours of this region which seemed to arise by extreme hyperplasia of these papillæ.

3.—TERATOMA.

This name has been applied by Virchow to tumours in which a number of very different tissues enter into the structure. The name is derived from τερας, a monster. The tumour contains various structures of the body as if from an ill-arranged fœtus. Thus we may have in such tumours skin, bone, muscle, glands, nervous tissue.

These tumours probably arise by the abnormal inclusion of a whole embryo or a portion of one. They are most frequently met with in positions where double monsters are usually attached to each other, namely in the sacral region, or further up the back, and the head and neck. They are also somewhat frequent in the ovary where they may arise by a kind of equivocal generation, the germinal vesicle endeavouring to develop some of the perfect tissues of the body.

The SACRAL TERATOMAS and those of the head and neck are the more typical ones. They frequently contain pieces of bone which simulate the bones of the fœtus, also brain substance and muscle. Considering that these tumours develop so frequently in the ordinary places of union of double monsters, they may safely be regarded as representing twin pregnancies in which one of the fœtuses has grown over and included the other.

The teratomas of INTERNAL ORGANS do not usually represent such complete systems or so many different tissues as the sacral. They are most frequent in the ovaries, but also occur in the peritoneum, testes, lungs, and so on.

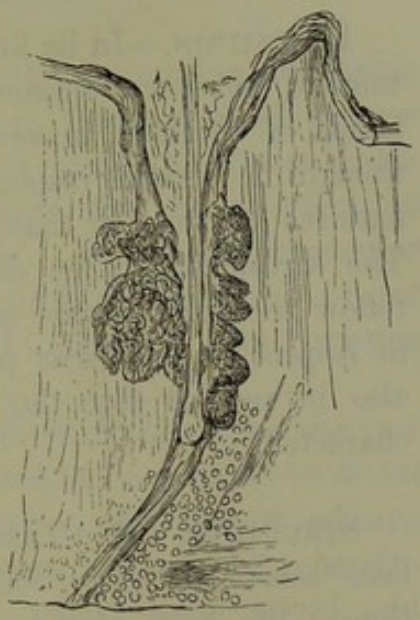


Fig. 86.—A hair follicle with hair and sebaceous gland from the wall of a dermoid ovarian cyst. × 50.

In these situations they occur in the form of cysts, approaching in structure to the DERMOID CYSTS of the skin and often grouped along with them as dermoid cysts, but having usually a more complex structure. These cysts, and especially those of the ovary, usually present at some part of their wall a structure similar to that of the skin. There is corium with epidermis, and well developed hair follicles with hairs in them (Fig. 86). The sebaceous glands are often specially developed so that a portion of the wall may present little more than open-mouthed glands. Then there is frequently bone in the wall, and in the bone there may be teeth. More rarely are muscle and nervous tissue represented.

The contents of these cysts vary according to the structure of the wall. There is usually a great accumulation of fat secreted by the sebaceous glands, so that we may have masses like lumps of butter. These are often mixed with silky hairs, which are regularly shed from the hair follicles just like the normal hairs of the skin. Then there are sometimes teeth mixed with the other contents, these being shed also at intervals. As many as 300 teeth have thus been found free in such a cyst.

C.—CELLULAR TUMOURS.

1.—SARCOMA.

DEFINITION.—In its literal meaning this term simply means a fleshy tumour, and it was formerly applied in a very indefinite way. In the hands of Virchow, however, it includes a group of tumours, which, though in certain respects differing in structure, yet present such features in common that they form a consistent class by themselves. The sarcomas may be defined as tumours which in their structure follow the type of one or other of the connective tissues, but differ in respect of the great preponderance of the cellular elements, and also in respect that the cells are more or less embryonic in their character.

STRUCTURE AND CLASSIFICATION.—The structure of sarcomas has been somewhat aptly compared to that of inflammatory new-formations. We have already seen that the tendency of these, as exemplified in the granulating wound, is to develop into connective tissue. The round cells pass into spindle-cells and then the connective tissue develops out of the latter. The round and spindle cells may thus be regarded as the preparatory, or in a certain sense embryonic stage of connective tissue. In sarcomas we have tumours composed of round cells and tumours composed of spindle cells without any tendency to further development, as if the embryonic form had been stereotyped for the whole life of the tumour. Besides these forms sarcomas sometimes contain giant-cells (myeloplaques). We know that cells of this nature occur normally in growing bones where, as Wegener and Kölliker have shown, they exercise an important function (osteoclasts) and they are not unknown in granulation-tissue, even apart from bone. They also are to be regarded as connective-tissue structures, and as belonging to a developmental stage of connective tissue.

In their MODE OF GROWTH also it may be said that the sarcomas resemble inflammatory new-formations. They very often form tumours

of considerable size, and may even be encapsuled, as if the tissue simply increased like that of a simple tumour. But they present a peculiar tendency, which has been already mentioned, to incorporate neighbouring structures. We have seen that in the disposal of dead animal tissue, such as a thrombus, or a catgut ligature, the inflammatory tissue advances, and, as it were, moulds itself in the first place on the dead structure, copying its general form. So an advancing sarcoma will incorporate the living tissues and mould itself on them, repeating their rougher anatomical details in tissue of its own kind.

In such cases it sometimes seems as if the sarcoma in advancing were inducing the neighbouring tissues of themselves to become sarcomatous in structure, and in the case of connective tissue which is present everywhere, we can easily suppose that by proliferation of its cells it might become sarcomatous. It is not impossible that this actually occurs, but it is more probable that the proper tissue of the tumour disposes of and displaces the existing tissues.

It has been said already that sarcomas follow in their type the various connective tissues of the body, and it might be possible to divide them according as one or other form is the type. So Virchow indicates the division into fibrosarcoma, myxosarcoma, gliosarcoma, chondrosarcoma, osteosarcoma, melanosarcoma, to which some would add, myosarcoma and neurosarcoma, if muscle and nerve are regarded as connective tissues, and lymphosarcoma if lymphatic gland tissue be taken as belonging to this group. It will be convenient to follow a different arrangement, however, and we shall describe sarcomas according to their structure apart from any inferences as to the type which they follow. It is to be added that the structure of the individual tumour is, as a rule, remarkably homogeneous. We often find cells heaped on cells without any intersecting bands of connective tissue. In other tumours THE BLOOD-VESSELS are supported and the tumour intersected by a kind of stroma, equivalent to the interstitial connective tissue of muscles, glands, etc., but here there is rarely any fully developed connective tissue, and the blood-vessels are in immediate contact with the cells.

VARIETIES.—(1) THE ROUND-CELL SARCOMA (Fig. 87) is also called the granulation sarcoma and the encephaloid sarcoma. It is composed of round or slightly oval cells generally about the size of white blood cor-

puscles but sometimes much larger. It is an exceedingly soft tumour, often half diffluent, and has usually a grey medullary appearance. Its blood-vessels are in the form mainly of large capillaries whose walls are embryonic in structure and often present varicose or aneurismal dilatations. The vessels are liable to rupture, and so these tumours often present interstitial hæmorrhage. Between the cells there may be some intercellular substance. This is sometimes homogeneous and becomes opaque with acetic acid (myxosarcoma), or it may be somewhat fibrous or reticulated.

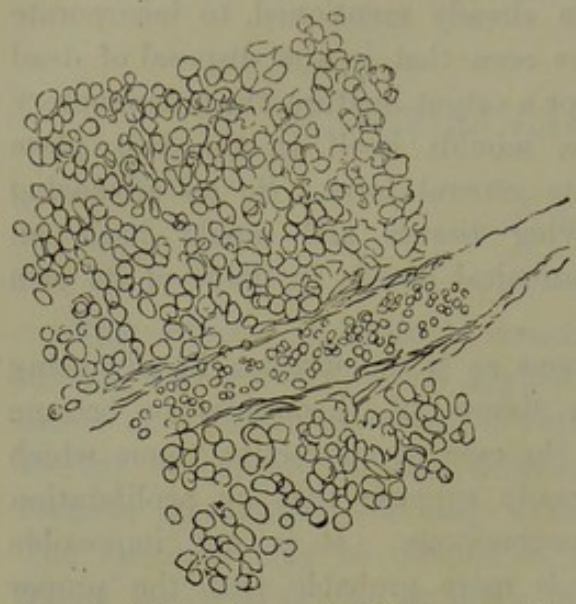


Fig. 87.—Section of a round-celled sarcoma of the brain. A thin-walled vein, with blood corpuscles in it, divides the section. × 175.

This form of sarcoma is met with in the skin where it may originate in a congenital soft wart or mole, in the subcutaneous tissue, in the bones—forming the majority of the so-called medullary cancers—in the muscles, in the glands especially the mamma and testicle, in the brain and elsewhere. Being a soft tumour with delicate vessels it more readily produces secondary tumours by metastasis than other sarcomas. It is also usually a tumour of rapid growth and commonly imperfectly delimited from the surrounding tissue.

(2) The spindle-cell sarcoma (Fig. 88) is also called the fibro-sarcoma and corresponds with Paget's class of recurrent fibroids, and

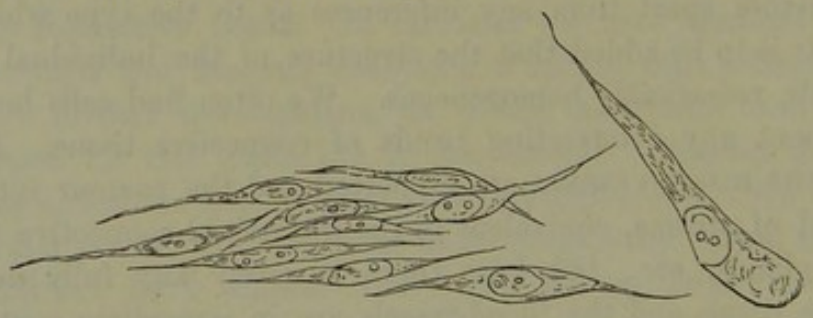


Fig. 88.—Large cells from a spindle-celled sarcoma. × 300.

Lebert's group of fibro-plastic tumours. The cells are spindle-shaped like those in the deeper layers of a granulating wound, and there is little or no intercellular substance, the tumour being composed of masses of spindle cells. They are arranged in bundles which to

a certain extent interlace like the bundles of fibre-cells in the myoma. There are great varieties in the size of the cells, some tumours being composed of very small cells, and these are usually soft, while at the opposite extreme are cases where the spindles are gigantic. When viewed in mass the individual spindles may not be apparent, but they are usually easily isolated, unlike the fibre-cells of the myoma. These tumours are usually firmer than the round-cell sarcomas except the small-celled forms, and may even approach the fibroma in hardness.

The spindle-cell sarcoma occurs frequently in the periosteum, and in that case is firmly attached to the bone. It is also met with in or under the skin (see Fig. 89), in muscles, in the testicle, etc. It is a frequent tumour in the mamma, and here it not infrequently forms the adenoid sarcoma and the cystic sarcoma, the latter of which deserves more particular notice.

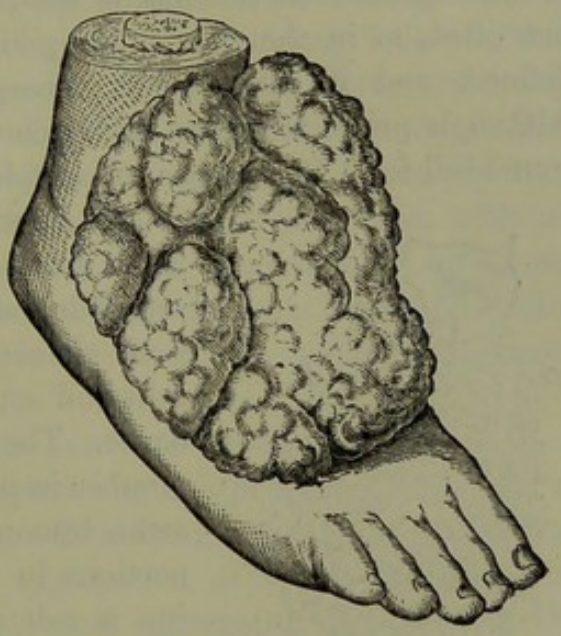


Fig. 89.—Large fungating spindle-celled sarcoma of the foot. (VIRCHOW.)

In the CYSTIC SARCOMA there is, along with the proper sarcomatous tissue, a certain amount of glandular tissue (see Fig 90). In some cases

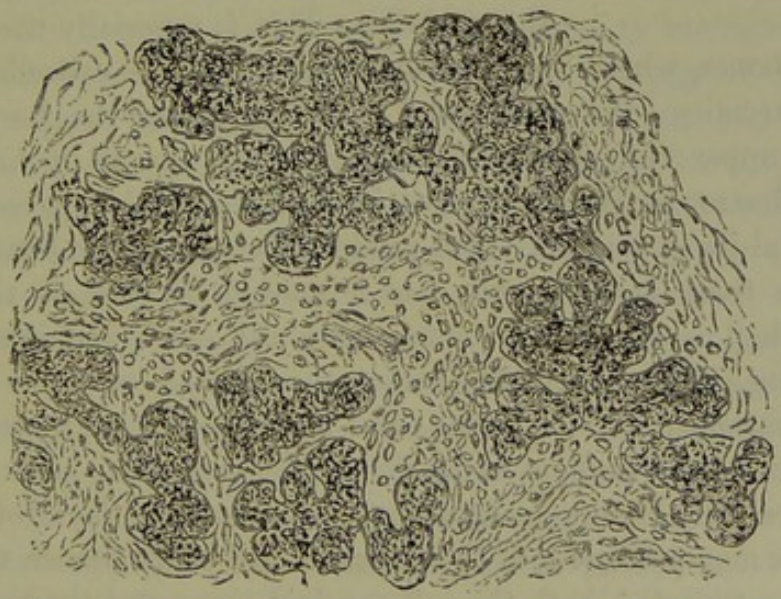


Fig. 90.—Section of an adenoid sarcoma of the mamma. Glandular masses are seen with a very cellular interstitial tissue. × 90.

the gland acini dilate and the sarcomatous tissue projects into the cysts thus formed. In this way the cyst which has now solid contents is sometimes enlarged by the intracystic growth. The ingrowing tissue is covered with epithelium which is usually more or less columnar. When these sarcomas recur the glandular tissue does not reappear, but there is often an appearance of the sarcomatous tissue which suggests an arrangement like that around glandular structures.

The spindle-cell sarcoma is sometimes a distinctly defined tumour, but often, as in the case of the periosteal form, its boundaries are not defined, and it advances by incorporating neighbouring structures. Although prone to return after removal, it has less tendency than the round-cell form to give rise to secondary tumours by metastasis.



Fig. 91. — Giant-cell sarcoma. × 175.

(3) MYELOID OR GIANT-CELL SARCOMA (Fig. 91) is a tumour in which the giant-cell is characteristic, but never forms the only sarcomatous element, there being generally spindle-cells and sometimes round-cells in great abundance. The giant-cells are in greater or smaller number in proportion to the others, and in the same tumour they may present various proportions in different parts. The tumour tissue is soft and very often of a brown colour. Cysts not infrequently develop.

The myeloid sarcoma occurs in connection with bone, and most frequently grows from the medulla. This is especially the case with the long bones, where the tumours originate in the cancellated tissue at the extremity—the most usual situation being the lower end of femur or upper end of tibia. As the tumour grows it has a great power of destroying the bone before it, so that by and by it eats through the external layer, and may thus produce fracture of the bone. At the same time there is commonly new-formation of bone so that a new external shell is formed continuous with the shaft, and internal septa representing a coarse cancellated structure. The tumour tissue is thus frequently contained in bony loculi, and after maceration the shell of the tumour looks like a bulbous expansion of the end of the bone with bony septa internally. Having broken through the external layer of the bone, the tumour may proceed into the muscular and other tissues, the tumour tissue being repeated, both the soft myeloid tissue and the bony septa.

Myeloid sarcoma is also met with outside bones, growing from the

periosteum, especially of the jaws. Many tumours, to which the name EPULIS is given, are myeloid sarcomas.

(4) The OSTEOID SARCOMA is a tumour which deserves special notice. It is the form which Paget has very skilfully described under the name of osteoid cancer. The disease occurs most frequently at the lower end of the femur, where it usually develops both within and without the shaft, but sometimes outside alone. The main mass is composed of bone which is usually very dense, but on the surface a tissue is found out of which the bone is being developed. This consists of dense fibres which are very abundantly nucleated. These dense fibres are really cells, and they present varieties of shape often tending to the stellate form. The new bone is developed out of them, and is usually very irregular in structure, the bone corpuscles often large and with no proper arrangement as in normal bone. The tumour, as it advances, often presents nodules slightly removed from the main mass, and it also forms secondary tumours in the lungs or in the lymphatic glands. These repeat the ossifying tissue.

(5) MELANOID OR PIGMENTED SARCOMA always originates in a situation where pigment already exists, the eye or skin. The cells of which it is composed are usually spindle-shaped, but may be round, and from the first they tend to the aggregation of brown or black pigment in their substance. The pigment aggregates first around the nucleus, but is very irregular in its distribution. In a melanotic tumour there may be bits unpigmented, and even in the pigmented parts some cells are free from pigment.

The melanotic sarcomas have a great tendency to metastasis, and as the material is conveyed by the blood there are pigmented tumours formed in a great variety of organs and tissues where they may grow to great dimensions, though the original tumour may be very small.

It is necessary to distinguish from these proper melanotic sarcomas those which become pigmented from blood. In the former the pigment is brown or black from the first, being obviously elaborated by the cells. In the latter the pigment is red or yellow, and the pigmentation may be related to a special weakness of the vessels allowing of hæmorrhage.

(6) ALVEOLAR SARCOMA.—In this form we have round cells, as if packed in spaces or alveoli, and so the tissue resembles that of cancer. But when the structure is carefully examined, two distinct differences can be distinguished. The connective-tissue stroma is very directly related to the cells, and the masses of round-cells seem to be developing out of the connective-tissue stroma. Between the cells there

is sometimes a delicate reticulum, but this may be absent, and the tissue may be very like that of cancer.

These tumours occur in connection with bone, skin, and muscle.

(7) PLEXIFORM SARCOMA OR CYLINDROMA is a name applied to a form of tumour whose relations are somewhat obscure, and it probably includes more than one kind. The peculiarity of the tumour is the existence of cylinders and rounded structures having a hyaline character, and like mucous tissue. In the centre of the cylinder there is often a blood-vessel, so that the hyaline material clothes it like a mantle. Then, between the cylinders of hyaline material there are frequently masses of cells which may form long processes so as to give a close resemblance to cancer, to whose cells these may also conform in general appearance.

The origin of these cylinders is not perfectly clear. In some cases it may be that we have a combination of sarcoma and myxoma, but this does not account for the peculiar form of the cylinders. A more probable explanation is that the cylinders arise by hyaline or mucous degeneration of the adventitia of the blood-vessels, and this is confirmed by the fact that they are often arranged around the vessels. If this be the proper view, then, in the tumour, the formation of blood-vessels is an important element. In this way we should have a sarcoma in which a peculiar transformation occurs in the external coats of the vessels. It is in this view that the name *plexiform angiosarcoma* is applied to this form of tumour.

The tumour as a whole is often of a gelatinous appearance, or it may be that the gelatinous material is seen to be in separate spaces throughout the tumour. It occurs in the orbit and its neighbourhood, or the upper and lower jaws ; it may form part of the constituents of tumours of the parotid, and it is also found in the brain and its membranes and the peritoneum, where it may grow to a large size.

2.—CANCER OR CARCINOMA.

We enter here on a class of tumours whose boundaries, when regarded from a clinical point of view, are rather undefined. In its more general use, the term cancer is applied to any form of malignant tumour, altogether irrespective of its finer structure, and in this sense would include most sarcomas. But in the study of Pathology such a general use of the word is not allowable ; the structure must be taken into account, and it will be found that clinical facts are in essential accord with histological and anatomical relations.

DEFINITION.—As the sarcomas are tumours whose structure follows the type of the connective tissues, cancers may be defined as tumours whose structure follows the type of the epithelial tissues, but with an excessive production of cells.

STRUCTURE.—It is well known that epithelial structures are non-vascular, and in order to the nourishment of any considerable mass of epithelium, it is necessary to have blood-vessels supported by connective tissue. This forms the stroma of cancers, and so it is always possible to distinguish in cancers a vascular connective tissue basis, enclosing and supporting masses of epithelial cells. This stroma may be in whole or part the remains of the pre-existing connective tissue of the part, generally giving evidence of the existence of irritation in the presence of large numbers of round-cells, but very often it is as much a new-formation as the epithelium, and may occur in the form of a delicate network with well-formed meshes (see Fig. 92).

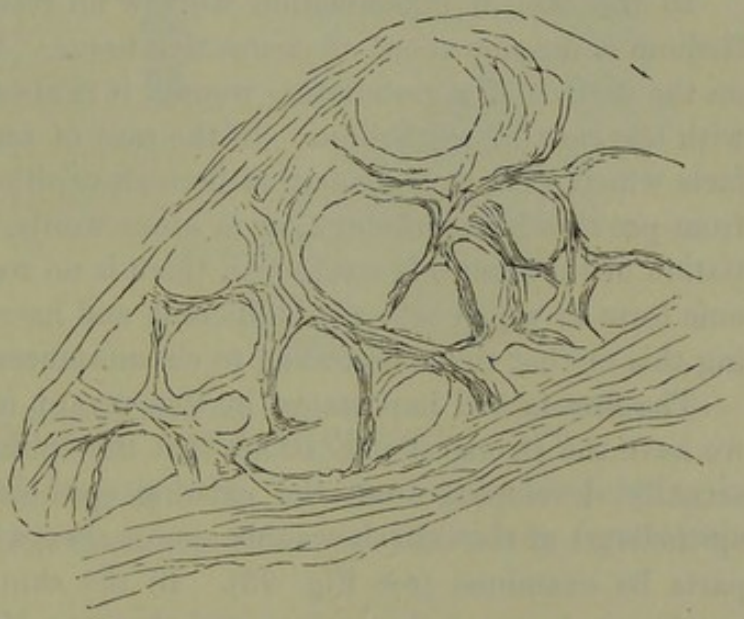


Fig. 92.—Stroma of a soft cancer of the mamma after the cells had been washed out. × 82.

Where a cancer produces a well-formed stroma along with the epithelial masses, it will probably grow more readily into a distinct tumour than where the epithelial masses depend for their nourishment on the existing blood-vessels. In this latter case the cancer will commonly present more the characters of an infiltration of the tissues with epithelial structures, and this infiltration may be associated with such irritation as to lead to considerable new-formation of connective tissue, giving sometimes a considerably fibrous character to the structure, as in scirrhous cancer.

An important question arises here as to the ORIGIN OF THE EPITHELIUM, which is the essential constituent of a carcimona. One view is that the epithelium in some cases takes origin in the existing epithelium, and in others develops out of the connective tissue, while an other

view is that it develops in all cases from the existing epithelium. We have seen in the study of inflammation that, as a precursor of the formation of organized tissue, there is always a rudimentary tissue, of which the granulating wound is a type. Now in the development of tumours in general, the formation of such rudimentary tissue precedes the formation of the ripe tissue, or, in other words, cells of all sorts, when young, have the form of round cells, which, from the fact that they are not distinguishable from one another, may be called INDIFFERENT or EMBRYONIC CELLS. In the case of cancers it is supposed by some that indifferent cells may be formed from connective tissue, just as those of the granulating wound are presumed to be, and that these may afterwards develop into the epithelium of the cancerous tumour.

In the case of inflammation we saw no reason to believe that epithelium is developed out of connective tissue. When epithelium forms on the surface of a granulating wound, it is always in direct continuity with the existing epithelium. In the case of cancers there are certain facts which seem to indicate that here also epithelium can only develop from pre-existing epithelium, or in other words, that when the differentiation of the tissues is completed, there is no recurrence to the embryonic form in which cells are indifferent and have the power of developing this or that tissue according to circumstances.

The first fact of importance in this regard is, that in some cancers we have the strongest indications that the epithelium of the cancer is actually developing from the existing epithelium. A section of an epithelioma of the skin shows this almost always if the growing marginal parts be examined (see Fig. 93). In the skin the epidermis forms a continuous layer on the surface, and the rete Malpighii, or deep layer, besides covering the papillæ also lies between them, forming what may be called interpapillary projections. At the margin of an epithelioma of the lip, we see an elongation of these interpapillary processes, and on passing more and more towards the tumour these processes pass deeper and deeper into the subjacent skin, forming penetrating cylinders.

Again, in some cases of cancer of the kidney it can be seen that the tumour is arising as if by transformation of the kidney tissue. The primary cancer of the kidney is not a tumour added on to the kidney, but it is generally a portion of, or sometimes the whole kidney, which has undergone an enormous enlargement while keeping its general shape; it is in fact the kidney or portion of kidney transformed. And when we examine the marginal parts of such a tumour we find the epithelium of the uriniferous tubules in an active state of germination, the

tubules getting distended with new-formed epithelium. The epithelium also is altering its shape in various ways, getting sometimes

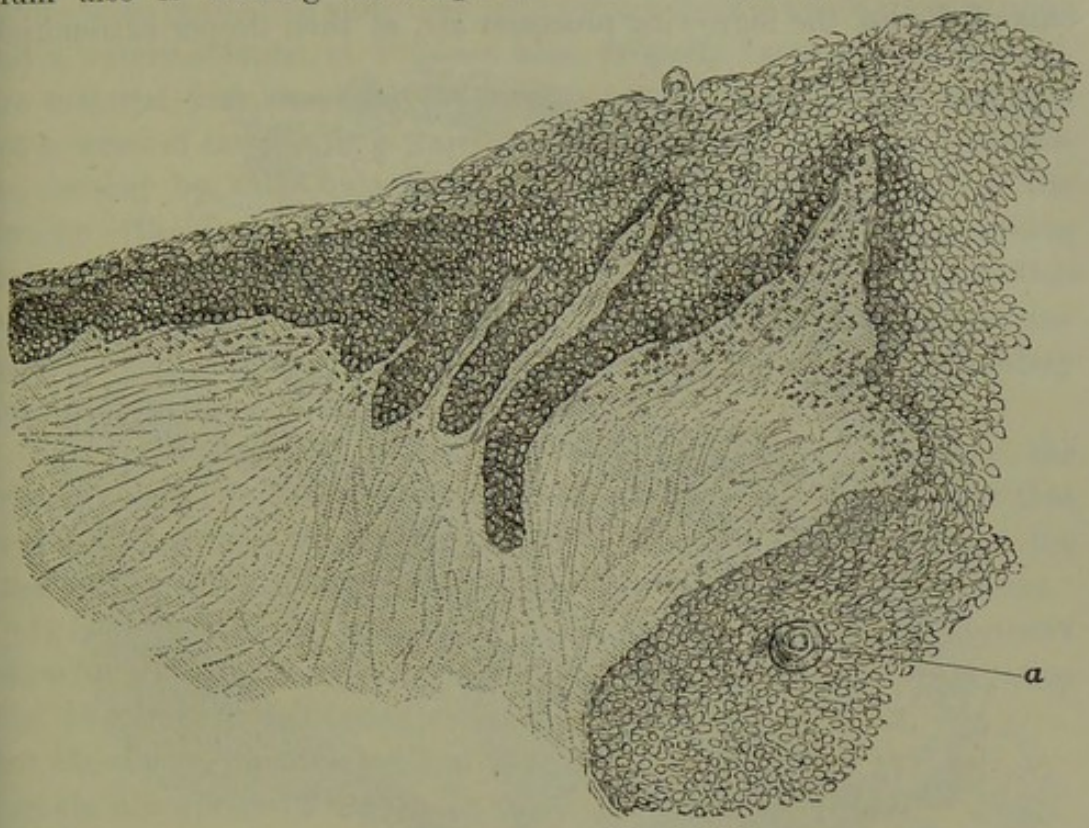


Fig. 93.—From the growing margin of an epithelioma of the skin. The interpapillary processes of epidermis penetrating inwards. *a*, a small laminated capsule. × 100.

elongated and tailed (see Fig. 94). In fact the tumour is forming by proliferation of the epithelium, the stroma of the kidney forming the stroma of the tumour.



Fig. 94.—From a cancer of the kidney. A tubule is represented in which the epithelium is undergoing alterations in shape. × 300.

Another fact of consequence in this matter is, that primary cancers in the vast majority of cases occur in situations where epithelium exists. There are some apparent exceptions to this, as where a cancer has been found growing into bone, but these are of the rarest occurrence, and even they can be explained by supposing that there has been a connection with the surface which was undiscovered. It is not impossible also that some of these rare cases may be referrible to a fœtal inclusion of a bit of embryonic epithelium.

It is here to be remarked that in a growing cancer there is often great irritation of the connective tissue, so that, say in a case of epithelioma of the lip, the ingrowing processes are, at their deeper extremities,



Fig. 95.—From an epithelioma of the skin. Cylinders of epithelium penetrating deeply and causing great irritation, as shown by the presence of abundant round cells. × 200.

buried in a mass of inflammatory round-cells (Fig. 95). This may obscure the exact new-formation of the epithelium, but the fact that the new epithelium is always in connection with the old is of sufficient significance.

THE GROWTH of cancers happens in various ways. We have already seen that in some cases there is a transformation of existing tissues and in others a penetration of the epithelium into surrounding structures. These modes are very common in primary cancers, and so we speak of CANCEROUS INFILTRATION very frequently. In some cases there is a distinct tumour, but even then at the marginal parts there is an infiltration of surrounding tissues, and the tumour is ill-defined. It is noteworthy that secondary tumours are frequently, or indeed commonly much larger and more independent in their growth than the primary ones.

Cancers show peculiar RELATIONS TO THE LYMPHATICS. For one

thing, the alveoli or spaces containing the epithelial masses seem to be in direct communication with the lymphatics. If a cancerous tumour, before being opened, be punctured with the needle of a hypodermic syringe and a watery solution of Prussian blue, properly prepared, be injected, the material first runs into the alveoli around the puncture, mapping out a series of cavities as it were, and then passes on into the lymphatics, issuing by their extremities divided during the removal of the tumour. Besides, it has been pointed out by Köster that in sending their processes into surrounding parts the lymphatic spaces are often taken advantage of and are largely occupied. From these two circumstances we can understand how cancers so frequently present secondary tumours in lymphatic glands.

The secondary tumours in the lymphatic glands reproduce the original tumour, but it has been pointed out by Cornil and Ranvier that at the first there is frequently a simple fibrous transformation of the gland as if the stroma was being formed in advance of the epithelium.

It is further to be remarked that cancers are liable to SECONDARY CHANGES. The epithelium readily dies or undergoes fatty degeneration (Fig. 96), and the result may be either that the stroma becomes predominant from the absorption of the fat, or that the whole tissue softens and an ulcer forms. In fact, when a cancer is superficial it very commonly undergoes ulceration. Sometimes, on the other hand, there is from the first a peculiar predominance of the stroma. The epithelial cells of cancers may undergo mucous or colloid metamorphosis, etc.

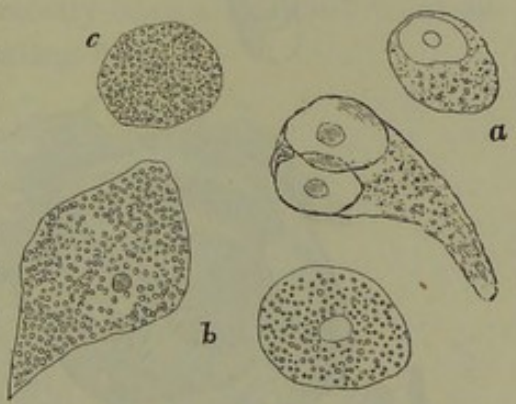


Fig. 96.—Cells from a cancer, showing fatty degeneration. × 350.

Having entered so fully into general considerations as to cancers, we may be correspondingly brief in regard to the individual forms.

(1) EPITHELIAL CANCER or EPITHELIOMA.—According to the description we have given of cancers, it might appear that all cancers are epithelial, but by custom the name has come to be used to designate tumours of the skin and mucous membranes, whose tissue reproduces in its characters to a large extent the surface epithelium of these regions. As there are two principal forms of epithelium, the flat and the cylindrical, so the epitheliomas may be divided into two forms, the flat-celled and the cylinder-celled.

The FLAT-CELLED EPITHELIOMA occurs in situations where there is normally a flat epithelium, namely the skin, mouth, pharynx, œsophagus, larynx, vagina, and urinary bladder. Here there is an excessive growth of pavement epithelium, generally in the form, as we have seen, of more or less cylindrical processes.

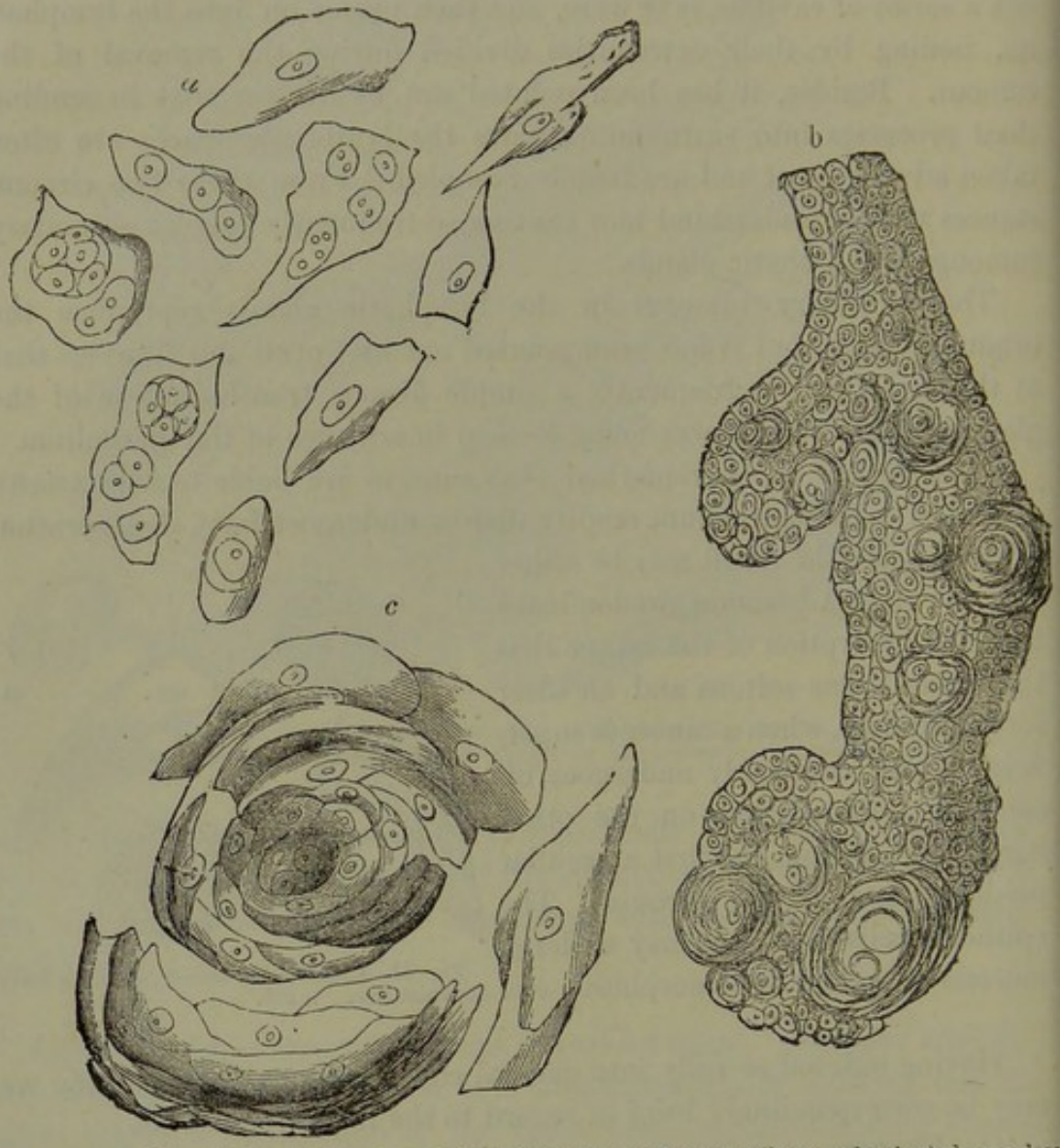


Fig. 97.—Flat-celled epithelioma: *a*, isolated cells; *b*, a cylinder with many laminated capsules; *c*, a laminated capsule opened out so as to show the cells composing it. (BILLROTH.)

In some of the cases the epithelial processes tend to penetrate into the underlying structures so as to produce a more or less diffused infiltration and thickening of the part. In other cases the extension is more along the surface so as to form raised, very often circular tumours. The common epithelioma of the lip is a good example of the infiltrating form; the epithelioma of the skin elsewhere is usually of the extended

flat form. The cylindrical processes of epithelium, as they grow, exercise pressure which, acting on their own cells, produces closely-compacted epidermic globes in the midst of them (see Fig. 97). These form very commonly a characteristic feature in epitheliomas, and are variously designated epidermic globes, laminated capsules, etc.

Along with the production of epithelial processes penetrating inwards, there is very commonly the formation of papillæ on the surface, and sometimes this is so marked as to give the surface a warty appearance. This is often seen in the flat extended epitheliomas of the scrotum and other parts of the skin. It is also very pronounced sometimes in the vagino-uterine epitheliomas, giving rise to the cauliflower appearance. In the urinary bladder there is very frequently such a marked production of elongated villi that the surface is quite shaggy, while the mucous membrane presents infiltration with the epithelial processes. So much is this the case that the name VILLOUS CANCER is often given to this form. Like the papilloma of the bladder, this tumour has a marked tendency to hæmorrhage.

The flat-celled epitheliomas are usually of slow growth, and are the least malignant of the cancers. They mostly have a tendency to ulcerate on the surface, especially the infiltrating ones.

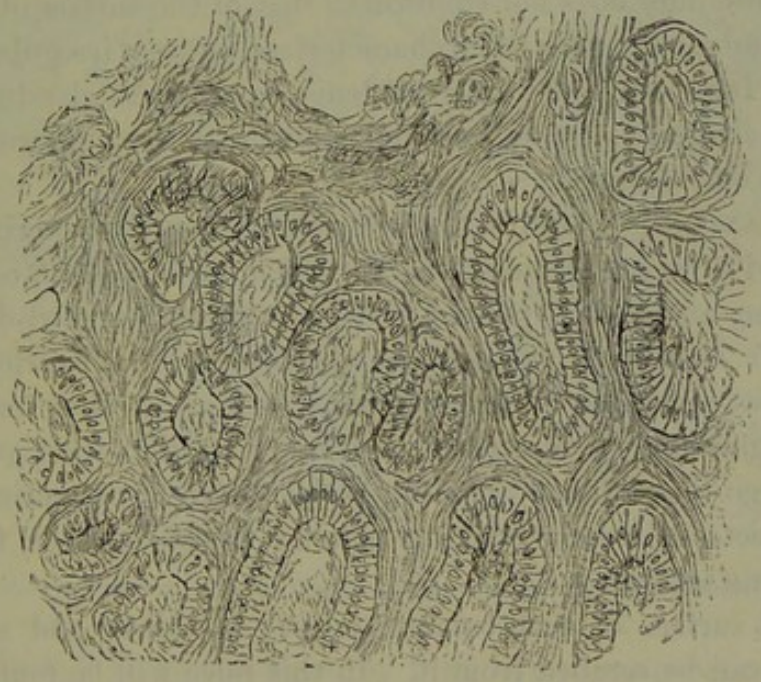


Fig. 98.—From a cylinder-celled epithelioma of the rectum.

CYLINDER-CELLED EPITHELIOMA.—This is a tumour of parts where cylindrical epithelium normally covers the surface, hence chiefly in the stomach and intestine, and more rarely in the uterus.

The tumour takes origin in the mucous membrane, and the tissue has a glandular appearance, forming a congeries of tubes and cavities, lined with cylindrical epithelium (see Fig. 98). Sometimes the glandular appearance is strictly preserved, but frequently the spaces enlarge, and as the epithelial cells accumulate they lose their cylindrical form, although the outer layer of cells next the stroma may still preserve their shape (see figure). The glandular elements are contained in a well-formed stroma, which is new-formed as well as the epithelial elements.

In growing the tumour infiltrates neighbouring parts, insinuating itself among the muscular trabeculæ very often, and extending further. It may form a considerable tumour, projecting from the surface, and is frequently ulcerated, as it occurs mostly in situations where it is exposed to friction.

From the strikingly glandular character of these tumours, many of them are included by some writers among the adenomas.

(2) ORDINARY CANCER or CARCINOMA is divided into several forms in a somewhat arbitrary way. There are soft cancers and hard cancers; there are pigmented and colloid cancers, and even mucoid.

The ordinary cancers consist of epithelial masses contained in meshes, but the epithelium does not conform to that of the surface of the skin or mucous membranes, and is often characterized by great irregularity in form and size. It presents also little tendency to assume a glandular arrangement, and altogether shows less conformity with normal structures than that of the epitheliomas.

SOFT CANCERS or MEDULLARY CANCERS are characterized by the existence of a very delicate stroma in which are abundant cells, usually of small size, and loosely packed in the alveoli with a good deal of fluid. They occur chiefly on mucous membranes, in the ovaries, testicles, kidneys, less commonly in the mamma. Being soft, they tend to bleed, and if originating on a surface or coming to it in their growth, they may undergo ulceration. Sometimes the softened, ulcerating, bleeding tissue projects in a very striking manner from a surface, forming the FUNGUS HÆMATODES.

The cut surface of such tumours is grey in colour, and a somewhat fluid juice can be scraped from it. In this juice will be found cells and free nuclei, the latter large and mainly oval in shape. Many of the cells contain fat granules, and there may be some in an advanced state of fatty degeneration.

Cancers of this kind may grow to a considerable size, as those of the

kidney, and they are often of very rapid growth. They are, as a rule, very malignant; the young cells, being loosely attached, readily pass away and lead to metastasis.

HARD CANCER or SCIRRHUS occurs most commonly in the mamma, but also in the stomach, the testicles, ovary, and kidney. It is characterized by the preponderance of connective tissue as compared with the epithelial structures.

The cancers of this kind have usually a very infiltrating character, the epithelial processes penetrating among the surrounding structures,

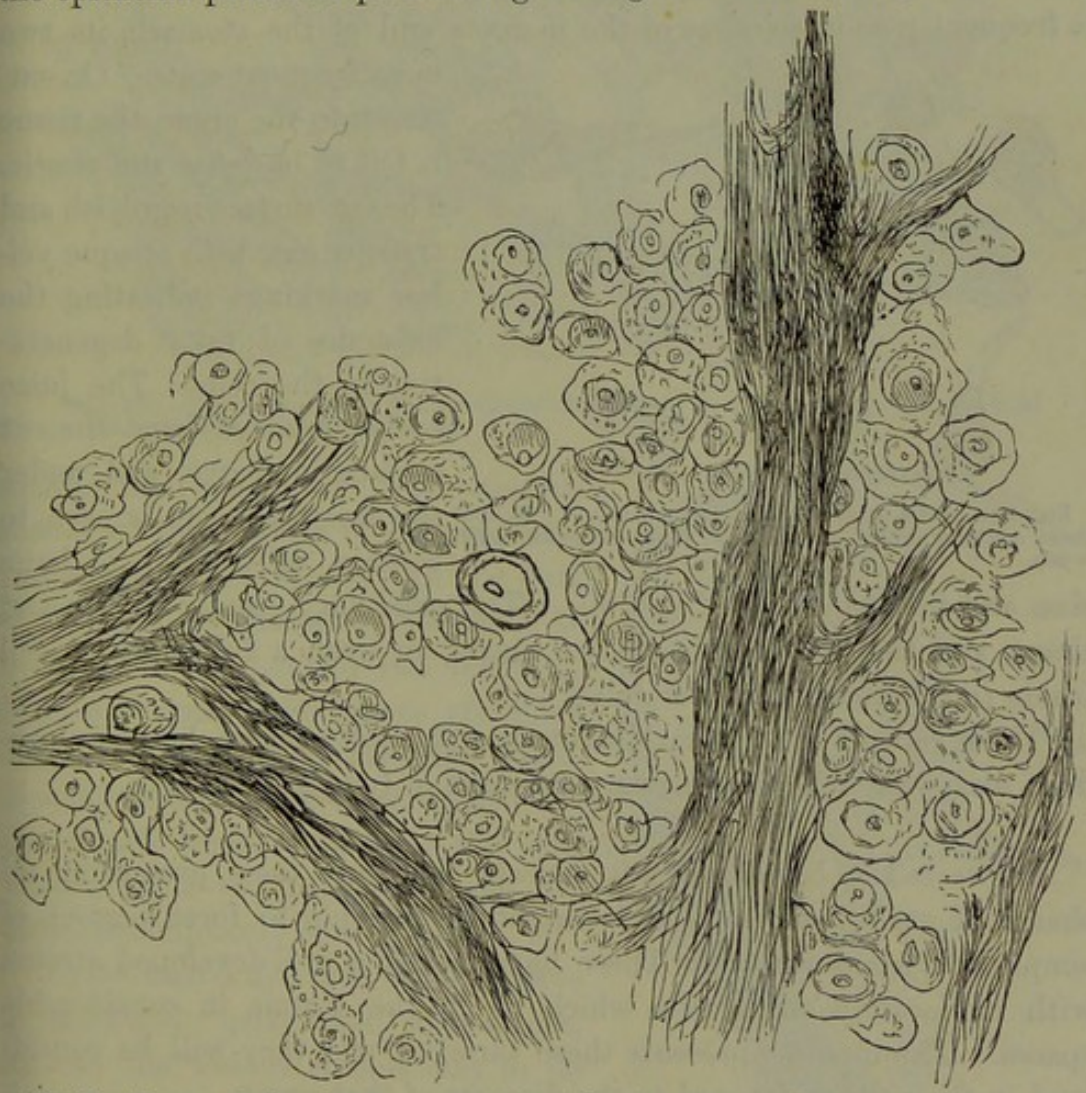


Fig. 99.—From a scirrhus of mamma, recent part showing stroma and epithelial cells. × 350.

and it looks as if these processes, by their irritation, produced an excessive amount of connective tissue. This view is borne out by the fact that the connective tissue is not usually in the form of a well-developed stroma as if planned to support the epithelial structures, but is irregular and even impinges on and destroys the cells. The cells readily undergo

fatty degeneration, and sometimes they to a large extent entirely disintegrate, the stroma assuming the upper hand. It therefore happens that different parts of such tumours have often very different structures. The more recent parts will show well-marked epithelial masses with stroma (Fig. 99), while in the older parts the cells have almost disappeared, and there is nothing but dense connective tissue.

As the scirrhus occurs more as an infiltration than a distinct tumour, the hardening and contraction of the connective tissue causes the organ in which it grows to be sometimes contracted rather than enlarged. It is frequently so in scirrhus of the mamma and of the stomach, its two most frequent seats. On cutting into the organ the tissue is felt to be dense and elastic. The cut surface is greyish and transparent, with opaque yellow markings indicating the existence of fatty degeneration in the cells. The juice to be obtained from the cut surface is scarce, and under the microscope it is seen to contain cells, often of large size, and free nuclei (see Fig. 100). The cells vary greatly in size and shape, and they often contain two nuclei, or even a fully formed cell inside (mother and daughter cells).

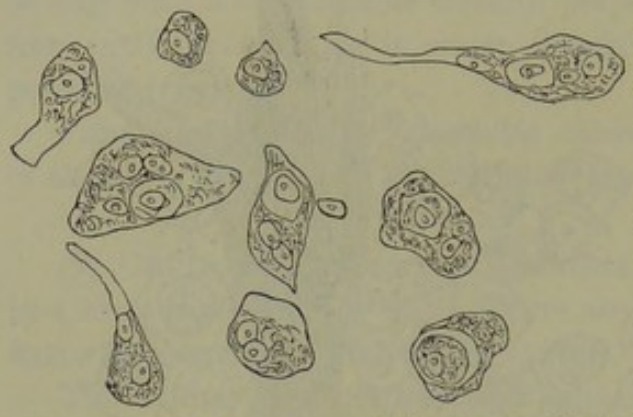


Fig. 100.—Cells from a cancer of the mamma. Most of them contain several nuclei, and some daughter cells. × 200.

These cancers are less malignant than the soft cancers, but they produce somewhat readily secondary tumours in lymphatic glands.

Between the hard and soft cancers there are cases presenting all shades of gradation; so that it might be possible to form a group of simple or normal cancers. These have mostly a well-developed stroma with moderately sized cells which lie in the stroma in considerable spaces. The mamma presents these varieties, and they will be considered in the section devoted to the diseases of that organ.

COLLOID OR ALVEOLAR CANCER is a tumour characterized by the occurrence of colloid degeneration of epithelial cells. It is met with chiefly in the stomach and intestines, and in the mamma, more rarely elsewhere.

There is here a definite new-formation both of stroma and epithelial masses, and the stroma is often produced in the most beautiful and

characteristic forms (see Fig. 101). As if it were in the plan of the growth, the cells regularly undergo colloid degeneration (Fig. 102), and



Fig. 101.—Colloid cancer. A finely reticulated stroma is seen with meshes full of colloid material, the cells having disappeared. × 90.

finally the masses of cells become converted into masses of colloid material which fill the spaces. In the bulk of the tumour therefore there may be nothing visible beyond the regularly formed stroma whose spaces are filled with clear transparent material. Occasionally there may be in the centres of the alveoli some remains of the cells visible, while the peripheral cells are already completely converted.

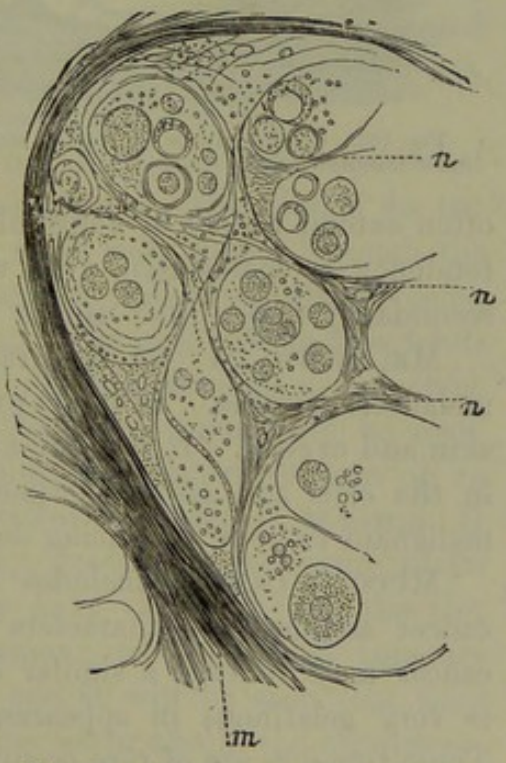


Fig. 102.—Colloid cancer. *m*, *n*, stroma in whose meshes are cells undergoing colloid degeneration. × 300. (Cornil and Ranvier.)

To the naked eye such tumours have a markedly gelatinous appearance, and as the fibrous stroma may in its coarser meshes be visible without the microscope, it may, even to the naked eye, look as if there were nothing but alveoli filled with gelatinous material, hence the name alveolar cancer. The tissue is frequently dense and hard to the feel. This arises apparently from the fact that the alveoli are tensely packed with the colloid mate-

rial, and, the fibres being on the stretch, a dense resistance is offered, just as a tightly blown up bladder is hard.

These tumours mostly occur as infiltrations, frequently penetrating among the constituents of the tissues (Fig. 103), and although they very



Fig. 103.—Colloid cancer in wall of stomach, penetrating among, and separating, the muscular bundles. × 90.

often extend widely by continuity (as in the stomach), they show little tendency to metastasis; even when they attack the lymphatic glands secondarily they do not usually produce large tumours.

Melanotic cancer is a rare form of tumour compared with the melanotic sarcoma. It occurs primarily in similar situations, namely the skin and eyeball. It is really a soft cancer in which pigment is present in the cells and also sometimes in the stroma. It is usually a very malignant tumour, producing secondary growths by metastasis.

Mucous cancer includes tumours in which the stroma of the cancer assumes the characters of mucous tissue. The cells of the cancer may undergo a similar degeneration. The tumour as a whole is very gelatinous in appearance, and resembles the colloid cancer. These tumours are of rare occurrence, being met with in similar situations to colloid cancer, but attaining the highest development in the ovary.

3.—THE LYMPHATIC GROWTH OR LYMPHOMA.

We have already seen that in LEUKÆMIA there is sometimes an enlargement of the lymphatic glands, and that secondary tumours occasionally occur in the liver, kidneys, and elsewhere. We also saw that in Hodgkin's disease, or adenia, there is an enlargement of the glands and other changes like those in leukæmia, without the peculiar condition of the blood which is the criterion of leukæmia.

In TYPHOID FEVER we have an enlargement of the lymphatic glands of the mesentery, and sometimes secondary lymphatic growths occur in the liver and kidney similar to those in leukæmia.

The names LYMPHADENOMA and LYMPHOSARCOMA are given to tumours of the lymphatic glands, and it will be necessary to consider them more in detail. The lymphatic glands of the mediastinum, for instance, sometimes undergo great enlargement, and get compacted into a bulky mass having the characters of a tumour, and to this condition the name of LYMPHADENOMA has been given. The glands, although greatly enlarged and adherent by their capsules, are still individually distinct, as may be seen on section. The enlargement may now proceed to the glands of the neck, or it may originate there and pass downwards. The neck may be enormously enlarged and rendered somewhat rigid. These tumours are of slow growth, do not show any malignant tendencies, and are even amenable to treatment.

But in the mediastinum tumours are not infrequent which consist of more than a simple enlargement of the glands. The glands do not remain distinct, and the new-formation as it were passes through the capsule, and the whole mass becomes one, the individual glands being no longer distinguishable even on section. The new growth also tends to incorporate neighbouring structures. It will envelop a bronchus, and gradually work through its wall replacing its tissue with its own. It will incorporate the parietal pericardium, and afterwards pass on to the visceral layer, and replace even the wall of the heart by its tissue. It will surround a vein and work its wall up, gradually penetrating to its interior. Before this, thrombosis may have occurred, and the clot is worked up or replaced by the tumour tissue. Such tumours are fitly designated LYMPHO-SARCOMAS, and it will be seen that they possess a high degree of malignancy. They occur also in the mesentery, and may extend to the wall of the intestine, replacing its tube by lymphoid tissue, and forming a bulky tumour through which the calibre of the gut is maintained. They also sometimes develop secondary tumours by metastasis.

PARASITES.

UNDER this designation we include all forms of living creatures, whether vegetable or animal, which exist in or on the human body, and provide themselves with nourishment from the body or its juices. The parasites are beings of the most widely different kinds, and their relations to morbid processes in the body also differ greatly. In the description of parasites we shall begin with the lowest forms, these being the forms also around which most interest at the present moment centres.

A.—VEGETABLE PARASITES.

MICRO-ORGANISMS OR BACTERIA.

If a fluid containing organic material, such as blood serum or infusion of flesh, be exposed to the air, it soon becomes putrid, and everyone knows that in such putrid fluid minute forms of organized beings are to be found. All of these, however, are of very minute size, so that they may be classed as micro-organisms. To the entire series of such minute organisms, as we shall see afterwards, the name bacteria is often applied in a general sense, although various forms of such bacteria are distinguishable. With this simple, every-day occurrence are connected questions of the highest importance and the greatest difficulty: Whence come these bacteria? What is their relation to the decomposition of the fluid? and many others of great importance.

One of the most important of these questions, and one of the easiest to answer, is that which we have given first:—WHENCE

COME THE BACTERIA? To answer this, a very simple experiment is alone necessary. Let a boiled potato be cut in two, and one half exposed with the cut surface uppermost in an inhabited room, while the other is kept under a bell-jar. After the exposure put the first half along with the other under the jar, and observe the condition of matters for the next few days. In the one which had been exposed, a number of little spots will appear in the course of a day or two, and these will increase in area in a more or less circular manner. These little spots will very likely present considerable differences in appearance, some yellowish, others whitish or pinkish in tint, and they have all the appearance of plants growing on the nutritious material supplied by the potato. It needs only the most superficial microscopic investigation to prove that some of these spots are due to the growth of fungi, while others are the seat of myriads of bacteria, which are obviously multiplying at an extraordinary rate. It is no less obvious that these micro-organisms have arisen from something which has fallen on the potato from the air. The substance which has fallen from the air may be spores of the organism or simply the organisms themselves in a dried state, but we are warranted in inferring that the one or the other is floating in the air, and that the dust, which we know from other sources to be composed largely of organic matter, contains the germs of numerous living micro-organisms. It is only those which will grow on potato that will be rendered visible by their growth in the way mentioned. If different kinds of material suited to their growth be used, more varieties may be obtained.

By thus exposing a proper soil to the air we may obtain a garden with several different plants in it. These plants we may propagate as much as we desire. We have only to transplant them with a needle or a knife, which has been recently heated in the flame of a lamp in order to destroy any organisms that may be adherent to it, and we obtain pure cultivations of the various plants. By inoculating several media we may find out the idiosyncrasies of the different organisms. Some will grow on potatoes, some need an animal diet, and for some a specially prepared soil is necessary. In this way we may cultivate the organisms through successive generations and in different media, and they retain their characteristics in every case.

We may now consider what are the FORMS AND CHARACTERS OF THESE BACTERIA. It is to be noted that all of these organisms are of very minute size, being scarcely visible with an ordinary low power

of the microscope. It is their extraordinary number that renders them at all readily appreciable even with the microscope, and, it may be added, it is their extraordinary number that makes their existence of such importance. The extreme minuteness of the individual bacteria renders the classification of them very difficult. In the aggregate, when cultivated, say on the surface of the potato, they often show much more distinctive characters than when examined under the microscope. From this it will be understood how it is that considerable divergence exists in the nomenclature of the bacteria, and differences of opinion as to their specific relations.

Bacteria may be defined as minute plants of globular or oblong shape which increase by transverse fission. The whole group of bacteria is included in the family SCHIZOMYCETÆ. Individually they are for the most part only slightly coloured, although in the aggregate they frequently show some shade of colour, by which indeed they may be recognized. They present, like the cells of plants which possess a cellulose membrane, a remarkable resistance to the action of caustic alkalies and acids, although it seems that their wall is not actually composed of cellulose.

According to Cohn's classification there are four forms of bacteria, namely, the spherical or globular, the small rod-shaped, the larger rod-shaped or thread-like, and the spiral. The first two are closely related,

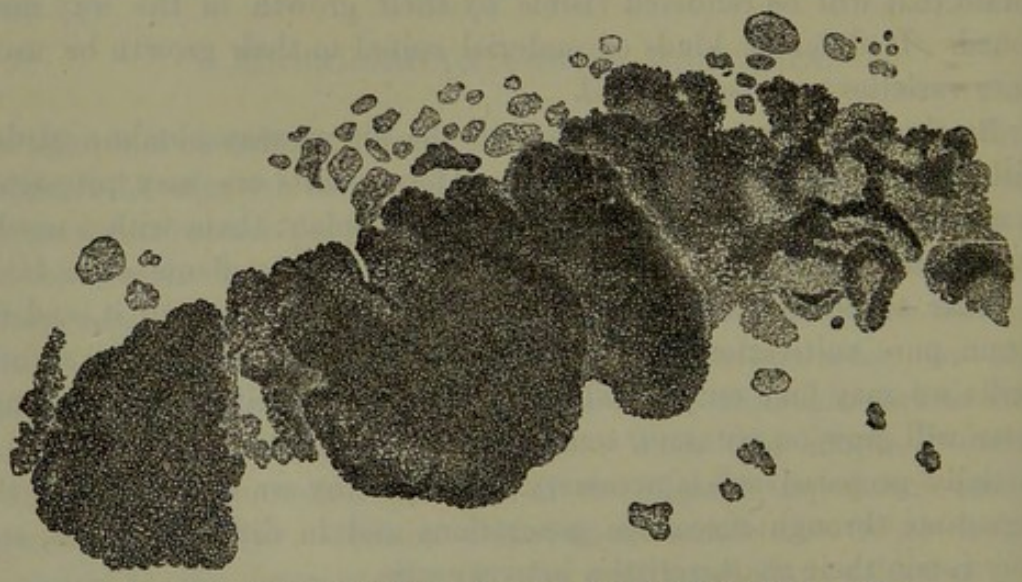


Fig. 104.—Swarms of bacteria growing in a nutritive material. × 90.

and we may even class them together as Klebs and Billroth do. In that case the globular bacteria and those which form short-beaded rods, as if from the imperfect separation of the globular cells, form

one class, and the more definitely rod-shaped or thread-like form another. The first class may be called COCCO-BACTERIA and the other BACILLI. There remains the third class of SPIRILLA whose relations are rather obscure.

The COCCO-BACTERIA are very minute organisms, but they present the peculiarity that they have a great tendency to occur in great multitudes or swarms together. These swarms are united by a kind of viscous material apparently secreted by the bacteria. Aggregated thus in swarms they appear under the microscope as opaque cloudy masses such as those represented in Fig. 104. These are variously named colonies or zoogloœa. When thus aggregated together it is difficult to make out whether the bacteria are really globular or formed of fine rods. But if the colonies be flattened out, or if the edge be carefully observed where they are less thickly set, we may find out their actual structure; they are probably most frequently formed of globular bacteria. The colonies often appear on the surface of decomposing fluids, forming the membranous-looking scum which we see so often in such situations. It should be mentioned that these globular bacteria are often called MICROCOCCI (Fig. 105), and that they have no power of spontaneous movement.

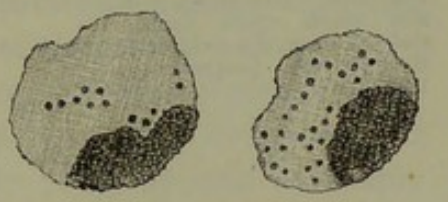


Fig. 105.—Two pus corpuscles containing bacteria. From a preparation which had been dried and stained with methylviolet. × 1500.

The minute rods, of which colonies are also sometimes formed, are believed by some to develop out of the globular bacteria. Klebs seems to believe that while colonies are often formed of globular bacteria, the peripheral ones frequently elongate into finer rods, and become free in the fluid. Whether this be the case or not, we meet with the fine rod-shaped forms free in fluids more frequently than the micrococci. It may be added that to this form of fine rods, which are so common in decomposing fluids, the term bacterium is sometimes applied in a more limited sense.

The BACILLUS is a rod-shaped bacterium, but more elongated than those just referred to (Fig. 106). It has also the tendency to elongate so as to form threads of some length. Sometimes, as in the tubercular bacillus (Fig. 107) and in the very important bacillus anthracis, the threads produce spores inside themselves, which afterwards may become free. In regard to the cocco-bacteria, there seems no evidence that they bear spores of any kind, but they propagate merely by fission.

The remaining form of bacterium is the spiral one or SPIRILLUM.

This organism is in the form of a fine thread with a cork-screw twist in it.

It has already been mentioned that the globular bacterium or micrococcus is incapable of spontaneous movement. In regard to the others,

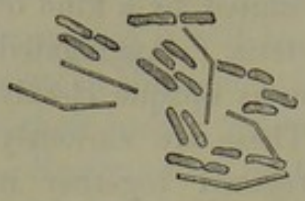


Fig. 106.—Two forms of bacilli which were growing together in the same nutritive material. One short and thick, the other long and thin. The short one was much more deeply stained than the long one. Methylviolet preparation. × 1500.

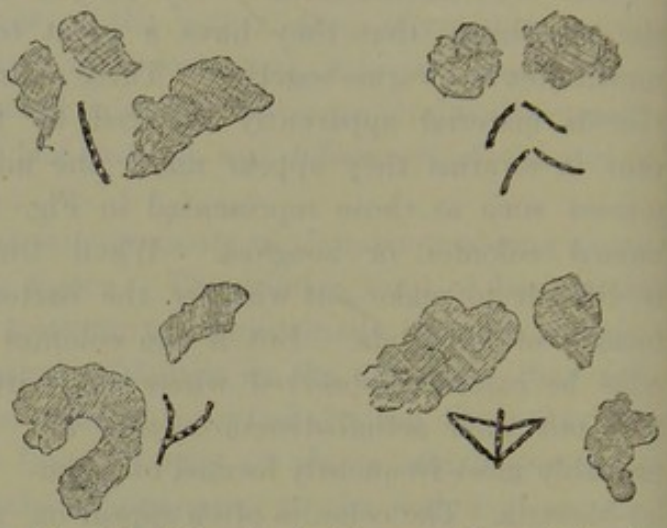


Fig. 107.—Tubercular bacillus, consisting of threads beaded with spores. In the preparation the bacilli are red, and the other bodies (pus corpuscles) are blue. × 1500.

some are motionless and some have locomotive powers. The rod-shaped forms have sometimes a wriggling movement which has caused them to receive sometimes the name of vibrios, although this name is often confined to the bacilli. The spirillar forms sometimes show a cork-screw movement and sometimes are quiescent. It may be said in general that bacteria which have power of motion become still at some period of their development, while others are motionless throughout.

Methods of Detection.—It will be obvious that these minute organisms are often very difficult of detection, especially when they are mixed up with other structures or lie in the midst of the tissues. When they are in colonies their opaque clouded appearance and their frequent brown colour make them often very prominent objects. But when more isolated, and even when in sparsely distributed colonies, it may be difficult to distinguish them from the mere granular debris of the tissues. In order to render them more easy of detection, various methods have been devised. The simplest is that originally suggested by Recklinghausen, which is based on the fact already mentioned, that these organisms present a much greater resistance to alkalies and acids than the animal tissues do. The addition of solution of

caustic potash to an animal tissue renders it transparent and obscures the structure. If bacteria be present, they will be rendered more prominent than before. Dilute acetic acid, which as we know clears up the connective tissue especially, may be used in a similar way. This often succeeds in bringing into prominence the zoogloœa of bacteria, but is not of much use in detecting isolated ones.

Much advance has been made by the introduction of improved methods of staining bacteria devised by Weigert and improved by Koch. Bacteria absorb readily several kinds of dissolved pigments, but they show a peculiar tendency to become coloured with aniline dyes. Many such dyes have been used, but the most suitable seem to be methylviolet, Bismarck brown, and methylblue, of which the first two have been most used. Methylviolet cannot be used with glycerine, as this agent extracts the colour, and so a strong solution of acetate of potash in water (1 to 2) may be used. Preparations stained with Bismarck brown may be mounted in glycerine or Canada balsam.

As the observation of bacteria is now of considerable importance, the more usual methods of investigation may be here briefly described. If bacteria be present in a putrid fluid, they can easily be seen by simply placing a drop under the microscope. But if it is desired to observe their characters more particularly, and to preserve them, the fluid may be subjected to the following treatment. A microscopic coverglass is taken, and a small quantity of the fluid smeared on it in a thin layer, which is allowed to dry into a film on the coverglass. To this film is added a drop of the methylviolet or other aniline solution (prepared by adding a few drops of a strong spirituous solution of the dye to water). This solution should not be too weak, otherwise the viscid material which unites the colonies will be swelled up and the film loosened. The staining agent is allowed to act for a few seconds, and then run off from the coverglass or sucked up with a pipette or blotting paper. If necessary, the stained film may be washed with a solution of acetate of potash (1 to 10). After this a drop of strong acetate of potash solution is added to the film, and the coverglass placed on a slide and examined. If aniline brown be used, then glycerine may be substituted for solution of acetate of potash. In some cases it is desirable to mount the specimen in Canada balsam, and in that case it is only necessary, after staining, to allow the film to dry and then add the balsam.

It is sometimes desirable to examine blood or other fluid containing albumen in solution. When that is the case the film obtained by dry-

ing contains soluble albumen, and if it be treated as above then the albumen is dissolved when the staining solution is added, and being afterwards precipitated in the granular form, obscures the appearances. It is necessary, therefore, to fix the albumen. This may be done by simply leaving the film unstained for several days or weeks. It is more quickly done by immersing the coverglass in spirits for a few days, but it is most quickly effected by exposing the film to a temperature of 120° to 130° C. If the coverglass be placed for five or ten minutes in an air bath raised to this temperature the further processes may generally proceed without difficulty, but sometimes it takes longer and sometimes shorter, these exceptional cases being determined by experiment. A more rapid way of effecting the fixation of the albumen is to pass the coverglass with the film three or four times through the flame of a spirit or Bunsen lamp.

If the presence of bacteria be suspected IN THE TISSUES, then the process of preparation is more detailed. The tissue should be hardened in alcohol. Fine sections are then to be made, and these stained in the aniline solution in the usual way. They are next to be placed for a few seconds in diluted acetic acid, and they can afterwards be mounted in glycerine or acetate of potash solution, according to the staining agent used. If it be desired to mount them in Canada balsam they may be transferred direct from the staining solution to absolute alcohol, where they may be left for a time; they are then cleared up with oil of cloves, and mounted in balsam. Methylviolet cannot usually be used for this latter purpose, and Bismarck brown or gentian violet is perhaps the most useful dye.

For the detection of bacteria in the tissues, Koch has introduced the use of a special form of illumination by means of Abbe's condenser. The use of this piece of apparatus is described in Koch's work on *Traumatic Infective Diseases*, translated by the Sydenham Society, and thus available to our readers. When sections stained as above are thus illuminated, the details of the tissues are obscure, but all coloured objects are rendered visible, and so the bacteria, being the most definitely coloured, may be prominently brought out.

It is not to be inferred that all bacteria react equally to the aniline dyes. The more ordinary bacteria are stained by most of the colours, but the tubercular bacillus, as we have already seen, the typhoid bacillus, and others, have special affinities.

INFLUENCE OF BACTERIA ON THE LIVING TISSUES.—We have already

seen that bacteria are present in fluids which are undergoing putrefactive decomposition, and it may now be regarded as demonstrated that the various forms of putrefaction are due to the action of these organisms. The details of these demonstrations need not detain us here, but it is important to consider whether the organisms or their products have any influence on the living body, or are the causes of disease.

It is clear that many of these bacteria are perfeetly innocuous when merely in contact with the surface of the body or the mucous membranes. The intestinal canal teems with bacteria, and the inspired air, as we know, contains many kinds of them. These ordinary bacteria are incapable of penetrating the living tissues, but when death occurs they at once begin to swarm into them. Even when directly injected into the blood, few of these bacteria seem capable of surviving, although, as we shall see immediately, some of them undoubtedly are.

Although ordinary bacteria and their products are incapable of penetrating into the healthy tissues, or at least work no mischief when they do, yet when they exist in wounds they find a more ready access to the tissues and the blood, and it will be proper here to consider the effects which occur in connection with PUTREFYING OR SEPTIC WOUNDS. It need hardly be stated that this subject is of vast importance in connection with the treatment of wounds, and that the antiseptic method of treatment is based on the view that the putrid wound is a source of mischief.

Of great importance here are the observations of Ogston (*British Medical Journal*, March 12th, 1881). These observations bear chiefly on the connection of micro-organisms with acute inflammations, especially where suppurations occur. The pus from a large number of abscesses was examined, and in all cases where the abscesses were acute, micrococci were found abundantly, whereas in the case of cold abscesses there were no such organisms. When pus containing these was injected under the skin of animals in small quantity it usually caused acute inflammation ending in abscess, and on examination the micrococci could be seen in the pus as well as invading the tissue around the abscess. A few organisms could also, in these animals, be detected in the blood, and the animal presented signs of general uneasiness.

In suppurating wounds also Ogston found micrococci, mixed here with bacteria of various kinds. The number and activity of growth of the organisms were proportionate to the intensity of the suppuration.

It would appear therefore from these observations that the active agents in producing inflammations in the tissues are micrococci, while

the ordinary bacteria of decomposition are not so distinctly concerned. From his further experiments Ogston inferred that micrococci grow best when not exposed to the air. He cultivated them by introducing a minute portion of pus into an egg, and protecting the latter from the access of air. He found that the organisms grew vigorously when kept at the temperature of the body, but that they did not produce ordinary decomposition. The egg albumen in which the micrococci had grown produced abscesses when injected under the skin of animals.

It may be held that these observations of Ogston prove that, of the organisms occurring in ordinary decomposing fluids, the micrococci are those which have the greatest power of resisting the living tissues, and propagating themselves inside the body. This is consistent with the fact that in pyæmia, septic peritonitis, etc., it is micrococci that are found in connection with the inflammatory processes. It is not to be inferred, however, that in the case of external wounds where decomposition is going on, the chemical products evolved are not concerned in the production of inflammation. We know that these products are highly irritating, and they are, doubtless, capable of producing local inflammations as well as giving rise to general symptoms when absorbed into the blood. In the present state of our knowledge it is impossible to say whether there are many or few kinds of micrococci as of other bacteria, but it may be presumed that if there are not different species there are great differences in their state of activity at different times.

Septicæmia.—The absorption of material from putrid wounds or, what is equivalent to that, the injection of putrid material into the blood or under the skin, is followed by certain symptoms, of which the chief are fever, vomiting, and diarrhœa. In some cases there are such general symptoms alone, but in others there are in addition local internal inflammations which have a marked tendency to go rapidly on to suppuration; the so-called metastatic abscesses. It has become customary to speak of cases where there is simply a general affection of the system, in which, in fact, there is a morbid condition of the blood, under the designation septicæmia, while those other cases in which there are metastatic inflammations, doubtless due to embolism by septic material, are called cases of pyæmia. We shall speak first of conditions where there are no embolic phenomena, and which are generally included under the term Septicæmia.

In considering the phenomena of septicæmia we have two possible

conditions to take into account. If putrid material be introduced into the blood it may produce symptoms due to the mere poisonous nature of the products of decomposition, namely, the volatile oils which give their odour of putrescence and other chemical principles. But on the other hand it may give rise to symptoms due to the bacteria which may live on in the blood and produce mischief there, multiplying as such organisms do with greater or lesser rapidity. We may thus distinguish a septicæmia due to chemical poisoning, and another due directly to the action of the organisms. We shall first take up the former of these, and it will be convenient to refer to it as *putrid or septic poisoning* as distinguished from *putrid or septic infection*. (German writers use the expression intoxication as equivalent—it is so etymologically—to poisoning, but this use is often rather confusing to English readers, especially when met with in translations.)

(1) Septic poisoning.—This is produced by the chemical products of decomposition entering the blood. It has been proved by many experiments that these products are capable of producing symptoms of poisoning, and as illustrative of such experiments we may cite those of Puky.

The putrid yolk of egg containing free fat and active bacteria as well as the usual products of decomposition was injected into the jugular vein or under the skin. The result was the production of symptoms such as those already mentioned, but in most cases without any apparent new-formation of organisms in the body. In these observations the organisms introduced may have had something to do with the symptoms, but for the most part they seemed to be nullified by the blood, and the symptoms were due to the poisonous chemical products. That this was so was proved by boiling and filtering the putrid material before injecting it. The effect of boiling would be to kill the organisms, and the filtering would get rid of everything except the dissolved chemical products. When the filtrate was used similar symptoms were produced, but it required a larger dose on account of some of the poison being carried down with the albumen.

These experiments taken along with others seem to show that in putrid material there are chemical products which, if taken into the body in sufficient quantity, act as poisons, and may even prove fatal. These chemical products have not been separated as yet, but it appears from the observations of Panum (Virchow's *Archiv*, vol. 60, p. 301) that they are soluble in water but not in alcohol. This observer evaporated the putrid material to dryness and extracted first with alcohol and then

with water. The latter solution produced the symptoms of poisoning, the former did not.

There are, doubtless, in the human subject many cases in which the chemical products of decomposition are absorbed, the amount of absorption depending on the amount of the material present, and the capability of absorption of the surface exposed. Substances introduced under the skin are very readily absorbed, as the material is introduced directly into the lymphatic channels. In a freshly made wound these channels are laid open, and any putrid material present is absorbed nearly as readily as if it were introduced under the skin. The WOUND FEVER which occurs so commonly in septic cases within the first forty-eight hours is doubtless due to septic poisoning, as is shown by its absence in aseptic cases. But, when the surfaces of a wound are covered up with granulations, the lymphatic spaces are shut off, and absorption is not so ready. The healthy granulations have a remarkable power of preventing absorption, as the most foul substances may be applied to them without any apparent absorption.

But in some cases there is a much more serious absorption of the products of decomposition in large or irregular wounds, such as those resulting from compound fractures of the bones of the limbs; or in the case of large suppurating and decomposing surfaces such as those in an opened pleura, or peritoneum, or joint, or chronic abscess. In these cases, the hectic fever so often leading on with diarrhœa to a fatal termination, is no doubt due to septic poisoning. It is to be remarked that the peritoneum and the pleura, being lymphatic sacs, have a very high power of absorption, and decomposing material in contact with them is very readily absorbed. Hence, probably, the rapid fatality of acute peritonitis, which, whether following on an operation, or due to perforation of the intestine, is usually septic.

On post-mortem examination in such cases, little that is definite can be discovered. The blood is dark in colour and coagulates imperfectly, and there are evidences of a tendency to hyperæmia and capillary hæmorrhage. The hæmorrhage is mostly in the form of petechiæ beneath the pericardium, endocardium, and pleura, and the hyperæmia is chiefly of the mucous membrane of the intestines, where it is sometimes very marked.

It is a question whether the septic poison may not produce, especially in persons predisposed to it, inflammations in distant parts. The acute inflammation of the pleura, or pericardium, or even of joints, which sometimes occurs in connection with decomposing wounds, may possibly

be due to the septic poison, although more probably caused by organisms which have been absorbed.

(2) SEPTIC OR PUTRID INFECTION.—This condition differs from septic poisoning in respect that here we have to do with a virus or contagium capable of propagating itself, and multiplying in the body. In septic poisoning the effects, as in the case of other poisons, depend on the dose of the poison. In septic infection a small amount introduced will lead to the disease as well as a larger amount, although it may take a longer time.

The term INOCULATION may be used to designate the application of minimum quantities of a virus to the living body. If we can induce putrid infection by inoculation in animals we may expect that much light will be thrown on the nature of other diseases which are also capable of production by inoculation, and, indeed, on the nature of contagion in general. With this in view, as well as on account of its own inherent importance, it will be well to go more particularly into the subject here.

The names of Coze, Feltz, Davaine, Pasteur, and Koch are associated with the investigation of putrid infection, and it may be said that Koch's observations afford the most recent and strictly accurate information on this subject. We shall here, therefore, refer more in detail to his researches, especially those contained in his work on *Traumatic Infective Diseases*, and recent papers by himself and his assistants.

If putrid material be injected under the skin of a mouse, the animal will die, as we have already seen, from septic poisoning, if the dose has been large enough. But if a small quantity be used, such as one or at most two drops, the symptoms of poisoning do not appear, and many of the mice recover. A certain number, however (about a third), of the animals become ill in about twenty-four hours, with certain symptoms which are quite constant, and they die in about fifty hours after the inoculation. If now a minute quantity of blood be taken from the body of the dead mouse and inoculated into a living mouse, the same symptoms occur, and the animal dies in about fifty hours. The disease may be propagated from animal to animal without fail for any number of generations, and an



Fig. 108.—*a*, The blood in septicæmia of mice, showing blood corpuscles and small bacilli. *b*, Blood from splenic fever, showing blood corpuscles and large bacilli. × 700. (KOCH.)

exceedingly minute quantity of blood is alone required in order to produce the disease. In this disease there are no metastatic abscesses, the only organic lesion being a considerable enlargement of the spleen, and so it is called by Koch SEPTICÆMIA OF MICE.

When the blood of such mice is examined, whether the disease was produced by the primary inoculation of putrid material or by the

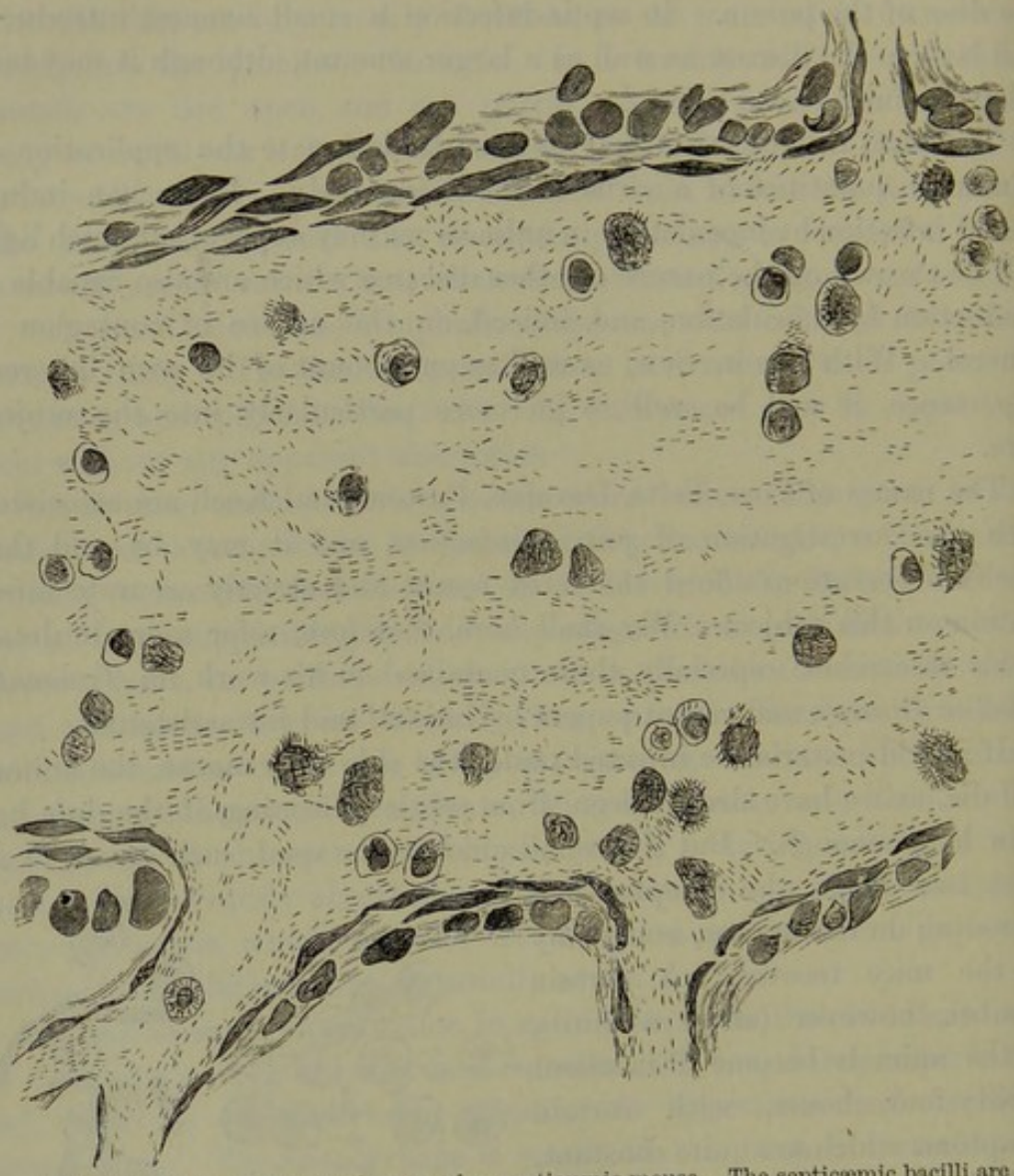


Fig. 109.—Vein of the diaphragm of a septicæmic mouse. The septicæmic bacilli are seen in great abundance, some of them attacking the white blood corpuscles, which are occasionally reduced to masses of bacilli. × 700. (KOCH.)

inoculation of the blood of the animal which had died, it is found to contain myriads of minute bacilli. The accompanying figure (Fig. 108 *a*) from Koch's work, showing the appearances presented by a drop of blood stained with methylviolet, dried, and mounted in Canada balsam, gives some idea of the appearance of these bacilli. Their size,

as compared with that of the anthrax bacillus, is shown by contrast with the other figure (Fig. 108 *b*). They can be shown also to be actually present in the blood-vessels in enormous numbers, as in Fig. 109, in which a vein from the diaphragm is represented, prepared by Koch's method. In this figure the relation of the bacilli to the white corpuscles is seen. They penetrate into them, multiply in their interior, and finally break them up. Many clusters of bacteria which might be taken for zoöglœa have this origin. The bacilli are found not alone in the blood but their path of entrance is discoverable. In the subcutaneous tissue in the neighbourhood of the inoculated spot they are very numerous, and they may extend widely in the loose connective tissue, but do not pass into the lymphatic vessels, although apparently finding access readily to the blood-vessels.

The explanation of these facts is obvious. The putrid material originally used contains many forms of bacteria. Many of these are, in relation to mice, innocent, but there is a form usually present (apparently in small numbers) which is capable of multiplying in the body of this animal. If bacteria of this kind be present in the fluid inoculated, they multiply in the subcutaneous tissue and pass into the blood-vessels, producing the disease which Koch calls septicæmia of mice. We shall not here follow the further facts in connection with this disease, as they will come up more suitably afterwards.

A somewhat similar but even more virulent infective disease has been produced in rabbits, by the injection of putrid material. This disease has been more particularly studied by Coze and Feltz and Davaine. For the first infection a large quantity of putrid material is required, and it is to be remarked that while different kinds of fluid will produce the disease, such as putrid blood, or peritoneal fluid, or the slime of sewers, yet these materials often fail entirely. When the disease is produced, the animal begins to sicken in ten to twelve hours, and dies rapidly in about six or eight hours more. While it takes a considerable quantity of the original fluid to produce the disease, a much smaller quantity of blood from the animal killed by the disease suffices to produce it in a fresh animal. Very striking statements have been made, on the ground of Davaine's observations, as to the progressive virulence of this disease when propagated from one animal to another. It has been said that as generation after generation is infected, a smaller dose is needed till the disease can be certainly produced by a trillionth part of a drop of blood. The observations of Koch, however, seem to show that these statements have arisen largely from misapprehension even of

Davaine's own observations. It is true that the propagated disease may be produced by such minute doses of blood, but it does not need to be propagated through several generations. In the first or at most the second generation it reaches its maximum of virulence, and a minimum dose is as capable of producing the disease as in a later generation.

Now this septicæmia of rabbits is also produced by a bacillus, but one of larger size than that of the septicæmia of mice. Koch succeeded in obtaining a disease which he believes to be identical with Davaine's putrid infection, and the bacteria were rods about a half larger than those of the septicæmia of mice, and with a clear space in the middle, while the poles were opaque, giving a kind of figure-of-eight appearance. This disease was communicable to several other animals, and in the blood of these animals the parasite was found to have multiplied.

It is clear from these observations that putrid material contains bacteria which may conveniently be classed into two groups in their relations to the living animal. The members of the one group produce, it may be, chemical matters which are poisonous to the living animal, but they themselves are innocuous, or at least the living tissues are able to resist their action and annul their virulent properties. The other class are able to propagate themselves in the animal body and, probably by means of the chemical changes which they effect in the blood, they produce symptoms which are rapidly fatal. To the latter class of bacteria the adjective PATHOGENIC may be conveniently applied, and the class may be conveniently extended to include all bacteria which by propagating themselves inside the body produce morbid conditions in it. These pathogenic organisms are of great importance not only in regard to septic infection but, as we shall see afterwards, in relation to other diseases.

In the case of the pathogenic bacteria already mentioned efforts have been made to cultivate them in the pure state outside the body. In ordinary putrid fluid they are mixed up with other organisms and may be difficult to distinguish, but by using those developed in the blood of the animals a pure cultivation may be obtained. The bacillus of the septicæmia of mice has been found to grow best in an infusion of flesh to which has been added 1 per cent. of peptone, 0·6 per cent. of common salt, and enough phosphate of soda to produce a weak alkaline reaction. This fluid may be rendered semi-solid by melting gelatine with it, and in this form it may be spread out on microscopic slides, and the blood containing bacteria sown on it. The bacteria cultivated

in this way multiply vigorously and they retain their pathogenic character. Koch and his assistants have cultivated them through thirty-five generations and found them equally virulent throughout. The bacillus of the septicæmia of the rabbit has also been cultivated in flesh infusion and peptone or blood serum stiffened with gelatine. They also have been cultivated through nineteen generations and found perfectly infective at the end.

We shall return afterwards to the subject of pathogenic bacteria, and meanwhile the characters of those just described must be borne in mind.

PYÆMIA.—We have hitherto considered those conditions connected with the absorption of putrid material in which the action of the virulent matter is mainly on the blood ; we have still to consider those cases in which local inflammations result from the penetration of decomposing material.

The name PYÆMIA is now commonly used to designate those conditions in which as a result of the absorption of putrid substances multiple abscesses occur in the body. The occurrence of these multiple inflammations implies that a violent irritant is carried inwards and acts on the tissues. It may be said at once that these inflammations are always associated with the presence of bacteria, which may at first be carried to the part in small numbers but afterwards grow into colonies. These organisms will primarily have their seat in the vessels, and the inflammations will therefore have an EMBOLIC ORIGIN. Sometimes considerable pieces of broken-down thrombi, arising as we shall afterwards see, are carried inwards and plug arteries ; in other cases it is minute fragments which are conveyed, and they stick in the capillaries. As we have seen, however, the bacteria are self-propagating, and even a capillary embolism may set up a considerable inflammation. Let us now trace the course of events in an ordinary case of pyæmia.

When putrid material is introduced into the blood from a wound, the active bacteria are usually destroyed by the living blood or vessels, and the result produced is, as we have already seen, a septic poisoning. But under certain circumstances, putrid material passes into the open mouths of veins, and the bacteria contained in the material survive and propagate. The first result produced is thrombosis in the veins. By and by the thrombi begin to soften, and they break down into a yellow material resembling pus. Hence the softening is sometimes called yellow or puriform softening. The material is not pus however,

it is composed of the debris of the thrombus, along with the organisms which have been the chief agents in the coagulation and in the subsequent softening.

It is easy enough to determine the presence of these bacteria both here in their original seat and in the embolisms which are secondarily produced, but it is much more difficult to determine their exact nature and relations. It is clear that they are different from the ordinary bacteria of decomposition, the form called bacterium termo. The fact that they survive within the body is evidence of this, but it is also evidenced by the communicability of the disease. Pyæmia when it once occurs in a hospital ward is very apt to spread to other patients who have septic wounds. Puerperal fever, which is often a form of pyæmia, is known to be in the highest degree communicable. The probability is that we have here to do with a specially virulent form of bacterium which occasionally develops in putrid wounds. It does not, like the septicæmia bacterium, propagate to any considerable extent in the circulating blood, but being carried along it fixes itself at particular points and there forms colonies. It is even doubtful whether it is always the same bacterium which is concerned in pyæmia. The form in most if not all cases is that of the micrococcus.

To return to the softened thrombus, it is clear that when the coagulum has broken down, the soft material and shreds of thrombus will pass up the vein and into the circulation, being carried to the right heart and the lungs. In passing up the veins it soon produces a second thrombosis, which for a time shuts off the vein with its softened contents from the rest of the circulation. The soft material at once proclaims its virulent character by setting up an acute inflammation in the walls of the vein, and this inflammation, like others produced by this virus, rapidly runs on to suppuration, so that a suppurative phlebitis is the result. On post-mortem examination the vein or veins are often found full of pus, and this led earlier observers to infer that a phlebitis was the origin of the disease. The name pyæmia also is derived from the presence of pus in the veins, and its inferred entrance into the blood.

It will be understood that successive coagulation and successive softenings of thrombi will occur, and that on each occasion a fresh series of embolisms will result. The products of the decomposition will also be conveyed into the circulation, and so a SEPTIC POISONING will coexist.

We have now to trace the effects which those emboli produce in distant organs, and it must be borne in mind that they are infective

emboli, containing organisms which in some way produce an intense irritation leading to necrosis and inflammations with a tendency to develop suppuration very rapidly. The embolisms will occur primarily in the lungs, where we meet most constantly with the characteristic metastatic abscesses. Many times the emboli, especially when superficial, lead in the first place to hæmorrhagic infarctions having the usual characters, but these soon break down into collections of pus with the slough of lung tissue in the midst. If the embolism does not issue in

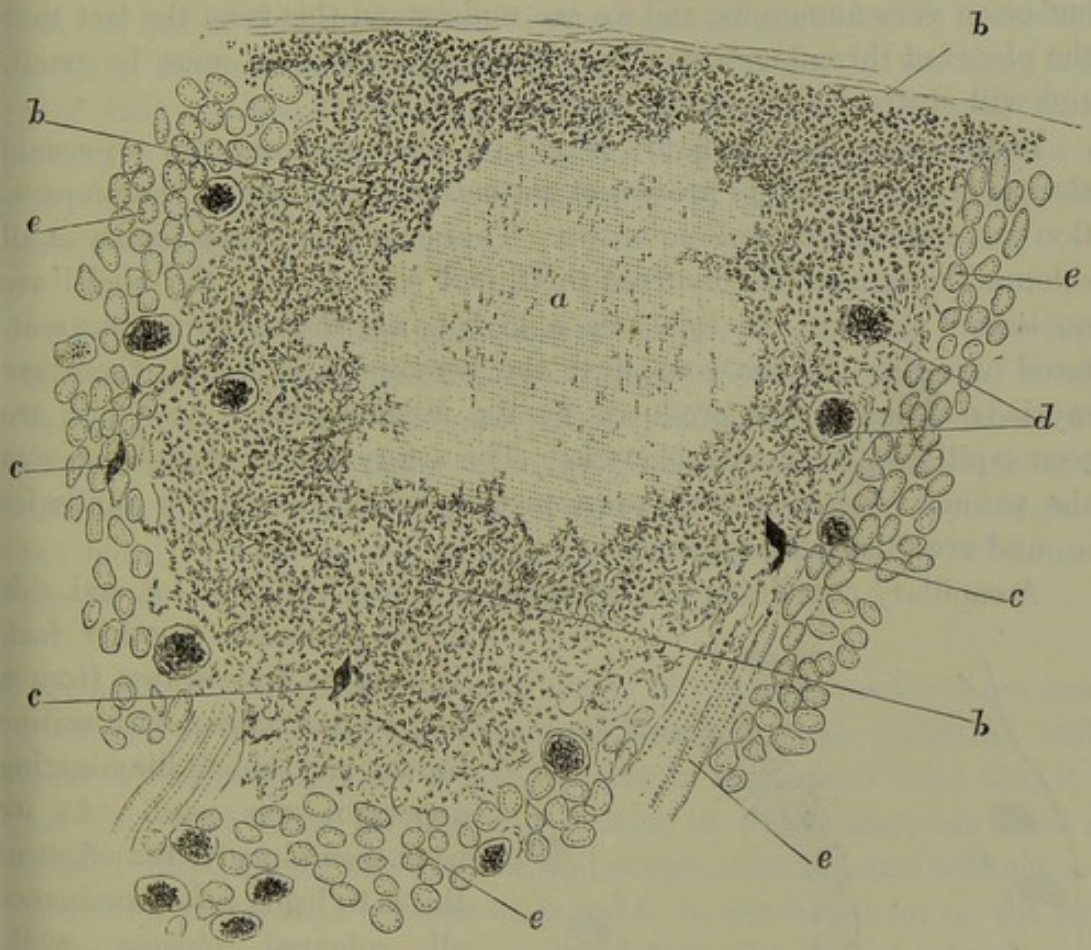


Fig. 110.—Pyæmic abscess of kidney; *a*, necrosed central part; *b*, area of inflammation, the tissue packed with pus corpuscles; *c*, capillaries filled with micrococci; *d*, Malpighian glomeruli; *e*, uriniferous tubules. × 16.

the infarction, then the first result of the inflammation is a condensation, the air vesicles being filled up with inflammatory products, a grey hepatization, which rapidly gives way to a purulent inflammation with necrosis of lung tissue. These various stages may be visible side by side in the same lung. If an abscess be near the surface, the inflammation spreads to the pleura, and an acute pleurisy having the same suppurative tendency results.

Besides, in the lung we may have abscesses in various other organs.

The infective material may pass through the lung capillaries, or else thrombosis having occurred in the pulmonary veins in connection with the abscesses, pieces of the thrombi may be afterwards carried away. In this way abscesses not infrequently occur in the muscular substance of the heart, in the voluntary muscles, in the liver, kidney, etc. Moreover, suppurations occur not infrequently in the joints, and it may be in those far removed from the seat of the original wound. These secondary suppurations in the muscles and kidney are usually small but often very numerous, and we can understand this from the fact that the pieces of thrombus which pass the lung capillaries must be small, and will obstruct either small arteries or capillaries.

In the accompanying figure (Fig. 110), the appearances of a pyæmic abscess of the kidney in process of formation are shown. The preparation was stained with aniline brown. The central part (*a*) is hardly at all coloured; necrosis has occurred in it, and consequently the nuclei are no longer stained. In this area a high power showed numerous scattered bacteria. In the zone next the necrosis (*b* in figure) there are myriads of leucocytes produced by the inflammation. At *c*, *c*, *c*, are seen capillaries filled with bacteria. The artery whose obstruction was the primary lesion is not shown in this section, but many capillaries around are filled with organisms.

A capillary containing the organism is shown in Fig. 111 *b*, and this figure illustrates another fact. The figure was drawn from a preparation stained with aniline brown, and Abbe's illuminating apparatus was used. As we have seen already, the effect of this is to bring into prominence all coloured objects, while those which are unstained are scarcely visible. In this case the nuclei of the uriniferous tubules are stained as well as the bacteria, and they are represented in the figure at *a a*. In the figure a tubule on either side of the capillary is shown, and it will be noticed that the nuclei on the sides of the tubule distal to the capillary are stained, while those next it are not. Here again we have evidence that the first effect of the bacteria is to cause necrosis. It

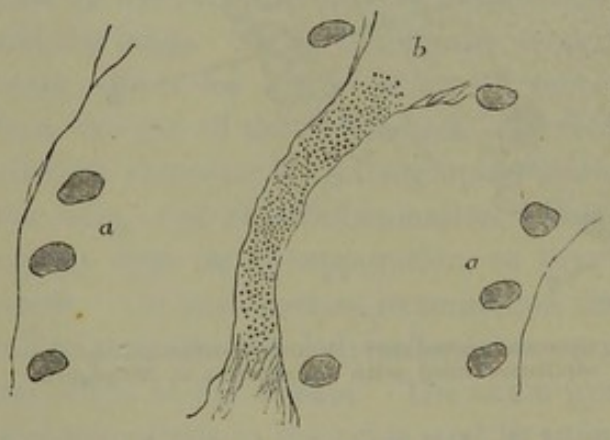


Fig. 111.—Capillary blood-vessel *b* in kidney filled with micrococci, from a case of pyæmia. There is a tubule on either side (*a*, *a*), the nuclei of which are visible except in the neighbourhood of the capillary. × 650.

is seen also that necrosis is produced at a certain distance from the bacteria in the uriniferous tubule while the bacteria are in the capillary. The organism here is a micrococcus.

In the liver the abscesses are frequently large, and they may be present here while absent in the lungs. There are also not infrequently considerable collections of pus in the joints. In these cases of the liver and joints it is probable that the phenomena are not so much embolic in the sense that distinct pieces of coagulum with bacteria are carried off, but rather that single bacteria or groups are conveyed by the blood, settle in the part, and propagate. The blood-current in the liver is so slow that bacteria may readily lodge in the capillaries, and there multiply. In the case of the joints also, if they once get admission to the interior, they are likely to multiply in the synovial fluid, and produce a general inflammation.

Besides these embolic phenomena, the blood is altered. We have seen that it is poisoned with the products of decomposition, and it may be as a result of this that the red corpuscles are to some extent dissolved, their colouring matter staining the tissues and producing icterus, called hæmatogenous, as the colouring matter is directly derived from the blood. There is also an increase in the proportion of white corpuscles as compared with the red, a leucocytosis.

Such is the ordinary course of events in pyæmia, but there are cases in which no thrombosis is discoverable in the veins. Putting aside cases in which thrombosis is present, but in such small veins that it is not discovered, there are undoubted cases in which abscesses occur in liver, kidney, spleen, and muscles, and suppuration in joints without any preceding thrombosis. These cases are to be accounted for on the supposition that the bacteria are introduced from the wound in such small numbers that they do not cause thrombosis in the veins, and consequently in these cases the probability is that they will pass through the lungs and over into the systemic circulation. The frequency of abscesses in the liver in such cases will be readily understood from what has gone before.

To these we have to add a further class in which multiple abscesses occur without any external wound being discoverable. Some of these are associated with ULCERATIVE ENDOCARDITIS, in which, with an inflammation of the valvular structures, there is an aggregation of organisms, but there are cases in which no such connection can be

found, and these are sometimes called cases of SPONTANEOUS PYÆMIA. In this condition, as well as in ulcerative endocarditis, the mode of entrance of the bacteria is obscure.

It is probable that in pyæmia, and in other diseases of a like nature, the bacteria do not of themselves produce the intense irritation manifested. It is the chemical products evolved by them that irritate. Hence the inflammation is frequently present for a considerable distance beyond the seat of the bacteria, the irritant passing out from them and acting on the tissues.

PATHOGENIC BACTERIA IN ACUTE SPECIFIC DISEASES.—We have now to leave the diseases connected with putrid wounds, and consider the question whether pathogenic bacteria exist apart from these. Much that has been already said will be of assistance here, and it will be necessary to make frequent reference to the facts already adduced. The diseases as they occur in man can only be made the subject of experimentation to a limited extent, and so recourse must be had to the similar diseases in animals.

Bacteria have been found in the tissues in a large number of acute diseases in man, and most of these diseases belong to the class of zymotics. Among the diseases in which up to the present such organisms have been seen may be mentioned small-pox, scarlet fever, measles, diphtheria, acute rheumatism, erysipelas, typhoid fever, typhus fever, splenic fever, relapsing fever, pneumonia, leprosy, tuberculosis. All that is asserted in the meantime is that bacteria have been observed in these diseases; it is not meant that each of these diseases depends necessarily on a specific form of micro-organism.

Most of these diseases have several things in common with the septicæmias of mice and rabbits, and it may be interesting to consider these points as well as some others, and to look at them in the light of ascertained facts. Most of them are communicable or infectious; that is to say, they are capable of being produced by the introduction of small quantities of their peculiar virus into the body. We have to inquire to what extent this virus is ascertained to be related to micro-organisms. Some of these diseases are apparently derived, not from persons already the subjects of them, but rather intermediately from foreign substances taken into the body. We have to inquire whether there is evidence that the micro-organisms of any of them are capable of cultivation outside the body, and in what kinds of media. Many of these diseases, when once they attack a person, create a complete or comparative im-

munity against further attacks. We have to inquire what light can be thrown on this fact. Under these three headings, we shall consider this subject.

(1) THE RELATION OF MICRO-ORGANISMS TO ZYMOTIC DISEASES.—Although our information in regard to the causation of most of the specific fevers, and other infective diseases, is very imperfect, still there are several in which the evidence is tolerably clear that they are as closely related to bacteria as are the septicæmias of rabbits and mice.



Fig. 112.—Bacillus anthracis, and of the septicæmia of mice. 700 (KOCH.)

Of these the most fully investigated is the disease now commonly called SPLENIC FEVER, but which has also the names anthrax, char-

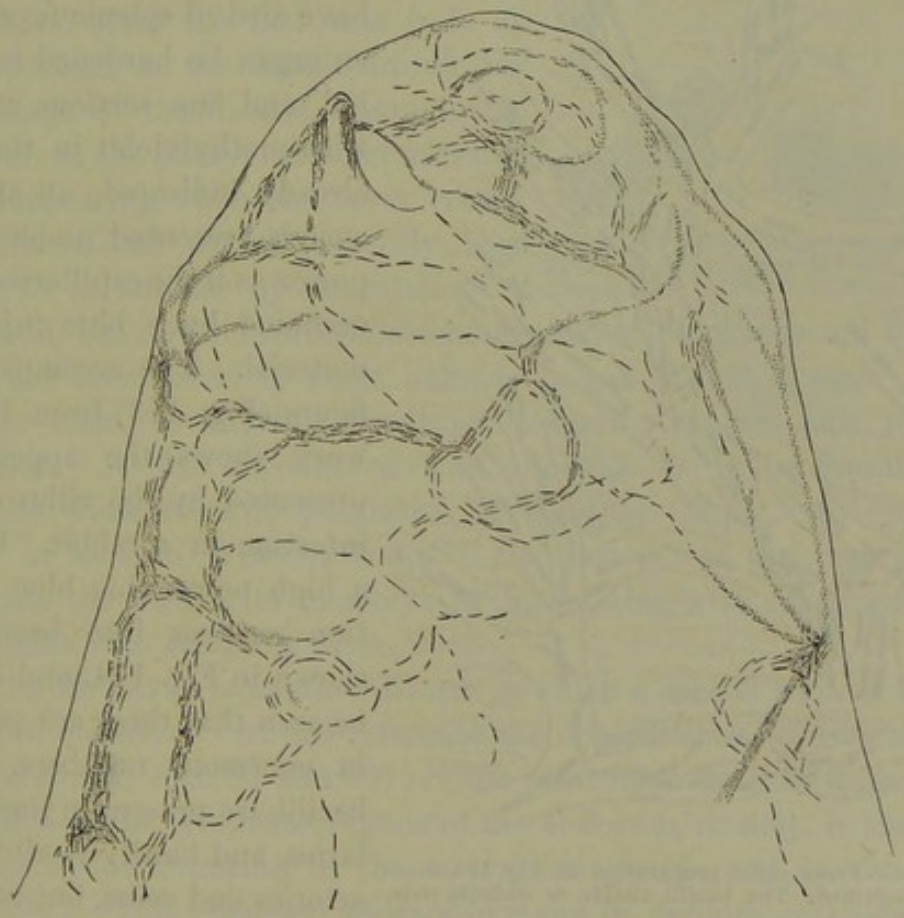


Fig. 113.—Villus of intestine in anthrax, the bacilli visible as minute threads. × 250. (KOCH.)

bon, malignant pustule, etc. This is a disease exceedingly prevalent among our domestic animals, especially cattle, and it is sometimes propagated

to man from these. The disease is an acute fever, in most cases beginning with shivering, and going on with elevation of temperature to a fatal issue. It sometimes has the characters of a local disease in the form of a malignant boil or pustule, and in many of these cases, as well as occasionally in cases of general infection, it does not prove fatal. Death, however, generally occurs, both in animals and man, in from twenty-four to forty hours after the onset of the first symptoms.

Now, in this disease there is present in the blood, and, if there is a local manifestation in the fluids of the part, a very definite form of bacterium which is called the BACILLUS ANTHRACIS. It is, as compared with most of these organisms, of a large size, as may be seen by comparing Fig. 112 *a*, in which it is represented, with Fig. 112 *b*, in which the bacillus of the septicæmia of mice is shown. In its distribution, the bacillus anthracis is very like the last-named form. It is present in quite enormous numbers in the blood of animals which have died of splenic fever. If an organ be hardened in alcohol, and fine sections stained with methylviolet in the way already indicated, an appearance is presented under a low power as if the capillaries were occupied by a blue injection material. The accompanying figure (Fig. 113) from Koch's work shows the appearance presented by the villus of the intestine in a rabbit. Under a high power this blue injection resolves into bacilli, as shown in Fig. 114, and it will be seen that these are present in enormous numbers. The bacilli are present in the capillaries, and hardly at all in the arteries and veins, but as they exist in the capillaries apparently of every organ they must be in incredible numbers. The smallest quantity of blood from such an animal inoculated into a living animal

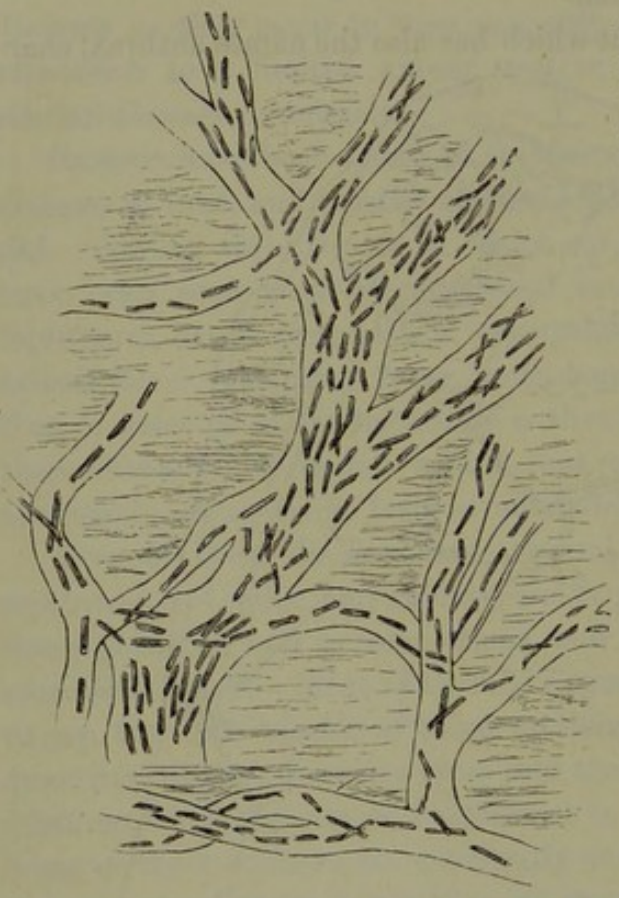


Fig. 114.—From same preparation as Fig. 113, more highly magnified. The bacilli visible as definite rods. × 700. (KOCH.)

such as the mouse, produces the disease, and there is the same enormous reproduction of the organism in the blood. It is clear, therefore, that this disease stands in the same relation to this particular form of bacillus as do the septicæmias of rabbits and mice to theirs.

In the next place, we have one of the acute fevers—RELAPSING FEVER—associated with the presence in the blood of a distinct micro-organism of a spiral form. This organism, which is shown in Fig. 115, belongs to the class spirillum, its specific name being Spirochæta Obermeieri, from its discoverer Obermeier. Spiral organisms have been found in stagnant water, so that this form is not without its analogues in organisms met with outside the body. The spirilla are met with in the blood, and their detection is rendered the more easy from the lively movements which they exhibit, causing the blood corpuscles to be moved about to some extent. That the disease depends on this organism seems to be established from the fact that it is always present in the blood during the acute stage of the disease, disappearing, however, in the interval of defervescence, but reappearing when the fever recurs. The disease had not, till recently, been conveyed to animals by inoculation of the blood, but now it has been communicated to monkeys, and the spirillum has been found in these animals just as in that of man. Other animals seem, so far, to present an immunity against this form of organism. A full account of this organism is to be found in an excellent work, recently published by Vandyke Carter, on "Spirillum Fever as seen in Western India." Dr. Carter was the first to communicate the disease to monkeys by inoculating with the fresh blood of patients with relapsing fever.

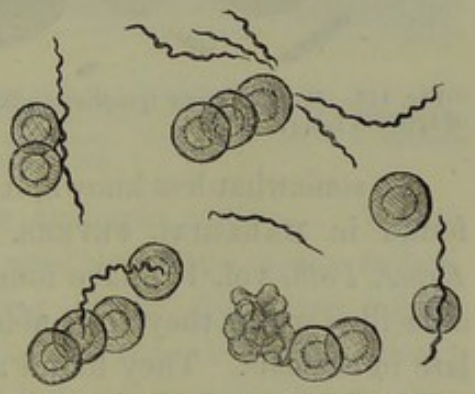


Fig. 115.—Blood from case of relapsing fever, showing corpuscles and spirillum Obermeieri. × 750. (CARTER.)

TYPHOID FEVER is another disease in which a special form of bacillus has been observed. In this reference the observations of Eberth (Virchow's *Archiv*, vols. 80 and 83) are the most important. He has found a bacillus in the lymphatic organs of the abdomen, namely, in the closed follicles of the intestine, in the mesenteric glands, and in the spleen (Fig. 116). This organism appears to stand in definite relation to the duration of the disease. At the beginning of the disease, and at its height, before the sloughing of the intestines has occurred, it is present most abundantly, but as the disease becomes prolonged it diminishes

and disappears. In the cases investigated it was found in a half, being absent in the more advanced cases. This bacillus does not stain so well as most forms, when sections have been made of organs hardened in alcohol, and it is most readily seen when it happens to be in colonies. But, if a lymphatic gland be laid open in the recent state, and a little of the juice from it spread on a coverglass, and stained in the way already described after drying, then the rods will stain well, and we obtain an appearance like that shown in the figure.

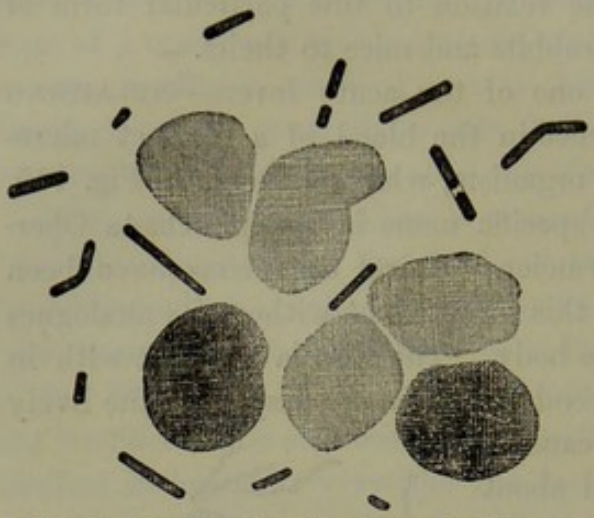


Fig. 116.—Bacillus from lymphatic gland in a case of typhoid fever. × 1800.

As somewhat less known, it may be mentioned that bacilli have been found in MALARIAL FEVERS. Klebs and Tomasi Crudeli (*Archiv f. Exper. Path.* vol. 11) have found in the air of malarial districts in Italy a bacillus which they were able to cultivate out of the body and inoculate in animals. They found a similar bacillus in the blood of men who had died of malarial fever. Klebs also states that in the blood in typhus fever there is a form of bacterium present.

We have already seen that TUBERCULOSIS is to be added to the list of diseases due to a specific bacillus (see Fig. 54, p. 158).

Hansen and Neisser have described a bacillus as being universally present in the nodules in the skin in LEPROSY. These bacilli lie partly in the round cells of the nodules. Klebs asserts that bacteria which can be cultivated are to be found in the SYPHILITIC CHANCRE, but these observations stand in need of confirmation.

ERYSIPELAS is another disease in which bacteria have been found by several observers. The bacteria occur in the lymphatics and lymph spaces, according to some also in the blood-vessels. In the milder cases the organisms, which are in the form of micrococci, are comparatively few in number, but in the more severe forms they fill out the lymph-spaces so as to give almost the appearance of an injection of them with finely granular material (see Fig. 117). The organisms are to be found only at the advancing edge of the erysipelas; when the inflammation once becomes pronounced with rich exudation of leucocytes then the organisms disappear.

Ulcerative endocarditis is a condition in which with acute inflammation of the valvular structures of the heart there is loss of substance by ulceration. On the inflamed surface there are colonies of bacteria, and these are evidently of a virulent kind, like, if not identical with, those in pyæmia. Pieces of the softened valvular structure with the bacteria are carried off, and produce embolism in various organs. The disease occurs nearly always in the valves of the left side of the heart, mainly the aortic, and so the emboli are carried by the systemic arteries. Wherever they come to rest the emboli produce, like septic emboli, necrosis of the immediately neighbouring tissue and acute inflammation, going on to suppuration around. Hence we have multiple abscesses, often with hæmorrhage, in the kidneys, muscles, heart, skin, etc. In the midst of these abscesses the micrococci may be found even when the pus corpuscles are crowded together. It may be added here that in ordinary acute endocarditis micrococci have been asserted by Köster to exist, not on the surface but in the substance of the altered valvular structure, and that by some, acute rheumatism which is the usual cause of acute endocarditis is regarded as due to the presence of bacteria in the blood.

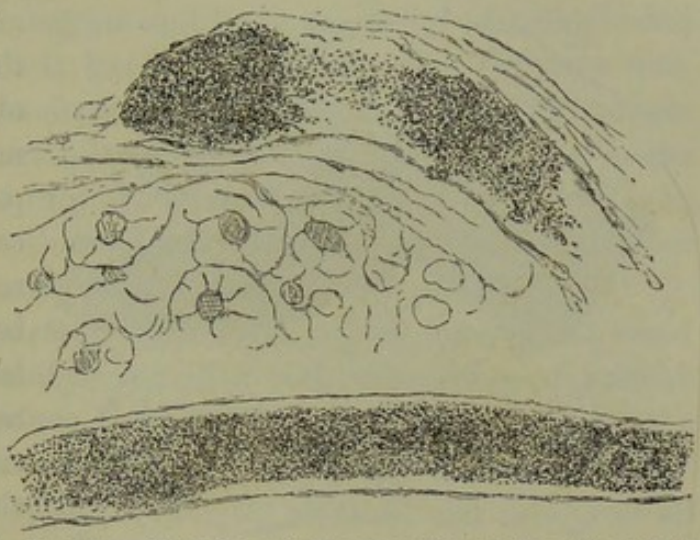


Fig. 117.—From the skin in a case of erysipelas. The upper drawing shows a lymphatic vessel at the border of a sebaceous gland filled with micrococci. The lower shows a straight vessel similarly filled. × 350.

Without going further into particulars it may be said that in a number of other diseases bacteria have been found in the blood or locally, although the question whether these are specific or are the generators of the disease must remain in abeyance. In diphtheria they have been found in the exudation on the mucous membranes, and, by some, in their substance. In scarlatina and diphtheria they have been found in the kidneys occupying the capillaries (Fig. 118), and uriniferous tubules. In small-pox they have been seen in the capillaries of the kidney and liver. In acute pneumonia micrococci have been found occupying the lung alveoli at the advancing border of the disease, in

this respect resembling those of erysipelas, and they have been seen also in the capillaries of the kidney.



Fig. 118.—From a section of the kidney in a case of scarlet fever. A capillary blood-vessel distended with bacteria is shown, with uriniferous tubules around. ×350.

It is here to be stated that our knowledge of the organisms in the diseases mentioned in the preceding paragraph is at present exceedingly imperfect. It is remarkable that the organisms are found in the capillaries of the kidneys in so many cases. The explanation of this may be that at the time of death the bacteria are present there in very small numbers, and that after death they grow into considerable colonies. There is not usually evidence of considerable inflammation around the colonies, and so they can hardly have existed long before death. The mere fact of their presence, however, is important as connecting these diseases with micro-organisms.

(2) CULTIVATION OF PATHOGENIC ORGANISMS OUTSIDE THE BODY. We have already seen that in the case of the septicæmias of mice and rabbits the micro-organisms are capable of cultivation outside the living body, and, if this can be done in the case of the acute infective diseases of man then much light will be thrown on the origin and extension of these diseases. In the case of infective diseases arising from septic wounds, there is no difficulty in believing that the bacteria develop in the putrid exudations. In decomposing fluids there are numerous micro-organisms, and apparently a considerable variety of kinds. Certain of these seem adapted to one kind of animal and certain to others. But when we come to the acute fevers there are as yet few facts having any considerable degree of certainty. Concerning one disease, however, our knowledge is tolerably complete, and on this account it will be treated of here in some detail.

The BACILLUS ANTHRACIS exists, as we have seen, in the blood of animals affected with splenic fever, in the form of minute rods, as in Fig. 113. In the blood it seems incapable of existing in any other form, but it can be readily cultivated outside the body. When placed in a proper medium and kept at a proper temperature, the motionless rods elongate

into threads, and if there be many bacilli present they form a network. After a short time there appear in the threads glancing oval bodies. By and by the threads disintegrate and leave these oval glancing bodies or spores free in the fluid. It has now been abundantly shown that, while the bacilli themselves do not survive long in the dry state, these spores are much more resistant and can be preserved for years in the dry condition. At the end they are as capable of producing the disease as ever. These spores are therefore the fruit or seed of the anthrax bacillus, and may be the means of spreading the disease.

This development of spores from the rods which exist in the blood can take place in a large number of media, both vegetable and animal. The bacilli grow and produce these spores very vigorously on the cut surface of boiled potatoes. They grow readily in hay infusion which has been rendered neutral or slightly alkaline, and in almost all kinds of vegetable infusions. They grow readily and form their spores in neutralized or weakly alkaline urine and in infusions of animal structures in general. It is quite clear that scattered over the surface of the earth there are abundant media for the propagation of this organism. If an animal with this disease is slaughtered, some of its blood is shed in the earth. If there is any piece of vegetable tissue lying there, and the conditions are such as to keep it moist and not too cold, and if it has not an acid reaction, then the bacilli will grow and produce their spores. These spores may be carried hither and thither, and if by accident they get into the body of an animal they elongate into the regular rods, multiply with enormous rapidity, and lead to the symptoms of splenic fever. There is evidence to show that there are in certain parts areas of land which are regarded by the people as particularly dangerous as giving origin to anthrax. These are usually marshy places, and the disease is most likely to extend among cattle after inundations in which presumably the water has carried the infective material about. In these marshy places, especially if a chalky substratum keeps the earth more or less alkaline, there may be a continual growth of the bacillus and a continual danger of propagation.

Another example of the propagation of a pathogenic bacterium outside the body is afforded by Pasteur's researches on CHICKEN CHOLERA. This disease of fowls is due to the existence in the blood of a minute bacterium constricted in the middle, so that at first it looks as if formed of two globular bodies. These organisms grow vigorously in chicken soup which has been neutralized and kept at a proper temperature. The organism may be propagated through several generations in the

chicken soup, and is as capable of producing the disease as ever. It is interesting that this disease is propagated not only by inoculation. If a few drops of the fluid in which it has been cultivated be put on bread, and this given to fowls, the animals acquire the disease, the organisms passing in by the alimentary canal. This disease will occupy us again in considering the question of immunity.

It has been already mentioned that the TUBERCULAR BACILLUS has been cultivated outside the body through several generations, and has retained its virulence throughout.

Regarding the existence of other pathogenic organisms outside the body, very little is yet known. Most of these have been only recently discovered, and are even now being subjected to observation. It may be said, however, that, as already mentioned, the malarial bacillus seems to exist in the air of malarial districts, and is probably propagated among the decayed vegetable substances there. A bacillus like that of typhoid fever has been described as having been found in the drinking water during an epidemic of typhoid fever. (Brautlecht, Virchow's *Archiv*, vol. 84, p. 80.)

(3) THE QUESTION OF IMMUNITY is the next subject with which we are concerned. We have to consider the fact that, under certain circumstances, an infective disease due to the existence of micro-organisms will certainly reproduce the disease in one animal, and will not produce it in another. There are different kinds of immunity. In some cases there is what may be called a natural immunity, and in others it is acquired or induced, as when an attack of small-pox confers immunity to a fresh attack of the disease.

In regard to NATURAL IMMUNITY, it seems that the same micro-organism will propagate itself and produce its special disease in one kind of animal and not in another. This has been brought out in a very striking way by Koch in his researches on the septicæmia of mice. This disease which is so highly inoculable in the ordinary house mice is not at all inoculable in the nearly-allied field mouse. It is inoculable in the rabbit, but, as we shall see afterwards, it produces a local disease, and the bacillus does not propagate in the blood. The anthrax bacillus seems capable of propagation in every class of animal, and we have seen that it can be cultivated in a great variety of media. But yet, animals even of the same species show remarkable differences in the degree of certainty with which they can be inoculated. Chauveau (*Comptes rendus*, 1880, vol. 1, p. 15-26) has shown that while ordinary sheep are highly

susceptible, those from Algiers do not usually acquire the disease from a simple inoculation by a lancet. But when these animals are inoculated with larger quantities of the virus they do succumb. It seems as if they could resist a small number of the bacilli, but that a larger number were able to obtain the upper hand. Again, Pasteur has pointed out that while in ordinary fowls chicken cholera is highly inoculable, yet when inoculated in Cochin China fowls it produces for the most part merely a local inflammation resulting in abscess. The micro-organism which produces the disease is found in the pus, but the pyogenic membrane seems to limit the inroads of the organism.

But even in the same species of animal there are some individuals which show the most remarkable resistance to the attacks of the various organisms. In nearly all the diseases of animals which have been proved to depend on micro-organisms, observation shows that, in the course of a considerable series of experiments, there are some which are proof against the disease, or at least do not acquire it from the same limited inoculation as the generality of their kind.

It would seem from these observations that the organisms are not indifferent to the kind of animal which forms their hosts. One form will flourish in one kind of animal and not in another. Besides, there are individual peculiarities among the same species of animal so that one animal will offer much greater resistance to infection than another.

These facts are perfectly consistent with what we know in regard to this class of diseases in the human subject. Among men there seem to be extreme differences in the degree of susceptibility to infective diseases. Anthrax itself forms sometimes in the human subject a local disease which is recovered from, while in other cases the bacillus enters the blood and produces a fatal general disease. In the former case the bacillus is found in the tissues which are the seat of local inflammation, in the latter it is present abundantly in the blood. We are familiar also with the fact that when several persons are equally exposed to the infection of small-pox, some may escape while others acquire the disease. It is known that among savage tribes measles may present an extraordinary malignancy; in this case it may indeed be that civilized nations have acquired a certain immunity rather than that the others have a special predisposition. A striking illustration of a similar fact is given by Grawitz (Virchow's *Archiv*, vol. 84, p. 110). A troop of Esquimaux visited Berlin, and some were vaccinated with ordinary vaccine lymph. Immediately afterwards three died of an acute fever. Shortly afterwards the remainder were vaccinated in Paris, and

they all perished of what the Parisian physicians called severe small-pox. Here again, it may be, that the European nations generally have acquired immunity from the vaccine virus.

We have now to consider the question of ACQUIRED IMMUNITY, and from what has gone before it will appear that the line between natural and acquired immunity can hardly be rigidly drawn. In the case of measles it is well known that a degree of immunity is acquired by a single attack of the disease against further attacks, but then it appears that this immunity extends in some degree to the descendants of the person attacked, and so in countries where the disease is common there is not an immunity to the disease, but certainly an immunity to the more severe forms of it. It is the same with vaccination. It confers a degree of immunity against small-pox, and even if this disease occurs it is in a milder form than usual. Without at present attempting any explanation of these facts we have to refer in the first place to certain observations which bear on the question of immunity.

In a practical point of view the protection afforded by vaccination against the attacks of small-pox is the type of acquired immunity. It is known that in the lymph of small-pox pustules as well as of those of vaccinia there are fine globular bodies present, which may be called micrococci, and it has been proved by experiment that the virus resides in these solid particles, and not dissolved in the fluid (see Chauveau's researches confirmed by Burdon Sanderson); but the organisms have not been cultivated apart from the body, and it is even possible to suppose that they are not organisms at all. While our information in regard to small-pox is thus limited, some recent researches on other diseases by Pasteur and other French observers are of great interest as throwing light by analogy on vaccination. The aim in these researches was to obtain what may be called a vaccine of certain diseases, that is to say to obtain the virus in a form in which it would produce the disease in a mild form, and yet be a protection against the virulent form of the disease.

Let us take Pasteur's observations on CHICKEN CHOLERA to begin with. By cultivating the bacteria of this disease in chicken soup with exposure to the atmospheric air he found that he could produce what he calls an attenuation of the virus. That is to say by letting the organisms grow on in the same medium for several weeks or months before planting them in a fresh medium he found that each successive generation thus produced was less virulent when inoculated than its predecessor. In fact, by varying the experiment it was possible to

procure viruses of varying degrees of intensity. The ATTENUATED VIRUS produces a local disorder rather than a general one, the bacteria being found in the locally affected parts. But the disease exhausts itself locally, the micro-organism being after a time nullified by the tissues. And now if animals which have been affected by the attenuated virus are inoculated with the virulent form, they do not contract the disease, they have acquired an immunity which lasts at least a year.

Next, in regard to ANTHRAX, Pasteur has produced most striking results. Proceeding on the same principle as in the case of chicken cholera, his object was by prolonged cultivation of the bacillus with exposure to the oxygen of the air to obtain an attenuated condition of the virus. But here a difficulty occurred. We have already seen that when the bacillus anthracis is cultivated it develops threads and spores in the course of a comparatively short time. Pasteur desired, however, to cultivate the organism in the bacillus form. This was effected by cultivating it at a comparatively high temperature. It is not possible to grow it at all at 45° C., but coming down to 42° or 43° it does grow but yields no spores. Thus, the bacillus can be grown for days with exposure to oxygen, and as the period extends the virulence of the organism decreases. In this way an attenuated virus can be produced, and when this is inoculated in an animal the disease is acquired in a mild form, and the animal possesses immunity from the virulent form of it.

Another instance of acquired immunity is afforded by the experiments of Koch. It has been already stated that the septicæmia of mice is not communicable to rabbits, but when the blood of such mice is inoculated into the skin of rabbits, it produces a disease like erysipelas; there is an extending inflammation of the skin, which, however, is recovered from. Similarly, the cornea of rabbits may be inoculated, with the effect of producing a spreading inflammation, the inflammation in both cases being accompanied by the growth of the bacillus. But when the animal recovers it presents a condition of immunity against further inoculation. It is noteworthy that this immunity does not become complete all at once, but takes in some cases three or four weeks.

We have now to endeavour to EXPLAIN THE DIFFERENT KINDS OF IMMUNITY. Here we are met with serious difficulties. Pasteur has suggested that for the growth of each micro-organism there is a certain substance in the blood necessary, and when this is exhausted the micro-

organism dies, and till that substance is reproduced there is no longer any possibility of its growth. There are obvious objections to this. For one thing the organisms may be cultivated out of the body in the very blood in which they would not grow while it was in the living body. Then such a view will hardly explain the natural immunity which we have seen to be so closely allied to the acquired. We cannot suppose that those who are naturally indisposed to these diseases have blood which is defective in particular chemical principles. That this is not the case has been shown by Chauveau, for he found that the Algerine sheep which are not affected by a small dose of anthrax virus do succumb to a larger dose. This points to an unusual degree of resistance to the virus—the bacillus is nullified by the tissues, and must attack in force before it surmounts the opposition. We may suppose that when an animal survives one of these diseases it has in its struggle with it acquired an increased power of resisting and destroying the organisms, and the power lasts a longer or shorter period.

It should be stated here that by no means all of these diseases confer immunity by a single attack. Relapsing fever has been proved experimentally to be capable of repetition again and again in the same monkey, and it is well known that ague repeats itself frequently. There are even persons who are liable to repeated attacks of those fevers which usually confer immunity by a single attack. We find, for instance, persons who take scarlatina several times during a limited period.

The question occurs here, How do these organisms produce their effects on the living body? It is quite clear that some of them produce chemical principles which act injuriously on the living tissues. This is abundantly evident in the case of pyæmia. The organisms here produce a necrosis with inflammation around. But neither the necrosis nor the inflammation occurs in immediate proximity to the bacteria, and it is clear that some chemical products passing off from the organisms act as violent irritants. It is so also in erysipelas. The organisms propagate themselves up the lymph spaces and leave behind products which lead to inflammation. And we may suppose it to be the same when the organisms multiply in the blood. It is not they themselves but the products evolved in the processes of multiplication and growth that are poisonous. Pasteur believes that the drowsiness which occurs in chicken cholera is due to the formation of a narcotic by the organism.

SARCINA VENTRICULI.

We have here to consider a form of parasite whose position in the vegetable kingdom is rather obscure. This organism occurs in the form of minute cubical bodies, each of which is partially divided by transverse grooves so as to make the cube somewhat like a parcel tied with crossing cord (see Fig. 119). It is as if the individual sarcina were made up by the coalescence of four smaller bodies, and by some methods of preparation the four smaller bodies assume a more nearly globular form, and so still more suggest such an origin. These bodies are found mostly in the stomach where processes of fermentation are proceeding. But they are met with in other situations besides. From the observations of Lostorfer and Ferrier it appears that the sarcina appears spontaneously in the blood when it is kept free from contamination at a certain temperature. If, for instance, blood be taken fresh from the vessels into a capillary tube, and preserved in a water bath at a temperature near that of the body, in almost every case sarcinæ will develop in the course of a few days (see Lostorfer, *Wien. Med. Jahrbücher*, 1871, and Ferrier, *Brit. Med. Jour.*, Jan. 27, 1872). The sarcinæ first appear as minute glancing globular bodies, and by and by they aggregate into the regular cubes. These cubes are much smaller than those of the sarcinæ found in the stomach, but when placed in a proper nourishing fluid such as Pasteur's solution, they grow to the size of these and assume their brownish colour.

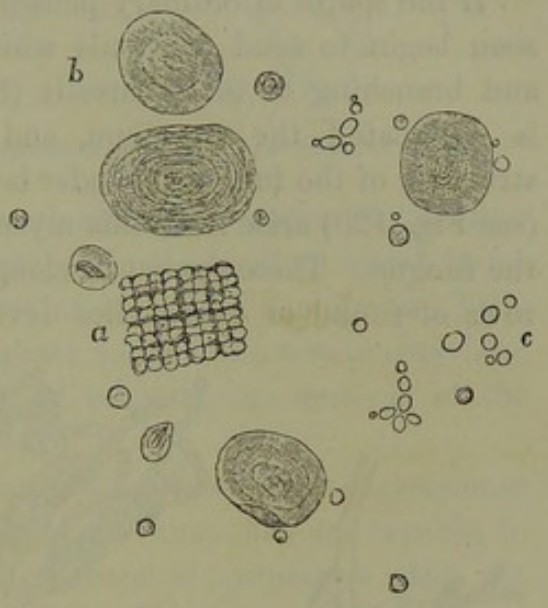


Fig. 119.—Sarcinæ ventriculi (*a*), starch granules (*b*), and fungus spores (*c*), from vomited matter. × 350.

It thus appears that, in the blood of man, and also, as experiment has shown, in that of animals, there are germs which have the capability of developing the sarcinæ. Occurring in the stomach, the germs are probably derived from the blood, the stomach acting as a breeding oven. This explains the fact that sarcinæ are met with elsewhere, as in urine, pus from cavities, gangrenous fluid, etc.

The exact botanical relations of sarcinæ are not determined. Some call them algæ. The fact of their appearing in the blood first as minute globular bodies suggests that they may be allied to the bacteria.

PARASITIC FUNGI.

The fungi are defined as consisting of cells devoid of chlorophyll, and occurring in the form of threads (hyphæ) and round or oval bodies (spores and conidia).

If the spores of ordinary penicillium fall into a fitting medium they soon begin to send out buds which become threads. By elongation and branching of these threads (hyphæ) a network is formed, which is designated the mycelium, and is regarded generally as the root structure of the fungus. Under favourable circumstances upright stems (see Fig. 120) arise from this mycelium which bear the fructification of the fungus. These consist of elongated cells at the extremity of which rows of round or oval bodies develop in a pencil-like fashion, as seen in Fig. 120. This appearance has caused this form of common mould to be called penicillium. These round or oval bodies are spores, and each of them when carried off from the fungus is capable of giving rise to a fresh plant. It is asserted that in addition to this mode of fructification which is non-sexual, there is, probably in the case of all fungi, a sexual fructification, and much speculation has arisen as to the powers of the spores thus variously produced. These speculations do not concern us here, but it may be observed that so long as the sexual fructification is not determined the exact generic and specific relations of the individual fungi must remain obscure.

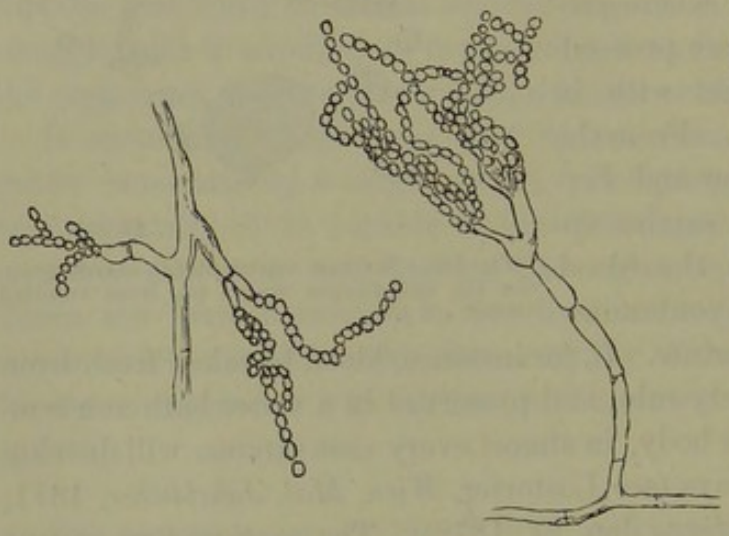


Fig. 120.—Aerial growth of penicillium.

The mode of production of spores figured above occurs when the fungus is able to send shoots up into the air; it is an aerial production as distinguished from the mycelium which is in the soil. But a process in some respects similar often takes place in the soil itself. This is shown in the case of the same fungus in Fig. 121, where it is seen that instead of forming elongated threads the cells are dividing into oval bodies. In many of these the hour-glass shape indicates the pro-

cess of division actually in progress. In this way spores may be produced which are here called conidia. It is clear that this also is a non-sexual reproduction, and that it is strictly comparable with the aerial reproduction already mentioned. In fact the spores produced in the latter way are also frequently called conidia.

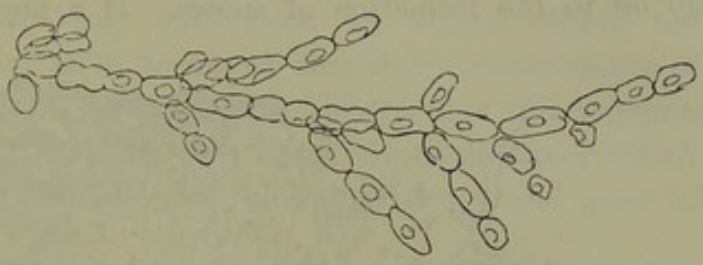


Fig. 121.—Formation of conidia in submerged portion of penicillium.

It is to be remarked further that, with almost no attempt to produce threads, the spores or conidia may multiply in the medium which forms their soil, and so we may have masses of spores or conidia and little else. This is the condition of the yeast fungus, the torula cerevisiæ, and we often find multiplying spores of fungi in the contents of the stomach, as in Fig. 119.

In their pathological relations fungi are of much less consequence than the schizomycetæ, and it does not appear that they are capable, to any considerable extent, of producing chemical principles that are seriously injurious to the animal tissues. There are some diseases in which the existence of fungi in the body is rather to be regarded as secondary, the primary diseased condition providing a fitting soil for the growth of the fungus, but there are other conditions in which they act injuriously by their presence and growth.

It may be well here to inquire whether FUNGI, like the bacteria, are divisible into PATHOGENIC AND INNOCUOUS forms. In answer to this, it may be said that there appear to be no fungi capable of actually multiplying in the body, but there are some which possess the capability of growing there. Most fungi, when the spores are injected into the blood, simply die and are destroyed, but according to the researches of Grohe, Block, and Grawitz (Virchow's *Archiv*, vols. 81 and 84) there are some which may survive and grow inside the body. When spores of such pathogenic fungi are introduced into the blood, they pass to various parts of the body, where they bud out and grow, by their growth producing numerous local necroses which may cause death in three days, or an inflammation which may lead to the death of the fungus and the formation of a capsule around it. In the illustrations to Grawitz's paper, the condition presented to the naked eye by the kidneys is shown, and the resemblance of the multiple necroses to

metastatic abscesses in pyæmia is very striking. In each of these a growing fungus is to be found, as shown in Fig. 122, but it does not go on to the formation of spores. If a piece of the tissue be used,

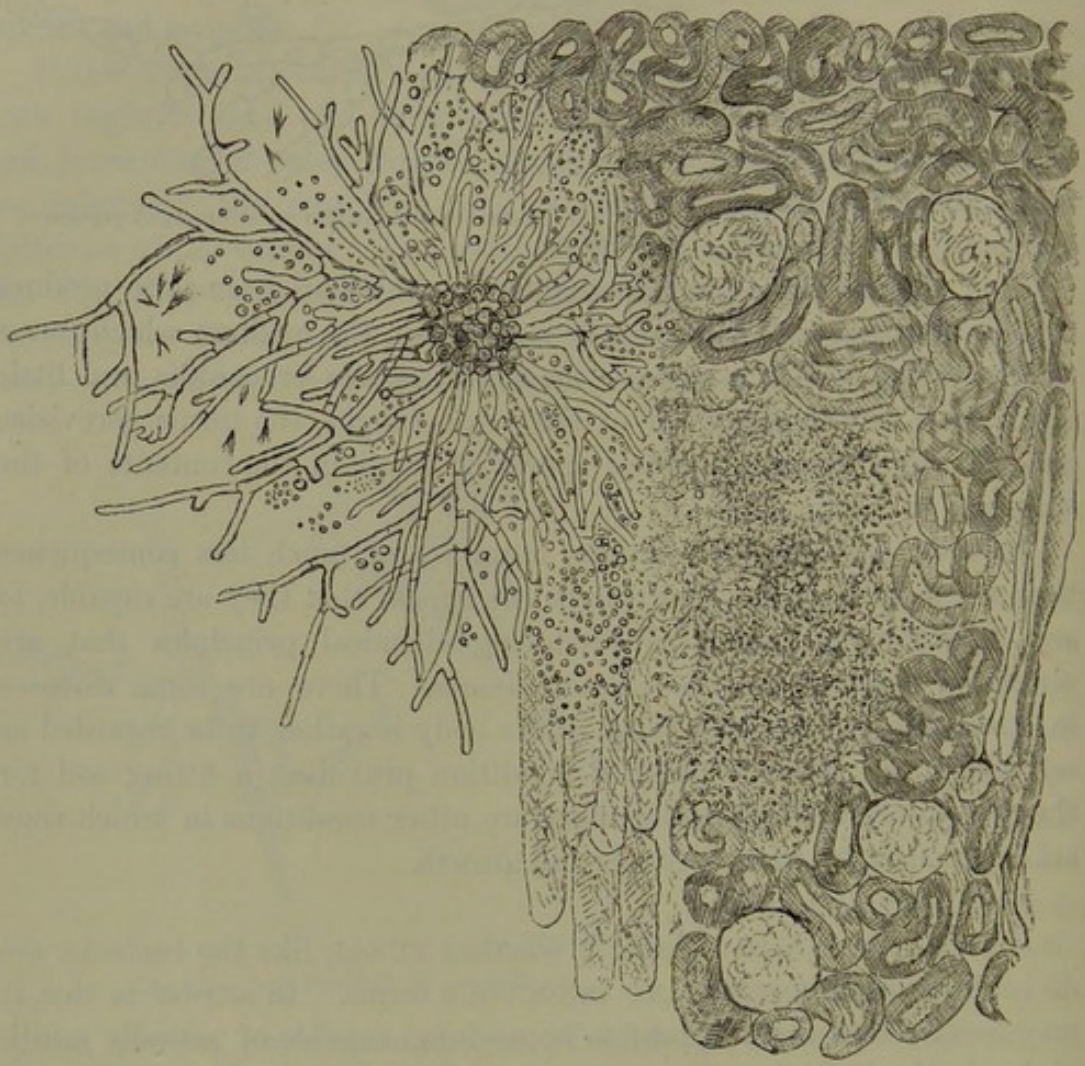


Fig. 122.—Fungus growth in kidney. To the left of the figure the kidney tissue has been cleared up by adding solution of soda so as to bring out the fungus (aspergillus). Fat drops and crystals of tyrosin are present, but no spores. (GRAWITZ.)

however, the fungus may be cultivated outside the body in a suitable medium, and it goes on to the production of spores in the usual fashion.

The question occurs here, Are there certain species of fungi which have this special character, or are the ordinary fungi capable of becoming pathogenic? This question has been answered in the latter sense by Grawitz. He asserts that the ordinary mould fungi, by being cultivated through several generations in alkaline solutions of albumen, at a temperature of 38° to 40° C., acquire virulent properties as above. Con-

siderable doubt has been thrown on these conclusions by the researches of Koch and his assistants. They have found that the spores of the aspergillus glaucus, without any cultivation in animal fluids, are always pathogenic, and they seem to assert that in the experiments of Grawitz there has been a contamination with the spores of this common fungus. We are to infer, therefore, that there are some fungi which are naturally able to resist the action of the living tissues, and grow in spite of them.

The MADURA FOOT is a disease which occurs in the East, and whose relations to fungi have been investigated by Vandyke Carter. In this disease a fungus, called in honour of its discoverer Chionyphe Carteri, penetrates into the substance of the foot, producing canals and cavities among the soft structures and the bones, and giving rise to severe inflammations. In the cavities and canals are masses of fungi of a blackish colour and forming frequent balls. The canals open externally and discharge a fœtid pus containing spores and threads of the fungus. There is great thickening and an appearance resembling that of scrofulous disease, and the condition is a chronic one for which amputation must frequently be performed.

In a considerable number of cases a fungus has been found IN THE EAR. It has its seat in the external meatus and on the membrana tympani, where it is accompanied by desquamation of the epithelium and other signs of inflammation. It is noteworthy here, in connection with what has gone before, that the fungus met with seems always an aspergillus, although spores of penicillium are as abundant in the air, and the two fungi are usually associated in mould. Fungi have also been met with in cavities of the lungs, on ulcers of the skin, etc.

FUNGI are of frequent occurrence IN THE SKIN, and there are three forms of skin disease which are always associated with the presence of these parasites, namely Ringworm, Pityriasis versicolor, and Favus. In all of these the fungus appears in the form of multiplying spores or conidia, with irregular production of mycelium, but there is no proper fructification, the nearest approach to that being in the case of pityriasis versicolor. The consideration of these fungi will come up for more particular study under the section on Diseases of the Skin. We have here to refer to the general conditions which they present. The fungus grows chiefly among the epidermic elements, spores and mycel-

ium penetrating among the cells and displacing or breaking up the structures such as the hairs, etc. (Fig. 123). It is usual to describe the

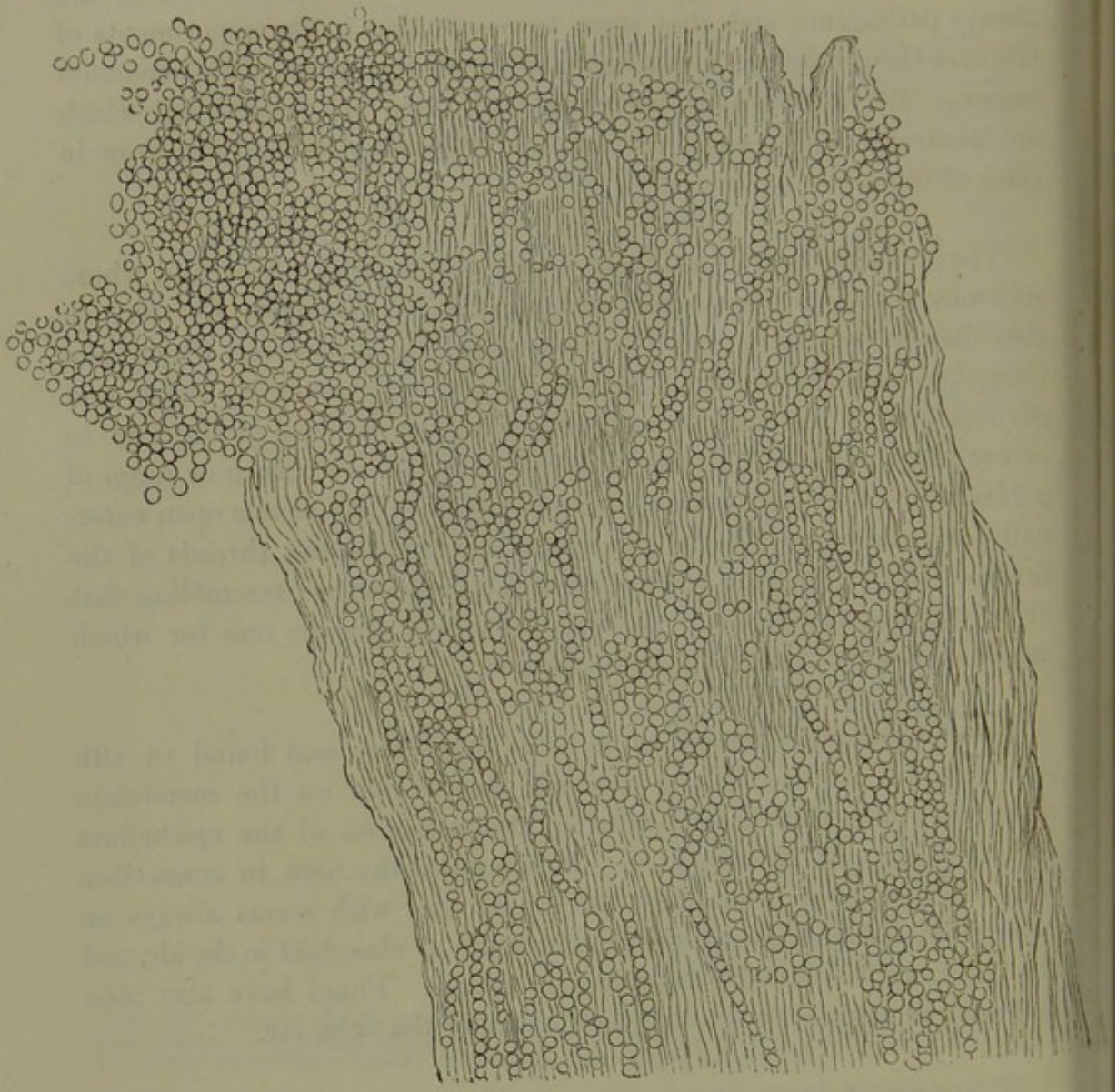


Fig. 123.—Hair from a case of ringworm, showing fungus penetrating and breaking up the shaft. × 350.

fungi of these three diseases as different, and they are named Achorion Schœnleinii (favus), Trichophyton tonsurans (ringworm), and Microporon furfuri (pityriasis versicolor). Doubts have been raised, however, chiefly at the suggestion of Hebra, whether the fungus is not identical in all the three, and whether it is not one of the common moulds occurring in a special form and locality. It might appear that such a question would be easy of answer by means of observation of the fungus and its cultivation. But there are two difficulties which are encountered

here. In the first place, as the fungus only occurs in the form of multiplying spores and irregular threads, the fructification is not manifested, and the classification of fungi, as we know, is based on the fructification. Then, in the second place, the cultivation of the fungus has, in the hands of different observers, led to apparently contradictory results. Almost all the commoner moulds have been developed from the products of these diseases, and considering the wide prevalence of the spores of fungi in the air, and the probability that many such spores are continually falling on the skin, it is difficult to be certain that accidental contamination has not occurred.

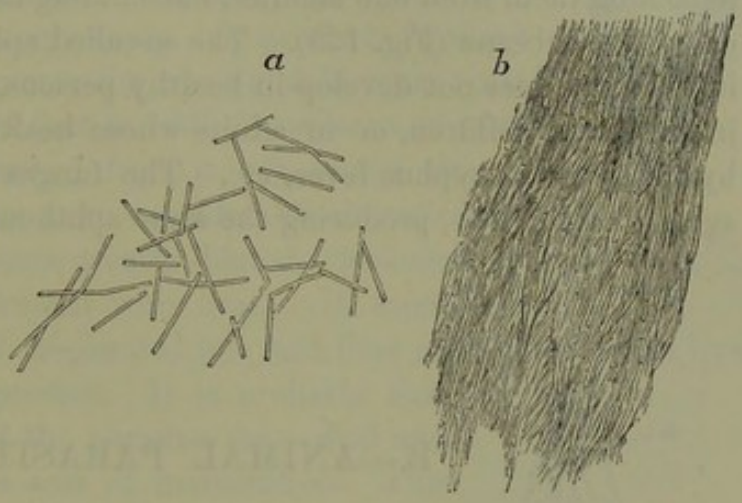


Fig. 124.—Leptothrix buccalis from the gums at edges of teeth, *a*, the filaments separated; *b*, masses of filaments × 350.

In the mouth, fungi are frequently to be found. The white material which lies in the angle between the teeth and the gums always contains multitudinous threads of a fungus or schizomyceta, called Leptothrix buccalis (see Fig. 124). This occurs in the form of fine threads which often hang together in bunches. It has been asserted by Leber and Rottenstein that this organism, by penetrating into the teeth produces caries; but, considering its universal presence in contact with the teeth, this seems doubtful. There is one circumstance which, however, is in favour of this view, namely, that the organism seems to aggregate lime salts in

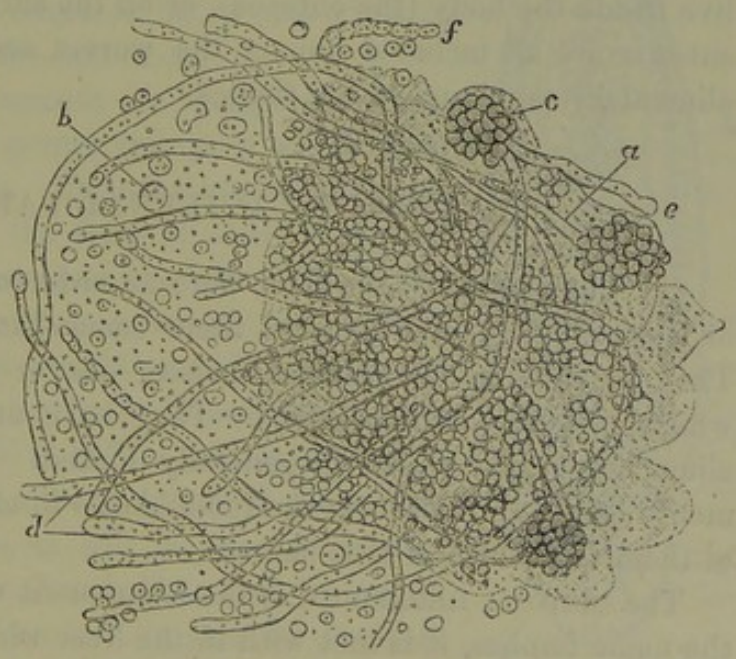


Fig. 125.—Oidium albicans, from the mouth in a case of thrush. (Kuchenmeister.)

its nutritive processes. It usually attracts the lime from the food, and forms with other matters the so-called "tartar" on the teeth, but it is conceivable that it may acquire lime from the teeth, and so produce softening of them and caries.

There is a disease of the mouth called commonly THRUSH, dependent on a fungus, the oidium albicans. Here, as in the case of the parasitic skin diseases, the fungus grows among the epithelial cells, detaching them from one another, but binding them together into a kind of soft membrane (Fig. 125). The so-called aphthous condition arising in this way does not develop in healthy persons, but is met with chiefly in emaciated children, or in adults whose health has been depreciated by tuberculosis, typhus fever, etc. The fungus may extend to œsophagus, stomach, etc., producing the same aphthous patches.

B.—ANIMAL PARASITES.

The Animal Parasites are divisible into two groups according as they live inside the body (the entozoa), or on the surface (the epizoa). The entozoa are all included among the worms, and are met with in the alimentary canal and in the tissues.

ENTOZOA OR INTERNAL PARASITES.

(1) TREMATODA.—We have here an order of flat-worms of a more or less oval form, and many of them somewhat in the form of a leaf. They possess, on the ventral surface, one or more sucking discs by which they attach themselves. They have only one opening of the alimentary canal which is generally forked. These worms are commonly called FLUKES from the resemblance in shape of the commonest of them to the fish of that name.

The DISTOMA HEPATICUM is the commonest worm of this order. As the name implies, it is met with in the liver where it inhabits the bile ducts. The liver fluke is generally about an inch in length (Fig. 126) and rather more than half an inch in greatest breadth. The body is very flat, and anteriorly it ends in an elongated process, forming a kind of head. This head bears the mouth, and a short distance behind it

comes the sucking disc. Between these lies the opening of the sexual apparatus, of which both male and female organs exist in each individual. The uterus forms a convoluted tube behind the sexual opening, and the seminal tubules lie still further back. This parasite is very common in certain of the lower animals, especially sheep. It occurs in enormous numbers in the bile ducts, which are dilated by it but not otherwise strikingly altered. As many as 1,000 have been obtained from a single sheep. It produces in sheep the disease called commonly the rot, which in some years is very fatal. It is said that in 1830-31 between one and two million sheep perished from it. It occurs also in oxen, where it produces more considerable alterations of the ducts. These become greatly dilated, thickened by inflammation, and incrusted with lime. It sometimes happens that masses of inspissated bile and lime salts form in the liver where the flukes are present. It is probable that in these cases many of the parasites have died and become themselves the seat of incrustation. This fluke has also been met with in horses and asses, and in some rare cases in man. In man it has not been observed in large numbers, but it may produce serious obstruction of the bile ducts.



Fig. 126. — Distoma hepaticum. (LEUCKART.)

The eggs of this parasite are small oval bodies, which, in water, develop into embryoes which swim about by the aid of cilia. Their further development is unknown, and also the form in which they pass into the animal which becomes the host of the adult.

The DISTOMA SINENSE is a parasite met with in the East, and described by M'Connell in the *Lancet* in 1875, and independently by Macgregor in the *Glasgow Medical Journal* in 1877. Although a much smaller worm it is of a more elongated shape than the distoma hepaticum, as will be seen from Fig. 127. It is rather more than half an inch in length, and about an eighth of an inch in greatest breadth. When seen in the bile in the fresh state, the edges show a beautiful delicate green colour, tinged with yellow, while the centre is of a deep brown. In the accompanying figure the position and appearances

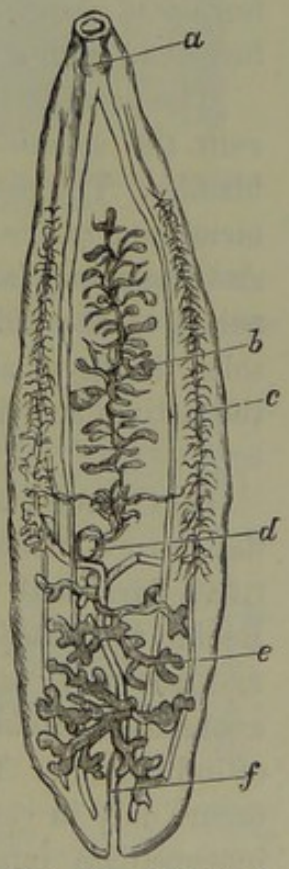


Fig. 127.—Distoma sinense, *a*, œsophagus and stomach tubes; *b*, uterus; *c*, yolk glands; *d*, ovary; *e*, testes; *f*, termination of water vascular system. × 5. (After MACGREGOR.)

of the various organs are indicated. The eggs are very small, and each animal possesses thousands.

This parasite has only hitherto been observed in man, and is found in very large numbers—not less than 500, probably more—in the ducts of the liver and in the gall bladder. In Dr. Macgregor's cases the persons affected with the parasites were Chinese, and they were the victims of a peculiar paralysis of the legs and arms. Dr. M'Connell's case was also in a Chinaman.

The DISTOMA LANCEOLATUM is another form of fluke. It is less than three-eighths of an inch in length, and about the fifteenth of an inch in breadth. It is seldom seen in man, and occurs in comparatively small numbers in sheep and cattle, producing little disturbance.

The DISTOMA HÆMATOBIUM, also called the Bilharzia hæmatobia, has the male and female organs in different individuals. The male is about half an inch in length, and flat, but rolled up at the edges, especially behind, so as to form a kind of gutter in which the female lodges. The female is about a half longer, but filiform. The eggs are small and furnished with a spine at the end or at the side.

The parasite inhabits the blood-vessels of its host, chiefly the portal vein, the splenic and mesenteric veins, and those of the rectum and bladder. The penetration of the eggs in large numbers into the mucous membrane of the rectum and urinary bladder produces great irritation, and frequently hæmorrhage. Similar irritation may be produced in the pelvis of the kidney and ureters. This parasite is met with almost solely in Egypt and Abyssinia, and it is said that in Egypt about half the natives are victims of it.

(2) CESTODA or TAPE-WORMS.—These are in the mature state long flat worms, without mouth or alimentary canal. Anteriorly there is a HEAD furnished with some apparatus for attaching itself to the host. Behind the head and neck the worm forms a series of segments called PROGLOTTIDES, each of which develops a bi-sexual apparatus and is, so far, a complete individual. The adult worm or STROBILUS is therefore a colony of individuals. The worm inhabits the alimentary canal and apparently occurs only in vertebrate animals. Besides this adult form there is an intermediate immature form, called the SCOLEX, which occurs in the tissues of animals. The scolex has a head like that of the mature worm, and generally possesses a sac or cyst into which it can retire.

There are representatives of two families of this parasite met with in man, namely the Tænia and Bothriocephalus.

The TÆNIA SOLIUM is of very common occurrence in this country. The strobilus or mature worm occurs in the alimentary canal, and the head is usually situated in the duodenum or upper part of the jejunum, while the rest of the animal extends downwards in the canal, attaining on an average a length of from ten to twelve feet. As already mentioned, this, like other tapeworms, has no alimentary canal, and supports itself by imbibition of nutritious material from the intestine.

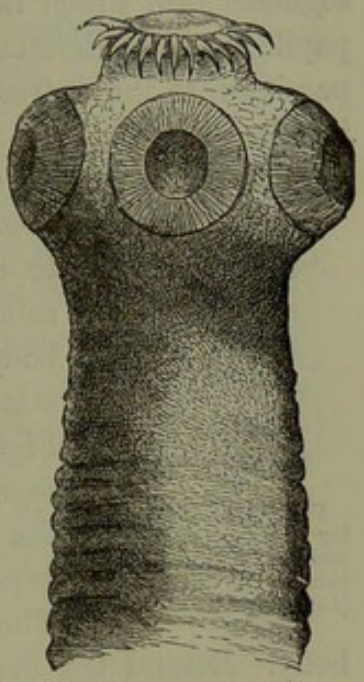


Fig. 128.—Head of T. solium. × 45. (LEUCKART.)

The head of the worm, which is represented in Fig. 128, is about the size of a pin's head, and of a generally rounded form. In front it is prolonged so as to form a proboscis or rostellum, which is surrounded by a circle of twenty-six hooklets. The wide part of the head has four large sucking discs. On the head follows a narrow neck, which is so thin that it readily breaks when the worm is handled, rendering it difficult to obtain the small head. The proper neck is about half an inch in length, and it gradually merges in the anterior part of the body in which fine transverse lines begin to appear as the first indication of the formation of segments. On passing down, the worm increases in breadth, while the segments elongate and become more completely divided. At first the segments or proglottides are homogeneous in appearance, but by and by the sexual apparatus begins to appear. The total number of segments in a worm ten feet in length is about 800. The sexual apparatus begins to appear about the 200th segment from the front, and is mature about the 450th; it consists of the male and female organs which are present in each segment. The male organs consist of a large number of vesicles scattered throughout the segment, as shown in Fig. 129, but more abundant anteriorly, as the female organs occupy the space behind. The vesicles are connected

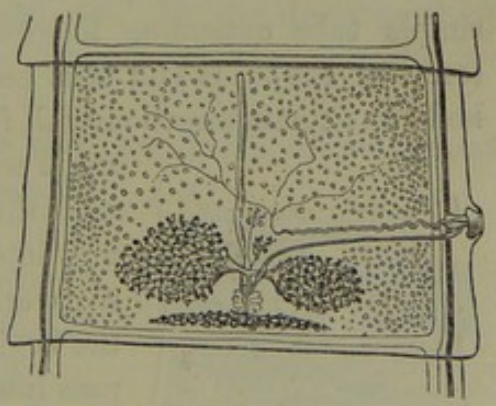


Fig. 129.—Unripe proglottis of T. solium showing sexual organs. The small vesicles scattered throughout are the male organs. The other structures shown are seminal tubes, vagina, globular body, yolk body, ovaries, and unbranched uterus. × 10. (LEUCKART.)

with fine seminal tubules which are difficult to make out, and are shown in the figure as fine branching lines. These end in a slightly convoluted tube, the vas deferens which is generally very distinct, and this passes across the segment to the papilla, a slight projection at the side of the segment into which the male and female sexual organs open. At the papilla the vas deferens ends in a projectile penis which is capable of passing into the extremity of the female organ, the first part of which is called the vagina.

The vagina forms a canal which passes transversely across the segment towards the middle line and tends also backwards, to end in a somewhat globular dilatation, sometimes called the GLOBULAR BODY. The connections of this body are difficult to make out, but they may be stated as follows, and understood by the annexed Figs. 129 and 130. In the posterior part of the segment as shown in Fig. 129 are seen on either side the comparatively large ovaries, forming tree-like expansions, consisting of a congeries of closed tubes. The ovaries have ducts which pass into the globular body. Behind the ovaries and the globular body is the yolk gland which is of a somewhat pyramidal shape and spread out laterally. This also communicates with the globular body in front of it. Besides these communications the globular body, which is thus the central part of the female organs, communicates with the uterus in front. At this period of maturity the uterus consists of a simple tube extending longitudinally in the middle of the segment (see Fig. 129). It will thus be observed (Fig. 130) that the globular body has communication with four distinct structures, *a* with the yolk-sac, *b* with the ovaries, *c* with the vagina, and *d* with the uterus. The eggs pass from the ovaries first into the globular body, where they receive a covering of yolk, are fertilized, and undergo the beginning of their development. Then they pass into the uterus, which they fill up. As the ova accumulate in the uterus, this begins to throw out lateral branches to the number of seven to ten (see Fig. 131). The lateral branches often show considerable ramifications, in this respect and in their number contrasting with those of the next tape-worm. In the fully mature proglottis only the uterus crowded with ova is visible,

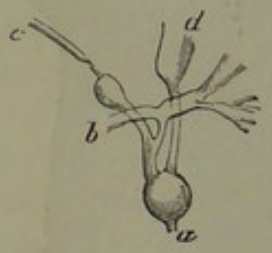


Fig. 130.—The globular body, or Mellis's body and its connections. See text. × 30 (LEUCKART.)

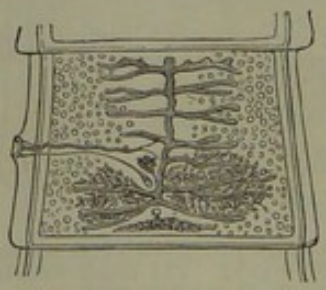


Fig. 131.—Proglottis of T. solium, showing branching of uterus. × 5.

the remaining organs having disappeared (see Fig. 132). The prominent ova often make the position and shape of the uterus very distinct, especially if the proglottis be spread out on a glass slide and allowed to dry.

Besides the sexual organs the proglottides possess muscular fibres, and a water-vascular system. The muscle is non-striated and consists of longitudinal and transverse bundles. The water-vascular or excretory systems (shown in Figs. 129 and 131) is in the form of tolerably wide channels, which begin at the head and are continued through the proglottides by two lateral channels right down to the last, where they open outwards. Near the posterior extremity of each proglottis the tubes form transverse communications (see figures). It is possible to inject these tubes from above downwards, but not from below upwards. In addition, the proglottides, as well as the head of the worm, possess numerous round or oval calcareous bodies, which are mainly in the superficial layers of the parenchyma.



Fig. 132.—Two ripe proglottides of T. solium, with branches of uterus shown. × 2. (LEUCKART.)

As the proglottides become mature they sever their connection with the worm and drop off from its lower extremity one by one. They pass down the alimentary canal, and are discharged with the fæces, or else work their way out through the anus by virtue of their contractile power. For a short time after discharge they still show a writhing movement, but they soon come to rest and die. By the decomposition of the proglottis the ova are set free and are ready under suitable circumstances to develop further.

It is mostly in the bodies of swine that the tænia solium passes through the next phase of its development, although sometimes it occurs in man. It is exceedingly doubtful whether a man who is the host of a mature tape-worm can be affected from it with the form now to be described.



a *b*

Fig. 133.—Ova of T. solium. *a* with yolk, *b* without yolk, as in mature segments. The hard brown shell is indicated. (LEUCKART.)

The ova (Fig. 133) are surrounded by a dense shell of a brownish colour. Inside the shell the egg develops an embryo which acquires six boring spines. When such ova get into the intestinal canal of the pig, the shell bursts, and the embryo with its spines escapes. It proceeds to bore its way outwards, and

after piercing the alimentary canal it finds its way to the muscles of the animal where it finds a lodgement.

Arrived in its desired seat, the embryo comes to a state of rest, and after a time develops into a vesicle or cyst, which afterwards forms the proper CYSTICERCUS. The appearance of these cysticerci in the muscular tissue is shown in Fig. 134, which is drawn of the natural size. The complete cysticercus or scolex has a head developed in connection with the vesicle, which closely resembles the head of the mature worm (Fig. 135), and we have now to consider how this head forms. The observations of Leuckart and others have thrown much light on this, as

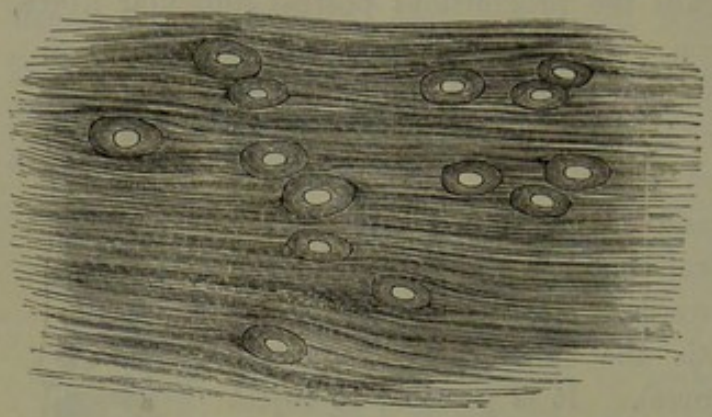


Fig. 134.—Cysticerci of tænia solium in muscle. Natural size. (LEUCKART.)

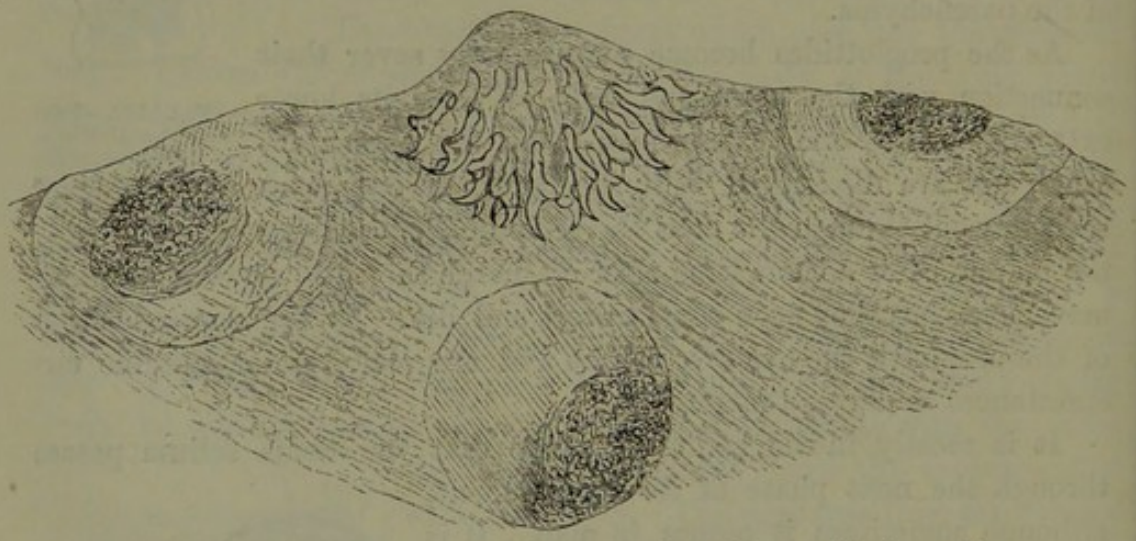


Fig. 135.—Head of cysticercus cellulosæ found in substance of brain. × 90.

they are based on actual experiments in which swine were fed with the ova.

We have seen that in the muscle a vesicle or cyst is formed. After a time a slight thickening of the wall of the cyst appears. This grows inwards into the cyst, carrying with it, however, the external wall, so that the projection inwards is hollow with an internal canal continuous with the surface of the cyst, and so opens externally; this is shown in Fig. 136, where a portion of the wall of the cyst is preserved, and the

projection is shown with its internal cavity communicating with the surface of the cyst. This projection enlarges, and by and by the peculiar structures of the head, namely, the four sucking discs and the hooklets, show themselves. But these are formed inside the canal, near its extremity, and they are in an inverted position as compared with that of the mature tapeworm. The head with its hooklets are thus at the bottom of the canal, and the four suckers, looking towards each other, follow. After a time the head acquires the power of inverting itself outwards, and thus projecting from the vesicle, or again withdrawing itself within the vesicle as before. This is effected by means of muscular fibres. For the completion of this phase of development a period of from three to four months is required from the time of the ova being taken into the alimentary canal.

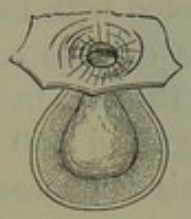


Fig. 136.—Cysticercus with beginning of development of head. A portion of the original cyst is shown with the projection inwards of a hollow process which communicates externally. ×25. (LEUCKART.)

It sometimes happens that this scolex of the tænia solium develops in the human subject, and then it is often spoken of as the CYSTICERCUS CELLULOSÆ. It occurs chiefly in the brain, in the eyeball, and in muscle. It is to be remarked that in rare cases the scolex assumes in the brain a very peculiar character. The cyst, developing in the membranes on the surface of the brain, presents pouches and swellings which give it somewhat the character of a bunch of grapes, and so has given rise to the designation cysticercus racemosus. The cysticercus is usually surrounded by a connective-tissue capsule which is produced from the surrounding tissue and encloses both cyst and head, but not infrequently, especially in the brain and eyeball, it is devoid of this secondary capsule. In that case the vesicle sometimes grows to considerable dimensions, and the head is able to protrude itself and move about in various directions, perhaps in the ventricle of the brain or the eyeball. In these parts the scolex may produce considerable disturbances.

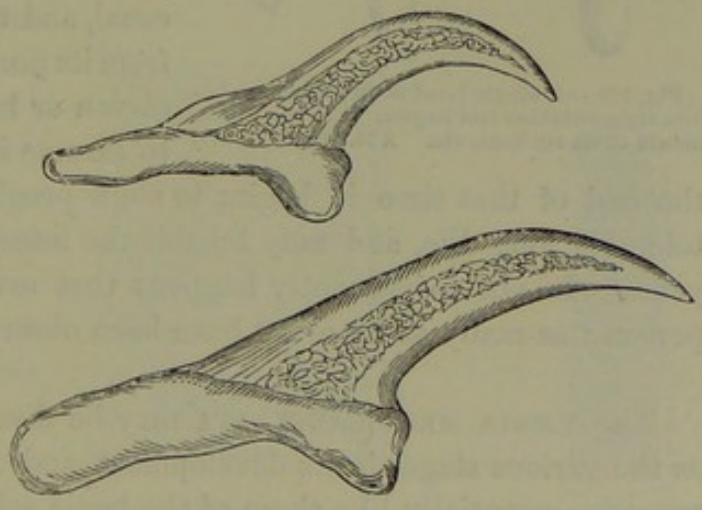


Fig. 137.—Hooks from head of cysticercus cellulosæ. ×350.

Although capable of a considerable duration of life, after a time the scolex usually dies, and then it shrinks and becomes, probably, incrusted with lime salts. The hooklets are the most resistant parts, and it is of some consequence to observe the size and general appearance of these. In Fig. 137 are represented the hooklets of this worm, magnified 350 times. They are to be contrasted with those of the tænia echinococcus (Fig. 138), which are magnified to the same extent.

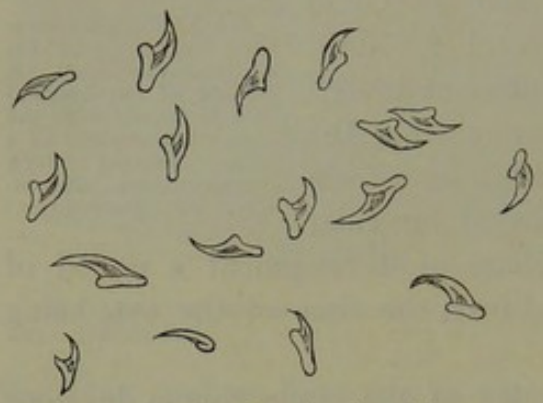


Fig. 138.—Hooks from tænia echinococcus. ×350.

It will be seen that in the tænia solium there are two sizes of hooklets, a larger and a smaller, and by comparison with Fig. 135 it will be seen that these are arranged alternately around the rostellum. In this as in other respects, the heads of the scolex and of the mature worm are identical.

We have now to trace the further progress of development where living scolices are taken into the alimentary canal of man. In the first place, the vesicle and everything but the head and neck are lost, and we have a small creature which has considerable power of elongating and moving about its suckers, as shown in Fig. 139. The head now fixes itself to the wall of the alimentary canal, and the body begins to develop from its posterior extremity. It takes eleven or twelve weeks for the worm to assume its full dimensions, and at the end of that time it begins to show proglottides. The worm is of tolerably long life, and may inhabit the intestine of its host for many years. It not infrequently happens that several co-exist in the same person ; as many as 30 or 40 have been observed.

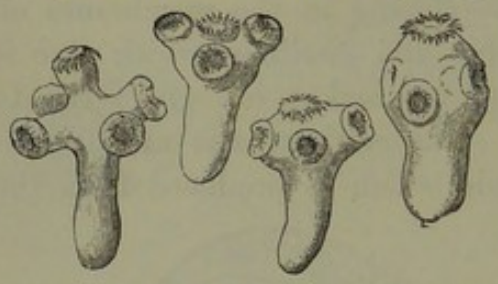


Fig. 139.—A single head of tænia solium before segmentation has begun. It shows movements of its suckers, etc. ×25. (LEUCKART.)

The TÆNIA MEDIOCANELLATA may be dismissed much more shortly as the various stages in its development and its structure are, in most respects, essentially like those of the tænia solium. Leuckart calls this tape-worm the TÆNIA SAGINATA.

The strobilus is a larger worm than the tænia solium, measuring from about thirteen feet in the contracted state to about twenty-four feet when

extended. Fig. 140 shows the head and neck of this worm in the contracted and relaxed conditions. The difference in length and breadth is very striking. The head has no rostellum or circle of hooks, but it possesses four large sucking discs which are usually surrounded by a zone of pigment. The segments are in the most of the worm broader than they are long, attaining a breadth of about half an inch. But as we come to the fully mature proglottides with embryoes in the uterus, then they are considerably elongated and at the same time narrower. The number of segments is greater here than in the tænia solium, reaching as high a figure as 1,300. There are generally about eight discharged from the posterior extremity daily, and these very often find their way outwards, through the anus, by their own movement.

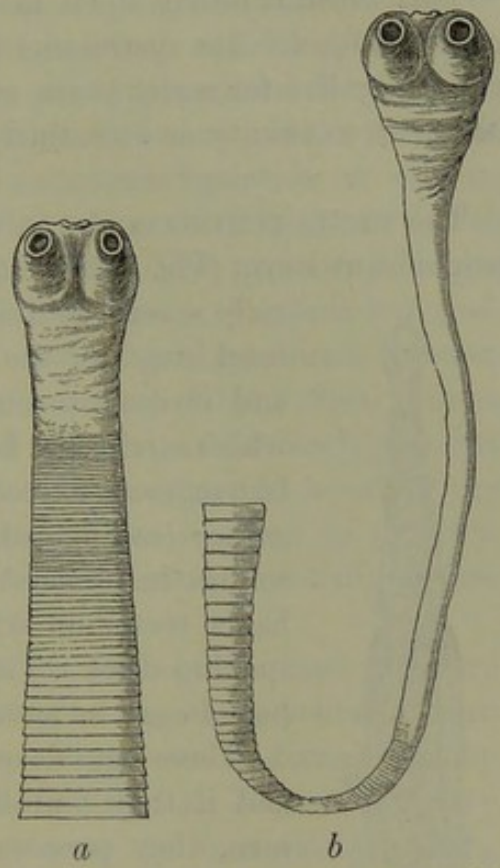


Fig. 140.—Head and neck of tænia mediocanellata; *a*, in contracted, and *b*, uncontracted state. ×8. (LEUCKART.

The sexual organs, except the uterus, are essentially the same as in the taenia solium. The uterus, however, presents in the mature proglottis a much larger number of lateral offsets, as many as twenty to thirty, and these mostly branch dichotomously instead of ramifying (see Figs. 141 and 142).

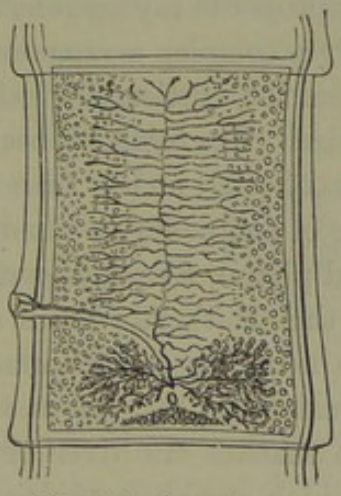


Fig. 141.—Immature proglottis of T. mediocanellata × 5. (LEUCKART).



Fig. 142.—Mature proglottis of T. mediocanellata. × 2. (LEUCKART.)

The individual segments, like the worm as a whole, possess muscular fibres and are capable of elongating and contracting.

The scolex form of this worm is found chiefly in cattle, and it inhabits mostly the muscles, but is also met with in

other organs. The cysticercus measures about the third of an inch, and is of a roundish shape.

This worm is nearly equal in frequency to the taenia solium in the human subject. Its cysticercus is not known to occur in man. The worm may live for many years, at least as long as eleven, and, as some assert, up to twenty or even thirty years.

The TÆNIA ECHINOCOCCUS in the strobilus form is a comparatively insignificant worm (Fig. 143). It inhabits the dog, and there are generally several individuals present at the same time. The total length of the worm is about an eighth of an inch, and it consists only of four segments, including that which carries the head. In the fully developed state the last segment exceeds in length the rest of the worm altogether (see figure). The head is like that of the tænia solium in miniature, being very greatly less in size. It has a rostellum with thirty to forty hooklets, and four sucking discs. The last segment develops a large number of eggs, as many as 5000.



Fig. 143.—Adult tænia echinococcus. × 12. (LEUCKART.)

These eggs develop the usual embryoes with six spines, and if they find their way into the intestinal canal of man, they pass out into the tissues. Settling in some organ of the body, they show the most extraordinary powers of development, producing the condition commonly called HYDATIDS.

It is proper to say here that hydatids occur in the form of large cysts, often of very complex arrangement, and they should be carefully distinguished from the cysticerci which form small cysts not more than half an inch in size. The hydatids occur in the majority of cases in the liver. Neisser has collected no less than 986 cases of hydatids in man, and he gives the scale of frequency in the different organs as follows:—Liver, 451; lungs and pleura, 84; kidneys, 80; muscle and subcutaneous tissue (including the orbit), 72; brain, 68; spinal cord, 13; female organs of generation (including the mamma), 44; male organs, 6; pelvis, 36; organs of circulation, 29; spleen and bones, 28; eye, 3.

When the embryo reaches the liver or other resting place, it soon develops into a cyst which at first is of slow growth. The membrane of the cyst is of considerable thickness, and consists of an external cuticle in several layers and an internal parenchymatous layer containing muscular fibre and a vascular system. Inside the original vesicle arise

very frequently secondary vesicles, and inside these even tertiary ones, the successive vesicles being sometimes spoken of as daughter or granddaughter vesicles. It sometimes happens that the secondary vesicles project outwards, and form a series of external vesicles which may separate from their mother and attain an independent development alongside of her. This latter form is particularly common in the domestic animals, and it is variously designated exogenous hydatids, or echinococcus scoleciparíens, or granulosus. There is a third form which has been met with in man, and always in the liver. The parasite develops a congeries of small vesicles, from the size of a grain of wheat to a pea. These are embedded in a gelatinous tissue and sometimes possess gelatinous contents. As the whole is surrounded by a firm fibrous capsule, the tumour is a somewhat solid one, and on section it presents a peculiar alveolar appearance. From this structure it is called the alveolar form, and it should be particularly borne in mind, as this condition has been frequently mistaken for a tumour, especially before Virchow demonstrated its true nature.

Except in the case of the alveolar form, the vesicles, both primary and secondary, enlarge very much and give rise to tumours of very large dimensions, so as sometimes to produce serious disturbance by their mere size. Those of the liver are usually the largest, and they may come to weigh as much as twelve, twenty, or even thirty pounds. The simple vesicles, in which no daughters develop, attain the size of an orange or a fist.

In all forms of hydatids the whole parasite is surrounded by a fibrous capsule, developed by the organ in which it has its seat. As the cysts enlarge, this also increases in size.

We have now to consider the formation of the heads of the worms, which differs in certain respects from that of the other tænias. In the walls of the vesicles, either primary or secondary, are to be seen when they are perfectly fresh, a number of small white points which have their seat in the internal wall. These are what are called BROOD-CAPSULES, and it is always in connection with them that the heads or scolices develop. The brood-capsules are little vesicles, in the walls of which the echinococcus head grows. The heads begin (see Fig. 144, in which the development of heads in brood-capsules is shown) as projec-

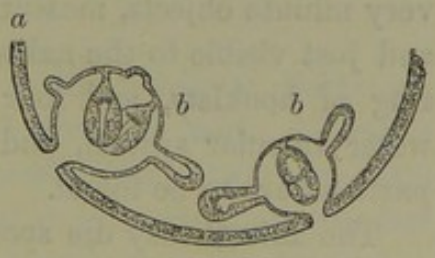


Fig. 144.—Diagrammatical illustration of development of echinococcus heads in brood-capsules. *a*, Wall of cyst. *b b*, Brood-capsules, with heads in various stages of development. (LEUCKART.)

tions outwards of the wall of the brood-capsule. The projection is hollow, and communicates with the interior of the brood-capsule. The head develops inside this projection, as in the case of the tænia solium, and very soon acquires the power of inverting itself. When it does so, it projects into the brood-capsule, so that in this respect the brood-capsule is not like the cyst of the cysticercus as the scolex projects outwards from the latter. A single brood-capsule develops several heads, up to twelve, and they may be found either in the extended or inverted position. All the heads are contained in brood-capsules, but if after death or during removal the brood-capsule bursts, then an appearance may be produced as if the heads were attached to the wall of the cyst itself. If the capsule bursts, its remains may gather round its stalk and the heads stand up from this as in Fig. 145 *b b*. Heads may also be

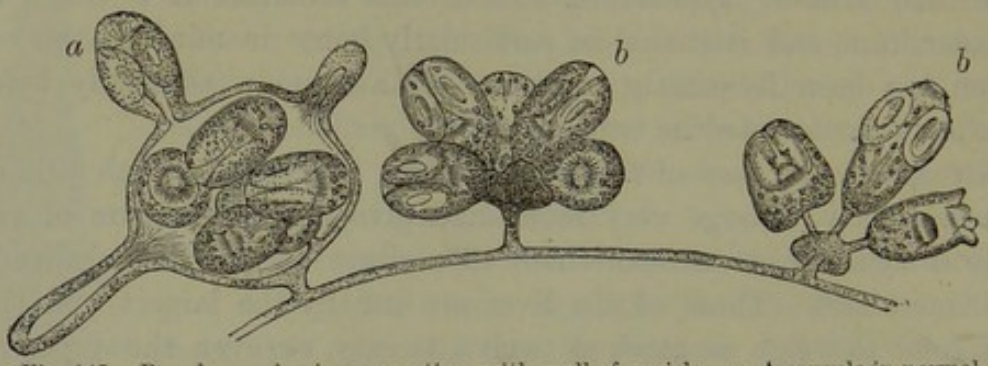


Fig. 145.—Brood-capsules in connection with wall of vesicle. *a*, A capsule in normal unruptured state. *b b*, Ruptured capsule. × 40. (LEUCKART.)

found lying free if the capsules have burst. It is to be added that sometimes the vesicles remain barren, neither brood-capsules nor heads developing in them.

The heads are exactly like those of the mature worm. They are very minute objects, measuring about $\frac{1}{70}$th of an inch in long diameter, and just visible to the naked eye. They possess a proboscis with the ring of hooklets, and four suckers. They are also provided with a water vascular system, and in their parenchyma abundant calcareous particles are to be found.

The animal may die spontaneously, or be killed by the fluid which fills the vesicles being drawn off. In that case the vesicles shrink, and their contents become converted into a fatty debris, which afterwards may become infiltrated with lime salts. In this way the hydatid mass may be represented by a cyst filled with an atheromatous material. This may dry-in, and at last we may have nothing left but a stony or mortar-like mass, in which careful search may still discover the

hooklets (Fig. 138). Besides the distinctive hooklets, or even without them, there are usually in these old cysts bits of the membrane of the cyst. The wall of the hydatid cyst consists of two layers, an external (called by Huxley the ectocyst) and an internal (the endocyst). The ectocyst consists of a structureless stratified membrane, composed of a chitinous substance, from which circumstance it is often called the cuticle. As this chitinous membrane is very resistant it may be found in the midst of the grumous contents and enable the structure to be recognized. In the case from which Fig. 146 was taken the diagnosis

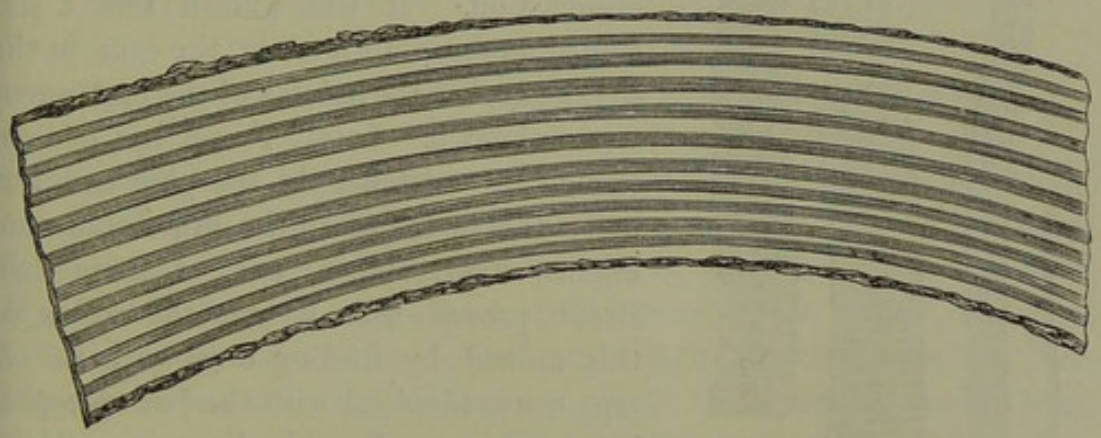


Fig. 146.—Transverse section of the chitinous membrane from an old hydatid cyst of the kidney. × 90.

was made chiefly by flakes of this membrane being found, the search for hooklets being in vain.

In regard to the distribution of the echinococcus, it is of pretty frequent occurrence in all known lands, but is particularly common in Iceland where the men, living in close companionship with the dogs, are much exposed to infection. It is also said to be very common in Australia and neighbouring colonies.

The BOTHRIOCEPHALUS LATUS belongs to the family of Bothriocephalidæ, and is the largest tape-worm which occurs in man. It attains a length of from 16 to 26 feet, and possesses from 3000 to 4000 segments, which are mostly much broader than long, although the last ones (see Fig. 147) become longer and narrower so as to assume more of a square shape. The breadth at the widest part is about half an inch. The worm is also thick and heavy.

The head (Fig. 148) is oval, and about the twenty-fifth of an inch in breadth. It is blunt at the extremity, and possesses neither hooklets nor suckers, but fixes itself by means of a slit-like groove on either side of the head (see figure).

The sexual organs, and especially the uterus, occupy the middle part of each segment, where they form a rather prominent knot or rosette (Fig. 149). The uterus is composed of a convoluted tube which gives the rosette-like appearance just mentioned. The sexual organs open in the middle line near the anterior extremity of the proglottis. The eggs are oval in form and are covered by a brown shell.

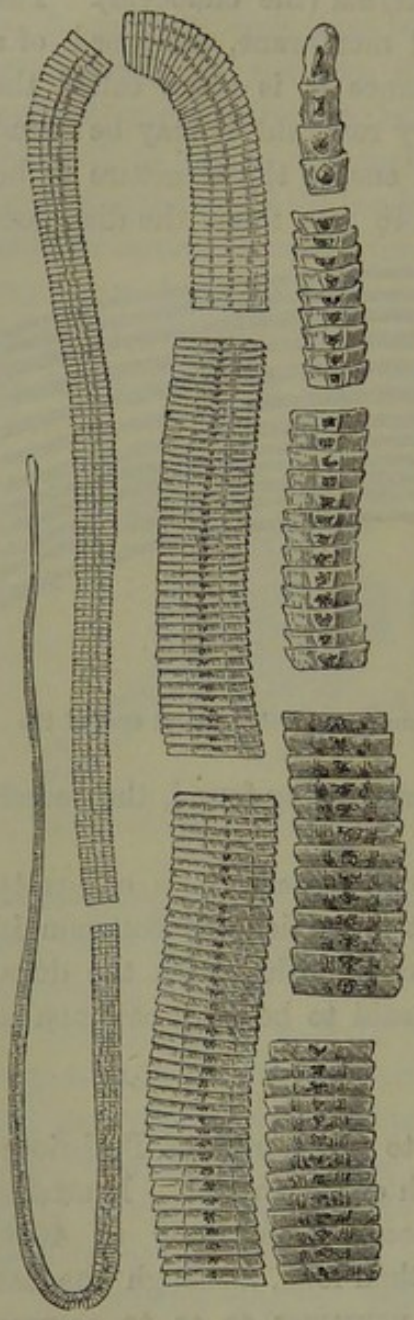


Fig. 147. — The Eothriocephalus latus. Natural size. (LEUCKART.)

The scolex form of the worm long eluded observation. It was known that a six-spined embryo formed in the eggs in the usual way, but the habitat of the cysticercus was unknown. Lately Braun has demonstrated its existence in the pike and turbot. It was found in the muscles, sexual organs, liver, spleen, etc., of these fish. Braun proved that it was the scolex of this animal by feeding dogs with it. A tape-worm identical with the bothriocephalus developed. By this discovery all the tape-worms which occur in Europeans have been traced in their mature and cysticercus forms.

This worm is of rather frequent occurrence in Switzerland and north-east Europe, but it is not unknown in this country. The frequency of fresh-water lakes in Switzerland explains its frequent occurrence there from the use of the fish which form the hosts of the scolex form. Like the other tape-worms the mature worm occurs in the small intestines.

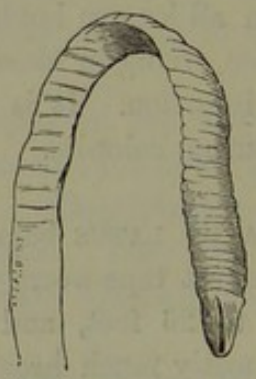


Fig. 148.— Head and portion of body of Bothriocephalus latus × 8. (LEUCKART.)

Several other small and infrequent tape-worms have been met with

in man. The TÆNIA NANA has only been observed once and in Egypt. It is very small, scarcely an inch in length, and about the fiftieth of an

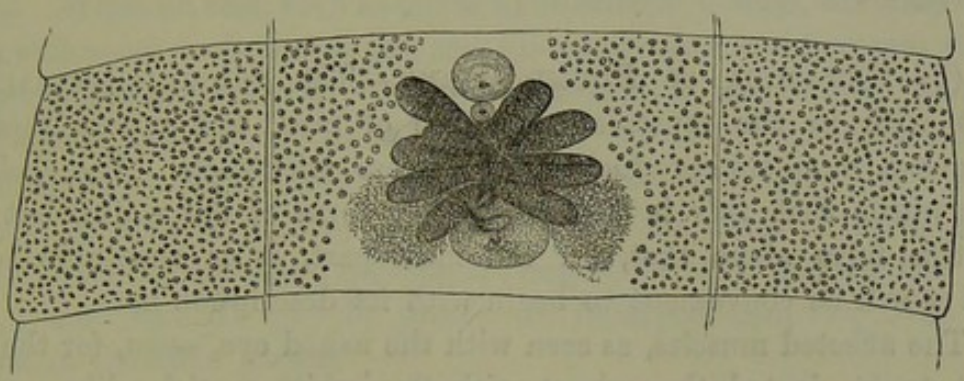


Fig. 149.—Proglottis of Bothriocephalus latus, showing female organs. × 12. (LEUCKART.)

inch in breadth. It possesses a rostellum with hooklets and four sucking discs. The TÆNIA FLAVO-PUNCTA has also been observed but once, in America. It is about a foot in length, and about one-twentieth of an inch in breadth. The head of this worm is not known, but it is believed to possess hooklets. The TÆNIA MADAGASCARIENSIS has been found in an island on the Madagascar coast. It is about 3 inches long, and the head is not yet known. The TÆNIA CUCUMERINA is from 7 to 10 inches long. Its head possesses a rostellum with a quadruple circle of hooklets to the number of about 60. The proglottides reach a breadth of about the twelfth of an inch. It occurs very frequently in dogs and cats, and is often present in large numbers, especially in dogs. It has been found in several cases in man, and it seems to be not infrequent in children. The scolex form has lately been found in the dog-louse (Trichodectes canis), and it can be readily understood how in the process of licking itself the dog often swallows its host and becomes itself the host of the strobilus. It may be conveyed to children from the tongue of the dog. The TÆNIA MARGINATA is a tape-worm of large size, and of common occurrence in the dog. Its usual length is about 5 feet, but it may be as long as 8 feet. It is very like the tænia solium, the head possessing a rostellum and hooklets of about the same size but more numerous. On the whole, however, the worm is smaller, and so are the proglottides. The scolex form inhabits swine and the ruminants, and as it often develops a large vesicle or set of vesicles, it is liable to be confused with the tænia echinococcus. The scolex form is called the cysticercus tenuicollis. Neither mature worm nor cysticercus is met with in man. The dog also frequently contains two other tæniæ, namely the T. SERRATA and T. CŒNURUS. These also resemble the tænia solium,

and the latter is important, as its scolex form frequently attacks lambs, and, lodging in the brain, is the cause of the very fatal disease "staggers."

(3) NEMATODA or ROUND-WORMS.—The TRICHINA SPIRALIS is met with in the muscular substance of man, and occurs there in immense numbers, producing the disease trichinosis. We shall see afterwards that this is not the mature form of the worm, but it is in this form alone that, for the most part, it is accessible to us, and it will be convenient to begin with its description here.

The affected muscles, as seen with the naked eye, seem, for the most part, to be dusted throughout with fine white particles like sawdust. These are most abundant near the places where the muscular fibres are inserted into the tendons. As a rule the particles are most abundant in the muscles of the trunk, the diaphragm, the intercostal muscles, and those of the abdominal wall, but they may extend to all the voluntary muscles of the body, even the most distant ones of the hands and feet.

On microscopic examination of the fine particles, they are found to consist each of an oval cyst with a tolerably thick wall (see Fig. 150),

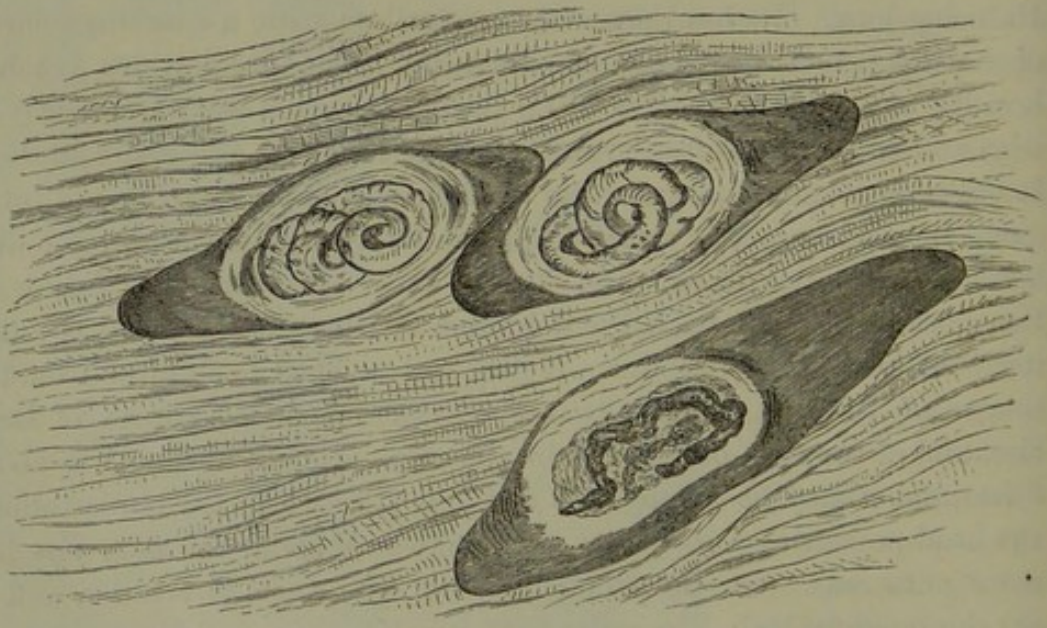


Fig. 150.—Trichina spiralis in muscle. The elongated shape of the cysts is due to the fact that these were near the insertion of the muscle into its tendon. In the lowest specimen the worm is dead and calcified. × 90.

within which is a small worm coiled up in a spiral manner. The cyst has very often abundant calcareous particles in its wall, especially at the

poles, and, if the case is an old one, the impregnation with lime may be so great as to hide the parasite unless the salt be first dissolved out with an acid. When an acid, such as dilute hydrochloric, is used, the lime dissolves with some evolution of gas, and the whole structure becomes very transparent. Sometimes the worm dies in its capsule, and in that case the wall thickens and the cyst collapses to some extent on the remains of the worm, which itself often becomes infiltrated with lime (see lower specimen in figure). It may be said here that the worm in the muscle is in an immature state and quiescent, lying rolled up in this manner for years it may be. It may be present in immense numbers, even in millions, in the same person.

We have now to inquire how these embryoes get to the muscles. To begin with, it is to be said that the embryoes exist in the muscles of swine just as in those of man. If, now, a piece of muscle containing them in their living state—that is to say, not killed by cooking the meat—be eaten, they undergo further development in the intestinal canal. The capsule is dissolved by the gastric juice, and the embryo set free. In the muscle, the embryo, if uncoiled, would measure about the twenty-fifth of an inch in length; but now it grows rapidly, and in the course of two and a half days it reaches the adult form when the female is about one-eighth of an inch in length; and the male slightly less. The male possesses a testicle consisting of a convoluted tube. The female has an ovary, vagina, and uterus. The adult worms have an intestinal canal from end to end, which is divisible into œsophagus, stomach, and intestine.

The impregnated ova pass into the uterus where they develop into living embryoes of minute size. In six or seven days after the female has attained sexual maturity, that is, eight or nine days after the trichinous muscle has been eaten, the birth of living embryoes begins. The female gives birth to large numbers, and probably continues to do so for some weeks, thus producing as many as 1,000 to 1,300. The adults do not live longer than five to eight weeks altogether.

The minute embryoes now begin to penetrate the intestinal canal, and they swarm outwards to the voluntary muscles. The route by which they reach the muscles is not absolutely certain. By most it is thought that they pass outwards into the peritoneal cavity, and thence into the connective tissue around, by which they travel to the muscles. By others it is thought that they pass into the submucous connective tissue, thence into the connective tissue of the mesentery, and so onwards. It is probable that they find their way by both these routes,

but it is inconceivable that, as some suppose, they get into the blood-vessels, as the vessels available to them are the portal radicles which would take them to the liver.

Swarming outwards from the intestine they reach first the muscles of the trunk, where they are usually most abundant; they then pass to those of the neck and larynx; and, lastly, to those of the limbs. Arrived at the muscles they grow larger, and apparently wander about for a time. They penetrate inside the sarcolemma of the primitive fibre of the muscle, and destroy the sarcous substance. In about fourteen days they have attained their full size, and begin to settle down. As they pass along inside the sarcolemma they are arrested at the insertion of the fibre into the tendon, hence they are particularly numerous near tendons, and here also the cysts, subsequently formed, are often much elongated (as in the figure). The sarcolemma collapses as the sarcous substance is destroyed, and as the worm coils itself up spirally the sarcolemma forms for it an oval cyst. The worm itself seems also to add to the cyst a layer of its own. It is not uncommon to find two, or even more, in one cyst. In the muscles the worms assume a quiescent state, as already mentioned, and may remain so for years, the cyst being impregnated with lime. They produce considerable destruction by piercing the sarcolemma, and disintegrating the sarcous substance, and there is often to be found a germination of the muscle nuclei around the worm.

During the migration of the embryoes considerable irritation is produced. There is in the first week intestinal catarrh (diarrhœa) with fever, and the case may be mistaken for typhoid fever. Later the muscles become stiff and painful, and œdema of the skin, especially of the face, may develop. The symptoms are usually at their height in the fourth or fifth week, and death occasionally ensues.

Besides in man, trichinæ have been found in the muscles of the pig, cat, rat, mouse, marmot, polecat, fox, marten, badger, hedgehog, and racoon. By some it is believed that the rat forms the permanent source of infection, as, when one of these animals dies, it is eaten by its neighbours, and so the infection spreads. From their habits, it will be understood how swine sometimes partake of dead rats. The parasite will be communicated to man by eating imperfectly cooked swine's flesh. It is said that a temperature of 50°—55° C. or 120° to 130° F., is enough to kill the embryoes, but it is quite conceivable that when large pieces of flesh are cooked rapidly, some parts may escape the thorough penetration of the heat.

The search for trichinæ in the muscles of swine before the flesh is sold is compulsory in some countries. For the examination pieces of muscle (preferably from the diaphragm and larynx) are snipped off with scissors and spread out in water on a microscopic slide. Some liquor potassæ may be added to make the preparation more transparent. It is then to be examined with low magnifying powers and afterwards with higher. Several specimens should be prepared from each animal.

The ASCARIS LUMBRICOIDES or common round-worm is probably the commonest entozoon in the human subject. It is most common in children, and inhabits chiefly the small intestine. It resembles the common earthworm in its colour and general appearance. It measures 6 to 16 inches in length, is marked by transverse striæ and tapers to both ends. It possesses an intestinal canal from end to end. The female produces a large number of oval eggs which have a dense shell.

The worm mostly occurs singly or in pairs, but is frequently present in considerable numbers up to one or two hundred. From the intestine it may pass into the stomach and be vomited, or may be discharged per anum. It has been known also to pass up the œsophagus and into the nostrils and sinuses of the head, or by the larynx into the bronchial tubes. Sometimes it penetrates into the bile ducts, which it may obstruct, or through the intestinal wall into the peritoneal cavity.

In the intestine they produce catarrh, and by reflex action they are supposed to lead to certain nervous symptoms. When present in large numbers, they have been observed rolled up in a ball, and so have obstructed the intestine. In cases where they have perforated into the peritoneum they have given rise usually to local abscesses pointing chiefly near the umbilicus or groin. More rarely they have led to general peritonitis.

The ASCARIS MYSTAX is a small round worm which occurs in the cat, and is said to be always present in the intestine of that animal.

The OXYURIS VERMICULARIS or THREAD-WORM is an exceedingly common parasite. It is white in colour, and the male measures about an eighth of an inch, and the female about three-eighths in length. It possesses an alimentary canal from end to end. The eggs are oval, and have a dense shell. The animal inhabits mostly the large intestine. It is stated by Zenker and Heller that the mature female is

in the large intestine, the males and young being in the small. The worm often wanders, especially during the night, to the neighbourhood of the anus, where it produces itching. Sometimes it passes over to the vagina, and up into it. It produces catarrh of the bowel, and, as in the case of the ascaris, nervous symptoms are ascribed to it.

The TRICHOCEPHALUS DISPAR (the whip-shaped worm) is of frequent occurrence in the cœcum and neighbouring parts of the intestine. It measures $1\frac{1}{2}$ to 2 inches in length, and has the peculiarity that the anterior portion is much thinner than the posterior, forming a long thread, like the lash of a whip, which is buried in the mucous membrane. The eggs possess a brown shell. The embryoes have been traced in water and moist earth.

The STRONGYLUS DUODENALIS or Anchylostoma duodenale is not met with in this country, but occurs in Egypt, Italy, and tropical lands. It has been found frequently among the workers at the St. Gothard Tunnel in Switzerland. It is a third to half an inch in length, and it possesses a mouth armed with four strong teeth. By means of these it fixes itself on the mucous membrane where it sucks the blood. When present in considerable numbers, as it often is among the valvulæ conniventes, it may give rise to considerable loss of blood and serious anæmia.

The STRONGYLUS GIGAS is a large worm, reaching a length of over a yard, and a thickness of about $\frac{3}{8}$ of an inch. It has been met with a few times in the pelvis of the kidney in man, and more frequently in the kidney, bladder, lungs, and liver of dogs.

The FILARIA or DRACUNCULUS MEDINENSIS, or Guinea worm, is of frequent occurrence in tropical lands, where it is met with in the tissues of the foot and leg chiefly. The female is a long thin worm from 12 to 40 inches in length, and it alone is known as a parasite. The male is much smaller. The worm wanders to some extent in the loose subcutaneous connective tissue, and may give rise to considerable irritation. When mature it presents its extremity at the surface, and a small pustule forms from which the extremity projects. The worm may then be removed gradually by rolling it gently round a quill from day to day as it becomes exposed, care being taken not to break it, in which case the part left in may give rise to severe inflammation.

FILARIA SANGUINIS HOMINIS. This name was originally given to a minute thread-like worm which has recently been found to be really the embryo of a larger worm. The embryo, as its name implies, has been found in the blood, although it has also been observed in chylous urine and elsewhere. The adult appears to live in lymphatic vessels, and so the name filaria sanguinis is not strictly applicable to it. Cobbold has given it the name filaria Bancrofti, from the observer who first discovered the adult. As it is inconvenient to give two different names to the adult and embryo forms of the same animal, we shall refer to them under the original designation of filaria sanguinis. In some respects the two forms of this worm are comparable to those of the trichina spiralis, which also obtains its name from the embryo form.

The adult filaria has the sexes distinct, and as yet the female alone has been fully examined, only a small portion of a male having been discovered. The female is a long hair-like worm, 3 or 4 inches in length, and only $\frac{1}{100}$ inch in breadth. It has an opaline appearance, and, as described by Manson (*Transactions of the Pathological Society of London*, 1881), it looks like a delicate thread of catgut animated and wriggling as it lies in the tissues. By the observer just named it was found lying in a lymphatic vessel while he was removing a scrotum which was affected in a way to be mentioned afterwards, and it appears that this is the usual habitat of the animal. The male is probably much smaller than the female, and they are supposed to live together in the same vessel.

The female is believed to live for years in the same position, and gives birth almost continuously to large numbers of embryoes. Near the head is the vagina, and behind it the uterus with two horns is

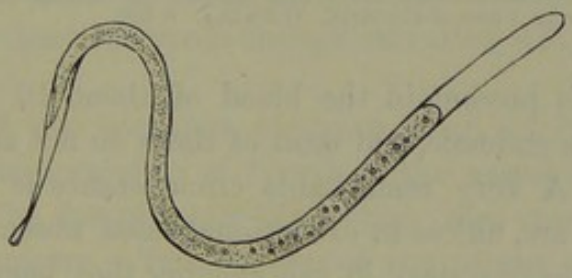


Fig. 151.—Filaria sanguinis (embryo) after preservation in weak spirit. The sac is seen at each end of the worm. × 300. (LEWIS.)

found, stuffed with ova, and extending almost to the tail. Manson states that the embryoes can be seen escaping fully formed from the vagina, in exactly the same form as they are found in the blood. But the female sometimes gives birth to ova, as these have been found in

the lymph and have been supposed to be the principal factors in producing certain local affections to be afterwards mentioned.

The living embryo (Fig. 151 and 152) is about $\frac{1}{100}$ inch in length and $\frac{1}{3300}$ inch in thickness; its breadth therefore nearly corresponds with that of a red blood corpuscle. It is enclosed in a delicate sac, which is rather longer than itself, so that while moving a portion of the sac extends beyond its extremity. The movements as seen in the blood and lymph are very active and snake-like in character.

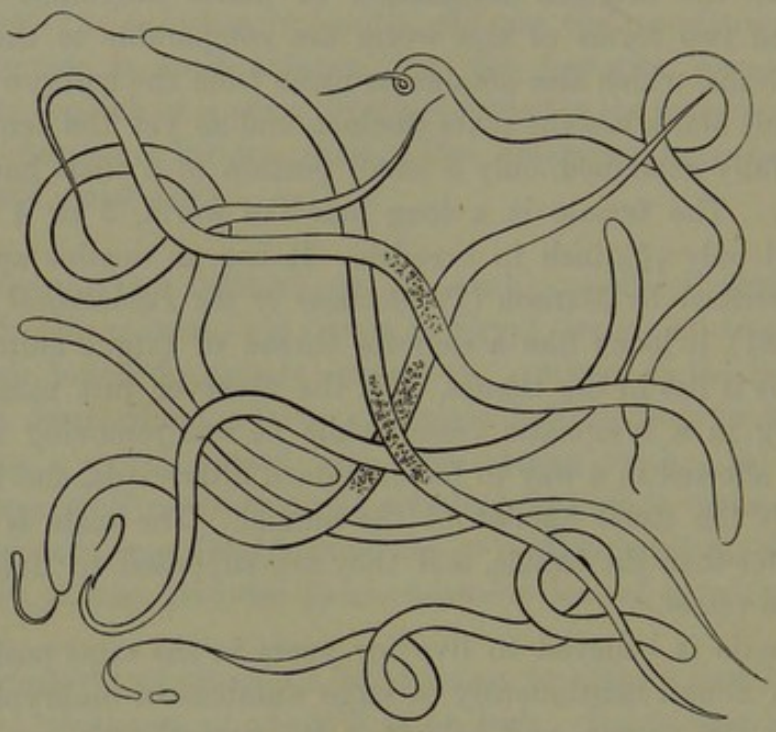


Fig. 152.—Filaria sanguinis as they appear in the living state in the blood. From a case of chyluria. (LEWIS.) × 300.

This embryo is present in the blood of about 10 per cent. of the natives where it is endemic, and most of these do not appear to suffer in health from it. A very remarkable circumstance is that, during the day, the parasites are, unless in exceptional cases, absent from the blood, but about six or seven o'clock in the evening they begin to appear, and by twelve o'clock are so numerous that as many as a hundred may be counted in every drop of blood. As morning approaches they diminish in numbers, and by eight or nine o'clock they disappear entirely. This regular rhythm may apparently go on for years, but it does not appear to be understood what becomes of the embryoes during the day.

We have next to consider how the embryoes find their way from the site of the parent worm in the lymphatics to the blood. It is probable that they travel by the way of the lymphatic fluid itself. Being not greater in breadth than a blood corpuscle, and possessing powers of locomotion, they may be supposed to traverse the lymphatic glands with the lymph, and to reach the blood by the thoracic duct. It is also possible that they may get into the blood by penetrating through the blood-vessels. In the blood they will readily circulate with that fluid, and from their size they are capable of passing through the capillaries and repeating the circuit with the blood corpuscles. They do not pass through any further stage of development in the blood, the embryoes found there being exactly like those which escape from the mother. It is clear also that they do not, either by themselves or their products act injuriously on the blood or tissues unless by using the nutritious material.

It has been stated above that ova are sometimes discharged by the female, and it is probably in connection with this that various forms of disease are found to occur in connection with this parasite. The sac which has been mentioned as enclosing the embryo is really the chorional envelope of the ovum stretched and rendered elastic. But ova are sometimes born with the sac confining the embryoes which are rolled up inside, and we have then an oval body $\frac{1}{300}$ inch to $\frac{1}{750}$ inch in length. This body is, of course, much thicker than the extended embryo, and when carried by the lymph to the glands it will be unable to traverse these. An infarction of the fine afferent vessels of the gland will thus occur, and as the vessels leading from the part where the mother is situated are plugged one after another, there will by and by be a complete stasis of the lymph in the vessels of these parts. It is probable that dead embryoes though extended will similarly plug the lymphatics.

The effect of this complete plugging of all the lymphatic channels seems to be an accumulation of lymph in the vessel below the seat of obstruction. The lymph thus distending the vessels often escapes apparently by rupture. The locality of the parent will determine the exact nature of the resulting disease. If it be in the lymphatics of the pelvis or lumbar region there may be distension of the lymphatics of the kidneys, ureters, or bladder. In that case CHYLOUS URINE is found, and the embryoes of the parasite have been observed in the urine. If the adult be in the lymphatics of the leg, there will be gradual plugging of the glands at the groin and accumulation of lymph in the

legs and scrotum. The accumulation in the scrotum is of very frequent occurrence, giving rise to the LYMPH-SCROTUM, in which vesicles appear on the surface which occasionally discharge lymph.

It is to be observed that the condition in these various situations is not a proper œdema, which we have already seen to consist in overfilling of the serous spaces, but rather an over-distension of the lymphatic vessels with occasional rupture of them.

If the explanation given above be the correct one, then as the glands get plugged the embryoes, even those born alive, will not get to the blood, and it has actually been observed that in some cases no embryoes were found in the blood although present in the urine or lymph from the scrotum.

It has been asserted that Elephantiasis is one of the diseases dependent on this parasite, and is to be placed in the same category as lymph-scrotum and chyluria. But there are serious objections to this view. Elephantiasis has the features, as we have seen, rather of a specific inflammation, than a simple stagnation of lymph, and is more nearly allied to leprosy. It probably depends on a virus which has a much more active influence on the tissues than the embryo filaria has.

In what has gone before the adult and embryo filaria have been described, but the stages by which the embryo attains to the adult form have been omitted. The embryo in the human body does not pass beyond the stage which it had reached at birth, and in order to complete the cycle of its development it must pass into the body of another animal. The intermediate host has been found to be a species of mosquito (Manson). The female of this animal has a proboscis which she inserts into the skin and through which she sucks blood into the stomach. With the blood the embryoes are taken in, and they have been found in the stomach even in larger proportional numbers than in the blood of the person from whom they were taken. In the stomach the embryo passes through certain stages of development occupying from four to six days. At this period the mosquito dies, and probably falls into water, the parasite passing from the stomach. The further stages are not known as yet, but by the time the mosquito dies the parasite has already acquired a boring apparatus fitting it to penetrate the tissues. If it reaches the alimentary canal of man, it will then bore through the tissues till it finds its selected site in the lymphatics. It selects this site just as the trichina selects the muscles or the echinococcus the liver. In its new position it attains to sexual

maturity, and being impregnated, gives birth to the embryoes as we have seen.

The species of mosquito here concerned is, like other mosquitoes, nocturnal in its habits, so that it attacks affected persons at the time when the parasite is present in the blood. The occurrence of the embryoes in the blood at night has been regarded as a provision of nature for the propagation of the species.

EPIZOA OR EXTERNAL PARASITES.

These do not call for extended treatment here, as they are fully described in works on diseases of the skin. Little more than an enumeration of them will be attempted.

The ACARUS SCABIEI, or Sarcoptes hominis, has an oval body just large enough to be visible to the naked eye, the female being one-fiftieth of an inch in length and the male about half that size. The anterior part has a head and four limbs, each of which has a sucker at its extremity. There are also four posterior limbs, all of which in the female have pointed extremities, but in the male two of them have suckers. The female burrows in the epidermis, forming long tunnels in which, as it proceeds, it deposits its eggs; it is usually to be found at the deepest end of the tunnel and the eggs at intervals. The eggs develop, and, as the epidermis desquamates, they come to the surface by degrees, the young being born usually as they reach the surface. The irritation of the animal in the epidermis gives rise to a slight inflammation causing the formation of a papule. Usually there is great itching, and the scratching leads to further eruptions, especially in predisposed persons.

The ACARUS FOLLICULORUM is a long narrow animal provided anteriorly with four pairs of short feet. It is found in the sebaceous follicles, especially of the external meatus of the ear and neighbourhood of the nose. It seems to produce no special irritation.

PEDICULI or lice occur in three forms, the pediculus capitis, corporis and pubis, which hardly require special description.

The PULEX IRRITANS, or common flea, is familiar to every one.

The LARVÆ OF INSECTS or MAGGOTS are occasionally found in the tissues of man. There are a few cases in which such larvæ have, by

migrating under the skin, produced considerable inflammation. There are also cases in which, deposited in neglected wounds, or even in the mouth and nostrils of excessively debilitated persons, they have actually produced considerable destruction by feeding on the tissues. In neglected military hospitals wounds are often abundantly tenanted by maggots.

PART SECOND.—DISEASES OF THE SPECIAL ORGANS AND SYSTEMS.

DISEASES OF THE ORGANS OF CIRCULATION.

A.—THE HEART AND PERICARDIUM.

MALFORMATIONS OF THE HEART.

FOR a very full account of the malformations of the heart we are indebted to Dr. Peacock, whose work forms the basis of the remarks under this heading.

MISPLACEMENTS of the heart are of rare occurrence, and the more important of them are merely part of a general malformation of the body. The heart may be transposed, that is to say, placed in a position on the right side of the chest corresponding with that which it normally occupies on the left. With this there is usually transposition of the viscera, but it sometimes occurs alone. Again, the heart may occupy the middle line as it does in early fœtal life. It may be placed outside the thorax altogether, but in this case there are other congenital malformations, and that of the heart only forms a part.

ABSENCE OF THE PERICARDIUM is a rare congenital malformation, and is mostly associated with misplacement of the heart. It is not to be confused with adhesion of the pericardium and consequent obliteration of the sac which is so frequent in after-life.

TRUE MALFORMATIONS OF THE HEART AND GREAT VESSELS for the most part represent survivals of fœtal conditions. In order to a comprehension of these conditions it will be necessary here to refer briefly to the state of the heart in early fœtal life, and the changes

which it subsequently undergoes. The heart at an early period consists of two cavities, an auricle and a ventricle. The simple auricle receives the two venæ cavæ, and the ventricle gives origin to the common arterial trunk. The ventricle, the auricle, and the common arterial trunk subsequently undergo subdivision each into two. This separation in the *ventricle* begins near the apex ; the septum gradually rises towards the base, its completion at the base being delayed after the rest of the septum has been formed. The common *arterial trunk* begins to show signs of division by a septum about the time that the interventricular septum is approaching the base. A septum passing from both sides of the artery meets and divides the vessel into what are subsequently the pulmonary artery and the aorta. These are so adjusted as to connect with the right and left ventricles respectively. The division of the *auricles* does not begin till the ventricular septum is nearly completed, namely about the ninth week, and after being fully formed the septum remains partially open during the whole of intra-uterine life.

Some of the malformations met with are survivals from a very early period of fœtal life. The heart may consist of only two cavities, an auricle and a ventricle, with a single arterial trunk representing both aorta and pulmonary artery. Then there is the heart with three cavities, an imperfectly divided auricle with two auriculo-ventricular orifices, and a single ventricle with no septum, or a very rudimentary one.

Leaving out of view these extreme cases, most instances of imperfect closure of the septa are directly related to obstruction caused by disease of the pulmonary artery or aorta at or near their orifices. In a way to be presently explained such obstruction leads to imperfect closure and other malformations. It is to be remembered that the part at the base is the last part of the septum to close, and that it is at the base that the great vessels arise. Consequently an imperfect closure will cause both ventricles to communicate more or less with both great arteries, and if one of the latter be larger than the other it will, as it were, overlap the imperfect septum and take origin partly from the other ventricle as well as its own.

Let us consider the effect of STENOSIS OF THE PULMONARY ARTERY occurring at an early period, when the interventricular septum has not yet closed ; or let us suppose that the common arterial trunk, instead of dividing into pulmonary artery and aorta, does so imperfectly, and so there is a large aorta and a small pulmonary artery, or even an entire

absence of the latter. In the case last mentioned the blood from the right ventricle, as well as that from the left, would pass into the aorta, and the constant recurrence of this passage of blood at each systole of the ventricle would PREVENT THE CLOSURE OF THE SEPTUM at the base, and cause the aorta to take permanent origin from the right ventricle as well as from the left. The condition would in fact virtually be that of a heart with three cavities, and it is possible that some of the cases in which this is the form of malformation may have such an origin. Short of this complete atresia (or obliteration) of the pulmonary artery, obstruction may occur in varying degrees, and the results will vary correspondingly. The aorta will, in the more serious cases, take origin to a greater or lesser extent from the right ventricle, while in those which are less extreme there will simply be a gap in the septum.

It has already been remarked that the last part of the septum to close in the fœtus is the basal part, and there is, even in the adult, a



Fig. 153.—Defect of inter-ventricular septum. The gap is situated at the base, in the position of the undefended space in the normal heart. (PEACOCK.)

small triangular space at the base of the septum, in which there is no muscular tissue, and which is composed only of the two layers of endocardium of the right and left ventricles and some loose connective tissue between. This space is called the UNDEFENDED SPACE, and in a considerable proportion of cases a minute aperture persists in adult life

at this point. If the septum closes imperfectly the gap has its seat here (see Fig. 153).

We have seen that imperfect closure of the septum and partial origin of the aorta from the right ventricle are the most direct results of stenosis or atresia of the pulmonary artery, but there are other results which also follow. The septum is bulged to the left, and the right ventricle is generally greatly hypertrophied. This hypertrophy of the right ventricle is probably of the same nature as the hypertrophy of the ventricles in adult life, which occurs so frequently in connection with obstruction of orifices. It is due to the extra powerful muscular efforts made by the right ventricle to overcome the obstruction of the pulmonary artery.

In addition to imperfection of the interventricular septum, there is very often in these cases imperfect closure of the FORAMEN OVALE after birth. This will be a natural consequence of the enlargement of the right ventricle. The obstruction of the pulmonary artery keeps back the blood, as it were, in the right ventricle and auricle, and the blood, accumulating in the right auricle, continues to pass through the foramen ovale, and prevents its closure. This consequence, however, does not invariably follow.

Another consequence of occasional occurrence is the permanent patency of the DUCTUS ARTERIOSUS. If the pulmonary artery at its origin is so much obstructed as to prevent the passage of the blood in due amount to the lungs, then the aorta will after birth augment the supply by the ductus arteriosus, through which the blood will pass in the reverse direction to what is normal in the fœtus.

We have hitherto considered the case of obstruction of the pulmonary artery at a time when the interventricular septum is still incomplete, but it may occur after the completion of the septum. In that case the most direct result will be dilatation and hypertrophy of the right ventricle, and permanent patency of the foramen ovale. Patency of the foramen ovale will be a more constant result here than in the former case, as this orifice will afford the only means of relieving the excessive accumulation of blood in the right side, whereas in the case of imperfect interventricular septum the excess is relieved by this communication.

We have been considering the effects of OBSTRUCTION of the pulmonary artery, but THE AORTA is sometimes, though by no means so frequently, the seat of obstruction. In that case the relation of matters is inverted. The septum of the ventricles is imperfect, but it is bulged

to the right, and the pulmonary artery takes origin more or less from the left ventricle as well as from the right. The aorta beyond the obstruction often continues after birth to be supplied with blood from the pulmonary artery through the ductus arteriosus. The foramen ovale may remain open.

It has been stated above that the pulmonary artery is much more frequently obstructed than the aorta during fœtal life, and this leads us to consider what may be THE CAUSE OF OBSTRUCTION in these cases. The obstruction may be due to disease of the valves or to contraction of the artery itself. We are familiar with malformation of the valves from adhesion in adult life as a consequence of inflammation, and there is reason to believe that it is due to the same cause in the fœtus. In the annexed figure (Fig. 154) a condition of the pulmonary valve is shown which is exactly similar to that which we so often see in the aortic valve in the adult. The three curtains are thickened and united by their margins so as to form a diaphragm instead of three mobile folds. In the adult, inflammation is immensely more common in the valves of the left side than in those of the right, and it is difficult to understand how it is exactly the reverse in the fœtus.



Fig. 154.—Congenital adhesion of the curtains of the pulmonary valve. The valve is viewed from above. (PEACOCK.)

The proclivity to disease shown by the valves of the left side in the adult is usually ascribed to the fact that these are exposed to greater strain than those of the right side. The blood-pressure in the systemic arteries is much higher, and is exposed to greater variations. But in the fœtus, as Peacock has pointed out, a much larger proportion of the circulation is dependent on the right ventricle than in the adult, the descending aorta and the umbilical arteries being fed by this ventricle. The blood in the umbilical arteries must be exposed to considerable variations in pressure, from obstructions occurring in the umbilical cord and placenta, and these variations will be reflected to the pulmonary artery and right ventricle. On the other hand, the left ventricle and aorta in the fœtus are related to a much smaller area of the circulation than in the adult, and the systemic arteries in the quiescent state of the fœtus will be little exposed to variations in pressure.

In the great majority of cases, the malformations hitherto referred to

are connected with and due to obstruction of the pulmonary artery or aorta, but it is to be added that incompleteness of the septum and the partial misplacements of the great vessels which go along with it may occur without any such cause being apparent. The same applies to patency of the foramen ovale, but in a much higher degree.

Mere patency of the foramen ovale is hardly to be regarded as a serious malformation, especially when we consider that in nearly a half of adult hearts there is a slight degree of incompleteness in the closure of this aperture. In these cases, however, there is no real mixing of the currents in the two auricles, as the remaining aperture is valved by folds in the septum. The imperfect closure becomes important when, through obstruction in the pulmonary artery, the blood pressure in the right auricle is raised sufficiently to cause the blood to pass through the aperture.

Before leaving this part of the subject it will be proper to refer to certain IRREGULARITIES OF THE PRIMARY VESSELS. There are cases on record in which the aorta has arisen posteriorly from the right ventricle and the pulmonary artery anteriorly from the left. In this case, the blood from the systemic veins is sent into the systemic arteries without passing through the lungs. Such a condition seems hardly compatible with the prolongation of life after birth; yet several cases of survival are on record, in one case life being prolonged as long as three years.

Another malformation is narrowness or obliteration of the ISTHMUS OF THE AORTA, or that portion between the giving off of the left subclavian and the insertion of the ductus arteriosus. In the fœtus this portion is hardly in use, and it may be imperfectly developed and form, after birth, an obstruction. In that case the pulmonary artery will usually supply the abdominal aorta, as in the fœtus, the ductus arteriosus remaining patent. The ductus arteriosus may close, however, in which case the descending aorta must be replenished by circuitous anastomoses through the subclavian, mammary, intercostal, and epigastric arteries.

In addition to these more serious malformations of the heart and its great vessels, there are certain CONGENITAL MALFORMATIONS OF THE VALVES which merit some attention. These malformations concern mainly the semilunar valves of the aorta and pulmonary artery. The valve may be in the form of a diaphragm in which there are merely indica-

tions of a tripartite formation. In this case the diaphragm is often protruded into the vessel in the form of a funnel. Again, we not unfrequently meet with some variety in the size or number of the semilunar folds. There may be only two curtains, usually a large and a normal one. The larger one commonly shows indications of a partial division (see Fig. 155). Then with three curtains there may be two large segments and a small rudimentary one between.

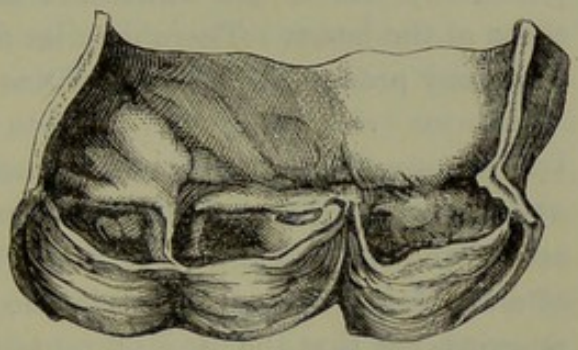


Fig. 155.—Congenital malformation of aortic valve. There are two curtains, but the larger one shows a partial division. (PEACOCK.)

These malformations are probably to be referred to endocarditis occurring in the fœtus. In adult life endocarditis often produces adhesion of the curtains, but there is also very great contortion of the valves. But, in the fœtus, the plastic power and adaptability of the structures is much greater, and the three coalesced valves may form a well-shaped diaphragm, or the two a single larger semilunar fold. In either case there are still indications of the coalescence in the form of thickenings along the line of union. It is obvious that these malformations will frequently interfere with the functions of the valves. In the extreme cases of complete union of the three curtains (as in Fig. 154) there will be great obstruction as well as imperfect closure. When there are only two curtains the middle part, where coalescence has occurred, is thicker, and the curtain will be more rigid at this point. This, itself, will interfere with the curtains falling back against the aortic wall during the systole of the ventricle, and so there will be a certain degree of obstruction. But, again, during the process of growth, the thickened line of junction being unduly rigid will not probably expand sufficiently, and the middle of the curtain will thus be held back. During the closure of the valve there will thus be an aperture left, allowing of regurgitation. The tendency to regurgitation is increased by the imperfect support which the large curtain receives from the smaller one. During closure the edge of the large one must partially double up in order to adapt itself to the small one, and so a gap may occur.

We have seen that these adhesions of the curtains are probably due to intra-uterine endocarditis, and there is apt to be a recurrence of the disease after birth. It may be said that the previous existence of in-

flammation renders the structures liable to a recurrence or possibly a prolongation from the fœtal period. But, in addition, the imperfect adaptation of the valves will itself afford a certain irritation and predispose the structures to inflammation. So it happens that valves malformed in this way are peculiarly prone to disease in after-life, even though their function is not at first imperfect.

Besides the variations already noted the curtains of the aortic and pulmonary valves are sometimes ABNORMALLY NUMEROUS, especially those of the latter. There may be four curtains instead of three, and they may present all varieties of size relative to one another.

The semilunar valves sometimes present a condition somewhat APPROACHING that of THE AURICULO-VENTRICULAR VALVES which are of the cuspid form. It is to be noted that during the closure of a semilunar valve the curtains do not come in contact by their free margins, but that the line of contact is somewhat removed from the margin. During closure, therefore, when the artery is full, a certain portion of the curtain floats free in the blood. Now the portion between the line of contact and the free margin is frequently the seat of apertures or fenestrations, and that without affecting the function of the valve. This fenestration may be very extreme and may graduate towards a condition in which (see Figure 156), instead of a piece of tissue, there are merely a series of tendinous bands passing from the curtain, near the line of contact, to the wall of the vessel at the point of insertion of the curtain. These tendinous bands resemble the chordæ tendineæ of the cuspid valves, and the resemblance may be increased by the neighbouring edges of the curtains being joined, and the tendinous bands from the adjacent borders of two curtains passing together to the wall of the vessel (see figure). There may be even on the wall of the vessel an elongated prominence into which the bands are inserted, and

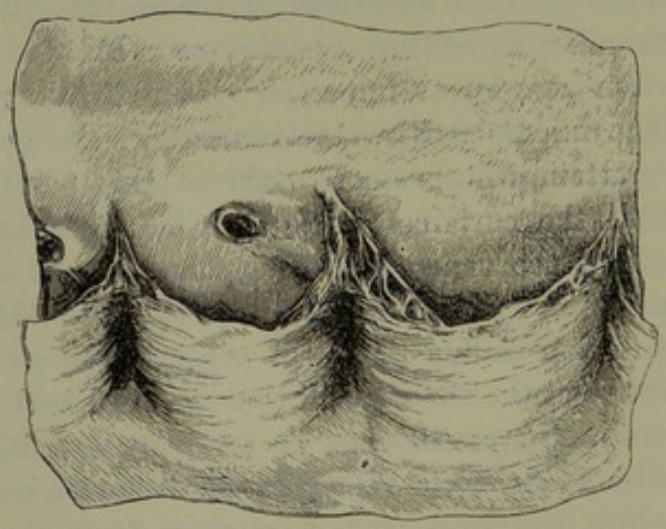


Fig. 156.—Fenestration of the marginal parts of the aortic valve. There is an appearance of chordæ tendineæ, and the bands from two proximal curtains are inserted into a projection from the aorta.

resembling a musculus papillaris. These bands may have a considerable free course from the middle of the curtain to the wall of the vessel. A certain indication of such conditions is very frequent in both the aortic and pulmonary valves.

It may be asked, Does such a malformation interfere with the function of the valve? Probably not much, but still to a certain extent. Each form of valve is appropriate to its own place. The cuspid form is adapted to an aperture between two cavities, the semilunar to the orifice or course of a vessel. The latter takes up less room, and by reason of the complete separation of the curtains it falls back completely when the blood rushes past it. But if the valve approaches to the cuspid form, especially if the margins of the curtains are united, and the tendinous bands from two have a common insertion, then there can hardly be that complete falling back which occurs when the function is perfect. This will probably cause a trivial obstruction, and the curtains being unduly exposed to the force of the wave of blood may be specially liable to inflammation.

CYANOSIS.—Before leaving the subject of malformations of the heart, we have to consider this condition which is so often associated with certain forms. Children born with malformations of the heart are usually liable to symptoms connected with the respiration and circulation, which are in many respects comparable with those from valvular disease acquired in after-life, and consist chiefly in attacks of dyspnœa and lividity. These symptoms may occur at birth or soon after it, but they may be postponed even for years, and develop apparently by some extra stress laid on the circulation. Occurring at first intermittently the dyspnœa and lividity very often, to some extent, become permanent, and this is particularly true of the lividity. This generally becomes such a marked characteristic of such persons that they are visibly the subjects of Cyanosis or MORBUS CÆRULEUS. The lips and finger nails are blue, and there is, perhaps, a deep lividity of hands, feet, and cheeks as well.

Two explanations of this symptom have been offered. The first is that, as in these cases, the septa of the heart are mostly imperfect, the lividity results from the mixing of the currents, venous blood being mixed with the arterial in the systemic vessels. This looks a very likely explanation, but there are two serious objections to it. Cyanosis has been found in cases where the currents did not mix, and it has been absent where they undoubtedly did. Besides this, it is found that the

degree of cyanosis is not at all proportionate to the mixing of the currents. The other explanation is that the cyanosis is due to venous engorgement, just as lividity occurring in valvular disease in the adult. In nearly all the cases there is obstruction of the pulmonary artery which we have seen to be at the basis of most malformations, and this has the effect of bringing about a general venous engorgement. During the early periods of life the blood-vessels are more yielding and plastic, and so the permanent congestion tells much more on them than it does in adult life. Cyanosis developed in after-life sometimes approaches in intensity to that from malformation, but it rarely reaches it.

It may be interesting to refer to the DURATION OF LIFE in persons affected with malformations of the heart. If there is merely slight imperfection of the septa, the defect is of little importance, and we have already seen that there is imperfect closure of the foramen ovale in a large proportion of the cases met with in the ordinary course of post-mortem examination. If there is moderate contraction of the pulmonary artery while the heart is otherwise well formed, the right ventricle will probably hypertrophy, and this may almost completely compensate, so that life is scarcely shortened. If the foramen ovale is distinctly patent, this generally implies a greater degree of obstruction of the pulmonary artery, and life is usually abbreviated. Peacock has collected twenty cases of this kind, and only eleven of these lived to the age of 15 and upwards, but some lived as long as 34, 40, and 57. In three cases the ductus arteriosus was also open, and these died at the ages of 10 months, 15 months, and 29 years. If the interventricular septum is imperfect, this implies an obstruction at an earlier period of fœtal life, and the duration of life is shorter. Of sixty-four cases, only fourteen survived the age of 15, but still three lived as long as 25, and one to 39 years. Where the pulmonary artery is entirely impervious, the duration of life is still shorter ; of twenty-eight such cases only seven lived over a year, and the longest duration was 12 years. Where there is still greater arrest of development, and the heart consists of but one ventricle, with one or two auricles, the period of survival is usually very limited, but it is interesting to find that four persons thus affected have lived to the ages of 11, 16, 23, and 24 years. Transposition of the pulmonary artery and aorta might appear to be a malformation almost incompatible with life, and yet of twenty-one such cases, four lived between 2 and 3 years. When the aorta is obstructed at its isthmus, and the descending aorta is supplied, wholly or partially, by the pul-

monary artery, the duration of life is usually very limited. The lungs seem to be deprived of blood, because it passes to the abdominal aorta, and the children die with symptoms of dyspnœa and syncope. If the obstruction, however, be only slight, the person may survive to adult or middle life, even though the ductus arteriosus remains pervious; thus there are cases of survival to 24, 32, and 43 years of age. If the constriction be so slight that the ductus arteriosus closes, it may yet become much more considerable afterwards, or the aorta may even be obliterated at the point indicated. Yet such patients may survive long, as even with obliteration the ages of 45, 50, and 57 have been attained.

ATROPHY OF THE HEART.

This condition is one of comparatively frequent occurrence, but is for the most part merely a part of general atrophy, or emaciation of the body. In emaciating diseases such as phthisis pulmonalis, stricture of the œsophagus, cancer of the stomach, etc., where the muscular system as a whole has undergone great reduction in bulk, the heart is found to take part in the same process. Taking the normal weight of the heart as 9 ounces for the female, and 10 or 11 ounces for the male, we may find it reduced to 6 or even 5 ounces. The heart as a whole is obviously smaller, and it has a darker colour than normal, while the coronary arteries stand out unduly, often as somewhat prominent tubes. This change of colour and the prominence of the arteries are largely due to the loss of the sub-pericardial fat, which normally covers the greater part of the surface and accompanies the coronary arteries, partially embedding them in the adipose tissue. The muscular tissue itself is darker in colour, presenting a dirty brown hue instead of the normal robust red. It is also tougher and dryer. The deepening of the colour is probably due to a concentration of the normal pigment from the diminution of the contractile substance without any loss of the pigment, just as red blood corpuscles become much deeper in tint when they shrink by drying in.

There is little doubt that the muscular fibres in this condition undergo an actual diminution in thickness, although from the great variety in diameter which the muscular fibres of the heart present this is very difficult to prove. The shrinking of the muscular fibres causes the connective tissue to be unduly prominent, and gives the muscle its undue toughness.

HYPERTROPHY OF THE HEART.

In entering on this subject it is necessary in the first place to consider under what circumstances such a condition may be brought about. It will be understood that the term is applied to hypertrophy of the muscular substance of the heart, giving rise according to circumstances to enlargement of particular ventricles or auricles, or of the heart as a whole. We have already seen that hypertrophy of muscle occurs as a result of repeated forcible contraction of the muscle, and apparently from no other cause, hence in each case of cardiac hypertrophy we have to look for some cause producing increased vigour of the contractions of the cardiac muscle. The cardiac contractions are regulated by the wants of the system. When we lie quiet in bed they are comparatively infrequent and deficient in force. When we exert ourselves by walking or climbing a hill, they increase, it may be greatly, in frequency and force. The needs of the tissues assert themselves by the nervous connections of the body on the cardiac ganglia, and the contractions become more forcible. Within the limits of health, and without any increase of the volume of the cardiac muscle, there are great variations possible in the force of the cardiac contractions. But where the heart is for a prolonged period impelled to unusually violent exertion, it may become hypertrophied. Thus, in soldiers who have had to execute a series of long marches, hypertrophy has been found to develop; in such a case it is comparable with that of the muscles of a blacksmith's arm, and is hardly pathological. Now, anything which interferes with the due carrying-on of the circulation will be likely to lead to increased vigour of the cardiac contractions, and, if prolonged, to hypertrophy. If the arteries are not duly filled at each systole, if the blood does not reach the capillaries with a sufficiently rapid current, then the heart replies to certain reflex impulses and contracts more vigorously. Conditions leading thus directly to impoverishment of the circulation, may be situated in the heart itself or outside it, and it will be understood that the hypertrophy will be COMPENSATORY, and may be sufficient to overcome the difficulty.

In many of these conditions there is a mechanical interference with the flow of the blood either in the heart itself or in the arteries, and as a consequence the heart is overloaded with blood. In such cases the cavities will be dilated and the dilatation may indeed be the primary condition, the hypertrophy occurring as a secondary consequence. It is usual, therefore, to consider dilatation and hypertrophy together, there

being commonly some dilatation along with the hypertrophy, although it is rare to find dilatation without hypertrophy.

For the sake of illustration we shall here consider some cases of cardiac hypertrophy. One of the commonest forms is that which occurs in ADHESION OF THE PERICARDIUM. In this condition, as we shall see afterwards, the sac of the pericardium is obliterated and the parietal pericardium has coalesced with the visceral. In some cases there is very little hypertrophy, but in others it is very great. It is to be remembered that adhesion of the pericardium takes origin in inflammation, and from this circumstance it results that in several ways the action of the heart is interfered with. During the acute stage of the inflammation there is fluid in the sac of the pericardium, and by the mere mechanical pressure of this fluid the cardiac contractions are interfered with; in order to overcome this obstacle the heart may hypertrophy, and if the effusion continue long enough there may be hypertrophy from this cause alone. But again, the inflammation extends a certain distance into the muscular wall of the heart beneath the pericardium. A certain portion of muscle is thus interfered with in its action and more vigorous contraction is required of the rest. There may even be considerable thickening of the pericardium by development of connective tissue, and this extending some distance in the connective tissue between the muscular fibres may seriously compromise them. But further, when adhesion is complete, the heart in contracting must drag in with it the parietal as well as the visceral pericardium. In the normal state the parietal pericardium lies against the visceral, and there is no cavity left, but then the two surfaces slide on one another, and the parietal layer accommodates itself to the movements of the heart. If there is adhesion, however, unless the adhesion be very loose, there can be no such sliding, and there must be some loss of force in dragging the visceral layer inwards. But there is a further very important element in the problem. The inflammation of the pericardium does not confine itself exactly to the sac, but extends somewhat outside it, so that when recovery occurs the visceral layer is united more firmly by new-formed connective tissue to parts around, to the ribs and intercostal spaces, the sternum, the pleura, and the roots of the lungs. This being the case, the heart will meet with greatly increased resistance in contracting, as it will have to drag in these adhesions in order to empty itself. In order, therefore, to send a normal amount of blood out of the ventricles, an excessive amount of

muscular force will be required, and the continuance of this will lead to hypertrophy. It will be seen that these causes vary to a considerable extent, and the amount of hypertrophy varies in proportion. As the causes also act nearly uniformly on the heart, the hypertrophy is general, that is, it usually affects all the cavities of the heart. Such a hypertrophy may almost completely compensate, so that a person with adherent pericardium and a very large heart may have no cardiac symptoms.

As other illustrations of cardiac hypertrophy we might refer to cases of VALVULAR DISEASE OF THE HEART. In these the force of the cardiac contractions is to some extent wasted, and the heart is spurred to increased exertion to supply the wants of the system. In studying the various forms of valvular disease we shall have sufficient illustration of this.

Outside the heart itself there may be causes interfering with the circulation and leading to cardiac hypertrophy. These causes, like disease of the valves, will mostly act primarily on one cavity, and so we shall have PARTIAL HYPERTROPHIES. One of the most obvious illustrations of this is afforded by diseases in which the circulation in the lungs is obstructed. In EMPHYSEMA there is great obliteration of the pulmonary vessels, and as the needs of the organism require a certain amount of blood to pass through the pulmonary vessels in a given time, the right ventricle is stirred to more vigorous contraction in order to force the due amount through the smaller number of vessels, and through time it hypertrophies. In the case of the systemic circulation, ANEURISMS and rigidity of the arteries are frequent causes of hypertrophy of the left ventricle.

We come now to a form of HYPERTROPHY OF THE LEFT VENTRICLE which it is somewhat difficult to explain, namely that which occurs IN BRIGHT'S DISEASE. It would carry us too far at the present stage were we fully to discuss the causes of this hypertrophy of the heart, which will be taken up again in considering the pathology of affections of the kidney. In the meantime it may be noted that the hypertrophy is purely of the left ventricle, and its cause is to be looked for in something which increases the force of its contractions, or, in other words, some obstruction in the systemic arterial circulation. It is natural to look for this obstruction in the kidneys where, in chronic Bright's disease, there is often great contraction and obstruction of the capil-

laries. There are serious objections to the acceptance of this view (which was that of Traube), at least in its simplest form, and we shall return to this point afterwards. In the meantime it may be stated that this form of Bright's disease is associated with an increased blood pressure (increased tension) in the systemic arteries, and that this is sufficient to account for the hypertrophy of the heart. An increase of the general blood-pressure is caused most effectually by a general narrowing of the smaller arteries throughout the body, and this would seriously stress the heart, if it had not sufficient force in its existing muscular fibre. In the case of Bright's disease increased arterial tension first develops, and this is followed by hypertrophy of the heart.

Even when we have enumerated all the cases of hypertrophy of the heart, and especially of the left ventricle, in which a definite cause can be assigned, there still remains a residuum to which no mechanical explanation is discoverable. In these cases it may be presumed that there is some peripheral obstruction to the circulation, perhaps a habitual contraction of the arteries and consequent increased tension. Such persons are often liable to palpitation, and sometimes to other signs of heart disease, but without any valvular lesion or other mechanical hindrance.

Forms of Cardiac Hypertrophy.—From what has gone before, it will be apparent that hypertrophies of the heart vary greatly in amount and in the distribution of the enlargement. The total increase in weight is greatest in cases where both ventricles are enlarged, and the weight of the heart in such cases not uncommonly reaches from 27 to 30 ounces. It is least where the right ventricle alone is enlarged, because this ventricle, as a whole, weighs much less than the left, but in pure right ventricle hypertrophy a weight up to 17 ounces is not infrequent. In hypertrophy of the left ventricle, as in Bright's disease, the weight is frequently over 20 ounces.

In general hypertrophy the general shape of the heart is not much altered. The heart is enlarged in all its parts, the ventricles and auricles are increased in capacity, and their walls are thickened. The heart is like that of a bullock in size, so that the name *cor bovis* is often applied to it.

When the right ventricle is mainly affected, the heart assumes a somewhat quadrilateral form (see Fig. 157). On examining the normal heart as it lies on its posterior surface, after removal from the body, the right ventricle is seen to occupy the greater part of the anterior aspect.

The position of the septum, as shown in the accompanying figure, is slightly to the right of the left border, and it reaches the apex region slightly to the right of the true apex. In the heart the position of the septum is always indicated on the surface by the coronary artery which, with its padding of fat, occupies a groove corresponding with the anterior border of the septum. In hypertrophy of the right ventricle, as shown by the dotted line in the figure, the apex is unduly obtuse, and it is often difficult to determine what is its exact seat. The septum is nearer the left border than usual, and it reaches the apex region rather to the left than the right of the most projecting point. The right ventricle also monopolizes the anterior aspect of the heart still more than in the

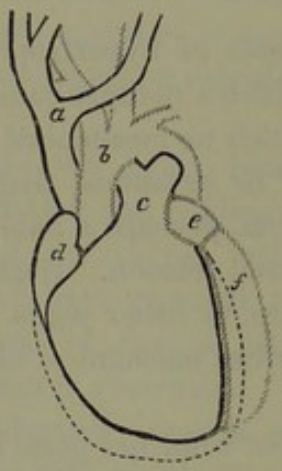


Fig. 157.—Hypertrophy of right ventricle. The alteration in shape is indicated by the dotted line; *a*, superior vena cava; *b*, aorta; *c*, conus arteriosus; *d*, right auricle; *e*, left auricle; *f*, left ventricle. (RINDFLEISCH.)

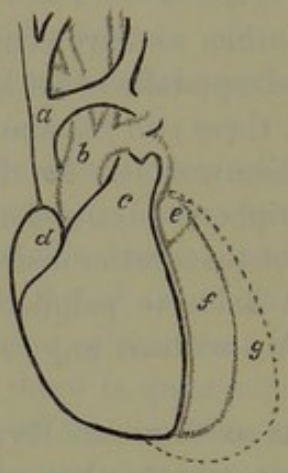


Fig. 158.—Hypertrophy of left ventricle. The alteration in shape indicated by dotted line; *g*, the hypertrophied ventricle. (RINDFLEISCH.)

normal condition. When the heart is laid open, the undue thickness of the right ventricle, as well as the enlargement of its cavity, becomes apparent.

In HYPERTROPHY OF THE LEFT VENTRICLE the relations are very different, as shown in Fig. 158. The heart as a whole is more elongated and pointed than normal, and this is often very striking. The apex part especially appears greatly prolonged. When the heart is viewed on its anterior aspect the septum is seen to lie more to the right, and the true apex is much further to the left of the point at which the septum reaches the apex region. On laying open the heart, the thickening of the wall of the left ventricle is very obvious, and the septum is often greatly thickened. The septum belongs partly to the left and partly to the right ventricle, but as the left ventricle is much thicker than the right the septum belongs more to the left. It will partake, in the

hypertrophy of either ventricle, and, in the case we are considering, the thickening is often very striking. The thickened septum frequently bulges into the right ventricle, sometimes diminishing its capacity greatly, and even producing actual obstruction of the conus arteriosus.

The hypertrophied heart often presents a peculiarly firm condition of its wall, and this has been ascribed by Sir William Jenner (*Med. Chir. Trans.*, 1860, p. 199) to a PASSIVE CONGESTION OF THE HEART. Cases of cardiac hypertrophy are very frequently such (as in the more common forms of valvular disease) as to lead to a general venous engorgement, in which the heart itself, being related to the general venous system, partakes. Now, prolonged venous hyperæmia produces in organs, as we have seen already, a certain hypertrophy and increased density of the connective tissue. Some part of the hypertrophy in such cases may even be due to increase of the interstitial connective tissue. Hence the result is that the walls of the heart are more rigid than normal, and when the cavities are laid open they do not collapse, but stand out with their outline retained, the walls having a tough leathery character. The muscular substance also is frequently of a very red colour, this being largely due to the excess of blood in the vessels.

FATTY INFILTRATION OF THE HEART.

The normal heart is well known to present on its surface a certain amount of adipose tissue. This fat is beneath the pericardium, lying between it and the muscular substance of the wall. It is normally most abundant along the course of the coronary arteries, along the inferior border of the right ventricle, at the apex and at the origins of the great vessels. In different individuals the amount of the adipose tissue and the extent to which it covers the muscular substance so as to conceal it from view, vary greatly, but it may be said generally that a considerable part of the surface of the right ventricle and the greater part of that of the left are usually free of fat. Sometimes this fat increases greatly, both in superficial area and in thickness. We know that adipose tissue in any part of the body is formed out of loose connective tissue by the infiltration of fat into its cells, and so the subpericardial connective tissue may become extensively converted into adipose tissue. In this way the entire right ventricle may be covered while a portion of the left is still free; or, the whole heart may be coated with a thick mantle of fat.

The conversion does not always confine itself to the pericardium, but frequently extends into the connective tissue in the proper muscular wall of the heart, lying between the muscular fasciculi. In such cases if we make a section of the ventricle we find streaks of adipose tissue extending in from the surface. In this way the superficial layers of the muscular wall may be largely replaced by adipose tissue, which may even appear in isolated patches immediately beneath the endocardium. Normally there is more fat on the surface of the right ventricle than on that of the left, and here also the pathological increase occurs to the greatest extent. It is not uncommon to find the proper muscular substance of the right ventricle largely replaced by adipose tissue, only a thin layer of red muscle appearing inside the thick layer of fat. Of course, in this case, there is great loss of the muscular power of the heart; the right ventricle is much more liable to this than the left.

In some cases the increase of the external fat is merely part of a general obesity, in which the fat in all its various localities throughout the body takes part. But sometimes its significance is much more serious, and this applies especially to the cases in which adipose tissue forms between the muscular bundles. The space occupied by the fat must be obtained at the expense of the proper muscular substance, and the question arises whether the atrophy of the muscle is the primary condition or the fatty infiltration. We are to take into consideration the fact that a fatty infiltration of an exactly similar character occurs, as we have already seen, in voluntary muscle, and is there associated with loss of function of the muscle. The muscle may have lost its function by fixation of the joints which it has to move, or by reason of paralysis of a nervous origin. In either case the loss of function is the primary condition and the fatty infiltration is secondary. And so in the case of the heart, we meet with fatty infiltration in cases where there is no general obesity, often in old debilitated persons, or even in those who have been subject to some emaciating disease such as cancer. In that case we may infer that the weakening and atrophy of the muscle has been primary and the infiltration of fat secondary.

FATTY DEGENERATION.

From our former study of fatty degeneration as a whole, it will be understood that there is here meant an actual transformation of the muscular substance. This condition is of exceedingly frequent

occurrence in the heart, especially in its minor degrees. Any disease which causes a serious deterioration of the blood will produce it, and it is seen in its most pronounced form in the various kinds of anæmia, in leukæmia, and in the acute fevers. It is also brought about in a very pronounced form in poisoning by phosphorus and arsenic. In a minor degree it is seen in debilitating diseases, and is often the more immediate cause of death in hypertrophy of the heart.

It is remarkable that, though the determining cause is a deteriorated state of the blood, yet the fatty degeneration frequently shows itself in patches, so that the muscular tissue is seen to be, as it were, flecked with pale spots or streaks. This is best seen on examining the muscular tissue from within, as the endocardium generally produces but little obscuration of these markings, and they are most abundant in the inner layers of the muscular substance. This flecked appearance is not always present, and it would be a mistake to infer the absence of fatty degeneration from its absence. The heart again is generally flabby, friable, and pale in colour, but a very flabby heart may be very little fatty, and fatty degeneration may coexist with a comparatively firm muscular tissue. Microscopic examination should therefore always be resorted to.

Under the microscope in those cases in which the degeneration is in patches, the transparent muscular tissue is seen with a low power to be

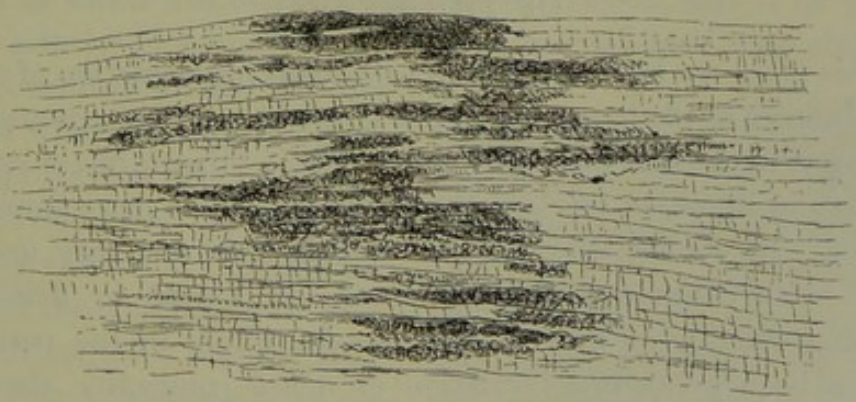


Fig. 159.—Fatty degeneration of the heart. The occurrence of the lesion in patches is indicated by the dark appearance of the fibres. × 90.

interrupted by opaque patches, as in Fig. 159. The general outline of the muscular cylinders is preserved, but they are evidently replaced by some foreign material. Under a high power, as in Fig. 160, the individual fat drops become apparent. These fat granules are frequently seen to be in rows, representing the original muscular fibrillæ, and the contractile substance is obviously lost or converted into oil.

In minor degrees the degeneration is, as a rule, more uniformly distributed in the muscular substance, and we can see that the fat granules generally appear first in the neighbourhood of the nuclei of the muscular fibres, forming elongated collections extending from either pole of the nucleus.



Fig. 160.—Fatty degeneration of the heart. A single fibre with oil drops in it, as seen in the fresh state. × 350.

It is clear that muscular fibres which have undergone this transformation in its extreme form, are incapable of recovering their original condition. The sarcous substance has undergone transformation. It is to be inferred, therefore, that when such a heart recovers there is an absorption of the fat and an actual new-formation of muscular tissue. This process must be a comparatively frequent one when we consider how common fatty degeneration is in severe anæmias and in acute fevers. The fatty heart is usually a dilated one, even where there is no dilatation to begin with. On recovery the ventricles will resume their former dimensions.

CALCAREOUS INFILTRATION OF THE MUSCULAR SUBSTANCE OF THE HEART.

In this place we have to consider calcareous impregnation of the muscular substance of the heart, which is a somewhat rare occurrence. But it is necessary, in the first place, to refer to certain other forms of calcareous impregnation in order to clear the ground for that more immediately before us. In connection with pericarditis it is not very uncommon to meet with calcareous infiltration of old fibrine or dried-in pus which may remain on the surface. Again, where in the pericardium there has been great new-formation of dense connective tissue from prolonged pericarditis, lime salts may be deposited in the hard tissue. In this way we may have the heart almost enclosed in a firm shell. But, further, in the muscular substance, old connective tissue may calcify, or an abscess may dry-in and become impregnated with lime salts. In this way we may have stony masses developed in the muscular wall, these being actually in the connective tissue of the wall.

But there is a true calcareous infiltration of the muscular tissue, and although recorded cases are few, the author is able to refer to two

cases in which he has met with it, the condition, however, being somewhat different in each. In the one there were pale patches seen with the naked eye in the muscular substance, somewhat like those of fatty degeneration, but larger and situated in the superficial layers just under the pericardium. These patches had, even to the naked eye, a streaked appearance, the streaks following the direction of the muscular fibres and indicating that the condition affected the muscular substance. On cutting into the patches a gritty feeling was experienced, and under the microscope the appearances seen in the Figure 161 were seen. The muscular fibres were converted into solid cylinders which had a markedly crystalline appearance. Many of the cylinders were fractured transversely.

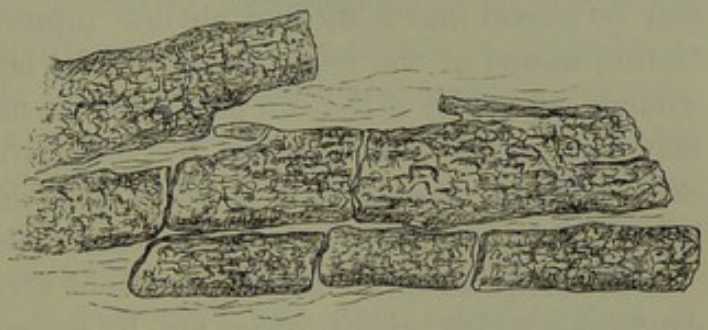


Fig. 161.—Calcareous infiltration of the muscular tissue of the heart. The branching muscular cylinders are shown in a petrified condition with transverse fractures. From a case of pyæmia. × 350.

On adding hydrochloric acid to these patches, there was an abundant evolution of gas and a solution of the lime salts. After the lime salts were dissolved the muscular fibres were restored so far as their outline was concerned, but their transverse striæ were gone. The case in which this occurred was one of pyæmia, and it is probable that the arteries in connection with these patches had been obstructed, causing a necrosis of the portion of tissue which subsequently became impregnated with lime salts.

In the other case the condition was very different. A certain portion of the muscular substance of the left ventricle was found of a pale colour suggesting fatty degeneration, but the colour was continuous, and it was the external layers that were affected, and that mainly towards the apex. On microscopic examination the muscular fibres were found clouded with fine granules not unlike fat granules (Fig. 162). The granules, however, were dissolved by hydrochloric acid, but without evolution of gas. Köster has met

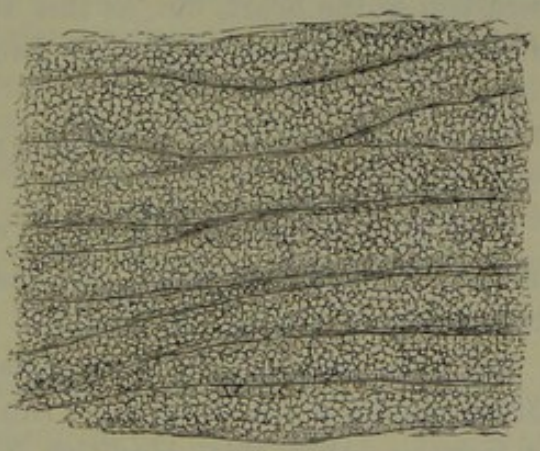


Fig. 162.—Calcareous infiltration of the muscular fibre of the heart. Fine granules occupy the muscular fibres. × 300.

with a somewhat similar case, and he believes that the salt here is, in part at least, sulphate of lime. In this case the true pathology of the condition was obscure.

INJURIES AND RUPTURE OF THE HEART.

Wounds of the heart are not by any means necessarily fatal, although, of course, commonly so. A needle or similar small instrument may be passed into it without obvious injury. In most cases of penetrating wound of the heart there will be fatal hæmorrhage, but such wounds, especially if they do not divide the muscular fibres transversely, may heal, and be finally closed by connective tissue. There are even cases in which the point of a knife or a rifle ball has lodged in the heart and become surrounded by a connective tissue capsule.

Spontaneous rupture of the heart is of very rare occurrence, and the conditions which bring it about are by no means clear. It is natural to suppose that fatty degeneration, especially when associated with a lesion which increases the blood-pressure in the heart, as, for example, stenosis of the aortic orifice, will be the most frequent cause, but it is by no means fully proved that fatty degeneration is always present. The rupture mostly occurs in the left ventricle and near the apex or towards the aortic orifice. There is usually a large escape of blood into the sac of the pericardium, and the patient dies rapidly.

Rupture of the heart may be the consequence of the bursting of an aneurism of the heart, but, as this subject comes up for consideration afterwards it will not be further dwelt on here.

MYOCARDITIS.

It is to be understood that here we include inflammations occurring in the muscular substance of the heart, although not necessarily originating in the muscular tissue proper. It is doubtful whether a true inflammation of the muscular tissue of the heart occurs, a true parenchymatous myocarditis. Rindfleisch describes a case in which he supposes that this condition was the cause of sudden death. He found the muscular substance of a pale violet colour and with ecchymoses under the pericardium and endocardium. Under the microscope the muscular fibres presented a granular appearance, especially around the nuclei. We can well understand that an inflammation affecting the proper muscular fibre will destroy its function, and in the

case of the heart cause death almost immediately. The designation INTERSTITIAL MYOCARDITIS is applied to inflammations which occur in the muscular substance but affect the interstitial connective tissue. These inflammations are mostly secondary, and are chiefly due either to propagation from the endocardium or pericardium, or to septic embolism.

In the course of acute endocarditis the inflammation may spread into the muscular substance, causing, it may be, softening of it. This is particularly the case with ulcerative endocarditis, to be afterwards described. In this disease virulent bacteria are present in the endocardium, and these may invade the muscular substance causing a suppurative inflammation of it, or a kind of abscess. As we shall afterwards see, there may in ulcerative endocarditis be abscesses in the substance of the heart from another cause. Again, chronic endocarditis not infrequently extends to the muscular substance. Like other forms of chronic inflammation, this is associated with great new-formation of connective tissue. For the most part it is the valvular structures which are involved, and they, as we shall afterwards see, are greatly thickened, but the inflammation frequently extends beyond the immediate valvular structures. This is most frequently seen in the case of the mitral valve. Here, along with thickening of the chordæ tendineæ, we often see a partial conversion of the musculi papillares into dense fibrous tissue, in fact an interstitial inflammation with destruction of the muscular tissue. The muscular substance is not so immediately continuous with the aortic valve, but we sometimes see, just beneath the valve, a tendon-like thickening of the endocardium with extension to the muscular tissue beneath. But chronic endocarditis sometimes attacks the endocardium at a distance from the valves, and in that case it is very liable to extend to the muscular substance. This form occurs perhaps most frequently towards the apex of the left ventricle, where a considerable area may be converted into dense connective tissue. By the distention of this altered wall of the heart aneurisms of the heart may take origin.

There has recently been described, especially by Fagge and Charlewood Turner, a more independent fibroid myocarditis. This may occur in patches, so that there are tendinous areas in the muscular substance in the midst of which the muscular fibres may be calcareous. But in other cases it is generalized so that a condition is brought about in which the interstitial connective tissue is greatly increased, and the muscular fibres correspondingly separated from each other, a condition

corresponding to cirrhosis of the liver or kidney. In the localized form the cause is probably some interference with the circulation, perhaps an obstruction of the coronary arteries by atheroma or syphilis. In the more generalized form the cause must be one which affects the whole heart, and as it occurs mostly in dilated or hypertrophied hearts, the strain or over-distention may have to do with it. The hypertrophy of the left ventricle in Bright's disease is stated to be associated with this fibroid change, but the author has failed to convince himself that this is the case. It is possible that in some obscure cases of hypertrophy and dilatation of the heart this lesion may be the primary one.

ABSCESS OF THE HEART is a form of inflammation which probably occurs only by the transplantation of septic material in pyæmia, ulcerative endocarditis, etc. In about a third of the cases of pyæmia there are abscesses in the heart. In connection with these abscesses, colonies of micrococci are to be found in the midst of the pus in the abscess or in the fine arteries and capillaries. These metastatic abscesses first appear as small pale yellow spots or streaks which rapidly soften and enlarge. The abscesses contain a brownish material composed of pus and the debris of muscular fibre. They are usually elongated in shape, and, while numerous, are individually of small size. If situated near the surface, they may burst into the pericardium, producing a septic pericarditis, but even without actual rupture they may, apparently by irritating material passing from them, give rise to pericarditis. When situated near the internal surface, they may communicate with one of the cavities, and it is said that an aneurism of the heart may occur in this way, and may even lead to rupture of the heart.

It will be understood that these abscesses rarely have the opportunity of healing, as the patient dies from the general disease, but it is asserted that survival may occur, and the abscess dry-in to a caseous mass which may afterwards calcify.

ENDOCARDITIS.

It will be necessary, in considering the subject of inflammation of the endocardium, to subdivide it. We shall consider in the first place simple acute endocarditis, then chronic endocarditis, and lastly the special form, ulcerative endocarditis.

(*a*) SIMPLE ACUTE ENDOCARDITIS is, in the great majority of cases, related to acute rheumatism, and, according to Bamberger, it occurs in

20 per cent. of the cases of that disease. Whatever view we take of the origin and nature of acute articular rheumatism, it must be admitted that in it the blood is in some way altered. The blood is in itself of an unusually irritating nature, or else it carries an irritant. The occurrence of acute inflammations in several joints often removed considerably from one another, and the frequent supervention of inflammation in the pericardium and endocardium, are sufficient evidence of this. The irritant, whatever be its nature, seems to act specially on connective tissue membranes, and on such as are exposed to friction of their surfaces. It affects the joints where the synovial membranes lie against each other and in the movements of the joints are moved on one another. It attacks the pericardium where the movements of the heart cause continuous rubbing, and when it attacks the endocardium it affects exactly the localities where the surfaces come in contact. It is as if in addition to the irritant in the blood, the mechanical irritation of friction were necessary to the occurrence of inflammation, and it may be added that in the adult the inflammation is almost limited to the valves of the left side of the heart, where the higher tension of the blood and greater force of the heart make the mechanical force of friction greater than on the right side. We shall see afterwards how this fact bears on the localization of the endocarditis.

The most characteristic effects produced in acute endocarditis are the so-called warty vegetations, which are irregular projections from the surface of the endocardium, generally of small size and somewhat shaggy in appearance. On their first occurrence these are limited to the parts of the valves which come against each other in the closure of the valves, and this localization continues more or less throughout. It is therefore important to know what are the lines of contact in the aortic and mitral valves, because it is there chiefly that we are to look for these endocarditic vegetations.

When after removal of the heart a stream of water is sent into the aorta cut transversely a short distance above the valve, we can look down on the valve closed by the force of the water. It will then be seen that the curtains are not in contact by their margins, but that the line of contact is slightly removed from their edges, and a certain portion of the valve floats free in the water, taking no direct part in the closure of the orifice. The line of contact is nearest the edge of the curtain at the middle of each segment or the corpus Arantii, and forms on either side of this a curved line with the convexity downwards. Between the line of contact and the edge

of the curtain the valve is often perforated, and it may even, as we have seen before (p. 306, Fig. 156), be partially resolved into tendinous cords, without interfering with the closure of the valve. It is by the modification of this portion that we may have the aortic valve showing approaches to the construction of a cuspid valve, as seen in considering malformations of the heart.

In the mitral valve the line of contact is also removed from the edges of the curtains. In the case of the aortic valve the line of contact is of course on the ventricular side of the curtains, but in the mitral it is on the auricular side, and in order to see the vegetation in acute endocarditis it is usually necessary to examine the orifice by looking in from the auricle. Acute endocarditis of the mitral often escapes notice from this not being done.

In acute endocarditis the warty vegetations frequently demarcate very accurately the lines of contact of the aortic and mitral valves, and the appearances produced in the former case are indicated in Fig. 163.

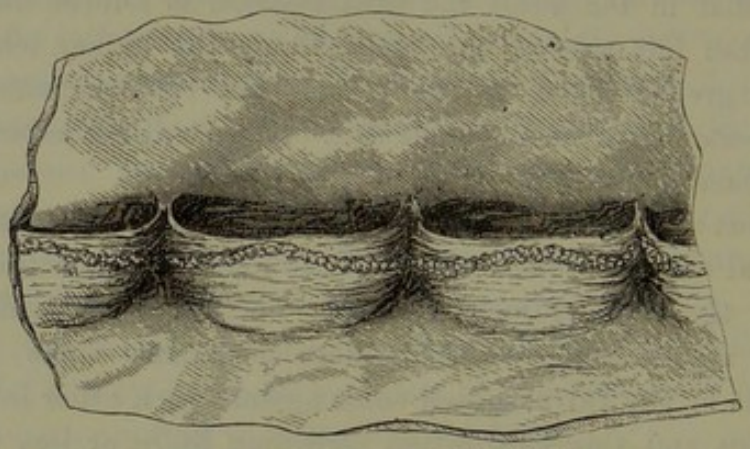


Fig. 163.—The aortic valve in acute endocarditis. The warty vegetations, occupying the lines of contact, are shown.

When the inflammation extends to the valves of the right side, the same principles apply. In the case of the pulmonary valve the vegetations appear along the line of contact on the ventricular aspect of the curtains, and in the tricuspid they are to be seen by looking down through the auricle.

We now turn to the consideration of the actual changes and the structure of these warty vegetations. The inflammation affecting the connective tissue of the valve leads to formation of round cells or granulation tissue. The structures by this change are increased in bulk and rendered more friable, and in this way irregular projections are produced. But the warty projections are not formed entirely or even

chiefly by the granulation tissue. The blood deposits fibrine on the inflamed irregular surface, and this covers up the granulation tissue and forms the principal part of the warty vegetations. Several authors have described micrococci as occurring in these vegetations, chiefly Klebs, Köster, and Osler, and some are inclined to associate these organisms with the essential pathology of acute rheumatism. But these micrococci are not of the virulent sort found in ulcerative endocarditis, and they are probably of subordinate importance.

The occurrence of these changes in the tissue renders it unduly brittle, and it is not surprising to find that bits of the vegetations are frequently broken off and carried by the arteries to distant parts, to produce embolism there. These broken-off pieces are mostly small, and, beyond the ordinary phenomena of embolism in small arteries and capillaries, they do not by their own nature produce much disturbance, in this respect contrasting with the emboli of ulcerative endocarditis. There is not usually any serious loss of substance of the valvular structures, but the softening of the tissue not uncommonly leads to the formation of valvular aneurisms, which we shall consider more fully further on.

(*b*) CHRONIC ENDOCARDITIS commonly follows on the acute form, and, like it, is related to acute rheumatism. It appears as if the irritation were prolonged in a less intense form, and the changes in the valvular structures extend beyond the localities which we have seen to be mainly affected in acute endocarditis. In the chronic form there is a great new-formation of connective tissue. The granulation tissue of the acute stage develops into connective tissue, and the process extends slowly to the remaining structures of the valves. In this way arise great thickenings of the valves (Fig. 164), and, as the connective tissue is of that dense nature common in chronic inflammations, the thickened val-

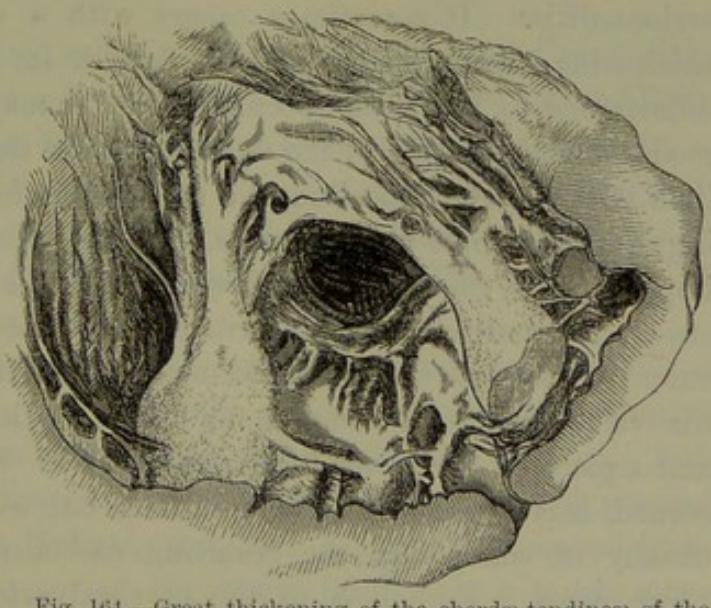


Fig. 164.—Great thickening of the chordæ tendineæ of the mitral valve, the result of chronic endocarditis.

vular structures are often exceedingly rigid. The new-formed tissue also contracts, and in this way we may have great retractions of the valves leading to serious deformities, as we shall see in studying valvular diseases. Again, it frequently happens that two opposed inflamed surfaces coalesce, and we may have still further deformity from this. We have already seen that the inflammation may extend from the endocardium to the muscular substance, leading to cicatricial transformation of it.

In the great majority of cases, the endocarditis is limited to, or has its centre in, the valvular structures, but it sometimes happens that in other parts of the heart an apparently independent endocarditis is set up. This may be along with valvular endocarditis, but separated from it by sound tissue, or it may be without any valvular lesion. We may find an isolated patch of thickening on the surface of the left ventricle, and we have already seen that the disease may penetrate into the muscular substance.

The thickened and rigid connective tissue frequently becomes the seat of secondary changes. Fatty degeneration may occur. But this is much less frequent than calcareous impregnation, which may be taken as evidence that the hard, dense, cicatricial connective tissue has, to a great extent, lost its vitality. This condition is of such frequent occurrence that it may be regarded as the normal termination of chronic endocarditis. It sometimes occurs with a very moderate degree of thickening, and its extent and the date of its occurrence are doubtless determined by individual peculiarities. It may occur in the form of a moderate calcification in the deeper parts of the thickened tissue, or the lime salts may be deposited in a more bulky form so as to give the feeling of considerable stony masses. This occurrence is often of serious import. The valvular structures are rendered still more rigid, and there enters the new element of brittleness. The calcified portion of the valve is exposed very often to mechanical violence in the closure of the valve, and it is common to find that the valve has been broken and a piece of calcareous matter carried off. So far as the valve is concerned, this is not usually very serious, but as the piece carried off is usually of some size, the resulting embolism is frequently of great consequence. Embolism of the cerebral arteries leading to extensive softening is much more frequent in chronic than in acute endocarditis, and probably the same applies to aneurisms of the larger cerebral arteries, which, as we shall afterwards see, may have their origin in embolism. Embolism of the spleen and kidneys is also a frequent result. The

rough surface left by the breaking-off of the calcareous piece gets coated with fibrine, and here again it is said that micro-organisms may be present. The fibrine may, by getting detached, form a fresh source of embolism.

Besides the form of chronic endocarditis hitherto considered, which is the most frequent and most important in its results, there is a form which deserves some notice. This form is closely allied to the disease of arteries commonly designated ATHEROMA, and it occurs most frequently in the aortic valve, being here continuous with atheroma of that vessel. In its causation, therefore, it has nothing to do with rheumatism, but is rather related to the degenerative tendencies of old age. It produces thickenings and indurations of the endocardium, with fatty and calcareous changes just as in ordinary endocarditis, but the processes are more chronic, and produce less considerable deformity of the valvular structures, although from calcareous deposition there may be great rigidity.

Besides this, and still more removed from inflammatory processes, we sometimes have simply OPAQUE PATCHES on the valves with very little thickening. In this case there is little more than a fatty degeneration of the endocardium. Such patches are not uncommon on the mitral valve, and are often erroneously regarded as due to endocarditis.

(*c*) ULCERATIVE ENDOCARDITIS, also called malignant and diphtheritic endocarditis, is regarded by some as merely a form of acute endocarditis, but it presents such differences that it seems necessary to place it in a class by itself. The special features in the disease are the activity of the destructive process in the heart, its connection with the existence of micrococci, and the virulence of the metastatic processes when emboli are carried to distant parts.

In its local manifestations this form presents some resemblance to simple acute endocarditis. The disease affects, usually, the valvular structures, and produces an enlargement and roughening of them. But there is not the same localization along the lines of contact, the process generally developing in a defined area, and sometimes removed from the valve. Again, the disease, as the name implies, is a much more destructive one, the parts concerned breaking down more readily. In this way perforation or aneurism of the valve may occur. Sometimes an actual suppuration manifests itself in the valvular structures, but the frequent passage of the blood prevents any considerable accumulation

of pus. The ulceration sometimes passes to the muscular wall of the heart, especially when the patch of ulceration is away from the valves. The destructive process spreads rapidly in the myocardium, and a distinct abscess may be the result. In this way also an acute aneurism of the heart may supervene.

In their more intimate characters, also, the conditions in ulcerative endocarditis differ from those in the ordinary simple form. As the accompanying figure shows, there is a very marked infiltration of the valvular structures with round cells, almost a suppurative condition.



Fig. 165.—Portion of valve in ulcerative endocarditis. *a*, fibrine with colonies of micrococci; the colonies are indicated by the roundish clumps; *b*, endocardium becoming raised by inflammatory infiltration; *e*, elastic layer of endocardium; *c*, round cells infiltrating endocardium, at *d*, passing into superficial layer of fibrine and micrococci. × 22.

This is immediately overlaid by a fibrinous coagulum, as in the case of simple endocarditis, but mixed with the fibrine there are colonies of micrococci which give quite a striking character to the layer. The appearances in distant parts are evidence that pieces are frequently carried off from the valves, and looking to the soft character of the superficial parts we are not surprised at the occurrence of multiple embolism.

Perhaps the most striking feature in this disease is the occurrence of metastatic abscesses in distant parts. These are found in the heart itself, in the spleen, in the kidneys, in the skin, etc. They are everywhere of small size, and usually in large numbers. These abscesses are obviously related to emboli carried off from the endocardial lesion, and lodged in the finer arteries or capillaries. The accompanying figure represents a small artery in the midst of an incipient abscess in the kidney. It is seen that its calibre is plugged by a material in which are occasional masses of micrococci. At the distal part the wall of the

artery is obscure, apparently from necrosis, and the vessel is buried in an enormous aggregation of inflammation cells. The peculiar virulence of this process is surely to be associated with the presence of the micrococci, yet it seems to be not the micrococci themselves, but rather the

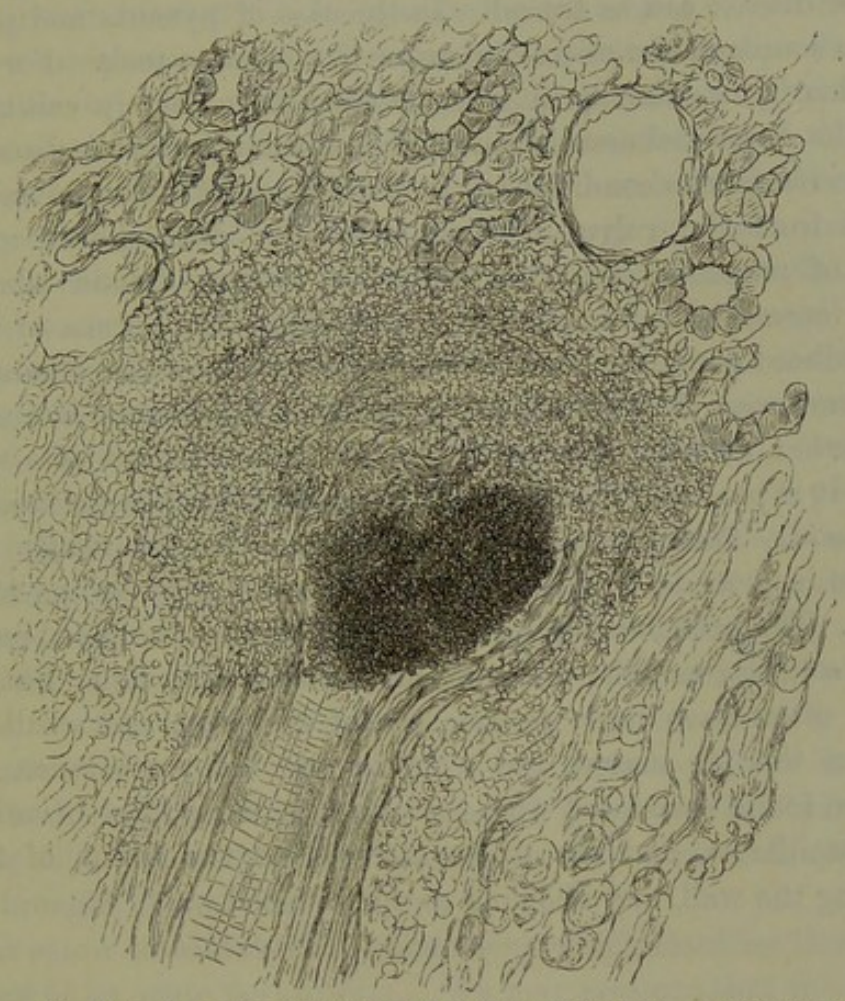


Fig. 166.—From the kidney in ulcerative endocarditis. An artery is shown, plugged with a dark material containing micrococci. Around these are myriads of leucocytes which are infiltrating the necrosed wall of the vessel and the kidney tissue around. × 90.

chemical products evolved by them, which set up the intense inflammation. For, in the illustration given, the micrococci are confined to the calibre of the artery, yet there is necrosis of the wall, and an intense inflammation around. Then, again, the micrococci are frequent in the capillaries and Malpighian vessels, but not generally with obvious inflammation; apparently they are in that case of recent development, possibly to some extent post mortem, and their products have not had time to produce inflammation.

A very important question remains for consideration, namely, the origin of the micrococci which give such special characters to the disease. The disease has been observed to occur in the course of a number

of acute febrile affections. It is met with in pyæmia, puerperal fever, acute rheumatism, small-pox, etc., and Osler has recently pointed out that in a large proportion of cases acute pneumonia has been the primary disease. There are, however, cases in which no definite connection with any other disease can be traced. In the case of pyæmia and puerperal fever the source of the micro-organisms is not far to seek. For the rest we are hardly warranted in going further than merely calling attention to the occasional association of this apparently septic disease with these specific febrile conditions. It may be added that the micrococci removed from the valvular lesion soon after death have been found capable of propagation in the tissues of living animals, where they produce intense inflammation. Inoculated into the cornea of a rabbit they produced panophthalmitis with rapid growth of the organism.

We have seen that the micrococci present, locally, an intensely irritating action, and that necrosis of the tissue attacked is a common result. It is probable that they also produce changes in the constitution of the blood. Patients affected with this disease frequently present, like those in pyæmia, a yellow colour of the skin approaching to that of jaundice. The probable explanation of this is, that the blood corpuscles undergo solution, and the colouring matter stains the skin. But, besides that, we often have little ecchymoses of the skin, and small hæmorrhages in the pia mater, and even in the brain substance. These have been found associated with the presence of colonies of micrococci in the capillaries, and are to be ascribed to the action of these in weakening the wall, and allowing escape of blood.

PERICARDITIS.

The pericardium is comparable in its anatomical and pathological relations to the serous sacs, and, to a certain extent, to the synovial. The pleura, peritoneum, and pericardium are to be regarded, as we previously found in studying œdema and dropsy, as large lymphatic spaces. These sacs are composed of connective tissue, and lined with a single layer of flat endothelium. By means of numerous stomata they are in communication with the lymphatic vessels, and to some extent with one another. The pericardium is in less direct communication with the pleura and peritoneum than these are with each other, but by circuitous routes there is some communication, especially with the pleura. It is to be remembered also that through each serous cavity there is a certain circulation of serous fluid. This fluid does not

accumulate in the sac, because it is carried off as quickly as it is transuded from the vessels, but if the transudation increases greatly there may be an accumulation and consequent dropsy.

(*a*) ACUTE PERICARDITIS.—In considering the causes of this disease it is of some consequence to note that the inflammation usually affects the whole surface at once. This seems to indicate that an irritant has found admission to the pericardial sac, and by the motions of the heart and the natural currents of the fluid in the sac, has been carried hither and thither throughout it. There are many cases in which the tubercular virus is the irritant; we find tubercles mixed up with the inflammatory products. The appearances in this case, however, are so peculiar, and the course of the disease differs to such an extent from that in ordinary cases that it will be proper afterwards to refer more particularly to tubercular pericarditis. The great majority of cases of pericarditis are associated with acute rheumatism. It is to be presumed that the irritant here is the same as that which produces the acute inflammation of the joints and of the endocardium. The irritant circulates in the blood, but we do not know its nature and form, nor why it settles in the pericardium and synovial sacs. The irritant, whatever it may be, having been conveyed to the sac by the blood is carried throughout the latter, and acts on its whole surface. There are some cases in which the disease appears to be of spontaneous origin; it is ascribed to cold. It is altogether obscure in what way such inflammations are brought about.

We have now to consider the phenomena which manifest themselves at the onset of an acute pericarditis. We may presume that the irritant induces the changes in the vessels which have been described in treating of inflammation in general, but opportunities are wanting for observing the consequent redness, as patients survive this early stage. Exudation from the vessels soon follows, and serous fluid begins to accumulate in the sac. As the inflammation affects the surface of the sac, the endothelial lining is very directly involved. The flat endothelial cells are to a considerable extent shed, being apparently killed by the irritant, but they may also be found showing signs of germination. The exudation consists primarily of exuded liquor sanguinis with contractile cells, but soon fibrine is deposited on the inflamed surface. The detachment of the endothelium seems to be the circumstance which determines the coagulation, on principles already explained. The deposition of fibrine occurs on both visceral and parietal layers of the sac, but it is usually

thickest on the visceral surface, where it may present shaggy masses on the surface of the heart. It is whitish in colour, and of soft, almost gelatinous consistence. The fibrinous layers on the opposed surfaces of the pericardium are usually separated by serous fluid which occupies the sac, but an appearance is often presented which suggests the application and withdrawal of the layers while still in a soft plastic condition. This appearance is variously described as the honeycomb or pine-apple condition, and it has been aptly compared to that presented when two pieces of bread thickly buttered are stuck loosely together and then separated. This honeycomb appearance, it will be understood, is most markedly present on those parts of the pericardium where the heart in its movement comes most frequently against the parietes. It will be most extensive and characteristic when there is little serous exudation, and may be taken roughly as an indication of the extent to which the soft fibrine of the opposite layers has been able to come in contact.

The exuded fibrine has the usual characters, as seen under the microscope, forming a fine reticulum ; and in its meshes are leucocytes, and sometimes red corpuscles, whose origin we have already considered in studying inflammation in general.

If the inflammation has been slight and transient, there may be little beyond a small serous and fibrinous exudation, which is gradually absorbed. But as a general rule further changes develop, and these are mainly in the connective tissue of the pericardial sac. This shows evidence of inflammation in the presence of innumerable cells, so that by degrees it is converted into what is equivalent to granulation tissue. This inflammatory transformation does not confine itself to the superficial layers of the sac, but, according to the intensity of the irritation, penetrates more and more deeply, even extending frequently to the interstitial connective tissue in the muscular substance of the heart. A layer of granulations thus forms beneath the fibrinous exudation, and like other such layers, it is abundantly supplied by thin-walled blood-vessels. The formation of this granulation tissue implies here, as elsewhere, that the acuteness of the inflammation has somewhat subsided, or at least that a considerable interval has elapsed since its onset. The layer of granulations has the general tendencies as well as the structure of granulation tissue elsewhere, it tends to develop into connective tissue as soon as the inflammatory irritation becomes sufficiently mild. With the subsidence of the inflammation there will be a reduction of the serous exudation. The fibrine is also disposed of, partly undergoing fatty degeneration and so becoming absorbed, and partly eaten into from

beneath by the granulation tissue. The result of this is that the granulations are, as it were, laid bare, and a vascular layer occupies the place of the former fibrinous deposit.

Looking to this substitution of the fibrinous layer by the vascular granulations, it is easy to understand how the inference was formerly drawn that an actual transformation occurs. The fibrine was regarded as plastic lymph which had the power of developing into the vascular tissue, first granulations and then fibrous tissue. The soft fibrine is still sometimes called soft lymph, and the name is even applied to shreds of connective tissue which have been formed from the granulations.

With the absorption of the exudation the two layers of the pericardium come in contact, and a coalescence of the granulating surfaces, more or less complete, occurs. The vessels intercommunicate, and the two layers so far as they are in contact become virtually one. As the granulation tissue passes on in its development into connective tissue the pericardial sac undergoes partial or complete obliteration, the uniting agent being vascular connective tissue. The connection will at first be delicate, and may be torn through, but as time goes on it gets firmer, and a condition results in which the two layers are absolutely inseparable. Under certain circumstances the coalescence of the two layers is not complete, and there is only a partial adhesion; in that case the adhesions are sometimes greatly stretched by the movements of the heart so that tags or ligaments may unite the surface of the heart to the peripheral layer.

This, which may be regarded as the normal course of pericarditis, is sometimes departed from, chiefly when the inflammation remains too intense to allow of the formation of proper connective tissue. Instead of progressing in this direction, suppuration occurs, and the serous exudation in the pericardium gives place to pus. The inflammation in that case is usually very prolonged, and even when it subsides there are obstacles to the adhesion of the layers. On the subsidence of the inflammation the pus dries in by the absorption of its fluid. The pus corpuscles undergo fatty degeneration and die, but the surface not being well adapted for absorption, the debris remains as dead matter. In this way caseous material is produced, which subsequently gets infiltrated with lime salts. At first the lime forms a pultaceous layer on the surface of the heart, but it may afterwards become consolidated so as to form calcareous plates in the midst of thick adhesions.

It is to be added that SEPTIC INFLAMMATIONS, such as those which occur in pyæmia when an abscess in the substance of the heart extends

to the surface and bursts into the pericardium or gives off septic organisms, or in the rarer case of perforation of an ulcer of the stomach or œsophagus into the pericardium, are purulent from the outset. The septic irritant acts so intensely that leucocytes are at once exuded in such numbers as to give a purulent character to the exudation.

In considering HYPERTROPHY OF THE HEART in a previous page, it was pointed out that this condition may be caused by complete synechia of the pericardium, and an endeavour was made to explain the mode of its production. It may here be stated that hypertrophy may occur even in the stage of pericarditis associated with fibrinous and serous exudation, but these conditions must have persisted long in order to induce it; the mode in which they bring it about has been already explained. It should be borne in mind, however, that, as pericarditis is often associated with endocarditis, we may have hypertrophy from valvular disease associated with adherent pericardium, and it may be difficult sometimes to assign the exact proportion of one or other agent in bringing about the result.

TUBERCULAR PERICARDITIS has commonly a sub-acute or chronic course. It is very often associated with tuberculosis of the pleura, and the conditions in that sac have similar characters. Occasionally we meet with an acute fibrinous pericarditis in which, when we remove the fibrine, numerous small white fresh tubercles are to be seen on the pericardium. More frequently, however, the two layers of the pericardium are firmly united by connective tissue, and it is impossible to separate them. In the midst of the thickened layers are to be seen yellow caseous masses, sometimes of considerable size. These represent old tubercles, and the whole process is a more or less chronic one, even from the outset. Under the microscope there will be found large masses having the indefinite characters of caseous necrosis with occasional fresh tubercles, in the midst of tissue which presents in some parts evidences of recent inflammation and in others merely dense connective tissue.

WHITE SPOTS, MILK SPOTS, OR SOLDIER'S SPOTS, on the pericardium.—These are very common pathological conditions and warrant a passing notice. They occur in about half the cases examined post mortem, and their frequency seems nearly in direct proportion to age. They are in the form of well-defined, whitish, opaque areas on the surface of the heart, of very various size, sometimes very small, at other times so large as

almost to cover the anterior surface. Their edges are usually abrupt and well-defined, but they may merge gradually in the pericardium. They have often a brilliant white tendinous appearance, but may be more dull. They are most frequently situated on the anterior surface of the right ventricle, and next on that of the left ventricle, especially near the apex. They are also met with on the posterior surface, especially near the base of the heart, and on the intra-pericardial portions of the great vessels. They are more uncommon on the parietal layer of the sac.

These spots actually consist in a thickening of the pericardium, presenting merely dense connective tissue covered with endothelium (see Fig. 167). The thickening is due to a chronic irritation, and the con-

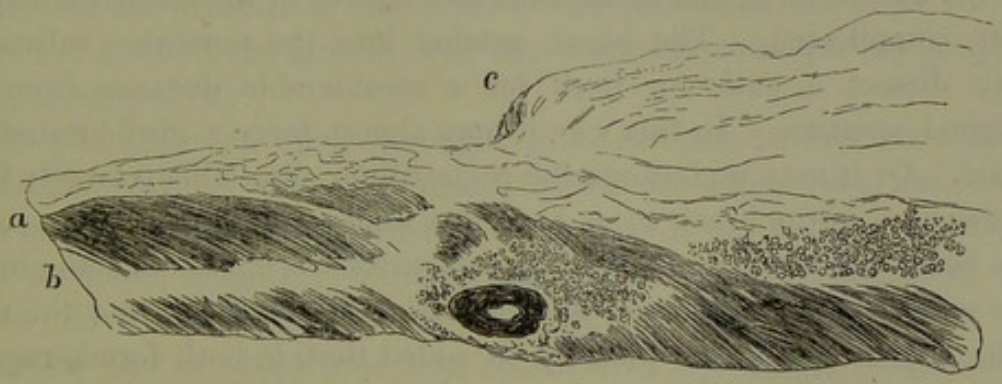


Fig. 167.—Soldier's spot on pericardium. *b*, muscular wall of heart; *a*, pericardium; *c*, thickening so as to form spot. × 25.

dition is really a chronic pericarditis. The cause of the irritation is not at first very clear. We have here a circumscribed inflammation affecting by preference certain districts, and the cause must be a local one. It seems to be due to the irritation resulting from the projection of the heart against its surroundings. The commonest seat is where the anterior surface of the right ventricle comes against the sternum at the place where the edges of the lungs turn aside and expose the pericardium. The sternum is less yielding than most surrounding parts, and so the irritation is greater here. The spot where the left ventricle near the apex strikes against the fifth rib, is the next most frequent site.

ANEURISMS OF THE HEART AND VALVES.

Although these aneurisms are not usually of independent origin or significance, we give them here a special treatment because of their frequency and importance.

By ANEURISMS OF THE HEART are meant aneurisms which, in the

form of sacs or diverticula, communicate with one of the cavities of the heart. These aneurisms are almost confined to the left ventricle, and they may be divided into two forms. In one form the aneurism projects out from the heart, so as to be visible externally as a protrusion; in the other form the aneurism burrows in the wall of the heart, and is not visible externally. The first form usually has its seat at the apex or the base, and in the latter case it may project up between the great vessels. These aneurisms mostly arise as a consequence of chronic endocarditis, or chronic myocarditis. The latter, especially when it produces a localised fibroid condition, or cirrhosis of the muscular wall, may allow of partial dilatation in the form of a pouch. In the second form, the dimensions and outline of the aneurism may be very complicated. The blood, getting into the muscular substance, may dissect a path for itself for a considerable distance from the original aperture. In this way it may almost form a girdle round the heart. Or it may undermine the pericardium, dissecting it largely from the surface of the heart, so as to form a kind of blood-filled sac around the heart. For the most part these aneurisms originate in softening of the endocardium, admitting of penetration of the blood into the muscular substance. It need hardly be added that, in both forms, rupture of the aneurism is liable to occur, usually into the sac of the pericardium, and with fatal results.

ANEURISM OF THE VALVES is the condition in which a pouch exists, projecting from a valve and with a narrow neck. This form of aneurism results from acute endocarditis, either simple or ulcerative. With the aid of the accompanying diagram, the mode of formation of the

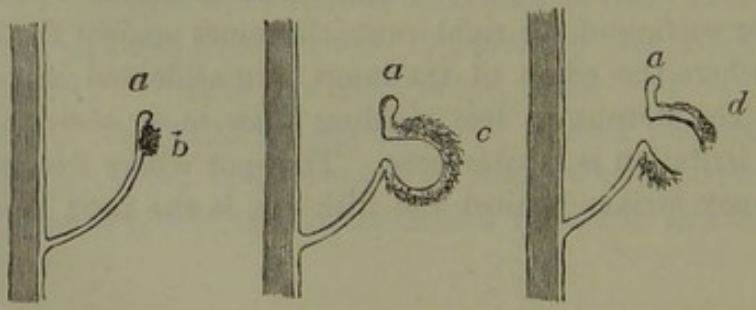


Fig. 168.—Diagram of mode of formation of aneurism of aortic valve. The curtain (*a*) formed of two layers. At *b*, its outer layer roughened and softened. At *c*, the aneurism, which has burst at *d*, so as to perforate the valve.

aneurism may be illustrated in the case of the aortic valve, which is its most frequent seat. The semilunar curtains which form the valve are each composed of a double fold of endocardium, as represented at

a. From what has already been stated, it will be known that in acute endocarditis it is the ventricular layer which is principally involved along the line of contact, as indicated at *b*. The aortic layer is usually smooth and unaltered to the naked eye. At the affected part of the ventricular layer the tisue is softened, and during the closure of the valve, the single aortic layer may be unable to support the full pressure of the blood. In this way it may be pushed towards the ventricle, carrying before it the softened ventricular layer, as at *c*. It will be apparent that, in the case of the aortic valve, the aneurism will always project into the ventricle. In the case of the mitral valve, on the other hand, the softened layer is on the auricular surface of the valve, and the pressure of the blood during closure of the valve will be exercised towards the auricle, and the aneurism consequently projects towards that cavity.

As the aneurism owes its origin to acute endocarditis, its surface is usually covered with vegetations, which are often very abundant, and may so conceal the aneurism as to lead to its being overlooked. The aneurism, again, may rupture, and so produce a perforation of the valve. It is sometimes as if the bottom had been blown out of the aneurism and a short tube left, surrounded by shaggy vegetations (as at *d* in figure). Even in that case, however, if the neck of the aneurism be examined, it is often found that the endocardium, as it passes into it, is smooth and unaltered.

VALVULAR DISEASE OF THE HEART.

In studying endocarditis, we have seen that the valves are frequently altered in their structure; we have now to consider these alterations more specifically, and their effects on the heart and circulation. It is not usual to designate anything as valvular disease unless it interfere with the function of a valve or orifice. The function of a valve is to close an orifice under certain circumstances, and we speak of valvular disease when the alterations are such as either to obstruct the orifice or to interfere with its closure by the valve. Hence valvular lesions may be divided into two kinds, namely, narrowing or stenosis of the orifice, and insufficiency of the valve. In referring to these same lesions, as they affect the current of blood in the heart, we speak of obstruction of an orifice and of regurgitation through the orifice or incompetency of the valve. Of course it would be a very incorrect use of language to speak of obstruction of a valve, or insufficiency of an orifice.

Valvular disease occurs much more frequently in the valves of the left side than in those of the right, and hence we have chiefly to do with the mitral and aortic valves. We have already seen that in the fœtus it is the valves of the right side which are most frequently affected, and we have connected this with the fact that these valves are more liable to variations of pressure in the fœtus than in the adult.

Insufficiency or Incompetency of the Mitral Valve.—This is a condition in which, during the systole of the heart, some portion of the blood passes back into the left auricle instead of the whole being forced into the aorta.

The actual physical conditions are somewhat various, but most of them are related to chronic endocarditis. The commonest is that in which the valvular structures are thickened by the new-formed connective tissue and retracted and shortened from its contraction. This applies to the curtains themselves, but still more to the chordæ tendineæ, which become thickened and shortened, and frequently grow together, so that they hold the curtains rigidly drawn down and do not allow them to go together during the systole of the ventricle (see figure 164, p. 325). Again, much more rarely, in acute endocarditis, the valve may be perforated, as in the case of valvular aneurism, or the chordæ tendineæ torn so as to allow a portion of the valve to flap upwards through the orifice. Lastly, without much alteration of the curtains, there may be a *relative insufficiency* of the valve. That is to say, the cavity of the ventricles sometimes enlarges greatly, and produces enlargement of the orifice, which the valve is no longer able to cover. There are some cases of permanent hypertrophy and dilatation of the left ventricle where this occurs, but it may be met with where the dilatation is temporary, as in the flabby fatty heart of typhus fever and anæmia. It is not to be supposed that the so-called anæmic murmurs are usually due to this cause, but there is in some cases an actual mitral regurgitation. When recovery occurs, and the heart resumes its former vigour, the valve will again cover the orifice.

We have now to consider what results ensue from insufficient closure of the valve. At each ventricular systole blood regurgitates into the left auricle, and the most direct result is over-distension of this auricle occurring at successive intervals. The wall of the auricle is weak, and does not offer much resistance to the distensile force. There is another result which often follows, apparently from the unduly forcible impact of the blood against the endocardium, and the over-stretching of this

membrane, namely a thickening of the endocardium. We may find it generally thickened and opaque, or there may be patches of opacity.

But the results do not confine themselves to the auricle—the abnormal blood-pressure is reflected to the pulmonary veins which feed the auricle, and they become distended. The distension is further reflected to the capillaries and the pulmonary arteries, and finally to the right ventricle. The right ventricle is over-distended, and unless it acts more vigorously than usual, so as to empty itself into the pulmonary artery at every systole with greater force, the overfilling is reflected to the systemic venous system.

We have already seen, however, that when necessity arises the heart is stimulated to increased action. The rhythmical contractions of the heart are referrible to its intrinsic ganglia, and the heart of a frog will beat for a time when empty of blood. But it beats much more vigorously when full, and the more its cavities are distended, up to a certain point, the more vigorous are its contractions. It is as if the stretching of the fibres supplied the reflex stimulus to increased vigour in the contraction of the muscle. In the case we are considering the increase in the amount and pressure of the blood in the right ventricle, as well as the necessities of the pulmonary circulation, act as a spur to more vigorous contraction, and we have already seen that this increased action when prolonged leads to hypertrophy. Hypertrophy of the right ventricle is therefore a very constant result of the lesion we are considering.

Returning now to the left side of the heart, it is clear that, as part of the blood in the left ventricle passes at each systole into the auricle, too little will go into the aorta, and the systemic circulation will be partially starved. But when the right ventricle acts with increased vigour, the blood passes into the left ventricle with increased force and in larger amount than normally. The result will be increased action and consequent hypertrophy of the left ventricle. We can see here again a double action such as we found in the case of the right ventricle. The systemic circulation, being starved, calls for increased supply of blood, and on the other hand the distension of the ventricle induces increase in the force of the contractions. The hypertrophy of the left ventricle is usually small in amount and quite subordinate to that of the right, which with the distension of the left auricle is the most prominent appearance. The heart presents the more globular or quadrilateral shape already referred to as characteristic of hypertrophy of the right ventricle.

These changes may completely compensate for the incompetence of the valve, that is to say the circulation may be restored to its normal efficiency; but it may not be so, or even when established, the restored efficiency may be impaired from some further interference with the pulmonary circulation or weakness of the heart. So there is apt, after a time, to be over-distension of the systemic venous circulation, and the train of changes which are usually more fully developed in mitral obstruction and will be described under that heading. The pulmonary circulation suffers even more than the systemic from any insufficient compensation on the part of the right ventricle. The pulmonary vessels are permanently over-distended, and œdema and hæmorrhage are frequent results. The hæmorrhage is in the form of slight oozing from the pulmonary capillaries so that the sputum is streaked with blood. It is not to be confused with that which occurs in consequence of embolism of the pulmonary artery, forming the hæmorrhagic infarction, which is of frequent occurrence in disease of the mitral valve, but from a cause to be afterwards considered.

Obstruction of the Mitral Orifice. Mitral Stenosis.—This name is applied to the condition in which the mitral orifice is not large enough to allow of the usual quantity of blood passing from the auricle to the ventricle. The normal width of the mitral orifice may be roughly estimated with the fingers; in the adult it should allow the index and middle fingers to pass freely through as far as the first joint. The contraction may be very slight or it may be to such an extent that hardly a crow-quill can be admitted into the orifice. In the case of stenosis of the mitral as well as in that of the aortic orifice, the obstruction is usually caused by the curtains of the valves becoming thickened and rigid, and especially by their coalescence. The thickened valves grow together by their edges, and so the valve is converted into a funnel with its apex turned down into the ventricle. The normal orifice is at the base of the curtains. But when the valves coalesce,

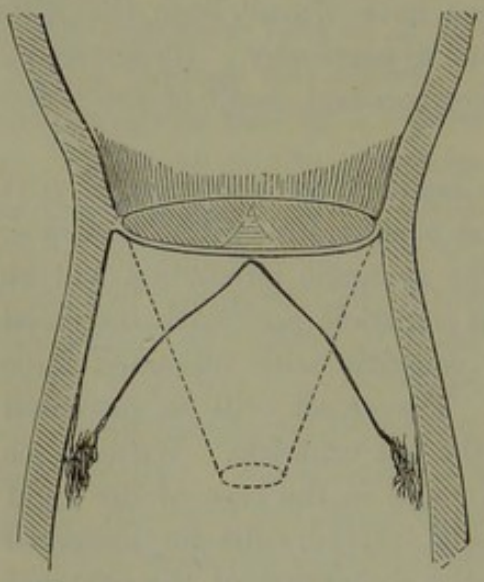


Fig. 169.—Diagram of funnel-shaped deformity of mitral valve. The dotted lines indicate the coalesced curtains forming a funnel projecting into the ventricle with a reduced aperture at the apex.

the orifice while becoming contracted is moved downwards, and comes to have its site at the apex of the funnel. This will be understood from the accompanying simple diagram (Fig. 169), in which black lines represent the orifice and curtains in their normal condition during the diastole of the ventricle, the curtains lying back against the wall of the ventricle, and the orifice at their base. The dotted lines represent the coalesced funnel-shaped valve; the contraction of the orifice and its removal downwards being shown. The chordæ tendineæ are commonly thickened and often partly incorporated in the funnel (see Fig. 164, p. 325). On laying open the ventricle this thick, rigid, funnel-shaped deformity is often strikingly prominent. These conditions result from chronic endocarditis, and it will be readily understood that the rigid valve is frequently incompetent, so that this condition is often combined with the one before. There are also not infrequently changes in the aortic valve.

It might be supposed that the vegetations occurring in acute endocarditis would obstruct the orifice, but although these rough projections undoubtedly interrupt the even flow of blood, and may produce during life what is technically a murmur of mitral obstruction, yet their actual influence on the function of the orifice must be very slight, and we are not to look for any definite evidences of their influence on the circulation.

Obstruction is occasionally produced by thrombi growing on the valve, or having their seat in the auricle and projecting into the orifice. This is a rare cause of obstruction, and a still rarer is the presence of tumours growing in such a way as to obstruct the orifice.

We have now to consider the results to the circulation of mitral obstruction. The most direct effect will be dilatation of the left auricle, as the blood is, to a certain extent, hindered in its passage into the ventricle. As a consequence, the whole pulmonary vessels will be loaded and the right ventricle distended with the accumulated blood. On the principles already laid down there will be increased action and consequent hypertrophy of the right ventricle, and this is commonly more extreme than in mitral insufficiency. The contraction of the orifice interferes with the passage of blood into the left ventricle, which, in extreme cases, is, as it were, starved of blood. The increased force of the right ventricle may in great part make up for this deficiency, and sometimes there is also aortic insufficiency, so that the ventricle is fed from the aorta as well. According to these various circumstances will be the state of the left ventricle. It may be actually

atrophied and appear as a small appendage to the enlarged right ventricle, or it may be normal in size or even hypertrophied. In any case the hypertrophy of the right ventricle is the predominating condition. The shape of the heart is more quadrilateral, the apex is blunt and formed by the right ventricle. During life, instead of the defined apex beat of the left ventricle, there is the more diffused heaving of the right.

Passing from the heart, we have a permanent passive hyperæmia of the pulmonary circulation, with consequent brown induration of the lungs. There will also be the tendency to slight hæmorrhages, showing itself in the sputa. Œdema of the lungs readily develops. The dilatation of the right ventricle, especially when followed by thrombosis, also frequently leads to embolism of the pulmonary artery and the hæmorrhagic infarction. The hyperæmia is reflected to the systemic venous circulation, especially if the dilatation of the right ventricle lead to relative insufficiency of the tricuspid valve, and we find evidences of passive hyperæmia of the liver (nutmeg liver), kidneys and other organs. Not infrequently serious œdema of the skin and dropsy of the serous cavities develop. Thrombosis in the veins of the legs often complicates the condition, and this again may be a source of pulmonary embolism.

Insufficiency of the Aortic Valve.—This is the condition in which, after the completion of the ventricular systole, a portion of the blood regurgitates into the left ventricle through the imperfectly closed semilunar valve. This condition is usually brought about by chronic endocarditis. The individual semilunar folds are thickened and shortened, the actual length of free margin being reduced. The consequence is that, during the closure of the valve, the edges have not sufficient length to meet perfectly and so a triangular aperture is left. This is illustrated diagrammatically in the accompanying figure. The contraction may reach such an extent as to leave only a nodulation on the wall of the aorta in place of the curtains. These changes are very commonly accompanied by adhesion of the adjacent folds

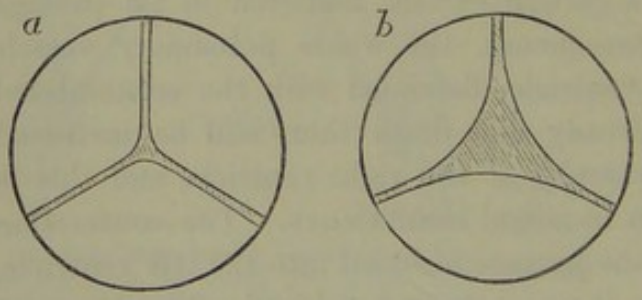


Fig. 170.—Diagram of aortic insufficiency. *a*, the normal valve closed, as seen from above; *b*, the valve with curtains shortened and leaving a triangular space.

of the curtains, and this necessarily causes contraction of the orifice; indeed, the curtains as such may disappear, leaving only a diaphragm with a permanent aperture in its middle, the condition being similar to that illustrated in Figure 154, p. 303. An unusual cause of aortic insufficiency is perforation of the curtains as a result of acute endocarditis or the bursting of a valvular aneurism. Of course the perforation of the curtains beyond the line of contact already referred to is not to be mistaken for a pathological perforation. A rare cause of aortic insufficiency is the tearing of one of the curtains. During severe exertion the blood-pressure in the aorta may be so much raised as to rupture a curtain, and such a wound will hardly unite as it will be torn aside at each closure.

It may be added here that aortic disease is often accompanied by mitral disease, chronic endocarditis, having its origin in rheumatism, attacking both. Chronic endocarditis of the aortic valve again is often connected, as we have seen, with endarteritis or atheroma of the aorta, and in that case it is not so likely to be associated with mitral disease.

It may be interesting here to observe that the origin of the endocarditis has an important bearing on the age at which these valvular lesions occur. Acute rheumatism is a disease of youth and manhood, and most cases of valvular disease take origin in it. Accordingly, diseases of the valves are most common, at least in their inception, between the ages of ten and thirty. But there are some cases of aortic disease which, as we have seen, stand in a different category. Chronic endarteritis or atheroma is a disease mostly of advanced life, and so it is more common in old persons to meet with aortic disease than with mitral.

We have now to consider the effect of this insufficiency of the aortic valve on the circulation. In the normal state during the diastole of the ventricle, the blood flows from the auricle into the ventricle. But just at the close of the diastole the auricle contracts and forces the blood more vigorously into the ventricle so as to distend it, and perhaps give it the impulse to contract. When the ventricle contracts the blood passes into the aorta, and the wave is propagated forwards, and at the same time partly distends that vessel. At the end of the systole the semilunar valve closes, and on the recoil of the distended aorta the blood is forced onwards in the systemic arteries. But now, suppose that the semilunar valve does not close completely, then the aorta in its recoil will force blood back into the ventricle as well as forward into the systemic arteries. This extra mass of blood driven with considerable force into the left ventricle will overfill it and forcibly

distend it, while the systemic circulation will be proportionately starved. The left ventricle is called on to make increased exertions to get rid of the excess of blood and fulfil the wants of the system, and we may suppose that the stimulus to increased action is afforded by the stretching of the fibres by the excess of blood. The natural result is dilatation and hypertrophy of the left ventricle, which may almost completely compensate. In this disease, therefore, the primary and prominent fact is the enlargement of the left ventricle. As previously mentioned, the heart becomes more conical in shape; the septum takes part in the hypertrophy and bulges into the right ventricle. This may exist to such an extent that the right ventricle is seen on transverse section as a mere crescentic appendage of the left, and there may even be, to some extent, obstruction of the right auriculo-ventricular orifice by the bulging of the septum, inducing general venous hyperæmia. As the ventricle propels a much larger amount of blood into the aorta, and with abnormal force, there is sometimes a resulting dilatation of the arch and great vessels. In this way there may even be an actual aneurism of the arch.

It is to be added, that as hypertrophy of the left ventricle is associated with dilatation of that cavity, there is frequently a consequent widening of the mitral orifice. As a result of this, we may have a relative incompetency of the mitral valve, which is incapable of completely covering the dilated orifice. In this way, the consequences already considered of mitral insufficiency may be brought about; but they are usually much less pronounced, and of late occurrence. It is to be remembered, also, that mitral disease often co-exists with aortic.

Obstruction of the Aortic Orifice. Aortic Stenosis.—In this lesion the passage of blood from the left ventricle into the aorta is interfered with. It is, in the great majority of cases, caused by chronic endocarditis. The conditions already described as leading to insufficiency of the valve by causing rigidity of the curtains, mostly produce obstruction of the orifice, and this is all the more marked when calcareous infiltration ensues. Where the valve is, in the way already mentioned, converted into a rigid diaphragm, then there must be great obstruction of the orifice as well as insufficiency of the valve. These two forms of lesion are, therefore, usually found associated. In acute endocarditis the roughening of the curtains may to some extent obstruct the flow of blood, but the interference is trivial, and will hardly lead to any of the secondary results of aortic stenosis.

The obstruction at the orifice prevents the blood getting away fully during the systole of the ventricle, and there comes to be an overfilling of the ventricle. The ventricle, as in the previous case, is stimulated to increased exertion, and the distensile force of the blood may again be supposed to afford the necessary stimulus. Increased action induces hypertrophy as before, and so here, as in the previous case, the primary phenomenon is hypertrophy of the left ventricle. This may completely compensate for the obstruction, and persons may go about comparatively well with an obstructed orifice and enlarged left ventricle. But this is not so likely as in the previous case, and any extra need for exertion on the part of the heart, or weakness of its muscle, may lead to incomplete compensation. In such a case the ventricle will get abnormally dilated, and the auricle will not be able to empty itself fully into the dilated ventricle. The pulmonary circulation will become engorged and the right ventricle overloaded, and so we may have all the evil consequences of mitral disease. It will be observed, however, that, as the left ventricle is much more capable of undertaking additional work than the right, it succeeds much more frequently in bringing about a complete compensation. The hypertrophied left ventricle having to dispose of an increased mass of blood, generally does so slowly, and the pulse is consequently slow and regular.

It will have become apparent that in many cases aortic disease is associated with mitral, and that there is frequently combination and complication of the resulting changes in the heart and circulation.

Valvular Disease of the Right Heart.—We have already seen that, except in the fœtus, this form of disease is uncommon. In cases of acute or chronic endocarditis with well marked lesions on the left side, however, there are very often slight indications of inflammation in the valves of the right heart.

There is one condition of the tricuspid valve which, although secondary, is often of considerable consequence on account of the effects to which it leads, and that is relative insufficiency of the tricuspid valve. We have seen that in mitral disease the right ventricle usually dilates and hypertrophies, and with this change in the ventricle the orifice widens. The valve may thus be unable to cover the enlarged orifice, and become insufficient. In other forms of dilatation and hypertrophy of the right ventricle as in that due to obstruction to

the pulmonary circulation, the same thing may occur. The tricuspid orifice normally admits readily three fingers up to the first joints, and when enlarged it is not uncommon to meet with cases in which it admits four, five, six, or even seven fingers. If the valve is thus incompetent to close the enlarged orifice the blood will, during the systole of the ventricle, regurgitate into the auricle. The wave will be propagated into the veins of the neck, and there will probably be an aggravation of existing congestion of the systemic veins.

It need only be added that if chronic endocarditis attacks the tricuspid or pulmonary valves, it may produce results similar to those effected in the mitral and aortic. The tissue here, however, is less substantial to begin with, and the inflammation is usually much less intense, and so the changes are rarely of any great consequence.

COAGULA IN THE HEART.

Simple Clots.—It is very common to meet with clots in the heart at post-mortem examinations, and very important to distinguish those that are of pathological significance. In a great majority of cases we meet with soft gelatinous clots occupying auricles and ventricles and sometimes extending from them into the aorta and pulmonary artery. These clots are produced just about the period of death. It cannot be said that they are always in the strictest sense post-mortem, because the fact that they are sometimes decolorized shows that the blood corpuscles have been in these cases removed from them. Yet they are to all intents and purposes post-mortem. During the last minutes of life the heart may give irregular and imperfect contractions, not sufficient to forward the circulation, but having the effect of churning the blood. Coagula may thus be formed somewhat in the way that the fibrine is separated in whipping blood. In that case the clot is apt to be stringy and slightly opaque in appearance. Again, the absence of the red corpuscles in a clot may be brought about in a different way. When blood is shed it coagulates quickly, and in human blood it is rare for the coagulation to be long enough delayed to allow of the sinking of the corpuscles so as to leave a buffy coat on the surface. In the heart, however, the coagulation, unless it be induced by the churning action just referred to, is delayed, because the tissue does not immediately lose all vitality. Time is often thus afforded for the sinking of the red corpuscles, and so we may find some parts of the clot deeply red and others colourless or yellow. For practical purposes all

this class of coagula may be designated simply, clots, the term thrombi being applied to those occurring during life.

The clots have more or less the shape of the cavity in which they are found. They sometimes extend into the great vessels, and show a constriction where they have taken the mould of the valve. They adhere very little to the endocardium, although they may have a deceptive appearance of adhesion from being entangled among the chordæ tendineæ and musculi papillares. The gelatinous character, transparent appearance, and smooth surface of these clots are other indications. They are also as a rule much more bulky than thrombi.

THROMBI are of various kinds and different significance, and it may be said that coagulation of blood within the heart during life is of frequent occurrence. We have already incidentally considered most of these forms of thrombi, and it will be necessary here to do little more

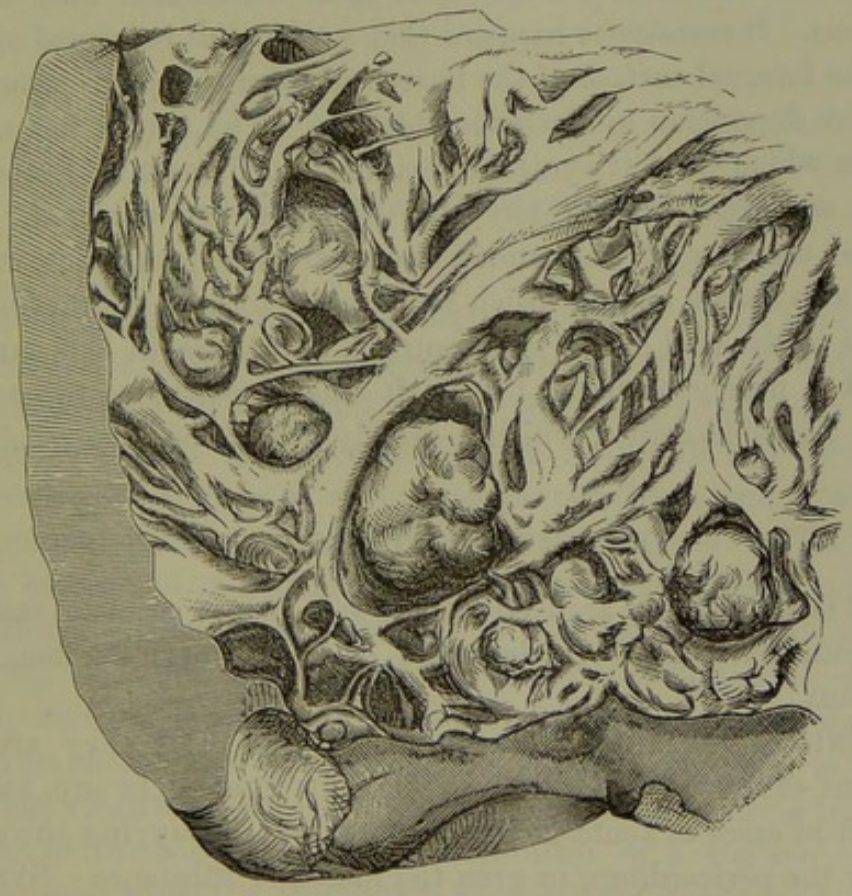


Fig. 171.—Globular thrombi near the apex of the left ventricle. Several of these are seen to project from between the musculi papillares.

than enumerate them. Thrombi are frequently designated vegetations, but it is not advisable to use this word in place of the more accurate

one thrombi. We may distinguish three forms of thrombi: warty, globular, and polypoid.

WARTY THROMBI we have already seen to occur in acute endocarditis, owing to the coagulation of the fibrine on the inflamed and roughened surfaces.

GLOBULAR THROMBI have been described in the section on thrombosis (see page 28) in the first part of this work, and are represented in Fig. 171. It is to be remembered that they are of frequent occurrence in dilated and hypertrophied hearts, and that they are prone to soften in the central parts and finally to break down, so that they may give rise to embolism. These thrombi are sometimes very loosely adherent to the endocardium and may be detached bodily and carried into the pulmonary artery or aorta—most frequently into the former, as they are more common in the right ventricle and auricle than in the left.

The POLYPOID THROMBI are much more uncommon than the other two forms. It sometimes happens that a thrombus is formed on a valve or on the internal surface of the heart and from this point grows out by successive deposition to a considerable size. The author has met with a case in which the left ventricle was filled with massive festoons thus formed, and great hypertrophy and dilatation had occurred. In this case also the coagula had undergone a partial impregnation with lime. He has also seen a case in which a thrombus, formed of firm fibrine and attached to the wall of the right auricle, hung free in the auricle and assumed a nearly globular form. It was so placed as to hang down into the tricuspid orifice, which it greatly obstructed, like a ball-valve.

TUMOURS OF THE HEART.

PRIMARY TUMOURS are exceedingly rare, but a primary sarcoma of the endocardium has been described, as also primary fibroma, myoma, and lipoma.

SECONDARY TUMOURS are not uncommon, and they are either malignant or infective tumours. MILIARY TUBERCLES are sometimes met with in cases of acute general tuberculosis, occupying the endocardium, or the pericardium, or even the muscular substance. SYPHILITIC GUMMATA are occasionally met with in the muscular substance, and as usual they are accompanied by interstitial inflammation. The gumma has the usual indefinite and varied structure, in the more recent stage softer and more cellular, in the more advanced stage largely composed

of dense connective tissue, with probably a caseous centre. There may be a single tumour replacing a portion of the wall, and surrounded by the cicatricial tissue of chronic inflammation, in which the endocardium or the pericardium may be involved. In the latter case there is adhesion of the two layers of the sac. Or the gummata may be multiple, in which case there is a more diffused interstitial inflammation. SARCOMAS occurring in the neighbourhood may spread to the heart, and especially those of the mediastinum, involving first the parietal and then the visceral pericardium. Sometimes also a CANCER of the œsophagus extends to the pericardium. Cancers when they become generalized very often occur in the heart, in the form of round pale tumours.

Of PARASITES, the echinococcus and the cysticercus cellulosæ have been found in the heart.

B.—THE BLOOD-VESSELS.

The blood-vessels are to be regarded as tubes of which the essential constituent is the intima. According to circumstances the intima becomes clothed with external and middle coats, and so we have arteries and veins. We have already seen that, in nearly all new-formations, blood-vessels are produced as well as the proper tissue, and it is first a tube composed of intima which is formed, or a capillary. This primary vessel is capable of enlargement and further complication in the way just indicated, so that a transformation of the primary capillaries into arteries and veins may take place. This process of formation of vessels and their further development according to the requirements of the tissues is an exceedingly common one, and may be regarded as equivalent to that which occurs in the formation of the tissues during the period of growth of the body as a whole. A process of a similar nature is sometimes seen when the obstruction of an artery causes the current to be in great part diverted into other channels. We know that in this case the anastomosing vessels enlarge, small arteries becoming converted into large ones, and perhaps even capillaries into arteries. The vascular system is thus an exceedingly plastic one, and possesses great

powers of new-formation and development according to the needs of the tissues.

INFLAMMATION OF THE VESSELS.

We have already seen that the blood-vessels bear an important, perhaps an essential, part in the inflammatory process, but apart from this we have to consider inflammations affecting the tissues composing the walls of the vessels, and some of these also have been already referred to incidentally.

Acute Inflammation.—Considering the close analogy between the endocardium and the intima of blood-vessels it might be supposed that the latter would be prone to acute inflammation under similar circumstances to the former. But this is not the case, and an acute endarteritis scarcely ever occurs. Sometimes an acute endocarditis affecting the aortic valve extends to the neighbouring portions of the aorta, resulting in the formation of irregular projections, generally on the surface of a chronic thickening, but even this is rare. The acute inflammations of the vessels are nearly always secondary.

A typical instance of acute inflammation is afforded by that which occurs in the veins in pyæmia (Phlebitis). The conditions here have been already considered, and we saw that the inflammation depends on the action of a septic irritant. In the metastatic abscesses of pyæmia we have also a septic inflammation of the arteries. Vessels which communicate with wounds are liable to inflammations at their mouths, especially when the wounds are septic. The arteries and veins in stumps are thus often inflamed.

In all cases of acute inflammation of blood-vessels, thrombi form in them, the blood coagulating on the inflamed surface. But the formation of thrombi may be the primary phenomenon, they by their presence inducing inflammation. This is sometimes because they are septic thrombi, as in the case we have already referred to of suppurative phlebitis in pyæmia; but a simple thrombus by its mere presence irritates the wall of the vessel, and induces inflammation. This is an essential factor in the organization of the thrombus itself, as we have already seen.

Again, inflammation is induced in vessels by injury to them. When an artery is ligatured, for instance, the internal and middle coats, as shown in Fig. 172, are torn through, and the result of this injury as well as of the continued action of the ligature is to induce inflammation.

The condition of the coats of the inflamed vessel varies considerably,

according to the nature of the case. In septic inflammations they are infiltrated with pus, softened and opened out, or even necrotic. Where the inflammation is less intense the coats are infiltrated with in-

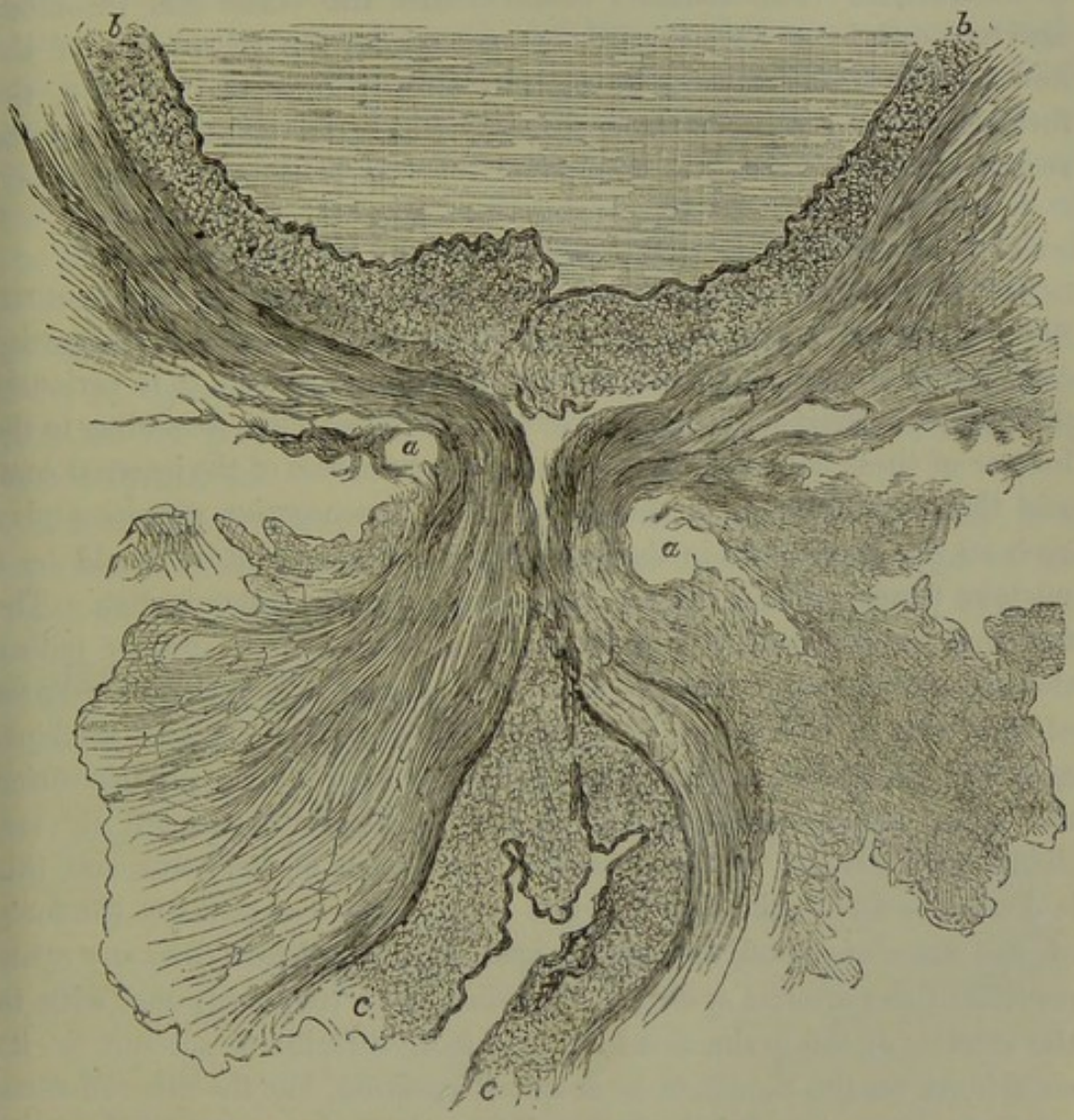


Fig. 172.—Longitudinal section of an artery at seat of ligature. *a*, *a*, apertures in which the silk ligature was found. The external coat is drawn in at this place, while the middle and internal coats are absent, being absolutely disjoined. These coats are seen above at *b* and below at *c*. × 35.

flammatory cells, and so thickened and rendered more rigid than normal. In this way a vein may assume the appearance of an artery. If the inflammation be prolonged there will be a partial organization of the contained thrombus. A similar new-formation of tissue occurs externally, and the thickened vessel is adherent to its sheath, and to parts around. In this way there is often considerable matting of the structures around the veins of the legs which are the seat of thrombosis.

In the regular progress of the inflammation, the whole new-formed tissue, including that in the wall of the vessel, and that which replaces the thrombus, develops into connective tissue having the usual tendency to contraction. The common result is that the vessel and thrombus are replaced by a fibrous cord, but sometimes the contraction of the new-formed tissue causes, in the way already described at p. 32, the formation of a cavernous tissue through which the circulation may be restored.

CHRONIC ENDARTERITIS—ATHEROMA.

These names are applied to a disease of very frequent occurrence in arteries, the nature of which has been differently regarded at different times. Besides the common name atheroma, it is variously designated chronic endarteritis, sclerosis of arteries, etc. According to the former of these names the disease is an inflammation of the internal coat, and this view is so far a correct one; but degenerative processes play such an important part in the course of the disease that it would be a mistake to regard it as merely an ordinary chronic inflammation. The fact that the disease is peculiarly one of advanced life is another indication of its degenerative nature, and it may almost be said that a weakness of the wall of the vessel must be regarded as one of the principal agents in the causation of the disease. While there is this predisposition the actual supervention of the disease is apparently caused by mechanical irritation. Its principal seat is the arch of the aorta, and this is doubtless due to the fact that this part is more exposed to the force of the wave of blood during the systole of the heart than any other portion of the arterial system. The disease is frequently met with in the arteries of the brain, and here it is more difficult to account for its occurrence on the theory of mechanical irritation, but the atheromatous patch is often situated just at a bifurcation, where, presumably, the vessel wall is more exposed to the force of the current. Again, it is met with in the pulmonary artery in cases of hypertrophy of the right ventricle, the excessive impulse of the blood from the hypertrophied ventricle apparently determining its occurrence. As we shall see afterwards, syphilis produces a disease of arteries in many ways similar to atheroma, and it is matter of uncertainty how far ordinary atheroma may be due to syphilis.

The disease consists in a more or less localized thickening of the internal coat. The thickening is nearly always distinctly limited in area, so that we speak of ATHEROMATOUS PATCHES. When we examine

the aorta in the earlier stages we see elevated areas with tolerably abrupt edges, and usually of a dead white colour as compared with the surrounding intima. These patches are hard, and cut like cartilage. They have the appearance at first sight of deposits on the surface of the intima, and so they were long regarded, but on making a section through patch and vessel, it is seen that the intima is continuous with the raised patch. In the arteries of the brain the diseased parts are seen as white opaque patches, and the vessel is more rigid than normal, so that it does not collapse; the calibre also is diminished by the inward projection of the patch. On cutting into the patch, either in the aorta or cerebral artery, there is often an opaque yellow colour revealed in the deeper parts, and this is an indication of fatty degeneration. Very often, too, there is, especially in the aorta, calcareous infiltration of the deeper parts of the patch, but these two conditions will be more fully discussed further on.

In considering more particularly the details of the process, it is instructive to examine microscopic sections including the edge of the patch and the neighbouring parts of the vessel (see Figs. 173, 174, and

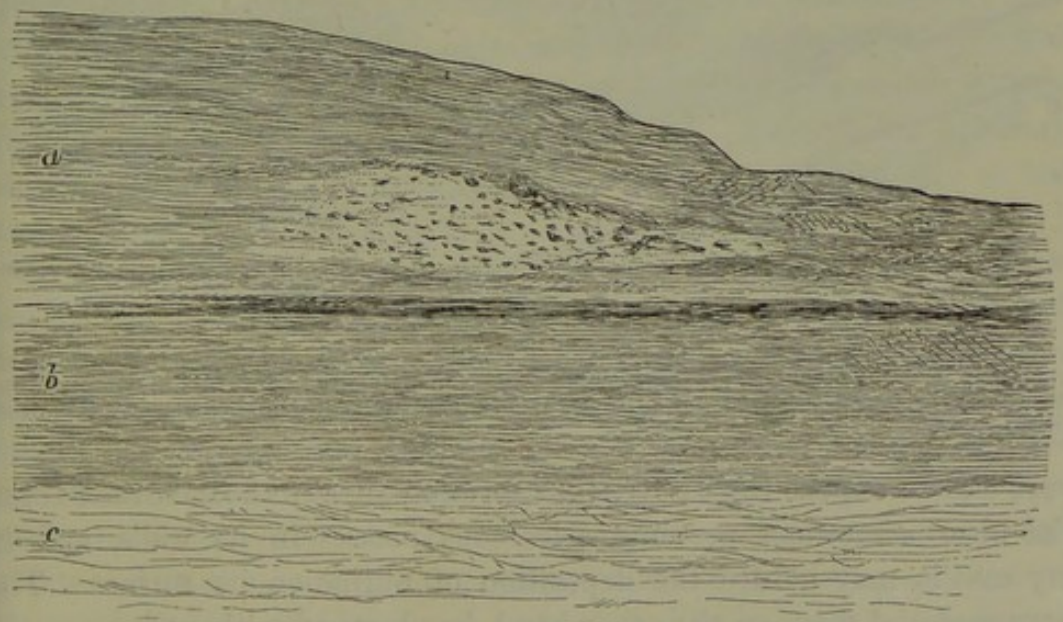


Fig. 173.—Atheroma of aorta. The internal coat (*a*) is seen to be thickened. In its deeper layers there are darker markings indicating the commencement of fatty degeneration. *b*, middle, and *c*, external coat. × 22.

176). In well-preserved recent cases it can be seen that the endothelium of the intima is continued over the patch, and in nearly all cases there is little difficulty in observing that the patch is really a thickening of the internal coat, as shown in the figures. The thickened intima is composed of a dense connective tissue, which in the early stages

contains many round, oval, and stellate cells. In a fully formed patch the structure is often exceedingly indefinite, and there are few cells that are at all prominent even when staining agents are used. The structure is indeed half obsolete, and, as already indicated, fatty degeneration readily occurs. The fatty degeneration begins usually in the deeper layers of the patch, so that on making a section one generally finds in the portion of the patch bordering on the middle coat an opaque yellow streak. (See also Fig. 173.) The fatty degeneration at first affects the cells of the intima, but as time goes on the intercellular substance gives way, and the tissue breaks down so that a cavity containing fatty debris and cholestearine is formed. From the character of this fatty debris the name atheroma is derived, and the cavity thus formed is sometimes called an ATHEROMATOUS ABSCESS. (See Fig. 174.) The tissue superficial to the cavity may ultimately give

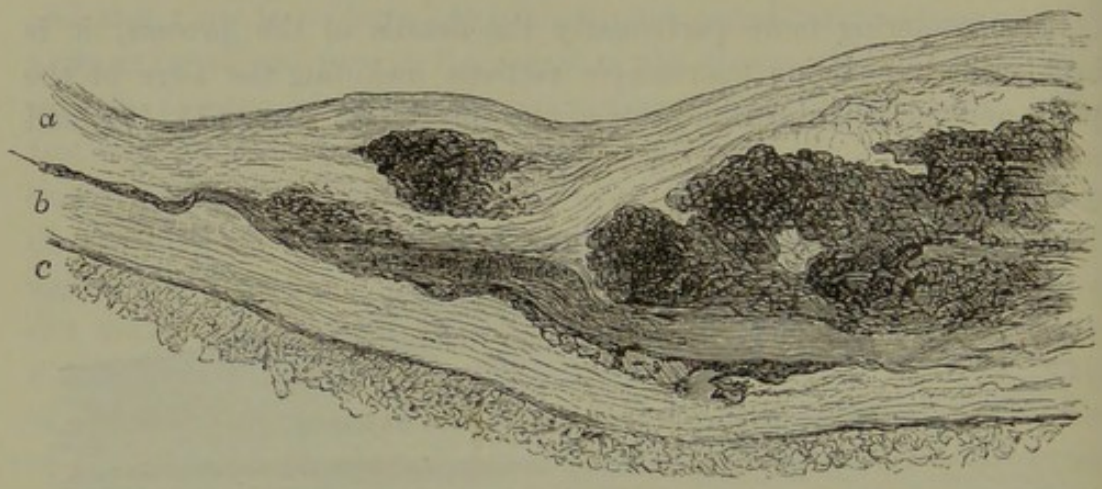


Fig. 174.—Atheroma of femoral artery. The greatly thickened internal coat (*a*) is shown. In the midst of it, towards the right, are dark masses consisting mainly of fatty debris, and representing the atheromatous abscess. At one part the middle coat (*b*) is considerably encroached on from within. × 22.

way, and so expose the cavity, thus forming an ATHEROMATOUS ULCER. The ulcer sometimes presents calcareous masses in its walls, and in any case it may induce the deposition of fibrine on its surface. The fatty material may, on the other hand, be absorbed without forming an actual ulcer, and in that case there will be produced depressions and irregular foldings and puckerings of the internal coat. These depressions and foldings have often a kind of cicatricial appearance.

CALCAREOUS INFILTRATION is a frequent result of the disease under consideration. It is generally stated that the calcareous salts are deposited in the fatty degenerated structure. But this is not always the case. The dense tissue of the patch may become infiltrated with

lime salts without a preceding fatty degeneration. This is peculiarly the case when the tissue is very hard and dry. We shall see, in studying calcareous infiltration of the middle coat, that some individuals present a very great tendency to the deposition of lime salts in the walls of their arteries, and there are cases of atheroma in which this tendency is very marked, so that with comparatively little atheromatous thickening there may be very extensive calcareous deposition. The peculiar tendency presented in some cases to the deposition of lime salts is a strong indication of the degenerative nature of the process. At first the salts are deposited in fine granules, and in the deeper layers of the patch, but as time goes on these aggregate into consistent masses which, from the lateral extension of the affected parts, have the form of plates. Thus we have CALCAREOUS PLATES of various forms and sizes, sometimes attaining to a square inch in area. These plates, having abrupt edges, not infrequently tear through the remaining layers of the intima, and present an edge or angle inside the vessel. They may even become to a considerable extent separated, and hang into the calibre attached only by a strip of intima like a hinge. The rough calcareous edge very commonly induces a deposition of fibrine, and the thrombus thus formed may subsequently get detached, and form an embolus. The determination of the preponderance of the fatty or calcareous change appears to depend on individual peculiarities. Both forms are very frequent in the aorta. The fatty change preponderates greatly in the cerebral arteries.

It is to be noted here that there are some cases in which the atheroma has a much more distinctly inflammatory course than that described above. The thickened intima is infiltrated with round cells, and there is also inflammatory infiltration of the middle and external coats, the round cells aggregating specially around the blood-vessels, so that the whole wall of the vessel is affected. Such cases are perhaps hardly to be placed in the same category as ordinary atheroma, but as this condition occurs like the other, mainly in the aorta, and the result is a thickening of the internal coat in patches, it is difficult to draw a distinct line of demarcation between them. By some, this condition has been specially distinguished under the designation ACUTE AORTITIS.

It is important to consider what CHANGES the atheromatous process produces IN THE MIDDLE AND EXTERNAL COATS. At first the middle coat is hardly at all affected, but if the process advances far, and especially if the degeneration of the patch causes much deformity of the internal coat, then the middle coat becomes softened and loosened. It

also becomes affected with fatty degeneration, the muscular fibre-cells being first involved (see Fig. 175). In advanced cases, especially in the cerebral arteries, we may even find, along with fat granules, crystals of cholestearine and margarine and pigment, so that through time the middle coat may be considerably broken up. This process may be present in the middle coat while the hard thickening of the internal coat is still present, and we may find a localized dilatation of the vessel occurring, into which the thickened intima dips. The external coat is much less seriously affected than the middle; if at all involved it presents increased thickening and vascularization.

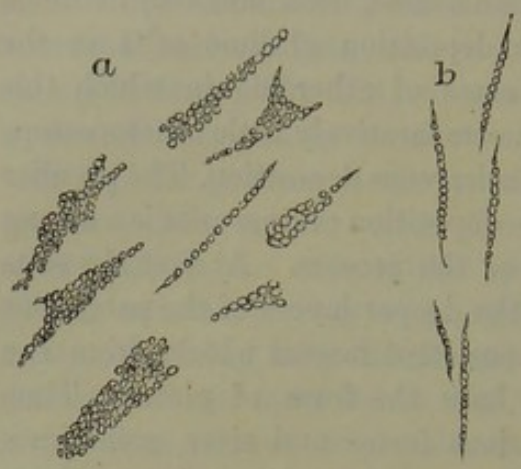


Fig. 175.—Fatty degeneration in atheroma. *a*, from internal coat; *b*, muscle cells from middle coat. × 350.

We have now to consider the effect of atheroma on the circulation. There are three alterations which it produces, each of which may, according to circumstances, have important effects on the circulation. The disease causes *narrowing of the calibre*, *loss of elasticity and rigidity* of the wall, and *interference with the muscular contractility* of the vessel.

The narrowing of the vessel will be of little consequence in such large arteries as the aorta, but in the case of the cerebral vessels and those of the legs, the interference with the circulation may be considerable (see Fig. 176). This is sometimes peculiarly the case in the coronary arteries of the heart, where an atheromatous patch, originating perhaps in the aorta, may cause very great narrowing and even complete obstruction. The disturbance of the circulation in the substance of the heart sometimes produces severe angina, and may lead to sudden death. If by reason of the roughness of the surface or the formation of the atheromatous ulcer fibrine is deposited, then the narrowing may be very serious, and may even amount to complete occlusion.

The interference with the muscular contractility will also affect mainly the arteries of smaller dimensions, and in the case of the arteries of the brain, the absence of that control of the circulation which is afforded by their varying calibre may lead to serious consequences.

But of all the consequences of atheroma the rigidity and weakening

of the wall are the most important. These consequences are most serious in the aorta, where they are probably the chief factors in the

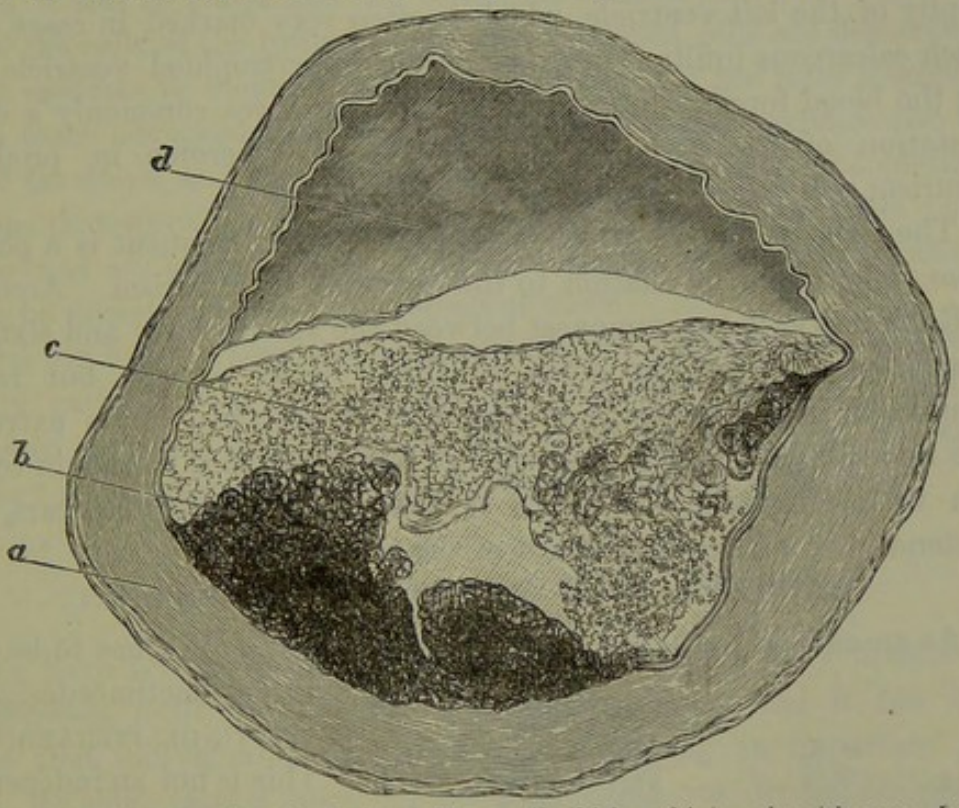


Fig. 176.—Atheroma of cerebral artery. The greatly thickened internal coat is seen. In its substance are dark masses (*b*) in which margarine crystals were found. On the surface is a paler layer (*c*) consisting of partially organized thrombus; (*d*) blood occupying the remaining calibre. × 34.

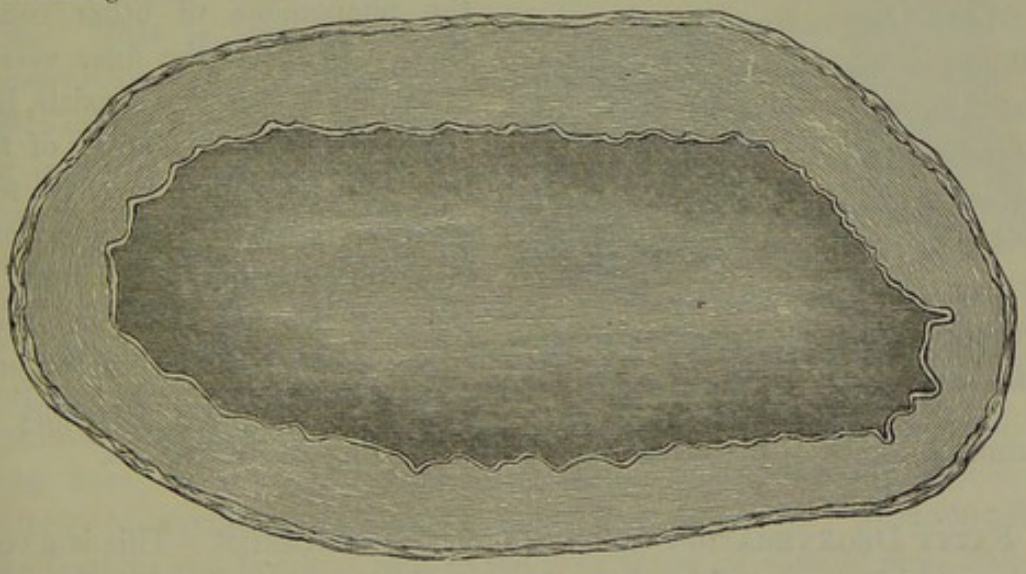


Fig. 177.—Transverse section of normal cerebral artery to contrast with Fig. 176. × 34

causation of aneurism. The immediate consequence of rigidity of the aorta is that during the systole of the heart the vessel does not dilate, and at the end of the systole it does not recoil, so that the force of

the elastic recoil is lost to the circulation, and in distant parts there is apt to be more or less stagnation. As a result of this we have hypertrophy of the left ventricle, which is often very marked in cases where much calcareous infiltration exists. The hypertrophied ventricle sending the blood forcibly into the rigid aorta produces commonly a diffuse dilatation of the arch. The influence of atheroma in producing aneurism will fall to be considered subsequently.

The time of life at which atheroma is most frequent is a point of some importance in relation to the causation of aneurism. According to Rokitansky, it is commonest between the ages of forty and sixty. It is still pretty frequent down to thirty years of age, but rapidly diminishes in frequency from that age downwards. It is extremely rare under twenty years, and when it does occur it is mostly in connection with congenital anomalies of the great vessels or heart, such as stenosis of a stem with defect of the septum, etc.

As an addendum to the subject of atheroma, mention has to be made of a condition sometimes designated ENDARTERITIS OBLITERANS (figure 178). This is not an independent disease, but is frequently of considerable importance as a part of the phenomena of other conditions. It affects the finer vessels of certain organs, and consists, like atheroma, in a thickening of the internal coat which, in these fine arteries, frequently leads to complete obliteration. This form of lesion is seen especially in interstitial inflammations of organs, and is particularly frequent in chronic interstitial nephritis, where it will be again referred to.

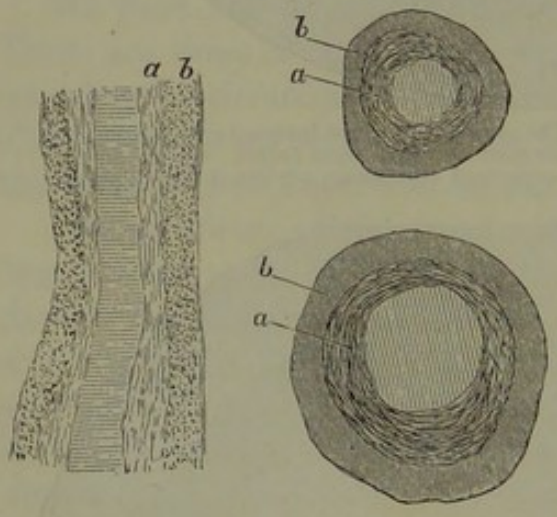


Fig. 178.—Endarteritis obliterans in arteries of kidney, *a*, thickened and fibrous internal coat; *b*, middle coat.

FATTY DEGENERATION OF THE INTIMA OF ARTERIES.—This is a condition which we consider here because it is apt to be mistaken for atheroma. We frequently see, especially in the aorta, yellow markings on the internal surface. These markings are only slightly raised above the surface, and have the appearance of superficial figurings. They are to be found in the aorta, pulmonary artery, and other parts of the

arterial system. If a portion of such a patch be examined under the microscope by removing a thin layer by a section parallel to the surface, it will be found that the condition consists in a fatty degeneration of the cells of the intima. The flat branched cells are demarcated by the presence in them of abundant fat drops. If the fatty degeneration is much advanced then the intercellular substance becomes also the seat of fat drops, and the cells are no longer demarcated. It sometimes happens that when the degeneration is very advanced the little patch softens and an erosion forms. This erosion is very superficial, and is not to be mistaken for the atheromatous ulcer.

This condition is sometimes met with in the bodies of comparatively healthy persons, but we have already seen that in anæmia and in emaciated persons it is frequent, and is to be classed in the same category as fatty degeneration of the muscular tissue of the heart.

CALCAREOUS INFILTRATION OF ARTERIES.

We have already seen that in atheroma there is very frequently a calcareous infiltration of the affected structures, and it has been stated that individual peculiarities appear to play an important part here. In some cases a more independent calcareous deposition occurs, and here individual peculiarities are of still greater consequence. Calcification of the middle coat is the most frequent and important form. This is very frequently associated with atheroma, but it is noteworthy that the atheroma and calcareous deposition very often affect different arteries or different parts of the same. We may have, for instance, an atheroma of the aorta and calcification of the middle coat in the femoral and smaller vessels; or there is atheroma as well as calcification in the femoral, but in their extreme degrees the two are present at separate parts of the artery. For instance, Figs. 174 and 180 are from the same femoral artery, and from parts near each other; but the one shows atheroma with fatty degeneration, while the other exhibits very advanced calcareous infiltration of the middle coat. It may here be remarked that calcification affects by preference the arteries of medium and smaller size. It is often very pronounced in the femoral and brachial, and extends to those of smaller size, but not to the finest arteries.

The deposition occurs primarily into the muscular fibre cells of the middle coat, and at first marks these out by the presence of fine opaque granules (see Fig. 179). The granules flow together till a patch is

formed of an opaque appearance, but confined to the middle coat. As the calcareous deposition increases, the patch sometimes assumes a

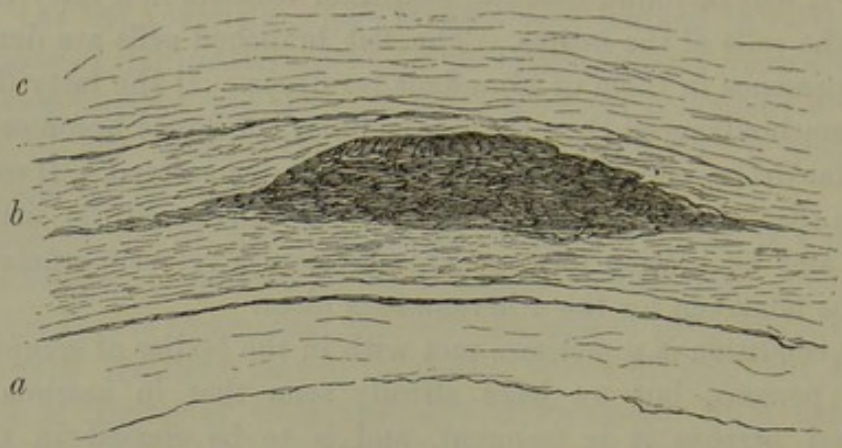


Fig. 179.—Calcareous infiltration of the middle coat (*b*) in an artery, early stage, with atheroma (*a*). At the edges of the affected part, the general outline of the muscle fibre cells can be made out. × 60.

crystalline appearance, and the material may become broken and irregular, as in Fig. 180. This condition necessarily gives greatly increased

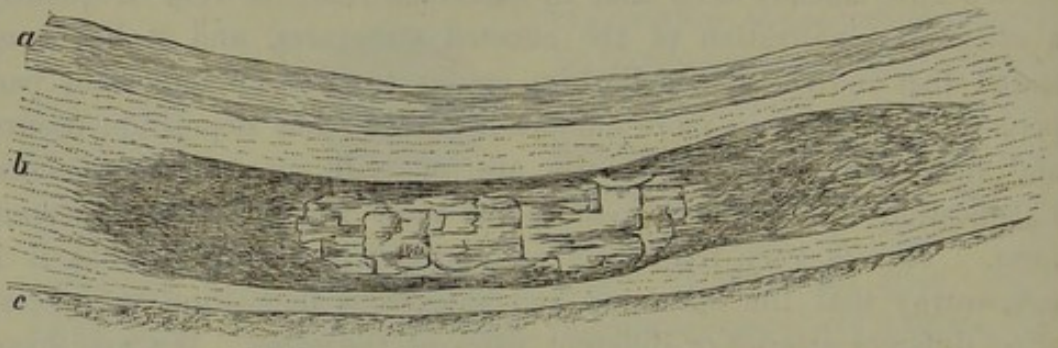


Fig. 180.—Calcareous infiltration of the middle coat in an artery. The lime salts have aggregated together so as to produce a crystalline appearance. This was taken from the same artery as Fig. 174. × 22.

rigidity to the walls of the arteries, and the feeling of rigidity so often felt in the radial and other smaller arteries is mostly due to this cause, and not to atheroma. The fact, however, that calcification of the middle coat is so often associated with atheroma renders this rigidity to some extent an indication of the existence of atheroma in the larger arteries. To the naked eye the calcified parts frequently manifest themselves by the appearance of a circular opaque striation, visible especially when the artery is laid open and viewed from within. The appearance is better seen if the artery be allowed to dry partially, as then the normal tissue becomes more transparent and the chalky structures more prominent. In that case complete or partial rings are seen, not unlike the irregular cartilaginous rings of the bronchi, but

smaller. Another method of rendering the calcification prominent is to tear off the internal coat, which is usually somewhat loosely attached,

The calcareous infiltration of the middle coat renders the artery peculiarly rigid, and, when extensive, induces hypertrophy of the left ventricle just as rigidity of the aorta does. The rigid vessels are also liable to dilatation, as in the case of the aorta. But besides that, the calcified middle coat is brittle and affords a much less effective resistance to the distensile wave of blood. An additional strain on the circulation, or some special movement of the body, may break the brittle coat and directly lead to aneurismal dilatation of the artery. It is not unlikely that peripheral aneurisms are frequently induced in this way, and especially those of the popliteal region, where the artery is peculiarly liable to mechanical injury from the movements of the limb.

A peculiar calcification of arteries has been described as a result of metastasis. We have already seen that when great destruction of bone is occurring the lime salts may be deposited in distant parts, the lungs and mucous membrane of the alimentary canal being the chief seats. Kuttner has described a case in which the incrustation occurred in the arteries. The deposition increased in amount the further the arteries were removed from the heart, and it was especially manifest where the current was permanently impeded, as where a small branch issued from a comparatively large stem. In this case it was the intima that was incrusted, and it was peculiar that the veins were not in the least affected. Apart from the incrustation, the arterial coats were apparently normal. The source of the lime salts was an acute caries of the vertebral column from the first dorsal to the last lumbar. In relation to the pathology of the case, it is to be added that there was a purulent interstitial nephritis, so that the excretion of lime salts was presumably obstructed. It is remarkable that in this case the metastasis was to the arteries, and that the lungs and mucous membrane of the intestine were entirely free.

SYPHILITIC DISEASE OF ARTERIES.

The condition met with in syphilis in many respects resembles atheroma, and it is sometimes difficult to say definitely which of these processes is present. In fact it is not safe to call a lesion syphilitic unless there be other evidences of syphilis. The condition has been most frequently seen in the arteries of the brain, but it has

also been observed in the pulmonary artery, and it probably occurs in other vessels. It is asserted by some that a large proportion of cases of atheroma of the aorta have a syphilitic origin, but this is exceedingly doubtful. Like atheroma it occurs in patches, but these are more frequently single and isolated than is the case in atheroma. Thickening of the internal coat is the most characteristic appearance, and it may be so great as almost to close the artery. The patch is dense, almost cartilaginous or fibrous to the feeling. The thickening is sometimes not confined to the intima but extends to the other coats, and this is especially the case when the patch is in the neighbourhood of a gumma or syphilitic inflammation. The disease begins with a cellular formation in the internal coat (Fig. 181), so that it comes to have the characteristics of granulation-tissue, and this cellular character is most manifest when the lesion is in the neighbourhood of a gumma. The new-formation extends outwards as well as inwards, and very often the middle and external coats become involved. There is little tendency to fatty degeneration or calcareous infiltration in this disease. The new-formed tissue follows more commonly the regular course of granulation tissue. Capillaries by and by form in it, and the coats of the vessel may be, to a considerable extent, restored with some narrowing. On the other hand there may be great cicatricial contraction, the new-formed tissue developing into a dense fibrous tissue with great narrowing of the vessel, or even complete obstruction if the vessel be a small one. It sometimes happens that a thrombus is formed on the patch, and the organization of this may aid or complete the obstruction of the vessel.

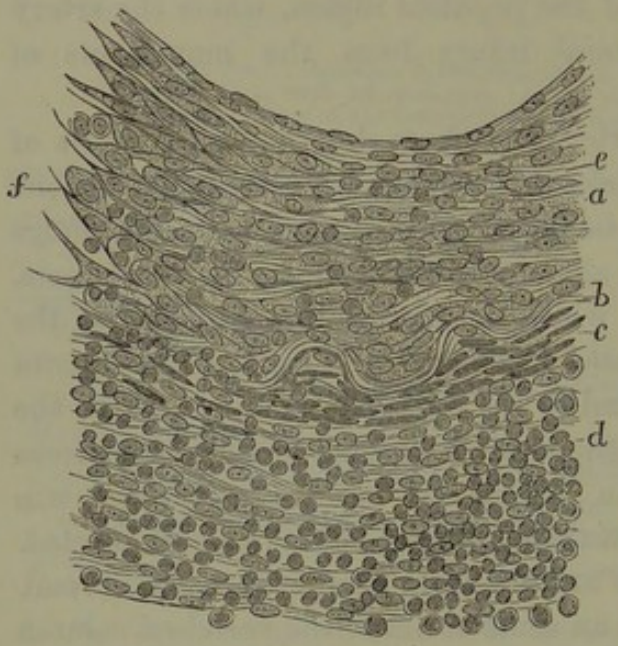


Fig. 181.—Syphilitic arteritis. The internal coat (*a*) thickened and infiltrated with cells. The external (*d*) and middle (*c*) coats also somewhat infiltrated. To the left the membrana fenestrata (*b*) is interrupted. × 150. (ZIEGLER.)

As already indicated, the distinction of syphilitic disease from atheroma is sometimes difficult, and the main points of difference may be here indicated. Atheroma is a disease of advanced life, while syphilis occurs mostly in comparatively young people. Both are very common

in the cerebral arteries, but in the case of atheroma the aorta is usually simultaneously affected, whereas in the case of syphilis it has frequently been specially noted that the aorta was normal. In the syphilitic disease again the new-formation is more cellular and tends more to extend to the other coats of the vessel. It has also been noticed that fatty degeneration and calcification are much less frequent. In spite of these differences there are many cases in which the distinction is impossible and the existence of syphilitic disease should never be absolutely concluded unless there are other evidences of the disease present.

It is evident that syphilitic disease will induce secondary changes similar to those produced by atheroma. As it affects the arteries of the brain with peculiar frequency, and leads to obstruction of them, it may induce softening of the brain. The narrowing may also induce dilatation of the artery on the proximal side, and, in this reference, it is stated that aneurism of the cerebral vessels is not infrequently present in syphilitic persons.

ANEURISMS.

An aneurism is a localized dilatation of an artery. Taking this as the definition it will follow that in forming the aneurism the coats of the artery are stretched, and, to some extent, retained as the covering of it. We shall afterwards see that there are aneurisms in which this is hardly the case, in which the coats rather give way and rupture. Such aneurisms are often designated spurious aneurisms, of which it will be necessary afterwards to describe several varieties. Even of the aneurisms which come under the above definition there are several varieties, but we have to consider here, in the first place, those which arise by a limited dilatation of an artery. The artery may be dilated in its whole circumference, thus forming a spindle-shaped or FUSIFORM ANEURISM, or the dilatation may be at a limited point and we have then a SACCULATED ANEURISM.

CAUSATION OF ANEURISMS.—It may be said that permanent undue dilatation of an artery can hardly occur unless the wall of the vessel be weakened. It is perhaps conceivable that the blood-pressure might be so increased as to dilate an artery unduly, but such increased pressure would, in its extreme form, be temporary, and unless there were some weakness of the vessel-wall it would hardly produce a permanent dilatation. We shall see reason to believe that in the actual production of

the ordinary aneurism, both of these conditions, namely, weakness of the wall and increased blood-pressure are nearly always to be traced.

The more important of the two conditions is weakness of the wall of the artery. By far the most frequent cause of this weakness is atheroma. We have already seen how atheroma with great calcareous deposition may lead to dilatation of the arch of the aorta. But aneurism is even more frequent in cases where the ordinary fatty change takes place in the patches, causing irregularity in the internal coat. By the formation of the atheromatous abscess and ulcer, or still more frequently by the absorption of the fat and consequent shrinking, depressions and furrows are formed in the internal coat. It is to be remembered also that the atheromatous part is rendered unduly rigid by the thickening of the internal coat, and that any extra distending force will act specially on parts which have been weakened. Another element of equal importance is the weakening of the middle coat, which we have seen to be a frequent consequence of atheroma. Fatty degeneration is of frequent occurrence in the media under the atheromatous patch. In the case of the peripheral arteries calcareous infiltration of the media may occur with or without atheroma, and the calcification may be such as to render the media exceedingly brittle. It is true that, according to old experiments of John Hunter and Home, destruction of the external or even external and middle coats of arteries in animals is not sufficient to cause dilatation of these vessels, but with a seriously weakened middle coat any considerable increase of the blood-pressure may be sufficient to cause dilatation.

While atheroma, especially when associated with weakening of the middle coat, is concerned in the causation of aneurisms, there are certain circumstances which indicate that this of itself is not a sufficient cause. One of these is the age at which aneurisms occur. We have seen that atheroma is a disease of advanced life, being most frequent after forty, although still very common between thirty and forty. Now aneurisms are most common between the ages of thirty and forty. Another circumstance is the great preponderance of aneurisms in the male. It is true that atheroma is commonest in the male, but not to anything like the same extent as aneurism. Bizot found in 189 cases of the latter 171 in males, and 18 in females, and Hodgson found in 63 cases 56 in males and 7 in females. It is noteworthy further that in some localities aneurisms are uncommon, while atheroma is by no means so rare. The great frequency of aneurism in the army as compared with civil life is another circumstance requiring explanation.

All these circumstances are to be explained on the view that, in addition to weakening of the vessel-wall increase of blood-pressure is needed to produce aneurisms. In severe continued exertion we find the most frequent cause of increased blood-pressure. The engineer who has to manipulate a piece of hot iron while wielding a heavy hammer, or the soldier who has to perform long marches with heavy accoutrements, must put a strain on his heart and larger vessels which ordinary persons are not liable to. It will be apparent that men are much more exposed than women to such excessive stress on their vascular systems. It is again between the ages of twenty and forty that men are mostly exposed in this way. Between the ages of twenty and thirty atheroma is uncommon, but between thirty and forty it is tolerably frequent, and if it exists the liability to excessive stress will render the occurrence of aneurism more probable. On the same principle we explain the greater frequency of aneurism in some countries as compared with others. The excessive stress to which workmen in our engineering establishments are frequently put in this country goes far to explain the frequency of aneurism here, besides the fact of the general greater vigour of the British workman in performing his appointed task.

Another circumstance of importance in relation to the matter under discussion is the localization of aneurisms in different arteries. Nearly half the cases of aneurism occur in the aorta, and the great majority of these in the thoracic portion. We have seen that atheroma is most frequent in this vessel, but, in addition to that, the aorta is most exposed to the excessive pressure of the blood when the heart is stimulated to unduly forcible action. Next to the aorta the popliteal artery is most frequently the seat of aneurism. It has already been pointed out that this vessel is especially liable to injury from sudden flexures of the leg, especially when the middle coat is rendered brittle by calcareous infiltration. But besides that, the vessel is so situated as to be liable to localized increase of blood-pressure. As it is sues from the popliteal space the artery passes between the two heads of the gastrocnemius, and is liable to constriction by the contraction of the muscle. On this principle has been explained the frequency of popliteal aneurism in flunkies whose principal occupation is to exercise their gastrocnemii in standing. But apart from that, when a person makes a severe exertion in a standing posture, the gastrocnemii contract vigorously, thus producing a partial obstruction of the artery and an increase of pressure above the obstructed part, while the general blood-pressure is also increased.

Before leaving the subject of the causation of aneurisms it should be

mentioned that anything which weakens the wall of an artery will render it liable to dilatation. Thus a blow whose effects extend deeply enough to affect the arterial coats, a piece of fractured bone pushed against an artery, may be regarded as causes. Again it has been pointed out by Ponfick that embolism is a frequent cause of aneurism in the cerebral vessels, the embolus injuring the walls of the artery.

The Coats of the Artery in Aneurisms.—We have next to study the development and growth of aneurisms, and in connection with that the comportment of the various coats of the vessel. An aneurism begins in a little pouching of a limited portion of the artery. Even at this early stage the middle coat is already impaired, and it has probably been affected to begin with. Such pouches, into which one can put the tip of the finger, are often to be seen in an atheromatous aorta. The little pouch enlarges. It may enlarge laterally so as to comprehend more and more of the vessel in its length and circumference. In that case it forms a fusiform or cylindrical aneurism. On the other hand the pouch may deepen, and while its opening remains small, it enlarges outwards in all directions into a distinct sac. The walls of the sac around the aperture often apply themselves to the external surface of the artery, and these may become mutually adherent. In that case the aperture has a sharp edge, and it appears as if the wall of the artery were folded over so as to form the wall of the aneurism. A sacculated aneurism sometimes develops out of a fusiform one; at a particular part of the wall a special dilatation begins and goes on increasing.

The internal coat enters variously into the constitution of the aneurismal wall. In the case of a fusiform aneurism it is continuous over the internal surface, and probably presents very marked atheromatous changes. In the sacculated form it is usually to be traced some little distance from the edge of the aperture on the wall of the aneurism, and even in the midst of the internal surface of the sac pieces of internal coat, greatly altered as a rule, may be discovered.

The middle coat appears to be passively affected in the formation of the aneurism. Its fibres are loosened and stretched as dilatation occurs, and from the first are liable to degeneration. Even in fusiform aneurisms it is often difficult to trace the middle coat far from the beginning of the dilatation.

The external coat, on the other hand, may be regarded as forming the chief constituent of the sac. It is composed of connective tissue,

and, as the aneurism grows, inflammatory processes occur and new connective tissue is formed, so that the sac does not necessarily undergo thinning as it enlarges. The connective tissue of the external coat usually makes common cause with that of neighbouring structures, and so the aneurism acquires adhesions, and the surrounding structures come to form, to a certain extent, constituents of the sac.

The connective tissue formation in the external coat generally keeps pace with the enlargement of the sac, especially if it be slow of growth, but there are circumstances in which this is interfered with. If the aneurism comes to project against an osseous structure like the vertebræ or the sternum, then the wall of the sac, being compressed by the recurrent wave of blood against the resisting tissue, atrophies, and the bare bone comes to be exposed and to form part of the sac, the proper connective tissue wall being adherent to the bone around. Under circumstances like these the sac is apt to get loosened from the bone and hæmorrhage is a frequent consequence. It is for this reason that hæmorrhage is so frequent in aneurisms of the aorta which project against the vertebral column. Again, if the aneurism grows very quickly, or if the sac is imperfectly supported at any particular place, then the connective tissue covering may give way. The blood issuing may collect in the tissue around, forming a secondary sac for itself, and so we may have a spurious aneurism attached to a true one. Or the bleeding may be into a large cavity or canal, and lead, as we shall see afterwards, to fatal results.

Thrombi in Aneurisms.—It is well known that blood-clots are of nearly constant occurrence in aneurisms, and they may almost be regarded as constituents of the sac, as they doubtless aid to a great extent in preventing rupture. Coagula are most frequent and most important in sacculated aneurisms. We meet with them in the form of firm, dry layers, which present a distinct stratification generally parallel to the wall of the aneurism. The coagula often form a kind of sac inside the proper sac, and after removal retain the shape of the aneurism. The coagula are primarily white thrombi. The white blood corpuscles adhere to the rough internal wall of the aneurism, and after they have accumulated to some extent coagulation occurs and a thrombus is formed. This process is repeated, and the formation of fibrine is thus in successive layers. Not infrequently the layers become partially separated, and the blood insinuates itself between them. A layer of whole blood is thus formed, and when it coagulates we

have a red thrombus mixed with the white. As time goes on the clots become firmer, drier, and more stringy. The layers next the sac are often of a pearly whiteness, and may be taken for connective tissue. Under the microscope, however, they are seen to be devoid of definite structure, and acetic acid brings out no elongated nuclei as in the case of connective tissue. There seems little tendency to the organization of these coagula unless the whole aneurism becomes filled and its cavity obliterated by them. The continual distension of the cavity seems to interfere with the process of organization; but, if the cavity be obliterated by the formation of clots, then organization proceeds, and by and by the aneurism is converted into a connective-tissue nodule which contracts more and more.

The CONDITION OF BRANCHES given off at the seat of an aneurism is a matter of great importance. These vessels are frequently obstructed, and there are various ways in which this may come about. The atheromatous process may occur to such an extent around the orifice of a branch as to narrow or even obliterate it. This is most frequent in small arteries like the intercostals, but is not uncommon in larger branches. Again, the coagula may come to overlie the aperture, already narrowed, it may be, by atheroma. Further, it will be apparent that, as an aneurism enlarges, especially a sacculated one, it will often drag on and contort vessels whose apertures are in or near its walls.

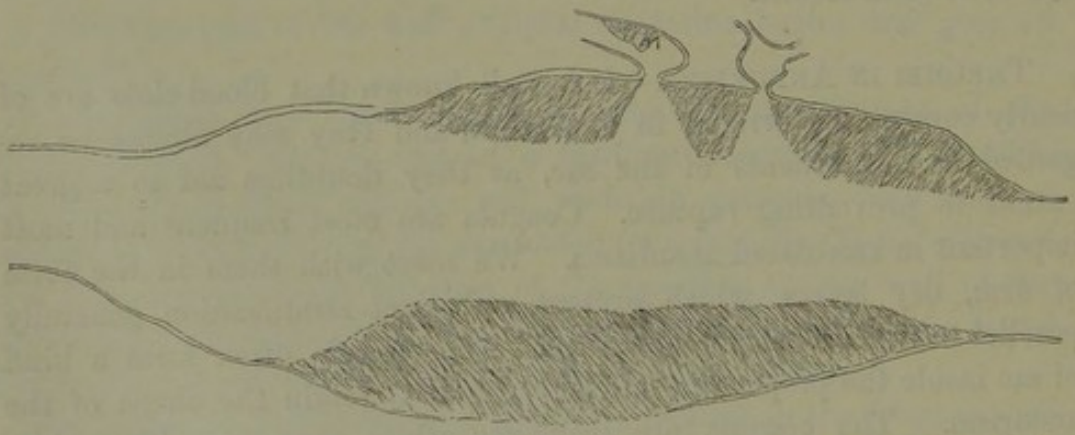


Fig. 182.—Aneurism of the abdominal aorta with clots tunnelled so as to allow the blood to reach the branches. The general lie of the stratification of the clots is shown. The cœliac axis and superior mesenteric artery are seen to be narrowed at their orifices. The posterior wall of the aneurism is absent where it impinged against the vertebræ. Half the natural size.

The aperture may thus be reduced to a fissure, and the edge may be so placed as to valve the aperture. This is particularly the case in the sacculated aneurisms of the arch of the aorta. Sometimes by the en-

largement of an aneurism the aperture of the branch is to be found at the summit of the aneurism. In that case the aperture may be obstructed in one of the ways already described, but it not infrequently remains at least partially free. The coagula may even be tunnelled in order to allow the current to flow into the branches (see Fig. 182). This channelling of the clots occurs mostly where the branch passes off nearly in the axis of the artery; if it pass off more at a right angle the clots are apt to close the aperture. Another mode of closure is by the pressure of the aneurism itself on the branch beyond the aperture. If a branch be closed in any of these ways it becomes the seat of a thrombus, and in the usual way becomes converted into a solid cord. In regard to the condition of branches it is lastly to be observed that the aneurism may, as it were, be continued into the branch, the first part of the latter being dilated along with the aneurism.

Effects on the Heart.—Aneurisms affect the heart somewhat variously. It is frequently depressed by the mere presence of the aneurism at its base. Room must be afforded for the increasing tumour, and as the position of the aorta forbids much movement upwards, the heart is pushed somewhat downwards. The extent of displacement will, of course, depend on the position and size of the aneurism. Besides this, the heart often undergoes enlargement, especially of the left ventricle. It is clear that in distending the aneurism a considerable amount of the force of the left ventricle is wasted, and on principles already considered the ventricle must act more powerfully; the hypertrophy is therefore compensatory.

Effects on parts around.—The effects of the aneurism on other parts will depend on the amount of pressure exercised, and the nature of the structures involved. An aneurism often presses on nerves, causing primarily irritation of them and sometimes ultimately interruption and consequent loss of function. Thus they often produce violent pains, and even symptoms of angina pectoris when the nerves of the heart are pressed on. By irritation of the recurrent laryngeal nerve they may cause spasm of the laryngeal muscles, or by destroying the nerve lead to their paralysis. The various canals within the chest—the trachea, bronchi, œsophagus, venous stems—are often narrowed or completely obstructed, so that a great variety of symptoms are produced. When an aneurism meets with a firm structure such as bone, it erodes it, as we have already seen. Cartilage resists more than bone; and in

the case of an aneurism advancing to the front of the chest we may find sternum and osseous ribs much eroded while the cartilaginous ribs, almost isolated, are very little destroyed.

TERMINATIONS.—Aneurisms have somewhat various terminations, much the commonest being unfortunate. Sometimes, although very rarely, a spontaneous CURE occurs. It sometimes happens that the artery is pressed on by the bulging aneurism itself, and is obliterated. Or the aneurism having burst, the blood collecting outside, by its pressure, obliterates the aneurism. It is well known that obliteration of the artery is often effected by ligaturing it. If the artery is obliterated, the aneurism fills up with clot, and by and by organization occurs, and the aneurism is cured.

But the majority of aneurisms are beyond the reach of surgical interference, and for the most part they continue enlarging till they lead to a fatal issue. This may be from the effects of pressure on parts around, so that death may result from hyperæmia and œdema of the lungs, from general venous engorgement and œdema, from marasmus, and so on. But even more frequently the aneurism ends by rupture, which occurs in various directions according to the circumstances of the aneurism. It may here be said that the probability of rupture is by no means in proportion to the size of the aneurism. A large aneurism, by the amount of pressure it exercises, will probably, by its irritation, and by causing counter-pressure from displaced organs, produce sufficient support, unless it comes actually to the surface of the body or bulges into a cavity. When rupture occurs it is into a cavity of the body, as the sac of the pericardium, the pleura, an auricle of the heart, etc.; or into a canal, as the trachea, bronchus, another artery or vein, such as the pulmonary artery; or into the substance of an organ as the lung or brain; or among the muscles or connective tissue of a part. The mode in which the rupture comes about varies somewhat. The aneurism may rupture into a cavity or on the surface of the body for want of support to its wall, a tear by and by occurring in the sac. Or the aneurism may undermine a mucous membrane or the skin, and produce a necrosis, rupture occurring on the separation of the slough. Or the aneurism may induce inflammation of the mucous membrane, and the softened tissue may give way. We have already seen that in the case of an aneurism meeting an osseous structure a gap may occur in the wall of its proper sac, and the edge of the gap may become detached from the bone, and so occasion a rupture. The rupture is not usually at the

very first fatal; there is, to begin with, a slight leakage of blood through irregular apertures which get occasionally closed with blood-clot. But from some accidental increase of blood-pressure or other cause the aperture is enlarged, and a fatal hæmorrhage is the result. Or death comes from exhaustion due to the prolonged drain and the interference with function that the aneurism otherwise produces.

VARIETIES OF ANEURISMS.—There are certain lesions to which the name aneurism is commonly given, but which do not accord with the description given above, and these merit a brief description.

The CIRSOID ANEURISM and the ANEURISM BY ANASTOMOSIS are somewhat allied forms. The cirsoid aneurism is sometimes called varix arterialis, and the name is suggestive of the condition presented. A portion of artery with its branches becomes elongated and widened, and the vessels become convoluted like varicose veins. Sometimes the dilatation extends to the corresponding capillaries and veins. This form of aneurism occurs most frequently in the arteries of the scalp and face, especially the temporal and occipital, and the enlarged and tortuous vessels are to be felt under the skin. The aneurism by anastomosis is almost an arterial vascular tumour. There is enlargement and lengthening of a large number of small arteries, with probably new-formation of arteries, and the mass of arteries can be felt like pulsating worms under the skin. The enlargement may extend to the capillaries. The affection forms a distinct growth of a bluish red colour, and with a somewhat granular surface. Its most frequent seat is the scalp.

The TRAUMATIC ANEURISM arises in consequence of an injury to a vessel. An injury has been sustained, and after a longer or shorter period an aneurism appears. The mode in which such aneurisms arise varies in different cases. In some cases an artery is wounded, and the blood makes a cavity for itself. The cavity remains in communication with the artery, and forms a kind of aneurismal sac. This is not a common result of wounds of arteries, as these usually close, but it does occur, and most readily when the wound has been an oblique or longitudinal one. It may result from a wound penetrating from the surface, but of such a form as to prevent the escape of the blood from the surface, or it may result from a broken bone tearing the coats. An aneurism arising in this way by direct rupture is called a SPURIOUS ANEURISM, as it does not arise from dilatation of the vessel.

But there are some cases of traumatic aneurism which are more slow of formation and in which it is not probable that any distinct tear through the whole coats has occurred. In the fully developed aneurism it is impossible to trace the exact mode of origin, but it is probable that in many cases a fractured bone projected against a vessel injures or even ruptures the middle coat, and possibly the internal as well. We know that in applying a ligature these two coats give way, and we can conceive a violent force applied to the wall producing the same result. A simple blow may act in a similar way, but it will do so the more readily if the middle coat be already brittle from calcareous infiltration. Many of the aneurisms of the femoral and popliteal arteries are referred to blows and injuries; but these are not all to be regarded as pure traumatic aneurisms, as the arterial coats are frequently so altered by atheroma and calcareous infiltration as to make the injury merely the determining cause.

Traumatic aneurisms, as appears from what has been said as to their origin, have usually less defined sacs than spontaneous ones. This is especially the case in those which arise directly from wounds. The blood makes an irregular cavity for itself. In the other case, where the coats are injured but the external coat is preserved, the sac may be more distinct, but is likely to be thin.

The Dissecting Aneurism is a somewhat interesting form, arising apparently by rupture of the internal coat, and partially of the middle. It sometimes arises from an injury, and is thus a traumatic aneurism, but it occasionally occurs spontaneously, and there is no form of aneurism which is so frequently multiple as this. The author has met with a case in which there were four separate dissecting aneurisms on the aorta and its branches. It may be inferred from this fact that in these cases there is often an abnormal brittleness of the internal coat, apparently not due to atheroma or any other definite disease of the coat, but an inherited or acquired brittleness. The internal coat is torn through, and the blood passes among the fibres of the middle coat. It is not that the middle coat is dissected up from the internal coat, but the layers of the middle coat itself are separated, and the blood lies between an external and internal layer of the middle coat, as in Fig. 183. The splitting up of the middle coat may be carried a considerable distance, and after passing along in the wall of the vessel the blood may make another tear in the internal coat and pass back into the vessel. The aneurism may thus come to have

two apertures, and a condition may occur as if the vessel were formed of a double tube, divided longitudinally by a septum composed of the internal and a part of the middle coat. The circulation may even be carried on to a great extent through the aneurism, the blood passing in at the original aperture and out at the secondary one. In that case the proper calibre of the artery may become considerably narrowed. The approximation of such an aneurism in character to the regular channel is still further increased by the fact that the aneurism by and by acquires an internal lining resembling the internal coat. It is a homogeneous membrane of about the thickness of the internal coat, so that in a section it may be difficult, even under the microscope, to say whether a particular place is wall of vessel or wall of aneurism (see Fig. 183). In

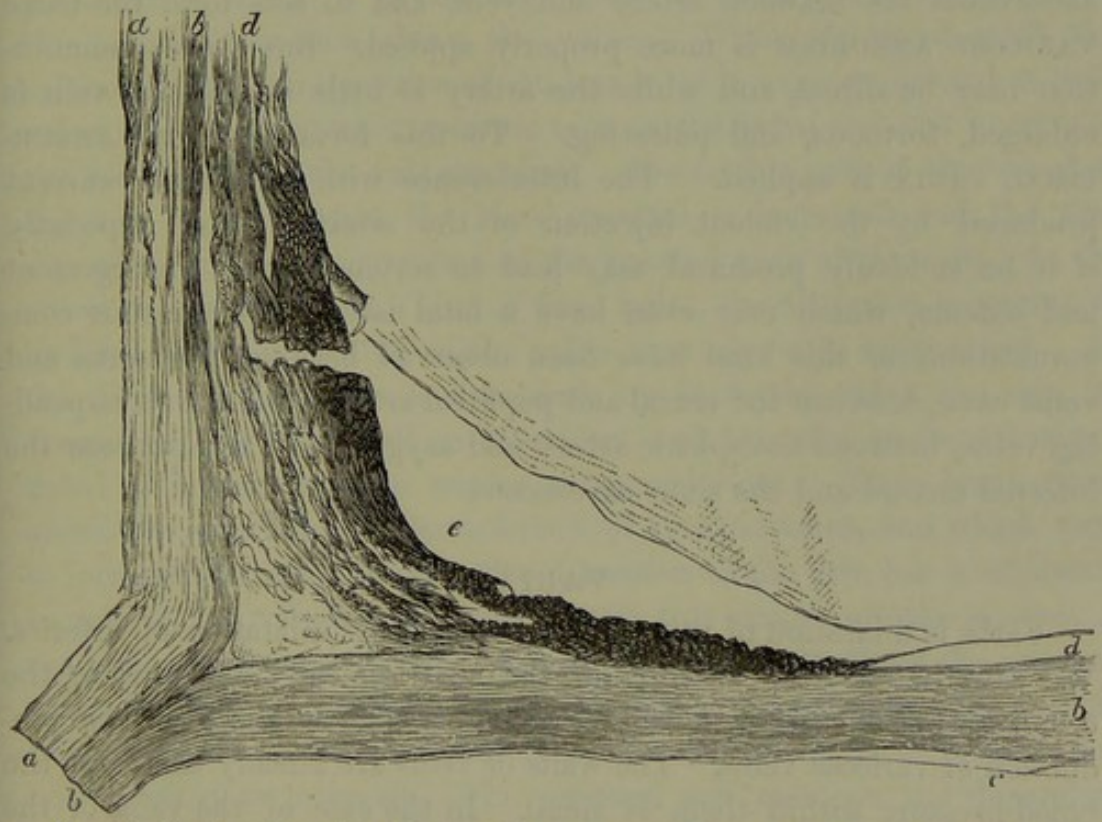


Fig. 183.—Section of portion of a dissecting aneurism of the aorta. At the left there is the entire wall of the artery, *a* being external, and *b* middle coat. The middle coat is split so as to form the aneurism. At *d*, *d*, a kind of internal coat is formed to the aneurism, but this is the seat of fatty degeneration at *e*. × 16.

the case already referred to, one of the aneurisms began in the thoracic aorta, and was continued down into the iliac arteries. There were two apertures, one in the thoracic, and the other far down in the abdominal aorta, and between these the aneurism had evidently carried on the circulation to a greater extent than the natural channel. Dissecting aneurisms being confined to the wall of the vessel will appear externally

as thickenings or dilatations of the wall, and they may produce bulging or bagging of the vessel to a remarkable degree. Occasionally, a dissecting aneurism tears through the remaining layers of the middle coat and the external coat, and so a spurious aneurism is attached to a dissecting one.

VARICOSE ANEURISM is a term applied to the case in which an artery and vein acquire a permanent abnormal communication. It may arise spontaneously or traumatically. This form used to be not uncommon at the bend of the elbow, when, in performing venesection, the lancet wounded artery and vein together. It occurs spontaneously when an aneurism ruptures into a vein. In some cases there is an actual aneurismal sac between artery and vein, and to this form the name VARICOSE ANEURISM is more properly applied. But the communication may be direct, and while the artery is little dilated the vein is enlarged, tortuous, and pulsating. To this form the name ANEURISMAL VARIX is applied. The interference with the venous current produced by the violent injection of the arterial blood, especially if it be suddenly produced, may lead to serious venous engorgement and œdema, which may even have a fatal issue. Spontaneous communications of this kind have been observed between the aorta and venæ cavæ, between the crural and popliteal arteries and the corresponding veins, between the splenic artery and azygos vein, and between the internal carotid and the sinus cavernosus.

VARIX.

Varix is dilatation of veins just as aneurism is dilatation of arteries. We saw that some weakening of the wall is always necessary to the occurrence of aneurism, but no such condition is required in the production of varicose veins. The walls of veins are already thin, and the blood-pressure within them is small. In the case of the veins of the skin we are familiar with the fact that, as a rule, the blood-pressure is not sufficient to overcome the atmospheric pressure to any considerable extent and the veins are flattened or partially collapsed, a slow and weak current passing through them. The circulation must be considerably excited, or the veins must be obstructed in order to make them stand out as cylinders under the skin. Such being the case it may be conceived that the thin-walled veins, accustomed to a slight blood-pressure, will readily dilate when exposed to an increased blood-pressure. Varix then is always due to some cause which is calculated to increase

the blood-pressure within the veins, such as obstruction of the veins by thrombi, tumours, the gravid uterus, passive hyperæmia from heart disease, and so on. It will be convenient to refer more particularly to the causal conditions when we review the various localities in which varix occurs. Meanwhile the mode in which the varicose condition develops will be considered.

If the arm be grasped firmly above the elbow so as to obstruct the superficial veins completely, the veins of the forearm will swell up, and at certain points, especially where branches unite, there may be seen slight swellings like knots. These indicate the position of the valves, the knots being the slight dilatations which represent the sinuses of the valves. In the early stages of varix, as we have frequently an opportunity of seeing it in the legs, there is simply an exaggeration of this natural dilatation above the valves. When we stand erect the column of blood in the veins of the legs is, as it were, supported at each valve, and the downward pressure tells on the valve and the portion of the vessel forming the valvular sinus. Hence this part of the vessel is the first to dilate when the blood-pressure is increased, and the first sign of varix is an exaggeration of the knotted state of the vein. At the outset each valve forms a kind of fixed point, the dilatation occurring at its level, and diminishing as the valve next above is approached. As the dilatation increases and extends up from the valve, the vein increases in length as well as in calibre, and in order to be accommodated it begins to form curves or convolutions. Thus begin those sinuosities which are so characteristic of varicose veins, and which tend to increase as time goes on. The dilatation of the vein has a tendency to render the valves incompetent, and this occurs all the sooner as the region of the valves is, as we have seen, the part where the pressure is most exercised. When the valves become incompetent the pressure tells much more on the walls of the veins as the column of blood is not now arrested at intervals. The pressure acts most on the dependent parts of the sinuosities, and will increase the projection of these. In this way we may have wide sinuses with their convexity downwards, and in some cases even diverticula or pouches projecting from the veins. In these exaggerated dilatations the blood stagnates greatly, and it is not uncommon for THROMBOSIS to occur. The vein is obstructed more or less completely by the thrombus, which may organize. On the other hand, the latter often dries in and becomes impregnated with lime salts. In this way varicose veins frequently become the seat of vein stones or PHLEBOLITHS.

Of the various forms of varicose veins those of the LOWER EXTREMITIES are best known. As we have seen above, the cause of varicose veins is to be looked for in increase of the blood-pressure in these vessels, but various circumstances may lead to this increase of pressure. It may be the result of direct obstruction of the iliac veins by the pressure of tumours, etc., in the pelvis. It may be the consequence of prolonged assumption of the standing posture, especially in persons of tall stature. In persons who stand about much the muscles of the legs are frequently in a state of contraction so that the blood is forced into the superficial veins. It is probable however that the intramuscular veins are more frequently varicose than is generally supposed, and they may even be affected without the superficial ones being much dilated. Cramps of the muscles are frequent in cases of varicose veins, and these are to be referred to stagnation in the muscular veins.

Inflammation of a chronic kind is common in the tissues around varicose veins wherever they may be, and so in the skin we often have very persistent eczema with a brown colouration of the skin which may be referred to hæmorrhage by diapedesis from the hyperæmic vessels. The skin is indurated and thickened, and ulceration is often induced. The ulcer is sometimes deep and sluggish and may persist for years.

A varicose vein may burst. It may be opened by the ulcerative process, or it may come to the surface and by its increasing dilatation at last rupture. In the case of the leg the results are sometimes exceedingly serious. We have seen that one effect of the dilatation is to render the valves incompetent, and if the varicosity extends up into the thigh, the veins of the entire leg may be virtually devoid of valves. But the veins in the abdomen are normally devoid of valves, and so it may come about that from the lower leg up to the heart there may be a single column of blood without an arresting valve. If now a vein rupture in the leg, the whole system up to the heart may be, as it were, tapped, and if the person is in the erect posture a fatal hæmorrhage may result. The hæmorrhage will cease if the person lies down, but cases have been known in which an immense amount of blood has been shed into the boots without warning.

HÆMORRHOIDS are varicose veins of the lower rectum. At the lower part of the rectum a network of small veins surrounds the bowel, lying immediately under the mucous membrane. These veins communicate with the inferior mesenteric vein which is a tributary of the portal, and with the internal iliac which is a tributary of the vena cava.

Any obstruction in the portal circulation (such as cirrhosis of the liver) or any abnormal pressure within the abdomen is apt to induce dilatation of this hæmorrhoidal plexus. The dilated veins push the mucous membrane before them and protrude as bluish flat nodules either immediately within or without the anus. They may assume considerable dimensions. The knots are composed originally of a congeries of small convoluted veins (Fig. 184 *B*), which may communicate so as to form a kind of cavernous tissue, but sometimes there are large ones (Fig. 184 *A*).

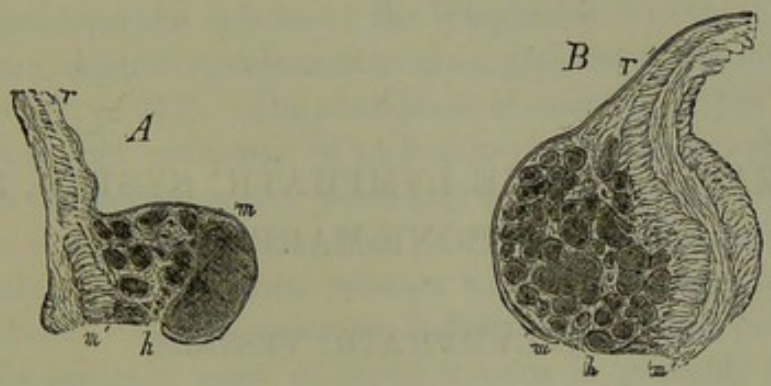


Fig. 184.—Hæmorrhoids of rectum, in section, natural size. *r* is internal surface of rectum, and *m* the mucous membrane continued over the hæmorrhoid. At *m'* is represented the muscular coat, the dilated veins being in the submucous tissue. At *A*, the veins are few but much dilated, one especially so, just beneath the mucous membrane. At *B*, the dilated veins are more numerous, but smaller. Both occurred in the same case. (VIRCHOW.)

Through time the mucous membrane undergoes alterations. The piles at each movement of the bowels are exposed to mechanical irritation, and so the mucous membrane is almost constantly in a state of catarrh. Then at intervals when the blood-pressure is unusually great by reason of an attack of inflammation or otherwise, the veins rupture, and so there is bleeding both in the substance of the mucous membrane and on to the surface. The hæmorrhoids thus get greatly altered. They become condensed from inflammatory new-formation of connective tissue. They sometimes become the seat of collections of blood, which may form blood-cysts. Phleboliths may also form in the veins. More severe inflammations sometimes occur, resulting in abscesses, fissures, fistulas, ulcers.

VARICOCELE is a dilatation of the veins of the spermatic cord and the external scrotal veins. It affects in a greatly preponderating proportion the left side, and the explanation of this seems to be that the left spermatic vein has a circuitous course, and enters the renal vein at a right angle, while the right opens into the lower vena cava. The

varicosity generally begins at the external inguinal ring, and extends downwards as far as the testicle. There is not infrequently atrophy of the testicle, and sometimes hydrocele or hæmatocele.

Varix may occur in other veins, such as those of the neck of the bladder and prostate. It is also met with in the female in the vesical plexus and veins of the vagina, and this may be combined with varix of the broad ligament. Varicosity also occurs in the veins of the dura mater.

C.—DISEASES OF THE LYMPHATIC SYSTEM, SPLEEN, AND BONE-MARROW.

THE LYMPHATIC VESSELS.

We have already had occasion to observe that the lymphatic system is intimately related to the blood vascular system, and may be regarded as a part of it. We have also seen that this system has close relations to the connective tissue, the spaces in the latter being lymph spaces lined with endothelium and having direct connections with the lymphatic vessels. Wherever there is increased exudation from the blood-vessels the serous spaces and lymphatic vessels are distended, and the current through them increased. We have seen this to be the case in inflammations and œdemas.

Inflammation of the Lymphatics. Lymphangeitis.—The lymphatics are liable to inflammations of a more independent kind, and warranting the name lymphangeitis. In order to such inflammation there must be in the vessels some irritant, and the irritant is similar to that which we find in the veins in suppurative phlebitis, namely a septic poison. In connection with wounds which have been exposed to decomposing juices, such as dissecting wounds, we sometimes find the course of the lymphatic vessels marked by red streaks in the skin. These represent inflammation of the lymphatics and surrounding connective tissue. The inflammation not infrequently goes on to suppuration, so that abscesses form at intervals in the course of the vessels or in the lymphatic glands. It is to be presumed that the material which passes into the vessels owes its irritating character to the existence in it

of minute organisms, and that these propagate inside the vessels and so the inflammation extends onwards; in some cases minute organisms have been found in the dilated and inflamed lymphatics. Thus decomposing material may get into the uterine lymphatics after delivery, and we may have an inflammation extending to the ligaments. This seems to be sometimes the primary lesion in puerperal fever.

ERYSIPELAS and other phlegmonous inflammations of the skin may be regarded as inflammations of the lymphatics, or at least of the serous spaces which form the radicles of the lymphatics. In these diseases, as we have seen, minute organisms extending, give rise to the inflammations (see figure 117, p. 257). The abundance of bacteria in the lymphatics of the skin in such cases may be such as to render the lymphatic vessels as well as the serous spaces peculiarly prominent, when the sections have been stained by aniline dyes. In that case the outlines of the serous spaces and even their relation to the lymphatic radicles may be brought out. The phlegmonous inflammation of the parotid which occasionally occurs in cases of septic wounds is probably of a similar nature. Epidemic parotitis (mumps) may perhaps be placed in the same category.

We have already seen that ELEPHANTIASIS frequently begins in recurrent attacks resembling erysipelas, in which the lymphatic vessels are obviously engaged. There are often red streaks passing up the limb, and the lymphatic glands may be enlarged. The irritation here is slighter and more chronic. The inflammation results in great thickening of the connective tissue, but there is often along with it dilatation of the lymphatic vessels, so that when the part is cut into an abundant lymphatic fluid exudes which sometimes contains oil.

LYMPHANGIECTASIS.—The lymphatic vessels are occasionally the seat of *dilatation*, but this is of comparatively rare occurrence. Obstruction of a lymphatic stem may produce a varicose dilatation of the vessels, and even their rupture. We have already seen this to be the case when the lymphatics are obstructed by the ova of the filaria sanguinis, resulting in lymph-scrotum, chyluria, etc. In the enlargement of the tongue called MACROGLOSSA, which is frequently congenital, there is commonly a great enlargement of the lymphatics which may form considerable cysts. The dilatation here appears to be due to obstruction of the lymphatics from interstitial inflammation of the connective tissue, although a different origin has been asserted.

There is sometimes a localized dilatation of many lymphatics so as

to form a distinct vascular tumour. These tumours are usually cavernous in structure and are classed as CAVERNOUS LYMPHANGIOMAS.

We sometimes find lymphatic vessels dilated in the neighbourhood of a cancerous tumour, the material in the vessels being derived from the tumour. This occurs mostly in the case of cancers which are undergoing softening. It is most frequently seen in connection with mammary cancers, where the lymphatics may have the form of firm cylinders as large as quills, filled with white material. The same thing is seen in the case of secondary cancer of the lung, where there are nodules immediately under the pleura. The subpleural lymphatics around the nodule are found, as it were, injected with white material. So is it sometimes in the capsule of the liver when cancerous nodules are near the surface. These naked-eye appearances indicate how prone cancerous material is to pass into the lymphatics, and, under the microscope, at the margins of a growing cancer the lymph-spaces may sometimes be found filled with the epithelial masses.

THE LYMPHATIC GLANDS.

It will be useful here in the first place to refer to some of the relations of lymphatic glands and to their structure. It is well known that all lymphatic vessels connect themselves directly with lymphatic glands so that no lymph passes into the circulation without first traversing a lymphatic gland. DISSOLVED SUBSTANCES introduced into the serous spaces of the skin and subcutaneous tissue are rapidly carried up the lymphatics and through the glands into the general circulation; this is matter of experience every day in the subcutaneous injection of medicinal agents. GRANULAR MATERIAL, however, does not pass through the glands, which form a filter for all solid particles. In the operation of TATTOOING granular pigment, such as Indian ink or vermillion, is introduced into the skin. Part of it remains permanently in the corium, but part is conveyed up the lymphatics and is caught by the glands, where it remains fixed. So is it in pathological conditions. The lymphatic glands are very frequently associated in morbid processes which are occurring in parts in which the vessels passing to the glands take origin. Dissolved and solid materials are thus conveyed to the glands, and according to the nature of the material will it affect the gland or not. We have seen that in septic inflammations the infective material is often conveyed to the gland and produces inflammation there. As this material is presum-

ably in the form of fine particles it is arrested at the gland, and the inflammation makes a pause there only to proceed further, if the organisms propagate onwards. But even in the case of simple inflammations, although the products are for the most part dissolved, still they are frequently of an irritating nature and the glands inflame. We have already seen that solid material from cancers is often conveyed along the lymphatic vessels and is caught at the glands. It is to be observed that in all these cases the material may produce no irritation in the lymphatic vessels along which it is being conveyed. If concentrated or very virulent it will do so, but it often does not, and it is only after lying in the glands for a time, and, it may be, increasing by self-propagation that it produces its results. In that case a wide interval of healthy structure intervenes between the primary disease and the lymphatic gland, and so it is common to speak of sympathy and metastasis in this connection. Most of the lesions to which the glands

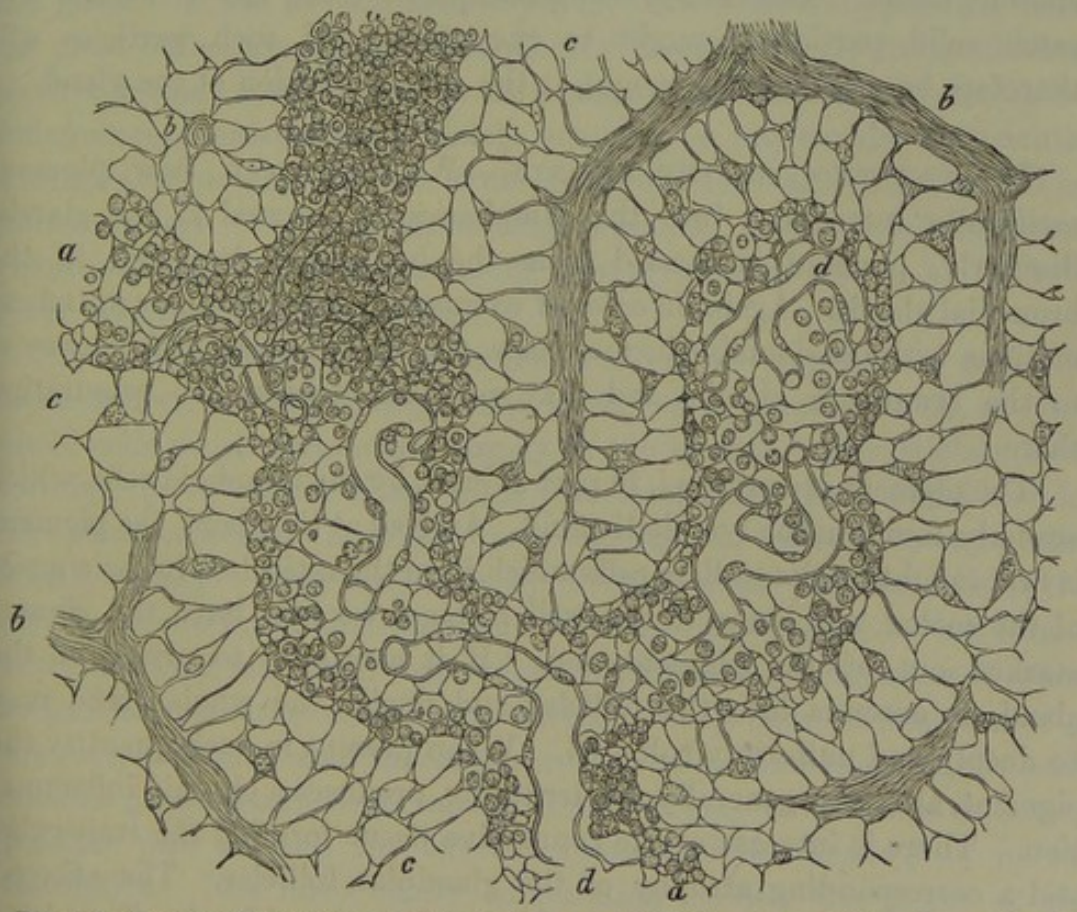


Fig. 185.—Section of normal lymphatic gland; *a*, *a*, *a*, follicular or lymphoid cords; *c*, *c*, lymph sinuses; *b*, *b*, connective-tissue trabeculæ; *d*, *d*, blood-vessels.

are liable are embraced among metastatic or sympathetic affections, but there are some which may be regarded as idiopathic. There are even

some inflammations which cannot be traced to a peripheral cause, although it is sometimes difficult to be sure that no such cause exists.

The apparatus by which the filtration of the lymph is effected deserves a passing notice, and is illustrated in Fig. 185. When the afferent lymphatic vessel coming from the periphery reaches the gland, it first forms a plexus in the capsule. On the other hand the efferent vessel emerges from a plexus of vessels at the hilus, and this plexus is connected with the medullary portion of the gland. In passing from the afferent to the efferent vessel, the lymph traverses a series of sinuses *c*, *c*, in figure. The sinuses are not clear spaces but contain a reticulum or mesh work shown in the figure. These sinuses surround the proper glandular tissue which is in the form of rounded follicles or cords composed of densely packed lymph cells (*a*, *a*, in figure). The lymph first passes from the afferent plexus into the sinuses of the cortex, then into those of the medullary part, where originate the radicles of the efferent vessel. The sinuses being occupied by the fine reticulum will catch solid particles brought to the gland, and such particles will therefore be most readily caught at the cortical portion of the gland.

Pigmentation of the Glands.—We have seen how pigment artificially introduced into the lymphatics, is arrested at the glands. Similarly, pigment is carried from the lungs and deposited in the bronchial glands. Again, in cases of extravasation of blood, or in inflammations with considerable hæmorrhage, the altered pigment is conveyed to the lymphatic glands, and may produce considerable colouration there.

The pigment is conveyed, in part at least, by the lymphoid cells, which are to be found in the lymphatic fluid. Arrived at the gland, the pigment is first caught by the stellate cells which form the reticulum in the sinuses of the cortex, and hence in the earlier stages we may have the sinuses marked out by the pigmentation. If it continues to arrive at the gland, it extends into the follicles and finally the whole gland may be deeply and uniformly coloured. When present in such quantity the pigment, although generally non-irritating, produces a chronic inflammation. There is increase of the connective tissue forming the trabeculæ, and a corresponding atrophy of the glandular follicles. The affected gland in addition to the pigmentation is enlarged and hard. The gland in this state is probably to a large extent stuffed up by the pigment and rendered impervious. When this is the case the lymph probably passes by anastomosing vessels to other glands which in their turn become

pigmented. In this way we may explain how pigmentation sometimes extends from gland to gland in the central direction. Thus in anthracosis of the lungs we may have not only the bronchial glands but also those of the mediastinum, and even those at the porta of the liver pigmented.

What has been said in regard to pigment applies also to other solid materials introduced similarly into the lymphatics. In stone masons the particles of stone which get into the parenchyma of the lung are in part carried to the glands, where they produce similar changes to those mentioned, but even more readily, as from their mechanically irritating characters they are more apt to produce chronic inflammation.

Acute Inflammation of Lymphatic Glands, Lymphadenitis.—As has already been said, this condition is nearly always a result of inflammation in the peripheral parts from which the vessels come to the gland. It has to be added, however, that in different persons there are great differences in the susceptibility to sympathetic inflammation, so that in some a slight catarrh of a mucous membrane may set up an inflammatory enlargement, which, however, is not usually very acute. The greater number of the acute inflammations are infective. The inflammations following dissecting wounds, those resulting from chancres, and the inflammation of the mesenteric glands in typhoid fever may be taken as examples.

The inflamed gland is enlarged, its vessels hyperæmic, and the tissue softened. The enlargement is due to a great increase of lymphoid cells which accumulate largely in the sinuses. The stellate cells forming the reticulum of the sinus also swell, and their nuclei divide. The exact source of the added lymphoid cells is difficult to determine with certainty. They may arise by division of the existing cells of the gland, and we know that the gland is normally occupied in cell-formation; but they may have their origin in part in the emigration of white corpuscles from the vessels, and further, the primary inflammation of the periphery may send its contingent. The inflammation may subside and the gland return to its normal condition; the new-formed cells may possibly pass on into the efferent vessel and be disposed of in the circulation. Not infrequently suppuration occurs, the tissue of the gland breaks down and an abscess is the result. We have thus a suppurating bubo. The inflammation usually extends to the capsule and surrounding tissue which is involved in the suppuration. In this way the abscess advances, and the pus is finally discharged at a surface.

It is a common occurrence for such abscesses to discharge on the surface of the body, but they may burst into bronchi, into serous cavities, etc. If the inflammation be of an infective nature colonies of bacteria may be found in the pus. Organisms have been found, for instance, in the pus of inflamed glands in pyæmia and in splenic fever. It is to be added that some of these severe inflammations have a hæmorrhagic and even a necrotic or gangrenous character.

Chronic Lymphadenitis.—This term might be made to include a number of conditions which will be afterwards referred to as occurring in leukæmia, Hodgkin's disease, etc., as well as scrofulous disease of the glands. Apart from these we have a chronic inflammation in connection with prolonged irritation of the glands. We have seen this in the case of the introduction of foreign substances, where the solid particles are conveyed to the glands. It occurs also in connection with prolonged peripheral irritation, as where an eczema of the leg or the scalp produces an enlargement of the corresponding glands. The inflammation here results in increase of the entire elements of the gland, or else in a preponderating increase of the connective-tissue stroma such as we saw to occur in the induration associated with pigmentation.

Scrofulous Disease of the Lymphatic Glands.—This is a condition concerning which considerable difference of opinion has existed. The process is a very chronic one, and in many of its features it may be regarded as an inflammation, but it is an inflammation presenting the peculiarity that caseous necrosis is of constant occurrence. There is no doubt that, if not at the very outset, yet at a comparatively early stage in the process, tubercles occur in the scrofulous gland, that is to say nodules having one or more giant cells in their centres and the remaining constituents arranged as in the miliary tubercle (see Fig. 53, p. 157). The observation of the tubercular bacillus in scrofulous glands is the culminating evidence that the disease is tubercular and is due to a specific virus. But this virus like many others acts on tissues which are predisposed. It is to be presumed that the virus is present in abundance around us, but it only finds a fitting nidus in certain persons. We may perhaps say that persons so predisposed are of the scrofulous habit, and of such persons some are specially vulnerable in the lymphatic glands and some in other structures.

Even in persons predisposed the disease generally begins in the glands in connection with a peripheral irritation. It is most common

in the glands of the neck and may take its start in a catarrh of the pharynx. At first there is simple enlargement, and it may be difficult to say whether it is a true tubercular disease or not, all the more as many of these indolent enlargements by and by resolve completely. We may suppose that the tubercular virus is conveyed to the glands along with the products of the peripheral inflammation, but that it may not be abundant enough to produce a permanent tuberculosis, or else the glands are vigorous enough to prevent a permanent lodgement for the time being. The evidence that the disease is definitely scrofulous in its nature is the occurrence of caseous metamorphosis.

As already indicated, the first change in the gland is enlargement, due mainly to a great accumulation of round cells chiefly in the lymph-sinuses and follicles. These may accumulate to such an extent as to obscure the reticulum, and when the gland is cut into the follicles project as little softer prominences. The gland, as a whole, is softer than normal, and of a greyish white colour. Caseous necrosis soon occurs. It begins usually at a number of different centres nearly simultaneously, and it extends outward from them. The occurrence of tubercles precedes the caseous necrosis, and in the extension of that process the tubercles are inextricably united with the remaining tissue. The tubercles may be overlooked in the lymphatic gland on account of the cellular nature of the gland itself, but they have all the characters of tubercles elsewhere.

The caseous necrosis of course stops all growth in the parts which it involves, but outside the caseous areas the gland may go on enlarging by increase of the glandular tissue and formation of tubercles. The caseous metamorphosis by its extension by and by comes to involve the greater part of the gland, which now has a very hard feeling, and on section presents a firm homogeneous yellow aspect which has been aptly compared to that of a raw potato. Sometimes a grey external zone can be seen outside the caseous material, and this represents the part where growth has been still going on. Under the microscope the caseous material has the usual homogeneously granular and opaque appearance, and differences of structure are hardly to be made out, the whole tissue including the tubercles being involved in a common fate. Sometimes the outlines of the tubercles are vaguely visible, and scaly looking objects may be discovered which represent the altered giant-cells.

After the gland has become caseous it may, in process of time, undergo further changes. It might be supposed that in each caseous

gland there would be a great laboratory for the tubercular virus which would thus be sown largely in the body. As compared with the great frequency of scrofulous disease, this occurrence, however, is one of great rarity. We do find general tuberculosis developing in connection with caseous glands, but it is by no means common. The change in the gland probably interrupts the flow of the lymph, and, just as in the case of cancer, the gland actually shuts off the general circulation from the infection. The caseous mass may then be regarded as obsolete, but by its presence it is very frequently a source of irritation and consequent inflammation. The inflammation may be chronic and result in thickening of the capsule and production of connective tissue around. In this way masses of caseous glands are sometimes united into firm packets; or the individual glands may be separately encapsuled. In either case one of two results may follow. The caseous mass may become infiltrated with lime salts, so as to form a mortary or putty-like mass, which may ultimately dry in and become like stone. This result we very often see in the mesenteric glands. Or the caseous material after a time may undergo softening, and be converted into a yellow grumous fluid resembling pus, but containing debris instead of pus corpuscles. This soft material often gives rise to an acute inflammation around the gland, so that a true abscess results in which pus is mixed with caseous debris. This process occurs mostly in subcutaneous glands, and the pus by and by finds its way to the surface and is discharged. The resulting ulcer is apt to be a very chronic one, the skin and underlying tissue are swollen and converted into granulation-tissue and tubercles may develop in them. This fact indicates that the caseous material does not readily lose its virulent properties, and it is well known that till the whole remains of the gland and unhealthy tissue are cleared out, sound granulations will hardly form. It sometimes occurs that, without undergoing softening, the caseous gland gives rise to acute inflammation around, with the formation of an abscess as already described. The suppuration in that case will follow much more rapidly on the enlargement, and the whole process will be a more acute one.

Besides this scrofulous disease which may be regarded as a primary tuberculosis, the lymphatic glands are liable to several forms of SECONDARY TUBERCULOSIS. They are very often the seat of tubercles in acute general tuberculosis. Here the tubercles are fresh and the enlarged glands are dotted with grey nodules. Again, in local tuberculosis of

other organs we find the corresponding lymphatic glands involved. This is commonest in the bronchial glands as a consequence of phthisis pulmonalis and in the mesenteric glands in connection with tuberculosis of the intestine. The glands in most cases undergo changes similar to those of the scrofulous glands, but the enlargement is not generally so great. On the other hand the tubercles and gland tissue sometimes undergo the fibrous metamorphosis, so that the glands seem to be the seat of chronic indurative inflammation.

Syphilitic disease of the glands partakes of the characters of a chronic inflammation in which the new-formed elements show the usual tendencies of the syphilitic new-formation partly to degenerate and partly to form connective tissue.

Degenerative changes in the glands are not of very common occurrence apart from scrofula and syphilis. Atrophy may occur just as in any other tissue in old age or emaciation. Amyloid disease is the commonest form of degeneration, but it does not usually occur in a high degree, and it is only occasionally that the glands are enlarged and rendered firmer by the degeneration. For the most part it is detected only when the glands are examined microscopically with the aid of iodine or methylviolet. The disease appears to attack mainly the reticulum of the gland, and one can sometimes make out the swollen hyaline network, or even detect how the normal reticulum swells out into the degenerated network. Recently a form of degeneration has been described under the name of colloid degeneration. It occurs in old persons and seems of no special significance. The gland shows a series of alveoli filled with colloid material, or the blood-vessels and trabeculæ of the gland become hyaline, the appearance resembling that in amyloid disease but without the reaction.

Tumours.—Of these the principal forms have been described already. There is the typhoid lymphoma, the leukæmic lymphoma, the lymph-adenoma and lympho-sarcoma. We have also seen that in Hodgkin's disease we have an enlargement of the glands similar to that which occurs in leukæmia but without the alteration in the blood. In that disease the spleen may also be affected as it is in leukæmia, and so the name of pseudo-leukæmia sometimes applied to it is warranted. Besides the lympho-sarcoma already described, we sometimes meet with more ordinary sarcomas of the lymphatic glands, and

these may be of the spindle-celled or round-celled kind. These tumours are not common, and, perhaps, their most frequent seat of origin is the retro-peritoneal glands near the head of the pancreas. Tumours arising here may grow to very large dimensions. Secondary sarcomas are very uncommon in the lymphatic glands. On the other hand cancer very frequently develops secondarily here, and in all its forms. A few cases of supposed primary epithelioma of the glands have been recorded.

THE SPLEEN.

The exact nature of the function of this organ is somewhat obscure. In order to understand the various changes which it undergoes, it will be necessary to bear in mind certain facts as to its structure. The splenic artery as it enters the organ is accompanied by connective tissue which forms a continuous sheath around its branches. In this sheath there develop at intervals little masses of lymphoid tissue, forming the Malpighian bodies, which are therefore lymphatic follicles closely related to the arterial branches. The arteries break up into capillaries which are mostly distributed in the Malpighian bodies, where they form a somewhat wide-meshed network. At the periphery of the Malpighian bodies the capillaries open into the splenic pulp, which is, as it were, interposed between the capillaries and the veins. This consists of a honeycomb-like structure, with frequent trabeculæ and meshes (see *e*, *e*, Fig. 186). The meshes contain blood, but also large cells and cells containing blood corpuscles and pigment. The mesh-work of the pulp develops occasionally wider channels or sinuses which are virtually the radicles of the veins. The pulp has a brownish colour both from its

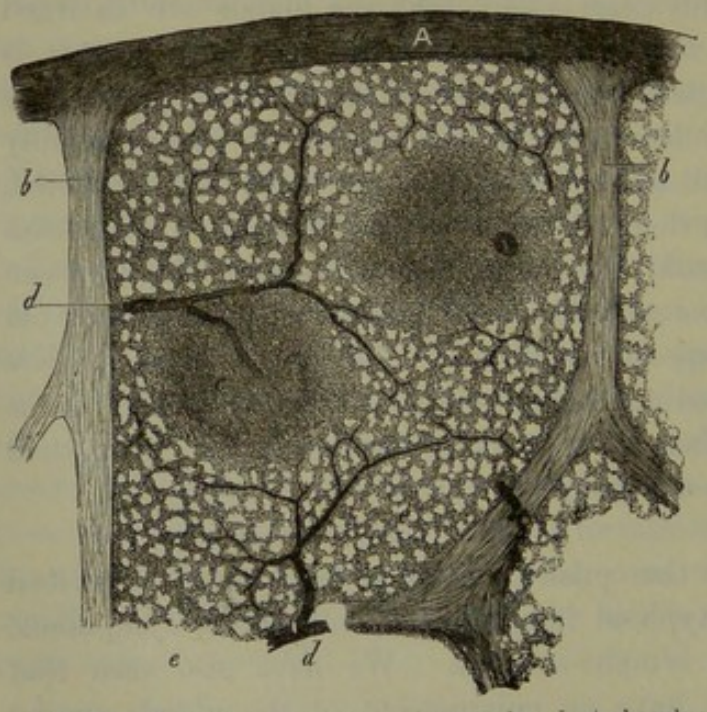


Fig. 186.—Structure of spleen. *A*, capsule; *b*, trabeculæ; *c*, *c*, Malpighian bodies; in that to the right an artery, cut transversely, is seen; *d*, *d*, injected arteries, one running into a Malpighian body; *e*, honeycomb-like pulp. (KÖLLIKER.)

pigment and from the fact that it is full of blood. The Malpighian bodies being lymphoid in structure, and sparely vascularized, are whitish in colour. It is clear from this structure that the blood passing into the spleen by the arteries will linger long in the organ, and will especially stagnate in the meshes of the pulp. It seems probable that in the pulp the red corpuscles are to some extent destroyed. The existence in the normal spleen of cells containing red corpuscles and pigment seems to indicate this. The spleen also probably gives origin to white corpuscles, but it shares this function with the lymphatic glands, and the medulla of bone, as well as probably the widely diffused connective tissue throughout the body. Some have supposed that the spleen also forms red corpuscles, but this is exceedingly doubtful.

From these remarks it will be understood that the amount of blood in the spleen will be subject to great variations according as the pulp is more or less distended. The pulp forms by far the greatest part of the substance of the spleen, and according as its honeycomb structure is more or less full of blood will the size of the organ vary. Accordingly there is no organ in the body which varies so much in size, even under physiological circumstances. During digestion there is an active hyperæmia which causes enlargement of the organ. Again, the capsule and trabeculæ of the spleen are abundantly supplied with smooth-muscle fibre-cells, and its size is influenced by the state of contraction of these. It is well known that by electric stimulation the size of the organ may be diminished, the muscular tissue contracting.

MALFORMATIONS.—In addition to the spleen in its usual site, and of its ordinary size, there are very frequently small SUPERNUMERARY SPLEENS lying in its neighbourhood. These are generally round in shape, and have the dark red or blue colour and soft structure of the ordinary organ. There are sometimes several of these present, and although usually seated in the neighbourhood of the spleen they may be away from it, having even been found embedded in the head of the pancreas. Cases have occurred in which there have been two spleens of nearly equal size. The spleen is also liable to variations in shape and position. These may be congenital, but alterations in position may occur during life, chiefly when the organ is enlarged and alters its position on account of its increased weight. Again, there may be an unusual length of the ligaments so as to allow of an undue mobility of the organ. This also may be congenital, or it may be due to a stretching of the ligaments from increased weight.

Active or Congestive Hyperæmia and Inflammation.—We have already seen that an active hyperæmia of the spleen occurs physiologically during digestion; it is met with as a distinctly pathological condition, and frequently in a very exaggerated form, in a variety of acute general diseases. In this country it is often seen in the highest degree in typhus fever, but it is found also in other acute fevers, in pyæmia, in pneumonia, diphtheria, erysipelas. This hyperæmia is generally to be regarded as inflammatory in its nature, the primary stage of an acute inflammation of the organ. In the group of diseases referred to, the blood is in a peculiarly irritating condition. We know that the various parenchymatous organs, the muscles, and so on, show evidences of inflammation in the presence of cloudy swelling, and this is to be traced to the irritating condition of the blood. In these organs there is doubtless dilatation of the vessels, but in the case of the spleen the hyperæmia produces much more marked results on account of the structure of the organ. The hyperæmic spleen is greatly enlarged, and the capsule stretched. In some cases of typhus and intermittent fever the enlargement has been so great and sudden as to rupture the capsule. The name acute splenic tumour is sometimes given to this hyperæmic enlargement. It will be inferred that in this condition the splenic tissue is exceedingly soft, sometimes almost diffluent, and the colour of the cut surface is a dark red.

But the condition does not continue as a pure hyperæmia. The cells forming the honeycomb structure of the pulp enlarge, the blood-vessels and the meshes of the pulp come to contain more round cells or white blood-corpuscles. These are all indications of inflammation, and a further indication is sometimes afforded by the deposition of fibrine on the capsule of the spleen. The Malpighian bodies sometimes undergo enlargement in this stage, but not in all the diseases named. This is most frequently seen in the later stages of typhoid fever and small-pox, and when it occurs the consistence of the organ is firmer than is usual in the acute splenic tumour. In this stage in which more definite inflammatory processes are superadded to the congestion, the spleen is even larger than in the earlier stage, and it may reach two, three, or even four times the normal size. The organ is unduly soft, and on section may look half-diffluent, although it is firmer than in the cases without enlargement of the Malpighian bodies. The colour of the cut surface is considerably paler than in the earlier period, being more of a greyish or whitish red. On scraping the surface a thick juice is obtained which is not unlike pus mixed with blood.

As a general rule the acute splenic tumour diminishes as the primary disease passes off, and the spleen may be left soft and loose with wrinkled capsule and unduly prominent trabeculæ. Sometimes there results a chronic inflammation with thickening of the trabeculæ, but this hardly occurs unless there have been repeated attacks of hyperæmia as in malarial fevers, and occasionally in typhoid fever.

It is a very rare circumstance for suppuration to occur in the inflamed spleen, but this has been met with in intermittent fever. In such cases the pus appears in numerous little points which represent the Malpighian follicles, or there is a more diffuse suppuration of the spleen If the abscess bursts externally a fatal peritonitis results.

Among the cases of suppurative inflammation of the spleen should be mentioned those in which ulcerative endocarditis or pyæmia is the primary disease. In that case minute emboli are frequently carried to the spleen as to other structures, and being of a septic nature they each form the focus of an acute inflammation, which has at first a hæmorrhagic character, and afterwards passes on to suppuration. The spleen as a whole is enlarged by active hyperæmia.

CHRONIC INFLAMMATION.—In cases where the inflammatory enlargement is repeated frequently, or there is a more continuous irritation of the spleen, we have what may be called a chronic inflammation, causing the CHRONIC SPLENIC TUMOUR. This is very common in malarious districts, and is regularly met with in persons who have been repeatedly subject to attacks of ague. But in such districts it occurs even in persons who have had no apparent ague, so that almost every *post-mortem* examination reveals a chronic AGUE CAKE. As already mentioned there may be a more or less permanent enlargement in prolonged typhoid fever. Syphilis in the acute stages produces an acute splenic tumour, which may result in the chronic form, but by no means constantly. Again, the chronic form may occur in congenital syphilis.

The enlargement may depend on a GENERAL HYPERTROPHY of the spleen, so that the consistence of the organ is nearly normal. There is, however, considerable increase of the lymphoid elements and the trabeculæ are thickened. There is frequently also increased pigmentation. In other cases there is a marked new-formation of connective tissue in the trabeculæ, the pulp is firmer and the blood spaces reduced in size. This condition warrants the designation FIBROUS INDURATION OF THE SPLEEN. The organ as a whole is not so much enlarged as in the other form, but it is much firmer and harder, so that the name ague cake is

peculiarly applicable here. In extreme cases there is atrophy of the proper constituents of the spleen; the pulp is much encroached on, and the Malpighian follicles are greatly destroyed. There is usually also much deposition of pigment in the splenic tissue, especially in the pulp, but also to a slight extent in the Malpighian bodies, and in the thickened connective tissue around the vessels (see Melanæmia). In both forms of chronic tumour of the spleen, the capsule is generally thickened. It is usually irregularly so, and we have tendon-like patches or loose shreddy connective tissue on the surface. Sometimes the capsule acquires adhesions to neighbouring structures, and the spleen may be so buried in adhesions as to make it difficult to dissect it out. It is to be remembered, however, that such adhesions are very frequent apart from any proper disease of the spleen at all, being due to inflammations in its neighbourhood. In this latter case the spleen is usually small and firm in its texture.

Passive Hyperæmia.—This condition occurs in the spleen when there is any considerable obstruction of the portal circulation. Hence we meet with it in cirrhosis of the liver, and in cases of heart disease which have gone on to general venous engorgement, the hyperæmia being, as it were, transmitted through the liver. It may, indeed, occur in consequence of any local or general obstruction whose effects extend to the splenic vein. The organ is enlarged, but not to such an extent as in the congestive form. As in other cases of passive hyperæmia the connective tissue increases in firmness, and so the whole organ is denser than usual, while the tissue presents a deep red colour. The thickening of the connective tissue affects the trabeculæ and the sheaths of the blood-vessels.

The Embolic Infarction.—This is probably of more frequent occurrence in the spleen than in any other organ, except perhaps the lungs. The explanation of this is probably the large size of the splenic artery. We have already seen that this artery and all its branches are end-arteries, and that obstruction of one of them can hardly fail to cause the hæmorrhagic infarction. At first the infarction is of a deep red colour, and has more or less the form of a wedge with its base at the capsule. On handling the organ it is to be detected by its density, forming a hard mass in the midst of the soft tissue. As a rule, there are several infarctions in the same spleen, and as the embolus in a larger trunk may break up and be distributed irregularly in various branches, we may have very complicated forms

assumed by the infarction. For example, it is not uncommon to find the superficial parts of the spleen involved over a large area, while the infarction does not extend much beneath the surface, as if the emboli had been swept into a number of terminal branches near the surface. THE SPLEEN, as a whole, IS ENLARGED, the obstruction of the arteries leading to a collateral hyperæmia by dilatation of those remaining open. This enlargement may reach considerable dimensions. On the capsular surface of the infarction there is often a deposition of fibrine, and it is interesting to know that during life the existence of this has been sometimes diagnosed by the discovery of friction sound.

From what has gone before, it will be understood that the piece of splenic tissue involved in the infarction is in a state of necrosis. At the very outset the elements of the spleen may be made out, the spaces in the pulp, the veins and venous sinuses being engorged with blood. After a time the tissues become less recognizable, they seem to undergo a coagulation, and at the same time fatty degeneration occurs in them. The blood-colouring matter is also dissolved out, being partly absorbed and partly deposited in solid granules throughout the infarction. The result is that the infarction becomes gradually paler in colour, and gains in consistence. Around the infarction a chronic inflammation occurs with the usual new-formation of connective tissue. As the infarction becomes absorbed this connective tissue draws together, the final result, as we have already seen, being a cicatrix in which some cheesy matter may be found representing the original infarction. During these processes the spleen gradually returns to its normal size and condition, with, it may be, some thickening of the capsule. We frequently meet with one or more cicatrices in the spleen from old embolism. These are always visible at the surface and penetrate inwards, but often they have little depth.

The condition of the spleen in LEUKÆMIA has been already described, and it is to be remembered that the spleen may be enormously increased in size, up to a weight of 40 pounds. The condition in pseudo-leukæmia or Hodgkin's disease is virtually the same.

RUPTURE OF THE SPLEEN.—This occurs occasionally, as we have seen, in acute enlargements of the organ. But traumatic rupture is much more frequent. This is effected by blows or falls on the abdomen, and also by injuries to the chest by which the lower ribs are forced against the organ. There may be considerable rupture without any

external marks of injury. It is important to remember that the enlarged and hard spleen is more liable to rupture than the normal one, both on account of its more brittle character and its size. This is important in a medico-legal aspect, especially in malarious districts. The rupture may lead to fatal hæmorrhage, but bleeding is often associated with other injuries, and only plays a part in the result. On the other hand, the hæmorrhage may be slight, and the wound may heal and leave a cicatrix.

DEGENERATIVE CHANGES.—Of these by far the most important is AMYLOID DISEASE. It has already been mentioned that the spleen is more frequently the seat of this disease than any other, and that it appears in a majority of cases to be the organ primarily affected. There are two forms of amyloid disease, called respectively the SAGO FORM and the DIFFUSE FORM. In the former the Malphighian bodies are mainly engaged; in the latter the pulp. We are entirely ignorant of the conditions which induce these differences in the situation of the degeneration, but there must be some important diversity in the causes of the two forms.

THE SAGO SPLEEN.—In this form the organ is moderately enlarged.

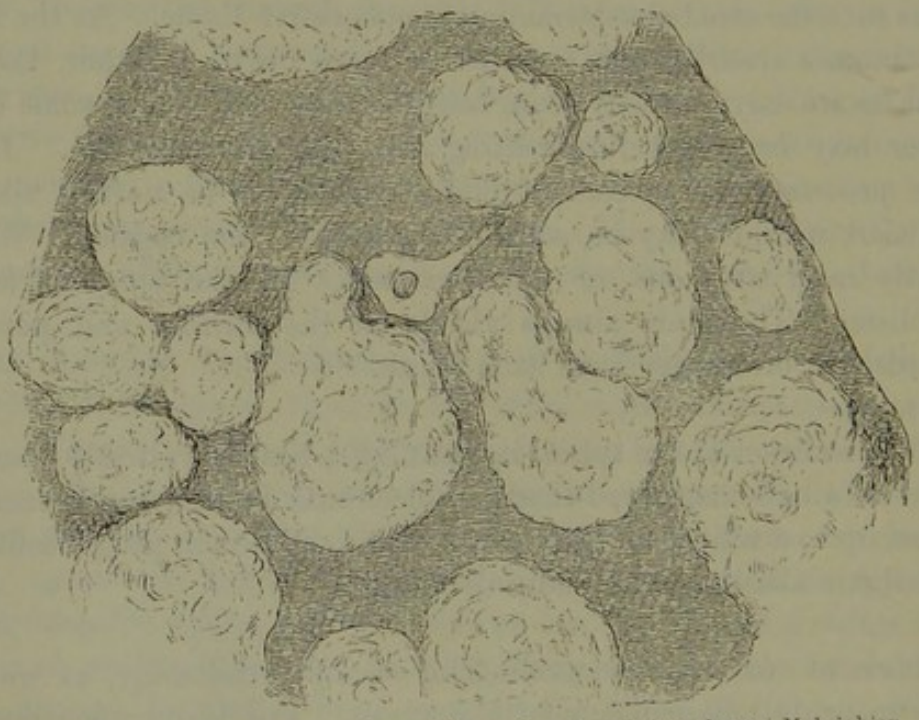


Fig. 187.—Section of a sago spleen. The enlarged and translucent Malpighian bodies are seen. In the middle an artery with amyloid walls. × 20.

On section we observe on the cut surface, instead of the normal small Malpighian bodies, transparent glancing areas which have been very

aptly compared to grains of boiled sago. These are dotted over the surface in great profusion. On applying iodine solution the affected areas stand out as brown spots, which become of a deeper colour on adding dilute sulphuric acid. Microscopic sections (see Fig. 187) show transparent hyaline areas of round shape and larger or smaller size, often so large that they are continuous with one another at their peripheries. These areas represent Malpighian bodies, which, when the disease is advanced, are entirely replaced by a nearly homogeneous transparent tissue. In the early stages, however, the addition of methylviolet or iodine brings out a beautiful network in the Malpighian body, and it is obvious that the reticulum is first attacked. Even in the early stage it can be seen that the lymphoid corpuscles are also to some extent involved, and as the disease progresses they are more and more affected, although to some extent they may be destroyed by the enlargement of the reticulum. The arteries whose lymphoid bodies are thus affected are often themselves degenerated, but they may remain unaffected. In advanced stages of the disease the enormous enlargement of the Malpighian bodies causes atrophy of the pulp, and we may have the spleen presenting little beyond large round, sago-like bodies. The pulp may, however, itself take part in the amyloid disease at the periphery of the Malpighian bodies.

THE DIFFUSE AMYLOID SPLEEN.—In this form the spleen undergoes much greater enlargement than in the sago form. It is in the highest degree hard and heavy, and the edges rounded. On section the tissue seems close and inelastic, and of a dark transparent appearance. The degeneration affects the greater part of the spleen, but there may be islands of normal pulp visible. The Malpighian bodies are hardly visible, and the cut surface has a smooth uniform appearance. The application of iodine produces a general deep brown colouration of the tissue. Under the microscope (as shown in Fig. 188) it appears that the trabeculæ of the pulp are involved, and the arrangement of these trabeculæ is brought out in the early stages on the addition



Fig. 188.—Diffuse amyloid spleen. The swollen and translucent tissue of the pulp (*a*) is shown. × 400. (After KYBER.)

of methylviolet or iodine. In the later stages the appearance is more uniform, but indications of the trabecular arrangement may still be visible. By the enlargement of the pulp the Malphigian bodies are greatly atrophied, but they may show traces of amyloid disease. In this form the walls of the arteries and veins are amyloid.

TUBERCULOSIS does not occur in the spleen as a primary disease, but in acute general tuberculosis we frequently find tubercles in great abundance. The tubercles are usually seated in the neighbourhood of arteries, and are often difficult to distinguish from the lymphoid Malpighian bodies which have a similar seat. The existence of the giant-cell structure and the tendency to caseous degeneration will assist in distinguishing them. Occasionally we meet with large caseous masses in the spleen, which may reach the size of walnuts. These occur mostly in children who are the subjects of scrofulous disease of the lymphatic glands. The general distribution of the nodules suggests that the infective material has been carried by the blood, and in some cases there may be a rupture of a softened gland into the splenic artery. SYPHILITIC gummata are very rare in the spleen, and have been met with chiefly in congenital cases. Other tumours are equally rare, but cases of FIBROMA, SARCOMA, and one case of a pulsating CAVERNOUS ANGIOMA have been observed. SARCOMAS occur SECONDARILY in the spleen with greater frequency than any primary tumour, and this is especially true of melanotic sarcomas, which may possibly originate in the spleen. SECONDARY CANCERS only occur in cases where, from the general diffusion of such tumours, we may infer that the infective material has found its way into the blood.

THE BONE MARROW.—The medulla of bone is now generally regarded as forming a part of the circulatory system. The red medulla of the spongy bones is to some extent, in structure and in function, analogous to the lymphatic glands and spleen. In normal conditions this medulla contains nucleated cells of a yellowish tint which are probably red corpuscles in process of development. Most of the conditions described as occurring in the spleen have their analogues in the bone-marrow. We have already seen that in leukæmia there are changes corresponding to the lymphatic new-formation in the spleen. In acute fevers, and especially in relapsing fever and small pox, but also in pyæmia, typhus, pneumonia, there has been found hyperæmia of the marrow and great accumulation of round cells. At present these facts must be regarded rather as indications of the direction in which investigation should go than as a solid basis of fact.

DISEASES OF THE NERVOUS SYSTEM.

INTRODUCTION.—In studying the diseases of the nervous system it is very important to carry along with us some general conception as to the anatomical and physiological relations.

The simplest idea of a nervous system is that of a central ganglion cell with an afferent or centripetal fibre and an efferent or centrifugal one. An approach to this simplest form of nervous system is afforded us in the case of the heart. We have here in the substance of the organ certain groups of ganglion cells, which possess on the one hand centripetal fibres coming chiefly from the endocardium, and on the other hand centrifugal fibres passing to the muscular fibres of the heart. It is to be presumed that impressions conveyed from the endocardium induce the development of impulses which are conveyed by the centrifugal fibres to the muscle and bring about its contraction.

But these intrinsic ganglia of the heart, although forming with their connections a complete nervous system, are not entirely isolated and independent. They are under the command of higher centres which control their action and through them effect the contractions of the heart. From these higher centres fibres reach the heart by two paths, by the vagus and by the sympathetic, and by means of these fibres the action of the intrinsic ganglia is restrained or stimulated.

Taking a general survey of the nervous system we find that among the innumerable centres there are grades or orders to be recognized, the lower or simpler being under the control of the higher and more complex. Leaving aside the peripheral centres and the sympathetic system we may fitly illustrate this in the case of the cerebro-spinal axis.

In the spinal cord, as we shall see more particularly afterwards, there are, chiefly in the anterior cornua, groups of ganglion cells which form distinct individual centres. Many of these appear to be of the

simplest and lowest kind, representing, as it were, single muscles or limited groups of muscles. The stimulation of such simple centres would produce no properly co-ordinated movement, but simply the contraction of a muscle or muscles. But in the cord itself there are centres of a higher order than this, representing, not single muscles or very limited groups, but more considerable groups of associated muscles, so that movements of some complexity are brought about by their stimulation. The lower order of centres are under the control of the higher, and it is to be presumed that the higher in bringing about movements do not act directly on the muscles, but stimulate in the first instance the lower centres, which then act directly on the muscles. It is to be understood that even the higher centres in the cord are, as compared with those in the brain, of a very low order, and are only capable of effecting such simple actions as the extension of the toes, the drawing up of the leg, etc.

The medulla oblongata may be regarded as simply an extension upwards of the spinal cord. Its centres are scarcely of a higher order than those of the cord, and the movements which may be effected by it alone are of the simplest character. In it are massed the great centres which have the control of the respiratory movements, and the contraction and dilatation of the blood-vessels. The muscles of the tongue, mouth, pharynx, etc., are represented here as are those of the legs and trunk in the spinal cord.

Passing to the centres next in order above the cord and medulla oblongata we reach the so-called middle brain, including the centres in the pons varolii, the corpora quadrigemina, and as perhaps of a still higher order, the cerebellum. Many animals can go through very elaborate movements when deprived of all parts above this middle brain. A pigeon can fly, a frog can leap, and a rabbit can run. There is however a want of spontaneity in the movements, which present many of the characters of complex reflex or automatic actions. A rabbit will remain quiet till its foot is pinched and will then set about running. It is to be observed that the movements effected by means of the middle brain require the action of the same muscles as those in which the spinal cord alone is concerned, but the combinations are more complex and the grouping of the muscles more intricate. It is to be presumed that in effecting these more complex movements the higher centres act in the first place on the lower, and, through them, on the muscles, the lower centres in the cord being thus a necessary link in the chain.

In man the middle brain appears to be much less independent than in the lower animals. In many animals, as we have seen, a stimulus coming from the periphery may induce such complex acts as flying, leaping, running, but it is not so in man. If the centres for such acts are situated in the middle brain in man, they are so dependent on the higher centres that when their connection with these is severed they are only able to act very imperfectly. A person may be completely paralysed on one side by the connection being divided between the middle and upper brain, but when such a person yawns the paralysed arm will often move in an exaggerated fashion entirely independent of the will. Yawning is an exaggerated inspiration, and in order to elevate the chest the arm is stretched upwards and backwards so as to bring the pectoralis into action on the chest wall. When we have command of ourselves we can control these movements, but when the middle brain is severed, the paralysed arm may act in an exaggerated fashion.

Passing now to the basal ganglia of the cerebrum we find here a series of centres of a very high order. When such animals as the dog and cat are deprived of all centres higher than the corpus striatum, they are capable of running about, these movements being of course automatic. But in man, and also in monkeys, although the general movements of the body may be regarded as gathered together in these ganglia, they are not sufficient for the more complex acts of locomotion, etc. The movements of the body, although represented in a complex form in these ganglia, are represented higher up in a still more complex form, and at the same time the lower centres are less independent of these higher ones.

In the convolutions of the cerebral hemispheres we have the highest order of centres, and in man the motor area may be taken to form the seat of all the centres which are concerned with the more complex voluntary acts. In the motor convolutions we have the movements of the body as it were written larger, occupying much more space than in the corpus striatum, and more individualized.

In regard to sensation we are not to look for a succession of centres such as we have in the case of motion. There are peripheral organs of a highly specialized character, which are engaged in the transmission of the various special kinds of sensation. Between these and the highest centres there are virtually no others interposed, the intervening structures being only concerned in conduction, perhaps with arrangements for fortifying the impressions as they are conducted through greatly elongated paths. Besides the apparatus engaged in sensation there are

afferent fibres which are related to reflex actions, and probably the same fibres to some extent subserve both functions.

In studying the specific diseases of the nervous system it will be necessary to carry these physiological considerations along with us, and in the case of each disease it will be proper to take into account the effect which it will have on the physiological action.

Lesions occurring in nervous structures may produce various effects. They may IRRITATE the centres either directly or by means of their communicating fibres. If a motor centre be irritated there will be muscular movements, spasm, convulsion. If a sensory centre be irritated there will be subjective sensations as of sight, smell, touch, hearing, taste. If a mental centre be irritated there will be subjective mental phenomena, that is, mental phenomena which are beyond the control of the individual, peculiar thoughts, illusions, etc. On the other hand lesions may DESTROY centres, in which case we shall have paralysis of motion, or loss of sensation (anæsthesia), or mental degeneracy.

It may also be remarked to begin with that lesions which are large and palpable are often called COARSE LESIONS, as where a tumour or a clot destroys or irritates, or does both. Coarse lesions are thus distinguished from those FINER CHANGES which are matter for microscopic observation. In some cases indeed the existence of actual physical changes is matter of inference, the anatomical demonstration of them being not yet furnished.

A.—THE PERIPHERAL NERVES.

INTRODUCTORY CONSIDERATIONS.—A nerve stem, whether met with embedded in the tissues of an organ or lying free, is composed of one or more bundles of nerve fibres united together by connective tissue. The accompanying figure (Fig. 189) shows the general arrangement of this connective tissue in a stem composed of a single bundle of nerve fibres. There is an external layer of connective tissue, the perineurium (*a*) binding the whole bundle together. But inside the bundle there is connective tissue binding the individual nerve fibres together and forming the endoneurium (*b*), the nuclei of which are prominently seen in

the figure. In a nerve stem made up of several bundles these also are bound together by connective tissue, the epineurium or neurilemma.

The nerve-fibres of such peripheral nerves are for the most part medullated, and when examined in the fresh state they present an opaque appearance and a double outline as in Fig. 190 *A*. When examined in the fresh state, it is only this appearance that is visible, but by proper methods of preparation the constituent structures of the fibre can be shown as indicated in Fig. 190, *B* and *C*, and

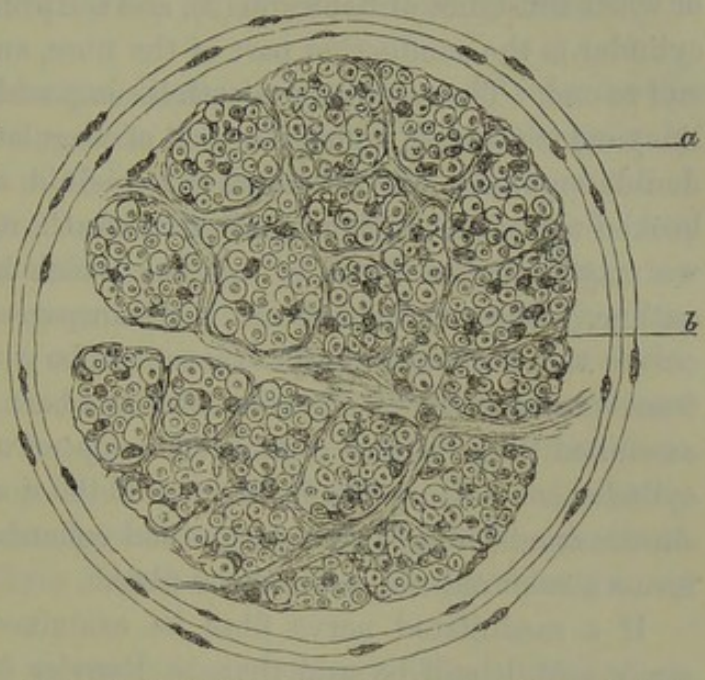


Fig. 189.—Transverse section of a nerve consisting of a single bundle; from a specimen stained and mounted by Clarke's method. *a*, perineurium; *b*, endoneurium. Inside the perineurium is the lymphatic space between it and the nerve bundle. The nerve-fibres are represented by rings with a central dot—the axis cylinder. × 120. (KLEIN.)

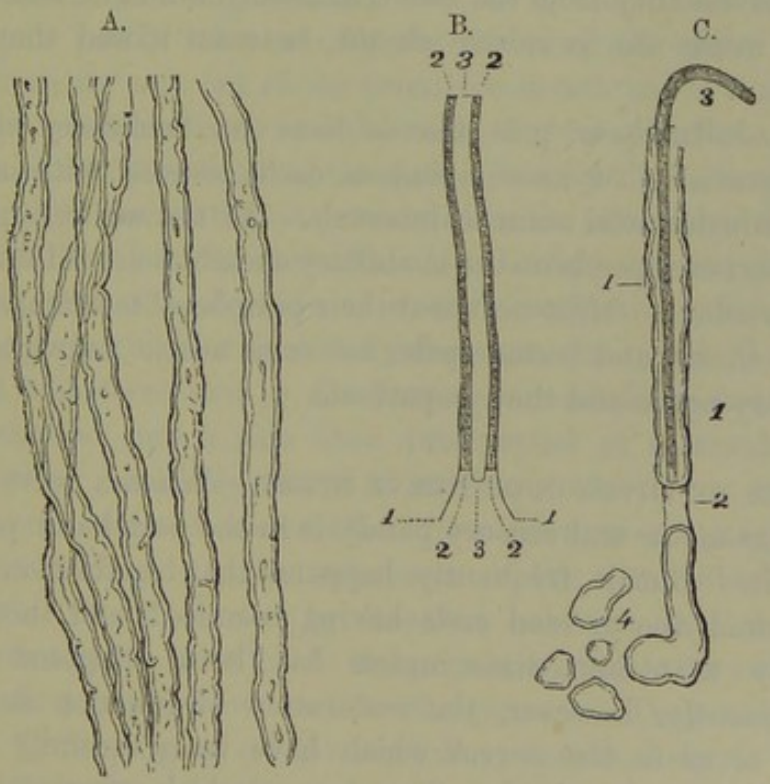


Fig. 190.—Medullated nerve-fibres. *A*, the natural appearance; *B* and *C*, diagrams showing the constituent structures as in text. (QUAIN.)

in Fig. 189. These are the axis cylinder (3, Fig. 190), the medullary sheath or white substance of Schwann (2), and the primitive sheath (1). The axis cylinder is the conducting part of the fibre, and runs continuously from end to end. The medullary sheath is composed of a fatty substance (myeline) and is prone to undergo a kind of coagulation which gives rise to the double contour. This substance is semi-fluid, and when the nerve fibre is broken up, either during life or after death, it is apt to flow out and so we may have free drops of myeline which have a strongly refracting outline. The primitive sheath is a transparent membranous tube which covers the fibre and keeps the medullary sheath together. When transverse sections of a nerve which has been hardened and stained are examined these various constituents appear as in Fig. 189. The axis cylinder is a coloured point in the middle of each fibre. The medullary sheath around this is transparent and colourless. The primitive sheath forms a coloured ring around the fibre.

If a medullated nerve fibre be examined after preparation with osmic acid, it will be seen that, as Ranvier has shown, the medullary sheath is not continuous, but is interrupted at intervals, the axis cylinder and primitive sheath being alone present. These *nodes* divide the nerve fibre into sections therefore, and each section receives a further individuality from the fact that about its middle an oval nucleus is present inside the primitive sheath, between it and the medullary sheath.

Non-medullated or pale nerves have no medullary sheath, and consist essentially of axis cylinders each covered with a primitive sheath in which nuclei occur at intervals. As the white appearance of ordinary nerves depends on the medullary sheath, non-medullated nerves are grey in colour. Most nerves at their peripheral terminations lose the medullary sheath and become pale, but some are so throughout, chiefly the olfactory nerve and the sympathetic.

Effects of Division of Nerve Stems.—When a nerve is divided, there occurs motor and sensory paralysis in the peripheral parts dependent on it. But it frequently happens that conduction is after a time restored, the divided ends having re-united, and this sometimes so rapidly that immediate union has been supposed to occur. Most frequently, however, the restoration of function is tardy, and processes occur in the nerves which have been carefully studied by experimentation on animals. The changes which ensue on the division of a nerve occur mainly in the peripheral portion of it, and they consist

in the first place in a degeneration, by which the structure is largely destroyed, and in the second place in a regeneration by which it is restored.

Before describing the changes themselves, we have to refer to the probable explanation of the peculiar degeneration which is the primary occurrence. The nutrition of the nerve fibres is under the command of certain ganglionic trophic centres, and when the fibres are cut off from these centres they suffer in their nutrition. For the sensory fibres the trophic centres are in the ganglia of the posterior or sensory roots. For the efferent nerves the centres are in the anterior cornua of the spinal cord. Most nerve stems consist of both afferent and efferent fibres, but the division of the stem will cut the fibres off from their trophic centres, whether they be afferent or efferent. It is interesting to observe that when the posterior nerve root is divided on the proximal side of the ganglion, its fibres degenerate in the central direction, or towards the spinal cord.

The degenerative process occurs in the whole peripheral distribution of the divided nerve, and almost simultaneously. The most obvious change is in the medullary sheath. It coagulates, breaks up into drops, and through time disappears by absorption. This disintegration of the medullary sheath occurs gradually, and the granular fat into which it breaks up is partly taken up by the nuclei of the nerve fibre, but partly also finds its way out of the primitive sheath and is found in the surrounding connective tissue and the walls of the capillaries. There is some difference of opinion as to the part taken by the axis cylinder in the process. Erb asserts that it persists after the medullary sheath has been destroyed, but Ranvier states that it is broken up, its interruption corresponding with the abolition of electric conductivity in the nerve. Whether the axis cylinder is destroyed or not, the nerve fibre undergoes a great transformation by the loss of its medullary sheath, and it becomes converted into a pale fibre, interrupted at intervals by the nuclei or by some persisting clumps of myeline.

It has been indicated above that these changes are degenerative in character, resulting from the severance of the nerve fibre from its trophic centre. It is asserted by Ranvier, however, that the nuclei, which we have seen to exist inside the primitive sheath between every two nodes, take a more active part in the process. They enlarge and divide, and, by impinging on the medullary sheath, help to break it up. It is by them also, according to this author, that the axis cylinder is interrupted. This enlargement and division of the nuclei is somewhat

similar to that which occurs in muscle in certain lesions of the spinal cord to be considered afterwards, and it may be regarded as inflammatory in its nature.

At the place of division of the nerve, as there is a wound, there are signs of inflammation. Leucocytes collect between and around the cut ends of the nerve, and even penetrate into the primitive sheath for some distance. These leucocytes, which are most abundant soon after the section, attack the medullary sheath, and assist in breaking it up; the myeline is taken up by the leucocytes so as to give them the appearance of compound granular corpuscles. In the central end of the divided nerve, however, the destruction of the medullary sheath is limited, as the invasion of leucocytes generally stops short at the first node.

After a time the inflammation subsides largely, and the wound, including skin and soft parts, is united by a cicatrix formed in the usual way. The divided ends of the nerves are united by a pale cicatricial band, which does not as yet contain any proper nervous elements, and does not effect a restoration of the conductivity.

Conduction is restored by a process of REGENERATION. According to the researches of Ranvier, this occurs entirely by the axis cylinders of the central end budding out and extending first into the cicatrix and then into the peripheral end. The axis cylinder enlarges at its extremity, and becomes divided longitudinally into several fine fibres, which grow out into the cicatrix. Arrived at the cut end of the peripheral portion they penetrate into it and very frequently pass into the primitive sheath. In this way a number of new-formed axis cylinders may be found inside an old nerve-tube, and there may be alongside of them some pieces of persisting myeline. These new axis-cylinders after a time acquire medullary sheaths, and the regeneration of the nerve is completed. It should be added that, according to Remak and others, the new fibres are not formed entirely by budding from the central end, but that they arise also from the remaining axis-cylinders of the peripheral end.

HYPERÆMIA AND ACUTE INFLAMMATION OF NERVES.—These conditions are exceedingly common as secondary processes in the neighbourhood of wounds and inflammations, but are rarely primary. Under such circumstances the vessels of the nerve may be highly engorged with blood, and there may even be capillary hæmorrhages. Leucocytes may be exuded, and may be found in the connective tissue between the nerve fibres. It is very rare, however, to find a proper suppurative

inflammation of a nerve. A stem may be bathed in pus and almost isolated by the suppuration around, and yet there may be almost no pus in the connective tissue of the nerve itself. This seems to indicate that the perineurium forms a barrier between the lymph spaces of the nerve and those of surrounding parts. If a nerve be exposed and isolated, and the wound filled with water in which vermillion is suspended, the leucocytes which accumulate take up the vermillion and carry it in various directions but not into the nerve, showing that there is no open path into it. But if a nerve in a suppurating wound be itself wounded so as to lay open its internal structure, the suppuration will readily extend into it.

Chronic Neuritis is, like acute, for the most part secondary. It may remain after an acute attack, but it may take origin in a prolonged inflammation of some peripheral organ. It may have its starting point in an inflammation of a joint, in dysenteric inflammation of the intestine, in inflammation around the kidney, and so on. It is very important to observe that inflammations originating thus may extend up the nerves. It is to be presumed that the irritant gradually finds its way along the lymph spaces of the nerve, which we have seen to be somewhat independent of those around, and the resulting inflammation may even extend to the spinal cord and its membranes. Many cases which have been regarded as reflex paralysis have been due, according to Leyden, to this extension of chronic inflammation to the cord. There may also be an extension downwards to the muscles and a consequent interstitial myositis.

The inflammation manifests itself in the connective tissue of the nerve, the perineurium and endoneurium presenting an excess of round cells and becoming gradually thickened. As a consequence of this the nerve fibres atrophy, the medullary sheath being first destroyed. The nerve as a whole may be thickened and indurated, while there is actually an atrophy of the proper conducting fibres. These will be recognized as the general characteristics of chronic interstitial inflammations.

Tumours.—Syphilitic gummata are very infrequent in the peripheral nerves, but they do occur, especially on the cranial nerves inside the skull, where they are probably propagated from the membranes of the brain. Leprosy, as we have already seen, sometimes manifests itself in the form of tumours of granulation tissue in the nerves. The

NEUROMA is strictly a tumour consisting of nervous tissue, but as the name is applied to simple tumours of nerves in general, it is customary to refer to true and false neuromata. The true neuroma, as we have seen, and as Fig. 191 shows, has a similar structure to a nerve stem.

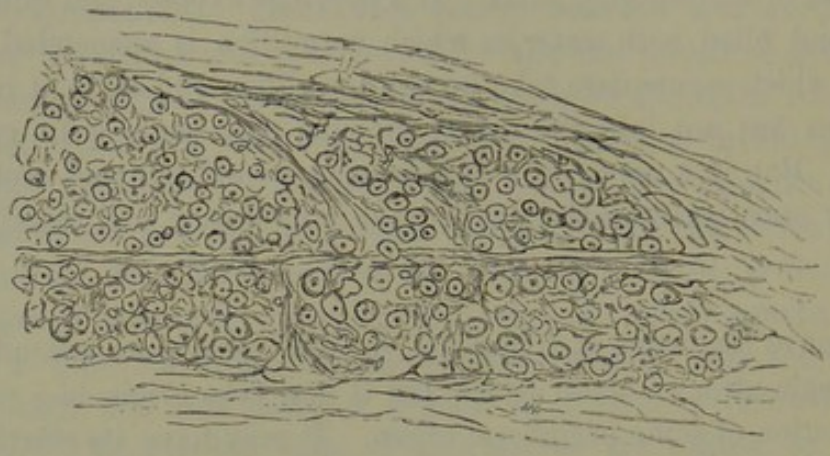


Fig. 191.—Transverse section of a neuroma, showing medullated nerve fibres. × 80.

It presents nerve fibres embedded in connective tissue. The fibres are usually medullated, but cases of non-medullated neuromas have been described. The neuroma forms a hard tumour usually oval in shape and very often multiple. Of the false neuromas there have been cases of FIBROMA, MYOMA, MYXOMA. The painful subcutaneous tumour (*tuberculum dolorosum*) is apparently sometimes a fibroma, sometimes a myoma, or even a non-medullated neuroma. SARCOMA is very rare in nerves. CANCERS do not occur as primary tumours, but nerves are often involved in the extension of such tumours. It often happens that a cancer or sarcoma grows around a nerve, which passes through its midst without becoming the seat of the tumour tissue. This is again to be associated with the apparent independence of the lymph spaces in nerves. Sometimes, however, a cancer breaks into a nerve and grows in the lymph spaces between the perineurium and the bundle of fibres. In such cases the nerve fibres undergo degeneration.

B.—THE SPINAL CORD AND MEDULLA OBLONGATA.

INTRODUCTION.—In what has gone before a general view has been given of the functions of the central nervous system. Before beginning the description of the special diseases of the cord and medulla we have to see how these functions connect themselves with the anatomical details of these structures.

The cord is made up of white and grey substance, the latter forming the ganglionic centres and consisting of ganglion cells in the midst of a fine network, the former consisting of medullated nerve fibres having essentially the structure of those in the peripheral nerves.

THE GREY SUBSTANCE of the cord is arranged in the well-known form of an anterior and a posterior cornu on either side. The ganglionic centres have their seat chiefly in the anterior cornua, and form tolerably definite groups which may here be more particularly indicated.

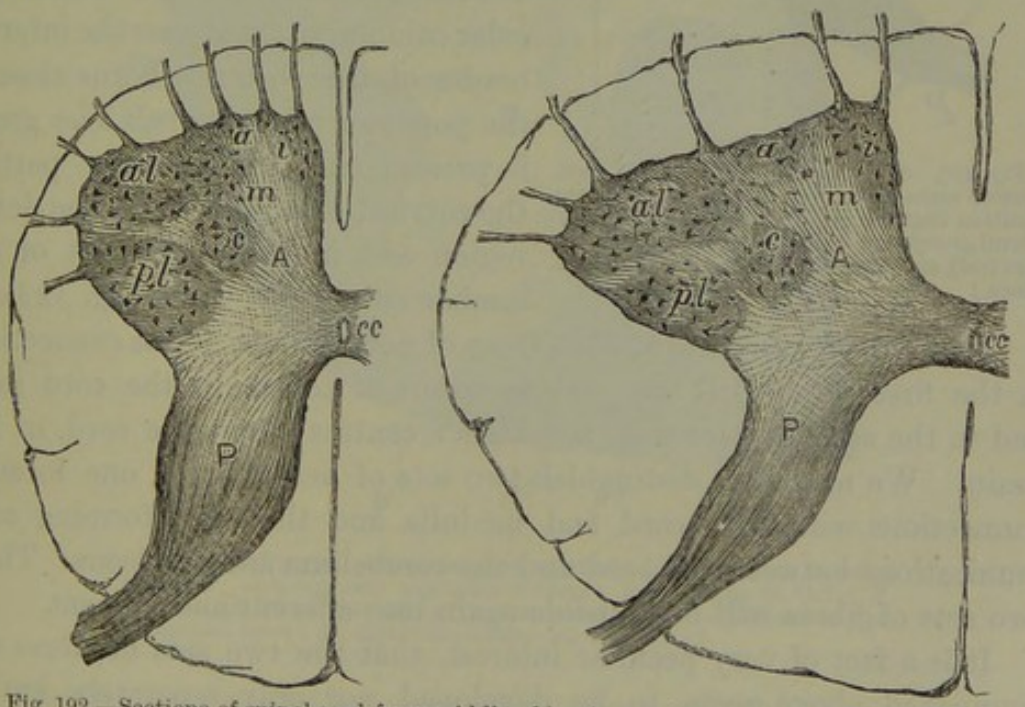


Fig. 192.—Sections of spinal cord from middle of lumbar and cervical enlargements, showing groups of ganglion cells; *a l* and *p l*, antero-lateral and postero-lateral, *a*, anterior, *i*, internal, *c*, central, *m*, median, groups. (Ross.)

The description may be followed by reference to Fig. 192, which shows sections of the lumbar and cervical enlargements. The groups

are named according to their situations. There are the lateral groups lying along the external parts of the horn and divided into an antero-lateral and a postero-lateral group (*al* and *pl*). Then in the front of the horn and inside the antero-lateral group is the anterior group (*a*), and inside it again and bordering on the white substance is the internal group (*i*). Towards the centre of the horn is the central group (*c*). There is further a group which is later in appearing in the development of the cord, and whose cells are generally smaller than those of the others. It occupies a place between the internal group on the one hand and the central and antero-lateral on the other, while the anterior group projects somewhat into it. This is the median group (*m*) which is much larger in the cervical than in other parts of the cord, and so causes the horn to be extended laterally much more here than elsewhere (see Fig. 192). Lastly, there is a group of cells, generally called Clarke's vesicular column, situated near the internal border of the posterior horns close to the posterior commissure. The group is present only in the lower part of the cervical enlargement, in the dorsal region and in the upper part of the lumbar enlargement (see Fig. 193).

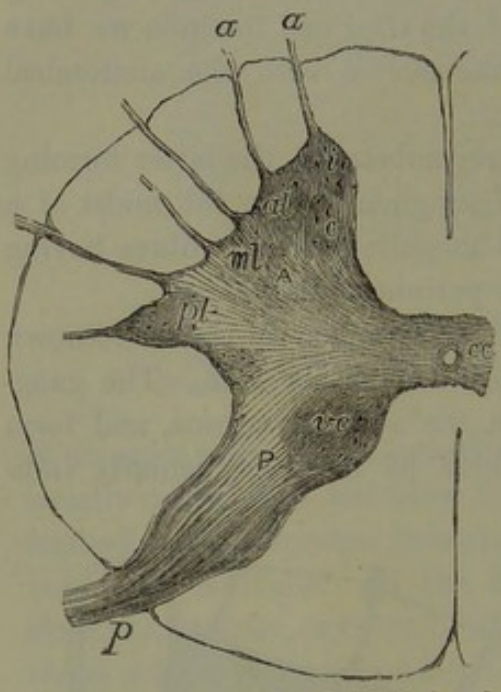


Fig. 193.—Section of dorsal region of cord. Letters same as in previous figure, with the addition that the antero-lateral and postero-lateral groups are separated by a medio-lateral area (*ml*), and Clarke's column (*vc*) is shown. (Ross.)

THE WHITE SUBSTANCE, consisting of nerve fibres, forms connections in the first place with the various orders of centres in the cord itself and in the second place with the higher centres above the cord, in the brain. We may thus distinguish two sets of nerve fibres, one forming connections within the cord and medulla and the other forming communications between the cord and the cerebellum and cerebrum. These two sets of fibres will be divisible again into afferent and efferent.

It is a fact of very peculiar interest, that the two sets of fibres distinguished above seem to be developed not only separately but at different periods, and so the aid of embryology has been sought to enable us to distinguish between them. The fibres which connect the different parts of the cord and medulla with each other may be regarded as the primary or fundamental ones, and it is found that they are the first

formed, while those forming higher connections are of subsequent development. As nerve fibres are first developed without the medullary sheath, and recently formed tracts are therefore much paler than those which have acquired it, we have in this a means of distinguishing the fundamental from the secondary. What follows will be understood by reference to Fig. 194, which represents a transverse section of the cervical cord in the fœtus of nine months.

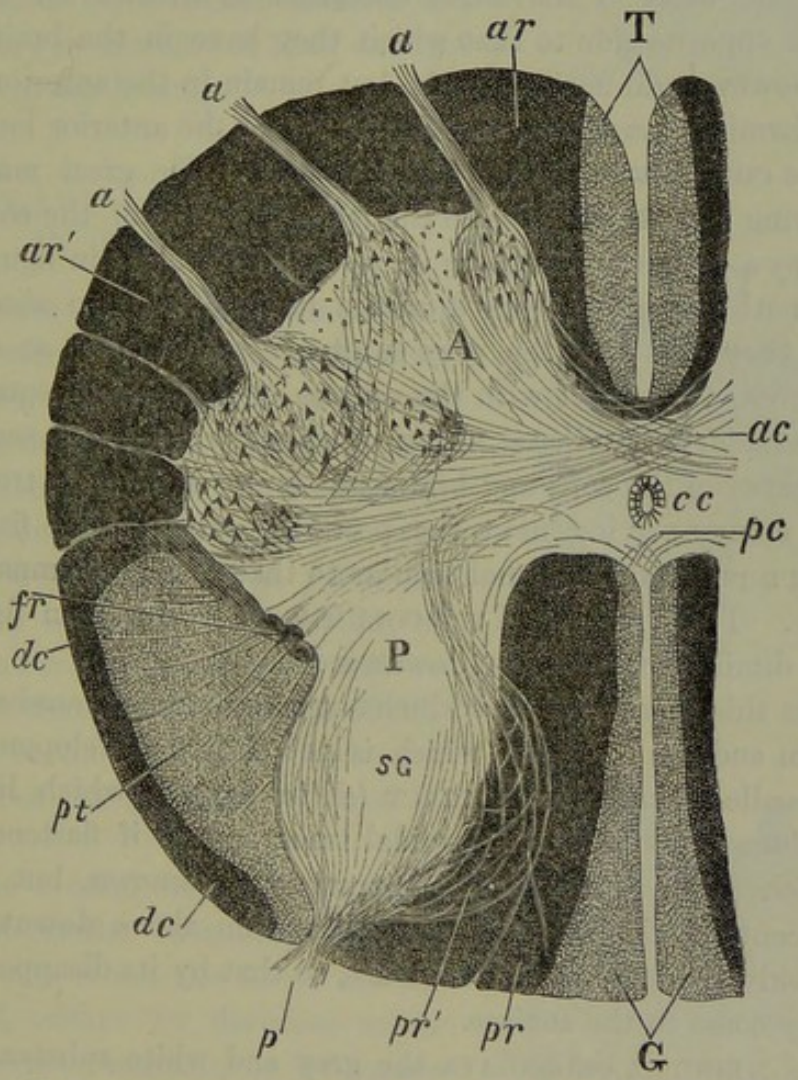


Fig. 194.—Cervical enlargement of cord in a fœtus of nine months. A and P, anterior and posterior cornua; G, columns of Goll; T, columns of Türck; *ar* and *pr*, anterior and posterior root-zones; *pt*, pyramidal tract; *dc*, direct cerebellar tract. (Ross.)

The first developed fibres immediately surround the grey matter, and are called the ANTERIOR and POSTERIOR ROOT-ZONES. As they form communications between one part of the grey matter and another, the fibres are comparatively short and their number is generally in proportion to the amount of grey matter, or at least of ganglion cells in

the horns. These fibres therefore do not diminish from above downwards as do the others.

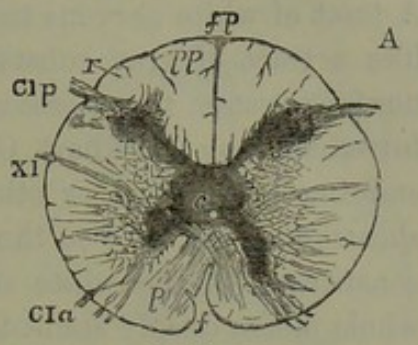
Of the fibres forming communications between the brain and cord, the best known are those which convey the motor impulses from the brain to the cord. These form the PYRAMIDAL TRACT. We shall afterwards trace them from the cortex of the brain downwards, but at present we take them up at the medulla oblongata. Here they form the anterior pyramids and most of the fibres decussate so that in the cord they occupy the opposite side to that which they have in the brain. Some of them, however, do not decussate, but remain in the anterior parts of the cord, forming a small band on either side of the anterior longitudinal fissure, the COLUMNS OF TÜRCK (*T* in figure). The great mass of the fibres, having decussated, pass to the lateral column of the cord, where they occupy a definite position in its posterior parts (*pt* in figure). The fibres in both these positions diminish in number from above downwards, as they pass into the grey substance of the cord at successive levels in order to connect with the centres in the anterior cornua.

The secondary centripetal fibres, or those which form sensory connections between the cord and brain, are represented by a tract in the posterior columns lying next the posterior longitudinal fissure, and occupying a position somewhat similar to that of the columns of Türck anteriorly. These are called the COLUMNS OF GOLL (*G* in figure), and they also diminish from above downwards.

Besides this there is a tract which forms communications between the cerebellum and the cord, but which is not of late development. This is the so-called CEREBELLAR TRACT (*dc* in figure), which lies in the lateral column outside the pyramidal tract, and as if flattened against the surface. The function of this tract is not known, but it is composed of centripetal fibres and diminishes from above downwards even more quickly than the pyramidal tract, so that by its disappearance the latter may come to the surface.

In the MEDULLA OBLONGATA the grey and white substances of the cord may be traced upwards, but they undergo considerable dislocation. From the examination of Fig. 195 it will be seen that, as the central canal passes backwards and finally opens out in the fourth ventricle, the grey matter, departing from its arrangement into cornua but still aggregated in the neighbourhood of the central canal and ventricle, forms various masses in the posterior part of the medulla. These masses have special importance as being the nuclei of origin of certain nerves, and will be afterwards more particularly referred to, in connection with bulbar

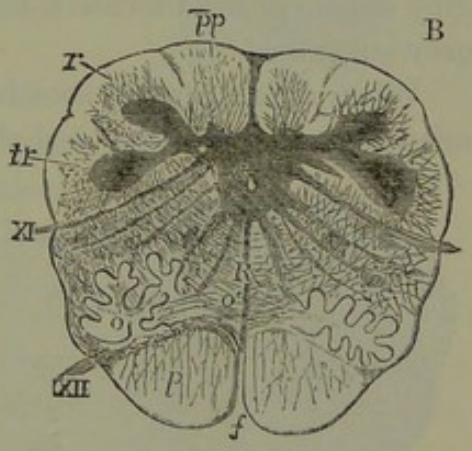
paralysis. The white substance gradually comes to occupy the middle and anterior parts of the medulla, and the olivary body is intercalated in its midst. The pyramidal tract is easily recognised here, forming the anterior pyramids (*p*), which decussate at the lower part of the medulla (*A*). The motor fibres having assumed a position in front remain anterior to the sensory in the rest of their course upwards in the brain.



SECONDARY DEGENERATIONS IN THE CORD.

We have already seen that when a nerve stem in an animal or in man is divided, the peripheral portion of the nerve degenerates. The most prominent changes are in the medullary sheath which coagulates, then breaks up, and is finally absorbed. The degeneration occurs from the point of section towards the periphery, and we have seen that the explanation of this seems to be that the nerve fibres are cut off from their trophic centres in the cord.

In the central nervous system a somewhat similar secondary degeneration occurs when the fibres are interrupted, either by division, as in experiments on animals, or by coarse lesions in man. The degeneration is of the same character as in peripheral nerves, and results in the destruction of the medullary sheath. It is known that the opaque dead white colour of the white or fibrous nerve substance is due to the medullary sheath, which is a highly refracting fatty substance. If this medullary sheath be lost then the white nerve substance becomes



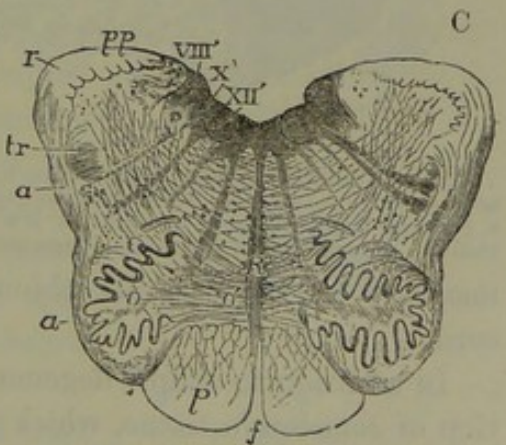


Fig. 195.—Medulla oblongata at various levels, *A*, at decussation of pyramids (*p*), the general shape of the cornua still retained. *B*, higher up, the grey matter passing backwards, and pyramids becoming more isolated. *C*, in fourth ventricle the nuclei in the floor of which are shown. (QUAIN.)

grey, and so we speak of GREY DEGENERATION in all cases where the medullary sheath is lost, whether from the cause we are considering or not. A tract of white nervous tissue affected with this degeneration will be like a tract of grey substance. Again, in preparing the tissue of the nervous system for microscopic examination, some form of the method introduced by Lockhart Clarke is generally used. In this method staining by carmine or other dye is employed, and as the medullary sheath does not take on the staining at all, and as it is the most bulky constituent of the white substance, the normal white substance as a whole is less deeply stained than the grey substance. When secondary degeneration has occurred, the effect of staining is to make the altered white substance appear like the grey substance. In figures representing grey degeneration therefore the affected parts will be shaded like the grey substance.

When a degenerated area is examined more particularly under the microscope the most marked change is the great reduction in the number of nerve fibres, as shown in figure 196. The connective substance is greatly increased, and the nerve fibres appear only at intervals, a few surviving in the midst of the general destruction. There is sometimes also considerable shrinking of the degenerated area, but this is much more manifest in the medulla oblongata and parts above it than in the cord.

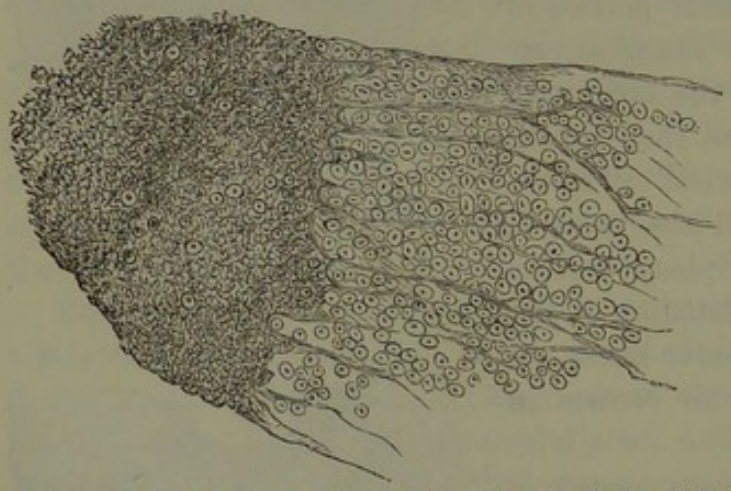


Fig. 196.—Sclerosis or grey degeneration of cord. To the right is normal white substance. To the left the degenerated tissue shows a granular basis substance in which a few nerve fibres are still visible. From a case of descending degeneration. × 80.

In addition to simple degeneration there is sometimes a new-formation of connective tissue, which some regard as inflammatory in character. The inflammatory character is little marked in secondary degeneration, but there are some forms of grey degeneration in which the inflammatory new-formation is perhaps the primary factor, and the degeneration of the nerve fibres the result of it. Whether there be new-formed connective tissue or not, and whether the process be inflammatory or not, the absence of the soft medullary sheath causes

a hardening of the tissue, and so the term SCLEROSIS when applied to the white substance is nearly equivalent to grey degeneration.

It has been said above that the degeneration occurs in the fibres which are cut off from their trophic centres, and it seems that in the cord the trophic centres are at the lower termination of the centripetal fibres and the upper termination of the centrifugal. Hence the degeneration follows the direction in which the nerve conducts, passing upwards from the seat of lesion in the case of centripetal fibres and downwards in the case of centrifugal. So we speak of ascending and descending sclerosis.

The degeneration takes some time to develop. According to experiments in dogs it begins fourteen days after the infliction of an injury, but it is many weeks before the appearances are fully established.

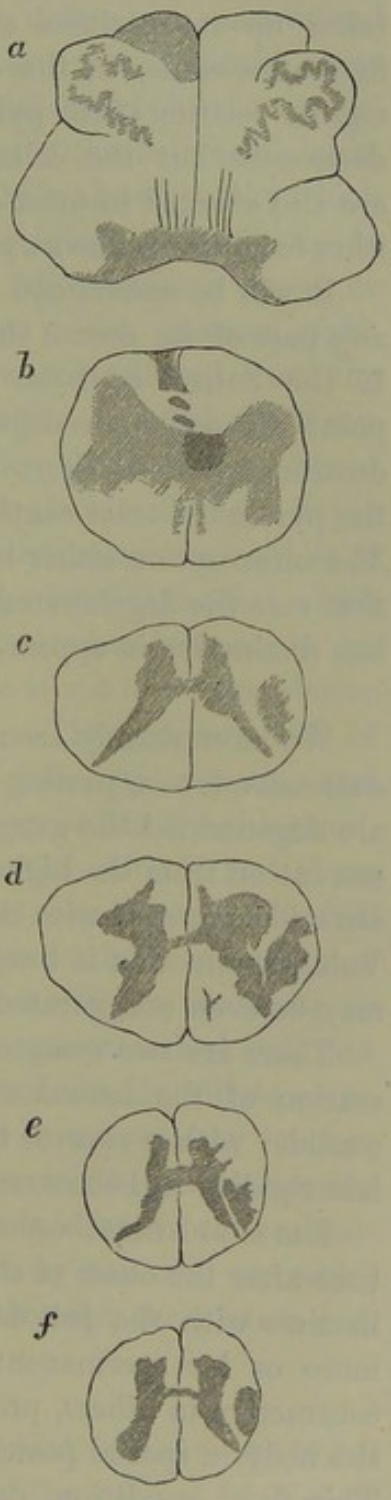


Fig. 197.—Descending degeneration in medulla oblongata and cord. *a*, medulla at fourth ventricle, *b*, at decussation, *c*, *d*, *e*, *f*, cord in upper and lower cervical, dorsal, and lumbar regions.

DESCENDING GREY DEGENERATION (*descending sclerosis*).—As we have just seen, this lesion affects centrifugal or motor fibres, including the fibres of the anterior root-zone and the pyramidal tract. The former are short fibres, and when they are interrupted there is a descending degeneration extending only a short distance downwards. But the fibres of the pyramidal tract are continuous from the brain downwards to the extremity of the cord, and wherever interrupted they show degeneration in all parts situated below the lesion.

The degeneration of the pyramidal tract is most frequently brought about by a lesion of the brain, and in that case it exists in the parts of the tract above as well as in those below the medulla oblongata, where we shall trace it afterwards. We have here to consider it in the medulla and cord. In the

medulla oblongata it occupies the anterior pyramid (see Fig. 197 *a*), where it frequently produces great shrinking. At the lower part of the medulla (*b*) the degenerated fibres decussate and the degeneration takes up its position at first at the side of the central canal (see fig.), afterwards, in the cord, passing into the lateral columns in the regular position of the pyramidal tract (*c*, *d*, *e*, *f*). In some cases it entirely decussates, but the columns of Türck in the anterior white columns are also affected in most cases. In its whole course the lesion diminishes from above downwards, but is traceable down to the lumbar region.

It will be understood that, if the pyramidal tract be interrupted in any part of its course the degeneration follows in all succeeding parts. If the entire cord be divided there is, immediately beneath the point of section, a degeneration of the anterior root-zones which is continued but a short distance. There is also a degeneration of the pyramidal tract continued downwards the whole length of the cord. The interruption either in the cord or brain may be incomplete, and in that case the degenerated fibres will be fewer in number and the area less distinctive in appearance.

We have already seen that the pyramidal fibres end in the cord at successive levels, passing into the ganglionic centres. When the fibres are degenerated the ganglion cells will not be affected except that they are cut off from the higher centres and left more to themselves. They are still connected with the muscles, which retain their contractile power. Voluntary motion is lost, but certain involuntary muscular phenomena may be even exaggerated.

There are two symptoms generally supposed to be related to degeneration of the lateral columns of the cord which it is proper here to consider with a view to their probable pathology, these are the so-called late rigidity and the exaggerated tendon reflex.

LATE RIGIDITY, occurring in hemiplegia, comes on a considerable time after the onset of the paralysis, and may be regarded as coinciding in time with the full development of the sclerosis. There is here a more or less permanent contraction of some muscles with absence of contraction in others, producing sometimes fixation of the members of the body in special positions so as to have the appearance of deformity. This fixed condition, due to the muscular spasm, is often called CONTRACTURE. It implies a continuous impulse to the contracted muscles originating in the cord or elsewhere. Charcot suggests that the inflammatory process which he supposes to be involved in the sclerosis may

irritate the fibres passing to the anterior cornua and so result in the stimulation of the muscular centres there. But this view can hardly be accepted; there may be almost no signs of inflammation in the affected part and yet marked rigidity. Besides, it is difficult to understand how irritation of degenerated and virtually lost fibres should cause stimulation of the ganglion cells. A more probable explanation is suggested by Hitzig. Taking as an example the case of the arm in hemiplegia, it appears that the contraction occurs most readily in those muscles which are in a position to contract most easily. The hemiplegic generally lies in bed with his forearm across his chest, and even when walking about he supports it across his chest, and it is the biceps which becomes rigid. Then it has been shown that when the fingers are released from the action of the muscles and left to assume the position to which the bones and ligaments best accommodate themselves, they assume a semi-flexed position, such as we see in the dead body. It is obvious that the flexor muscles will most easily contract under these circumstances, and it is they which get rigid in hemiplegics. Take along with this the fact which Volkmann points out, that muscles can actively contract but cannot actively relax, and it is seen that any slight impulse is apt to be cumulative when there is no action of antagonistic muscles. The ganglion cells of the anterior cornua are still in connection with the muscles, and although cut off from the upper brain are still exposed to irregular and, as it were, accidental stimulation. There are reflex stimuli, and there are stimuli from above conveyed in a roundabout way through the still open communications in the cord. A multitude of slight stimulations will reach the ganglion cells and feeble impulses will be conveyed to the muscles. Those which from their position are stretched will not contract, but those which are so placed as to contract easily will do so, at first feebly but with cumulative force. This view is supported by the fact that, in the early stages of late rigidity, there is often considerable relaxation of the muscles after prolonged rest as in sleep, so that a limb which was rigid at night is found in the morning soft and movable. The ganglion cells in sleep are protected from external stimulation and they cease acting.

The exaggerated TENDON REFLEX may be regarded as due to the isolation of the muscular centres in the cord. When the control of higher centres is removed, lower centres usually act more readily. The skin reflex is frequently decreased, but the muscular centres seem to be more powerfully acted on by stimuli coming from the muscles.

It may be added that these two symptoms are prominent in the spastic paralysis of Erb, where there is, as we shall see farther on, a spontaneous sclerosis of the lateral columns.

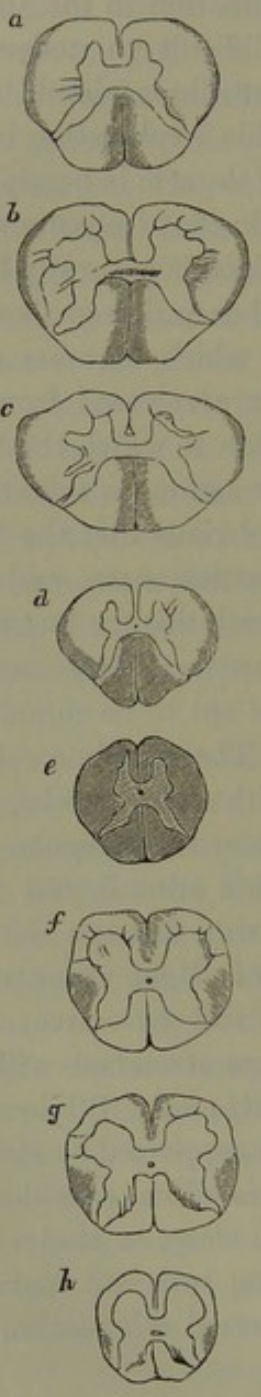


Fig. 198.—Transverse myelitis (*c*) with secondary ascending and descending degeneration. At *d*, the ascending degeneration affects the posterior root-zones, the columns of Goll, and the direct cerebellar tracts, but above that it is confined to the two latter. At *f* to *h*, the columns of Türck and the pyramidal tracts are affected. (Erb.)

Ascending Grey Degeneration (*ascending sclerosis*).—This condition occurs as a result of any cause which interrupts the ascending or sensory fibres of the cord. It may be the consequence of pressure by tumours, hæmorrhages, abscesses, fractured or displaced vertebræ, inflammatory products, etc. It occurs in parts above the seat of interruption, and the degenerated fibres are centripetal.

The degeneration affects the centripetal fibres, and these we have already seen to be of two kinds. There are the short fibres communicating between different segments of the cord, and forming the posterior root-zones, and there are the longer fibres communicating between the cord and brain, and forming the columns of Goll and the direct cerebellar tracts. Immediately above the lesion, both of these are affected so that the degeneration has considerable lateral extension involving the whole of the posterior columns and the direct cerebellar tracts. But the lesion soon limits itself to the columns of Goll and the direct cerebellar tract (see Fig. 198), and in these parts it can be traced up to the restiform body on the one hand, and the cerebellum on the other. According to Schiefferdecker, the degeneration in these two situations diminishes from below upwards, the diminution occurring at intervals as if at definite levels fibres passed into the cord.

Some cases have been recorded in which a tumour pressing on the cauda equina, or a

severe traumatic lesion of the sciatic nerves, had led to ascending degeneration of the cord. In the lumbar and lower dorsal regions the whole posterior white columns were degenerated, but on passing upwards the degeneration became limited to the columns of Goll and cerebellar fibres as above.

It will be evident that a lesion which interrupts the cord will lead to an ascending degeneration above its seat and a descending degeneration below it, as in figure 198. The degeneration will diminish in both cases as we pass from the lesion, quickly at first, but afterwards more gradually.

DEGENERATION IN THE CORD AFTER AMPUTATIONS has been observed in a number of cases. The removal of a limb abolishes the function of the nervous structures concerned in the movements and other actions of the limb, and so these structures undergo atrophy from disuse. The posterior roots of the nerves are often slightly atrophied, but the white columns of the cord are not affected. The principal change is in the anterior cornua, where some of the ganglion cells completely disappear, and others are shorn of their processes and atrophied. This occurs at a part of the cord corresponding with the amputated limb, and on the same side of the body. If the amputation has been made comparatively late in life, there is usually little change in the cord; the earlier the age of the person at the time of the amputation the more likely are these changes to occur.

In a case recorded by Edinger, in which intra-uterine amputation of the forearm had occurred, and the person lived to the age of 52, there was considerable atrophy of the nerves and of the corresponding half of the cord, especially of the grey matter. There was also some atrophy in the motor region of the convolutions in the brain.

INFLAMMATIONS OF THE SPINAL CORD.

In its widest acceptation, inflammation of the spinal cord, or myelitis, includes a large number of widely different conditions, each of which will be considered separately afterwards. The cases may for convenience be divided into two groups. In one of these the affection has a limited longitudinal extension, but involves the cord rather in its thickness. For this class of cases it is customary to use the expression TRANSVERSE MYELITIS in order to distinguish from those in which a considerable length of cord is attacked, while the inflammation has a limited transverse extension. The former are usually

due to a definite cause which acts on the cord at a particular level. In the second group the inflammation follows a particular physiological system in the cord, as for instance a tract of white substance, and extends in it for some distance from above downwards. Such inflammations may involve the white substance or the grey substance, and they are often distinguished by the names POLIOMYELITIS (πολιος = grey) and LEUCOMYELITIS (λευκος = white). These inflammations have for the most part no assignable cause, and are sometimes called spontaneous. Closely allied to these SYSTEMATIC INFLAMMATIONS there is a form of spontaneous myelitis in which the distribution is somewhat irregular, but still has a certain tendency to localize itself. We shall consider the two classes indicated above under separate headings.

TRANSVERSE MYELITIS.

1. ACUTE TRANSVERSE MYELITIS, or simply Acute Myelitis.—Acute inflammation of the spinal cord is nearly always secondary to some other condition. It may be produced by fracture, dislocation, acute curvature of the vertebræ, direct injury to the cord. It may be caused by extension of inflammation, as when an abscess penetrates into the spinal canal, producing inflammation first of the meninges. A tumour may produce it by compression, but as the compression is usually gradual there is more frequently a chronic myelitis, and the same applies to most cases of curvature of the spine. Acute myelitis also occurs in consequence of exposure to cold, especially when the body has been overheated. It may be a complication or sequel of an acute specific fever, as typhus, and it is said to be not uncommon in syphilitic patients.

The myelitis is limited in longitudinal extent, and as the usual result is softening of the cord, the expression ACUTE SOFTENING OF THE CORD is almost equivalent to myelitis. The softening is usually most manifest in the grey substance and may even be apparently confined to it, but it really involves the white substance as well, and usually the whole thickness of the cord.

The softened nervous tissue presents, in different cases, considerable variations in colour, so that red, yellow, grey, white, and even green softening have been described. If much blood has escaped from the vessels, there will be red softening merging into yellow.

The characteristic morbid changes are the breaking-up of the nervous tissue and fatty degeneration of the other structures. In the white

substance drops of myeline escaped from the medullary sheath are found, and the axis cylinders are swollen. The fatty degeneration is manifested in the presence of abundant compound granular corpuscles, which, to a large extent, are probably leucocytes or neuroglia cells, which have picked up the disintegrated myeline; but there may be abundant leucocytes apart from these cells. There is also fatty degeneration of the walls of the blood-vessels, the fat here having a similar source.

The myelitis rarely goes on to suppuration, but usually passes into a chronic stage. The fat, both of the medullary sheath and of the compound granular corpuscles, is absorbed, and a condition of grey softening remains. As the inflammation becomes more chronic there is new-formation of connective tissue of a cicatricial character. In this way the cord at the part affected may be replaced by a cicatrix, or by a cyst, and its conduction completely interrupted. In some cases the interruption is not so complete, and there may even be a partial regeneration of the conducting fibres, and a partial recovery from the consequent paralysis. As a consequence of the interruption in the white substance, there is ascending and descending grey degeneration of the usual distribution.

2. Chronic Transverse Myelitis.—We have just seen that this condition may follow on an acute myelitis, but the inflammation may be chronic from the first, when it is produced by an irritant which acts gradually. It is most frequently the result of chronic compression of the cord, as in the case of curvature, or pressure by a tumour. It may also be propagated from the membranes, a spinal meningitis passing into a myelitis. We have already seen that it may arise by extension from a peripheral nerve, the inflammation travelling upwards to the cord.

The changes produced are those common to chronic inflammations. There is new-formation of a dense connective tissue, developing in the usual way from cells like those of granulations. The new-formed tissue causes compression of the proper nervous elements and their atrophy. In the white substance the nerve fibres disappear, and in the grey substance the ganglion cells. With the growth of this dense tissue there is an induration of the cord, and the term sclerosis is applicable. In the white substance sclerosis, causing the disappearance of the nerve fibres, brings about a grey condition, so that the appearances of grey degeneration are produced. There is also a degree of

shrinking of the parts, and this is often especially manifest in the grey substance.

As the nervous structures are partially or completely destroyed there is a greater or less interruption of the cord, and this results in the usual secondary degenerations above and below the seat of the lesion.

SYSTEMATIC MYELITIS.

As already indicated, in the diseases included here the affection follows certain physiological systems, and we have, in the first place, to inquire whether any explanation of this can be suggested.

In almost all the examples of inflammation studied in other parts of this work, the extension of the process is along definite paths. The irritant has been brought to an organ by the blood-vessels, or by some path of transit, such as a mucous canal, and it has extended, it may be, by the lymphatics or along a surface. In the lesions here to be considered, however, the problem is much more difficult. The localization of the disease bears no relation to the blood-vessels or lymphatic vessels, and if the irritant is brought by the blood there must be local peculiarities leading to differences in the susceptibility of different structures.

In studying the various structures which constitute the cord we saw that in the development of the cord a certain difference is apparent. In the white substance there are certain fundamental structures constituting the root-zones, and certain accessory tracts which are separately developed, and mostly of later formation. In the grey substance also there are differences in the periods at which the groups of ganglion cells appear, so much so that some of them which appear later than the rest have been named accessory nuclei. These are chiefly the median and medio-lateral groups. It is hardly remarkable that these various tracts of white substance and groups of ganglion cells should have various powers of resistance, and that the more recently developed or accessory structures should be least resistant. It is even conceivable that some of these should be, from their origin, so unstable that without any exciting cause they may tend to degenerate. In this way the boundary line between actual inflammations and simple degenerations is reached. There are some of the diseases here to be considered which have undoubtedly the characters of inflammation, and even of acute inflammation. But there are others in which the characters are rather those of a chronic degeneration or atrophy of the structures concerned, with very little of an inflammatory character.

There are thus various degrees of susceptibility in the different structures of the cord and medulla oblongata, and when an irritant exists in the blood, developed perhaps in connection with exposure to cold or otherwise, there will be, according to circumstances, various manifestations. In this connection it will be understood how syphilis has frequently something to do with the causation of these diseases.

1. Sclerosis of the Posterior Columns (*Locomotor Ataxia, Tabes Dorsalis*).—If the cord is examined in well advanced cases of this disease, the posterior white columns are found grey and shrunken, and the posterior roots are also atrophied. There is often meningitis, the soft membranes being thickened and adherent to the cord beneath as well as to the dura mater on the surface. The meningitis corresponds in its extent to the degeneration, and is evidence of the inflammatory nature of the disease in the cord itself. In early stages of the disease the changes in the cord may be invisible to the naked eye, but can be detected with the microscope. In advanced stages there may be similar changes in the optic nerve, the oculo-motor, the hypoglossal, etc.

The lesion consists primarily in an inflammatory new-formation, round cells are first produced which may be seen most abundantly near the blood-vessels; afterwards there is the usual inflammatory new-formation of connective tissue, which may even be fibrillated. There is corresponding destruction of the nerve-fibres; in the earlier stages the fibres are still present, but separated by connective tissue; through time, how-

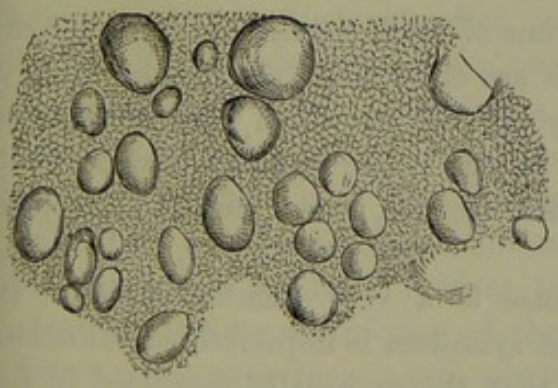


Fig. 199.—Amyloid bodies from cord. × 300.

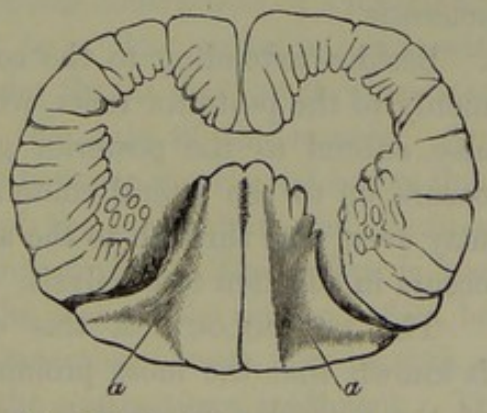


Fig. 200.—Posterior sclerosis in an early stage, confined to the external part of the posterior columns. (Pierret quoted by Erb.)

ever, very few nerve fibres are left in the degenerated part. In earlier periods compound granular corpuscles may be met with, and in later stages there are commonly large numbers of amyloid bodies. These

are round or oval bodies three or four times the size of blood corpuscles, and presenting a peculiar bright glancing appearance (Fig. 199). They frequently present a concentric striation like grains of potato starch, and with iodine they take on a deep brown colouration. These bodies are sometimes present in such numbers as to form the most prominent feature under the microscope.

The posterior columns are the parts affected, but Charcot has pointed out that the disease does not invade these columns uniformly. Its special seat is the outer parts of the posterior columns, those next to the posterior cornua (the posterior root-zones), and it is stated that these alone are affected in the earlier stages (see Fig. 200). The columns of Goll are secondarily invaded, and probably as the result of an ascending sclerosis. That this is so appears from the actual examination of the cord at various levels. The disease begins, and is usually most advanced, in the lumbar region, but in the lowest part of that region the lateral parts of the posterior columns may be alone involved. On passing upwards the columns of Goll become also affected, so that in the upper half of the lumbar swelling the degeneration may be co-extensive with the posterior columns. This continues in the dorsal region, but in the cervical the sclerosis begins to diminish laterally, and shades off into the columns of Goll, in which it may be continued up into the restiform body. The actual primary lesion is therefore that in the lateral parts of the posterior columns, and the affection in the columns of Goll is really an ascending secondary degeneration, these columns being, as already stated, the principal seat of ascending sclerosis.

Besides extending to the columns of Goll, the disease spreads commonly to the posterior roots, which are often much atrophied. It may also extend to the posterior grey cornua, in which case anæsthesia occurs, or to the lateral columns, in which case paralysis ensues; or it may even pass through to the anterior cornua, when muscular atrophy occurs in addition to paralysis.

The PHYSIOLOGY of this disease is a very difficult subject. It is known that the most prominent symptom is imperfect coordination of the muscular movements, and that this is usually associated in its early periods with violent pains, and sometimes in later stages with anæsthesia. There are two views as to the cause of the in-coordination. According to one, the connection between the cerebellum (which is the centre for coordination) and the cord is interrupted; and according to the other, it is centripetal or sensory fibres that are interrupted. The

severe lightning pains of the early periods point to irritation of sensory fibres, and the region affected is one where centripetal fibres are undoubtedly in preponderating numbers. The secondary extension to the columns of Goll also points to interruption of centripetal fibres, and on the whole there seems no escape from this view. It is no objection to it that anæsthesia is absent in most cases, and is usually a late symptom, because sensory conduction appears to be by many paths, and interruption of one set of centripetal fibres does not abolish it.

Taking it for granted that the in-coordination is due to interruption of centripetal fibres, we have to inquire how it comes about. Lockhart Clarke has made a very suggestive observation in this regard. He notes that there is probably an interruption of the centripetal fibres which are concerned in the reflex function of the cord. We know that in locomotor ataxia the tendon reflex is abolished (according to Erb whenever the ataxia is developed), and this seems to indicate that the reflex fibres from tendons and muscles are specially involved. Lockhart Clarke suggests that the normal tonicity of the muscles is due to the continuous stimulation of the ganglion cells of the anterior cornua by stimuli conveyed from the cutaneous surface, is in fact a kind of permanent reflex action. The reflex fibres being interrupted, the tonicity is interfered with, and the contraction of the muscles starts, as it were, at a disadvantage, from an indeterminate state of relaxation. To this it may be objected, that the tonicity is probably as much due to accidental stimulation of the motor ganglia from above, and, besides, that ordinary reflex action may be well retained with advanced ataxia. It is here to be noted that in order to an efficient contraction of a muscle the centre producing the contraction must be in close communication with the muscle by centripetal fibres, in order that it may, as it were, start the contraction with a knowledge of the state of the muscle. Any interruption to this delicate adjustment between muscle and centre must seriously interfere with the efficiency of the contraction, and the in-co-ordination may be accounted for on this ground. That there is such interruption is rendered evident by the loss of the tendon reflex, but short of absolute destruction of the connections, there may be such an interference with them as to render the contractions inefficient. The absence of this knowledge of the condition of the muscles previous to contraction may be partly compensated by using the eyes to direct the movements, the motor cells in the cord being, as it were, informed from above of the state of the muscles.

The occasional supervention of anæsthesia in locomotor ataxia is to

be held as indicating an extension of the disease to the grey matter of the cord. The occurrence of true paralysis indicates that the neighbouring motor tracts in the lateral columns have become involved.

The sclerosis not infrequently extends beyond the cord. Of very common occurrence is atrophy of the optic nerve from sclerosis, and there may be affections of the auditory and other cerebral nerves. There may be in-coordination of the muscles of the eyeball and of those of speech, indicating the extension of the disease to the medulla oblongata.

In addition to the conditions already referred to, Charcot has called special attention to certain TROPHIC LESIONS which occasionally occur in locomotor ataxia. These are of three kinds, namely, certain cutaneous eruptions, muscular atrophy, and affections of the joints. The CUTANEOUS ERUPTIONS occur in the earlier periods, usually coinciding with the attacks of lightning pains, and they are in the form of local eruptions of herpes, lichen, pemphigus. As these occur in the earlier periods, and are coincident with the pains which are evidences of irritation of the centripetal fibres, we may infer that the trophic fibres of the skin are situated in the posterior roots, and that it is because these are involved in the inflammatory process that the cutaneous eruptions occur. MUSCULAR ATROPHY is not very common in locomotor ataxia, and is of later occurrence. The muscles may waste as a direct result of paralysis, but this is a slow atrophy from disuse. In some cases, however, there are localized atrophies of special muscles similar to those in progressive muscular atrophy and in bulbar paralysis. In these cases the disease has extended to the anterior cornua in which are situated the trophic centres of the muscles, and there is destruction of the ganglion cells there, just as in progressive muscular atrophy. The AFFECTIONS OF THE JOINTS consist in comparatively acute swellings, with exudation, followed by atrophy of the ends of the bones. Dislocations of the joints may occur in consequence. These trophic disturbances of the joints seem also to occur in cases where the disease extends to the anterior cornua, the trophic centres for the whole organs of locomotion having their seat there. The propagation of the disease to the anterior cornua, leading to muscular atrophy or trophic affections of the joints, seems to be not uncommon, and may occur at a comparatively early period. This can hardly be regarded as remarkable when we consider that there are, for purposes of reflex action, direct connections between the posterior root-zones and the anterior cornua.

FRIEDRICH'S HEREDITARY ATAXIA.—A considerable number of cases have been described in which motor in-coordination has appeared at an early age in several members of the same family. There is, in these cases, probably a congenital faulty development of the cord, and the ataxia is the consequence rather of a degenerative than an inflammatory process. Consistently with this there are seldom lightning pains, or any affection of sensation. There is also little tendency to transverse extension of the lesion in the cord, but, on the other hand, the longitudinal extension is very rapid, the disease attacking almost the whole extent of the cord at once. It also extends to the medulla oblongata, as evidenced by the occurrence of disturbance of speech and nystagmus.

GENERAL PARALYSIS of the insane is often associated with ataxia, and the spinal cord presents sclerosis of the posterior columns similar to that in ordinary ataxia.

2. SPONTANEOUS LATERAL SCLEROSIS (*Erb's Spastic Paralysis*).—In studying descending degeneration, we saw that the pyramidal tract is liable to secondary changes when interrupted in its course. In the disease now under consideration, we have an independent disease of the pyramidal tract, having a similar anatomical distribution. It usually begins in the lumbar cord, and attacks simultaneously both pyramidal tracts. These cases are of somewhat frequent occurrence, but seldom come to *post-mortem* examination. In a case recorded by Dreschfeld, however, sclerosis was found in the lateral columns.

The symptoms already referred to as characteristic of descending sclerosis are here very pronounced, namely, spasm of the muscles chiefly of the lower extremity, with exaggerated tendon reflex. There is also, of course, paralysis.

The sclerosis appears to extend not infrequently from the pyramidal tract to the anterior cornua of the grey substance. In that case there is muscular atrophy in addition to the other phenomena. To conditions of this kind, Charcot has given the name AMYOTROPHIC LATERAL SCLEROSIS.

3. POLIOMYELITIS ANTERIOR ACUTA (*Infantile Paralysis, Acute Atrophic Spinal Paralysis*).—This is a disease mostly of infancy and early childhood, but not by any means unknown in the adult. At the onset there are usually signs of acute inflammation (fever, sometimes convulsions), but these symptoms may be very slight, and the first thing noticed is the paralysis. Whether accompanied by fever or not, the paralysis develops

suddenly, and generally attains its full extent almost at once. It may affect both arms and both legs, or the legs alone, or the arms alone, or the leg and arm on one side, or one leg or one arm alone. After some weeks, the paralysis begins to improve, and may go on improving for some time. Complete recovery rarely results, and generally the paralysis affects certain muscles permanently. The whole muscles of a limb may remain paralysed, or the paralysis may be limited to a group or two of muscles. In the permanently paralysed muscles a rapid atrophy occurs which becomes very extreme. The bones of the paralysed part do not grow normally, and the articulations are imperfectly adjusted. Certain deformities ensue, the commonest and most prominent of which is clubfoot. Curvature of the spine is also a comparatively frequent result. All through the disease the patient may maintain good general health, and after recovery from the initial fever he may present nothing abnormal but the paralysis and atrophy. Through time he learns to use his remaining muscles to the best advantage, and may pass through a long life maimed by the infantile attack.

In its anatomical aspects, the disease is an acute inflammation of the grey substance of the anterior cornua of the cord. There are no observations as to the changes at the very outset of the disease, but there can be little doubt that there is the usual inflammatory hyperæmia and œdema, causing by pressure interference with the ganglion cells of the anterior cornua. Some cases have also been observed in which there was hæmorrhage in the anterior horns. The earliest cases examined had been already two months affected with the disease, and at this date little can be made out with the naked eye. Under the microscope, however, the anterior cornua are seen to be altered, not continuously, but in patches. They contain numerous round cells and compound granular corpuscles. The ganglion cells in certain of the groups have disappeared or have shrunk considerably. At the periphery of the affected patches round cells are aggregated and there is already some shrinking of the patches. The condition is most manifest in the lumbar and cervical enlargements. The anterior roots are also somewhat atrophied, and show evidences of degenerative changes.

Many cases have been examined years after the onset of the disease, at intervals varying from seventeen to sixty-one years, and the changes have been very obvious even to the naked eye. These consist of sclerosis with shrinking, mainly of the anterior grey cornua, but also of the anterior and antero-lateral columns of white substance (see Fig. 201).

These changes are very manifest when the cord has been hardened and fine transverse sections made. The shrinking of the horn affects certain of the groups of cells specially, and the shrunken part consists

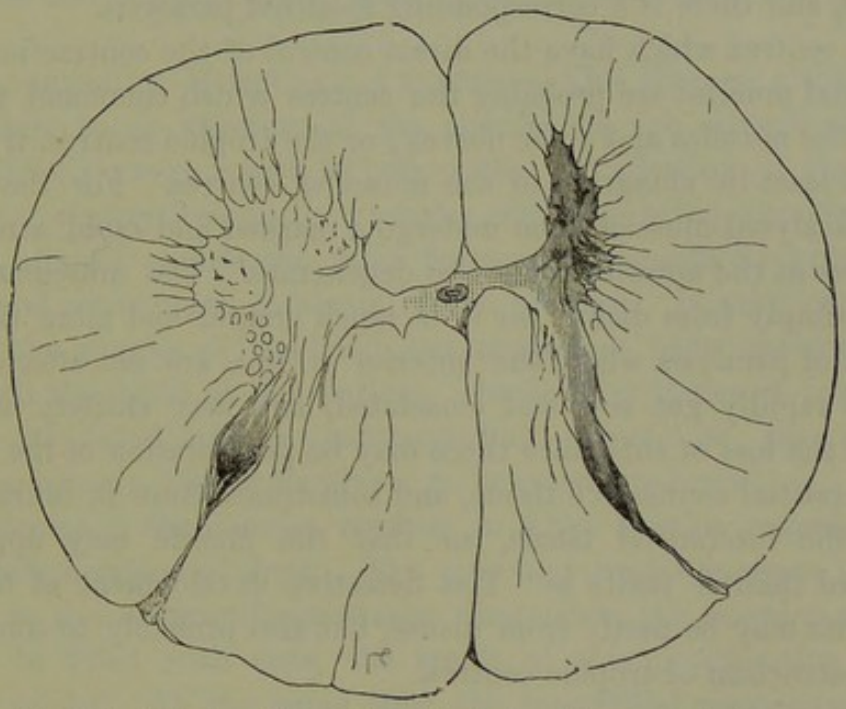


Fig. 201.—Anterior poliomyelitis. The left anterior cornu in the cervical region is shrunken, and there is atrophy of all the white columns on that side. From a woman, aged 50, who was the subject of infantile paralysis of the right arm. (CHARCOT.)

largely of connective tissue in which no ganglion cells are visible or only deformed and pigmented ones. There is connective tissue with abundant nuclei and enormous numbers of amyloid bodies. There is also sclerosis of the antero-lateral columns, the connective substance being increased and the nerve fibres to some extent atrophied. The lesion in the anterior cornua is by no means homogeneous or symmetrical. One cornu may be atrophied and the other normal, and on examining sections at different levels there is great variety in the longitudinal distribution.

In the early periods of the disease the extensive paralysis seems due to pressure by the distended vessels and inflammatory exudation, and in some cases by extravasated blood. In this period some ganglion cells may be destroyed, but those not destroyed may recover as the acute inflammation passes off. In many parts the inflammation is slight and subsides completely, in others it is severe and goes on to sclerosis, and there is permanent destruction of the ganglion cells. Hence it is that a paralysis which has been at first almost universal may be recovered from almost completely. The improvement goes on

till all the cells which are capable of it have recovered, and there is a residue which have been permanently lost and cannot be restored. These permanently lost cells represent single muscles and groups of muscles, and there is a corresponding localized paralysis.

The centres which have the direct control of the contractions of the individual muscles are probably the centres which command the nutrition of the muscles and their nerves; or the trophic centres, if separate, must at least lie alongside of the muscular centres. For the permanently paralysed muscles soon undergo a marked and rapid atrophy and the fibres of the anterior roots also degenerate. The muscular atrophy is not simply from disuse, for it is much greater and more rapid than in cases of paralysis where the anterior cornua are not affected. The muscles rapidly get soft and emaciated, and may entirely disappear. Besides the loss of substance there may be proliferation of the nuclei of the interstitial connective tissue, and sometimes there is infiltration of fat in the interstitial tissue, so that the muscle may appear less atrophied than it really is. The defective development of the bones and joints may be partly from disuse, but also probably to some extent from destruction of trophic centres.

Although most common in children a good many cases of this disease have now been recorded in ADULTS. Here also it is ushered in by acute symptoms such as fever, pain in back and extremities, vomiting, headache. The paralysis develops mostly in a few hours, but it may be as long as a day or two. After a time recovery begins, and is more frequently complete than in the case of children. It is frequently incomplete, and then we have paralytic deformities, which, however, as the bones are fully formed are not so striking as in the case of children. Here, also, there is rapid atrophy of the muscles, which is not so liable to be concealed by fatty infiltration as in the case of children.

4. POLIOMYELITIS ANTERIOR CHRONICA.—Some very interesting cases have been recorded in which, with little or no fever or disturbance of the general health, a motor paralysis has occurred, and in the course of a few days or weeks has extended to the entire lower limb and then rapidly to the upper. It rarely takes the opposite course. The muscles become slack and soft and lose their reflex irritability, and they rapidly atrophy. There have been few post-mortem examinations as yet, but they seem to show a chronic inflammation or sclerosis of the anterior cornua with loss of the ganglion cells. The disease is fre-

quently recovered from, but recovery is slow and complete restitution may take years. On the other hand, the disease may extend upwards and produce death. In this disease, also, it will be observed centres for contraction and trophic centres seem to be simultaneously affected.

5. Progressive Muscular Atrophy.—This disease, although its name points to an affection of the muscles, is yet considered here, because there is every reason to believe that an affection of the spinal cord is the primary lesion, the muscular condition being secondary.

In its clinical aspects the main feature is a gradually progressive atrophy and consequent paralysis of the muscles. It very commonly begins in the muscles of the hand, but progresses from one muscle to another till the death of the patient. In its later stages it frequently becomes associated with a corresponding disease of the medulla oblongata, namely, bulbar paralysis, to be considered next.

The change in the muscles consists in what may be regarded as a chronic inflammation of them. The muscular nuclei increase in number, and as the contractile substance diminishes, the sarcolemma may come to be filled with cells, the result of this proliferation of the muscular nuclei. At the same time the interstitial connective tissue shows active changes, increase of nuclei, and new-formation of connective tissue. In the muscular substance various forms of degeneration have been observed, chiefly fatty and waxy, or simple atrophy. In any case the muscular fibres are lost by degrees and the connective tissue increased but not sufficiently to make up the bulk of the lost muscular substance. Sometimes a fatty infiltration of the connective tissue occurs, so that adipose tissue comes to occupy the place of the muscle to a large extent. This change, if it occurs, is only local, and pure atrophy may exist side by side with atrophy with formation of adipose tissue. This formation of adipose tissue is mostly a late, and by no means a characteristic, occurrence in this disease.

Although these changes are very manifest in the muscles those in the spinal cord are doubtless the primary ones. There have been now not a few trustworthy observations in which the large ganglion cells in the anterior cornua have been found destroyed. Their destruction is variously described as due to chronic inflammation or atrophy, and at the best nothing can be found in the affected region but the shrivelled remains of these ganglion cells. This is probably an inflammation extending slowly along the cord and confining itself to the anterior grey cornua.

As to the exact locality of the affected ganglion cells, it is, according to Ross, the central grey column (the grey substance on either side of the central canal) which is most affected, being traversed by large canals and fibrillated. In the annexed figure (Fig. 202) it is also seen that the cells of the median group have entirely disappeared, while the other groups of the anterior cornua are limited in size, the peripheral cells of the groups having disappeared, leaving only the more central ones. It very commonly happens that, short of absolute destruction of the ganglion cells, they are greatly atrophied and pigmented (*pigmentary atrophy*).

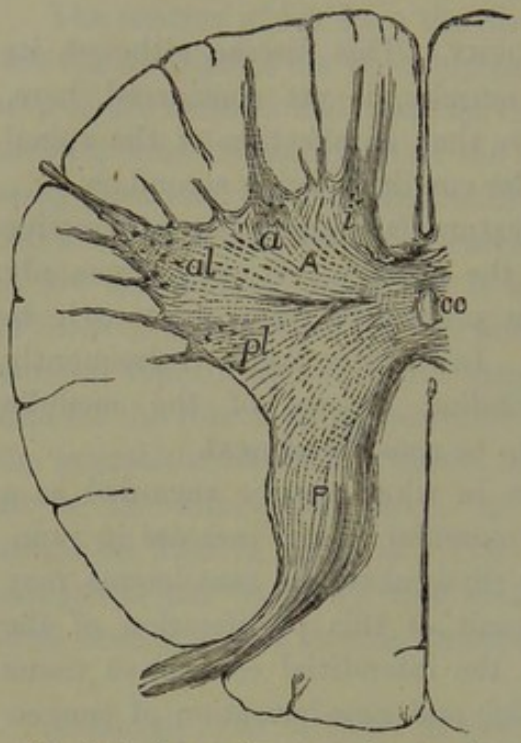


Fig. 202.—Progressive muscular atrophy—section of cord in cervical region, from an advanced case. The central portion of grey substance is fibrillated; the median group of cells has disappeared, and the other groups are atrophied. (Ross.)

It is to be added that Leyden has recorded a case of progressive muscular atrophy in which there was the peculiar condition of the cord designated SYRINGOMYELIA; in this there are gaps of a longitudinal shape and filled with fluid present in the cord. These cavities result probably from an inflammatory process, and there is along with their formation a destruction of ganglion cells, so that fundamentally this case is not different to the others.

In some cases there has been, in addition to disease of the anterior cornua, atrophy of the anterior roots of the nerves, but this has not been observed in all cases. There has also been observed at the peripheral terminations of the nerves and in immediate connection with the muscles a condition somewhat analogous to that of the muscles. There was thickening of the nerve sheath with multiplication of nuclei. Although generally confined to the fine intramuscular twigs these changes sometimes extend into the nerve stems.

It may be asked How is the atrophy here such a remarkable feature, apparently preceding the paralysis? It is difficult to answer this question, but it looks as if the trophic ganglion cells and proper muscular ones were different and yet situated close to each other. The trophic are in this disease first affected seriously.

6. Bulbar Paralysis, or Glosso-Labio-Laryngeal Paralysis. —This condition is called bulbar paralysis from the fact that the part affected is the medulla oblongata, which is frequently designated the bulb. There is progressive atrophy and paralysis of muscles supplied from the medulla oblongata. The muscles are mainly those of the tongue, lips, arches of palate, pharynx and larynx, and in consequence there is progressive interference with articulation, chewing, swallowing, and even with the production of the voice. The disease may pass on later to affect the more important functions of the medulla oblongata, those concerned in respiration, etc.

We have already seen in connection with the normal structure of the medulla oblongata that on passing from the cord the grey substance is dislocated backwards, and that in the posterior region of the medulla a set of grey nuclei appear, which, as the spinal canal opens up in the fourth ventricle, present themselves in the floor of that ventricle. These nuclei are mainly motor, corresponding with the anterior cornua, and they form the immediate centres for certain cerebral nerves (see Fig. 203). In the lower half of the fourth ventricle we find the hypoglossal nucleus (xii′) occupying the part next the middle line. Outside it there is the spinal accessory nucleus which begins in the cord, and does not extend far in the floor of the ventricle; it is not shown in figure, but gives place to the nucleus of the pneumogastric or vagus (x′). Outside the vagus appears the glosso-pharyngeal, which partially divides the vagus nucleus into two. As we pass upwards the vagus nucleus gets smaller and the hypoglossal and glosso-pharyngeal approximate to each other. Above that again come in the nucleus of the sixth (the abducens) in the middle line, and outside that the motor nucleus of the fifth and the facial. Outside these again are sensory nuclei, those of the acoustic and of the fifth.

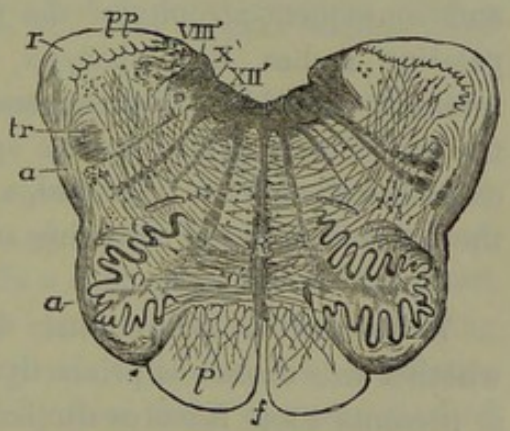


Fig. 203.—Medulla oblongata at the level of the fourth ventricle, showing the position of the grey nuclei. (Quain.)

In bulbar paralysis there is atrophy of these grey nuclei. It is seldom that opportunity is afforded of examining the medulla in recent stages, but according to Benedikt, who had such an opportunity, there are definite signs of inflammation, hyperæmia, thickening of the walls of the vessels, and numerous round cells. In later periods increase of

the connective tissue, with round cells and amyloid bodies, have been observed. These changes centre in the nucleus of the hypoglossal, and this nucleus is usually most seriously damaged, but they pass soon to the accessory and vagus, while the glosso-pharyngeal sometimes, but not usually, escapes. The nucleus of the facial is often attacked, and sometimes that of the motor branch of the fifth. The disease seldom extends to the abducens, and never attacks the sensory nuclei of the acoustic and fifth.

The corresponding nerves usually show considerable atrophy, espepecially the hypoglossal, and next to it the accessory, vagus, and glosso-pharyngeal. In them may be found a fatty degeneration involving destruction of the medullary sheath and subsequent overgrowth of connective tissue. In this way the nerve-root may come to be almost nothing but a connective-tissue strand.

In the affected muscles the change is exactly parallel to that in progressive muscular atrophy with which sooner or later this disease is so frequently associated. There is increase of the muscular nuclei and connective tissue, with destruction of the proper contractile substance, and consequent atrophy of the muscle as a whole. Thus the tongue, palatine arches, lips, pharynx, and larynx may have their muscles intensely atrophied. Sometimes also the muscles of the neck, especially the trapezius (supplied by the spinal accessory), are affected. In some cases the atrophy is obscured, as in progressive muscular atrophy, by the interstitial tissue becoming adipose.

7. Pseudo-hypertrophic Paralysis. — It is a disputed point whether this disease is primarily one of the muscles or of the cord, but it presents some features similar to those of the last two affections we have considered, and deserves notice here.

The disease consists in a great atrophy of the muscular substance proper, with a great new-formation of adipose tissue in the muscle. Gowers describes the appearance in a case where a post-mortem examination was procured as follows :—" On cutting into the gastrocnemius it was difficult to believe that the section was that of muscle. Its appearance was precisely that of a fatty tumour—a yellow greasy mass of fat, in which no trace of muscular redness could be perceived. Under the microscope the resemblance to a fatty tumour was also strikingly close. Cells distended with homogeneous fat covered the field. Passing among the fat cells, however, were narrow bands, which consisted of fibrous tissue and muscular fibres." This is a very correct description

of the appearances in advanced cases. The muscular fibres which remain are of various sizes, and many of them in an advancing state of atrophy so as hardly to be recognized as muscular fibres, except by the transverse striæ (Fig. 204). The primary process here is an increase of the connective tissue with atrophy of the muscle, the addition of fat and conversion into adipose tissue being secondary. This conversion takes place variously in different muscles. In the same individual you may find some muscles almost converted into fat and others in which there is very little adipose tissue, the condition in the latter case being virtually identical with that in progressive muscular atrophy.

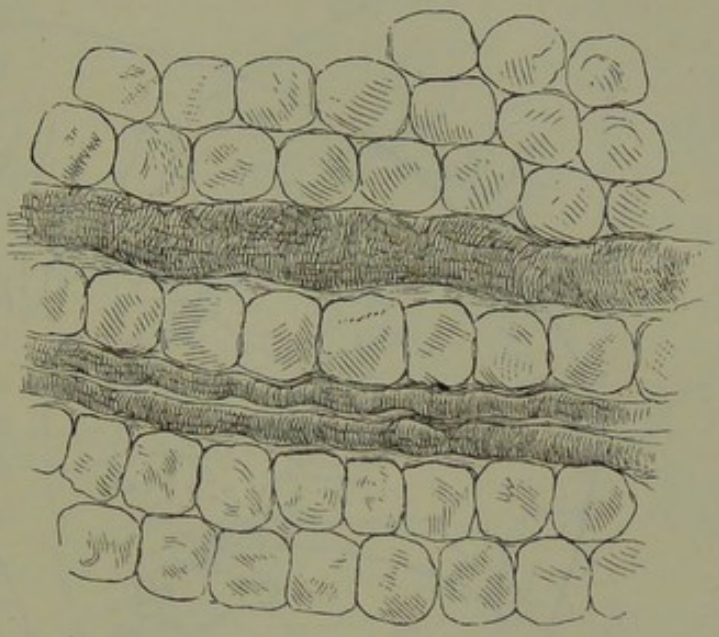


Fig. 204.—Muscle in pseudo-hypertrophic paralysis. There is chiefly adipose tissue with a few atrophied muscular fibres. × 180.

In regard to the condition of the spinal cord in this disease, not many careful observations have been made, and some of these have afforded apparently negative results. In a case examined by Lockhart Clarke and Gowers there were obvious changes in the cord, consisting of sclerosis and consequent disintegration of white and grey substance in various regions. In a case examined by Ross there was very marked atrophy of certain groups of ganglion cells in the lumbar dorsal and cervical regions, the distribution of the atrophy varying in the different regions.

Figures 205 and 206 represent the cervical and lumbar enlargements in a case examined by the author in conjunction with Dr. Alexander Robertson. The ganglion cells in the anterior and internal groups in the cervical region, and in the internal group in the lumbar, are deficient in number, but elsewhere they are abundant, and it could not be made out that there was any special shrinking or pigmentation of the ganglion cells of the various groups.

Opinions are divided on the question whether this disease is primarily muscular or nervous, but the analogy with progressive

muscular atrophy renders it probable that it is primarily a disease of the cord.

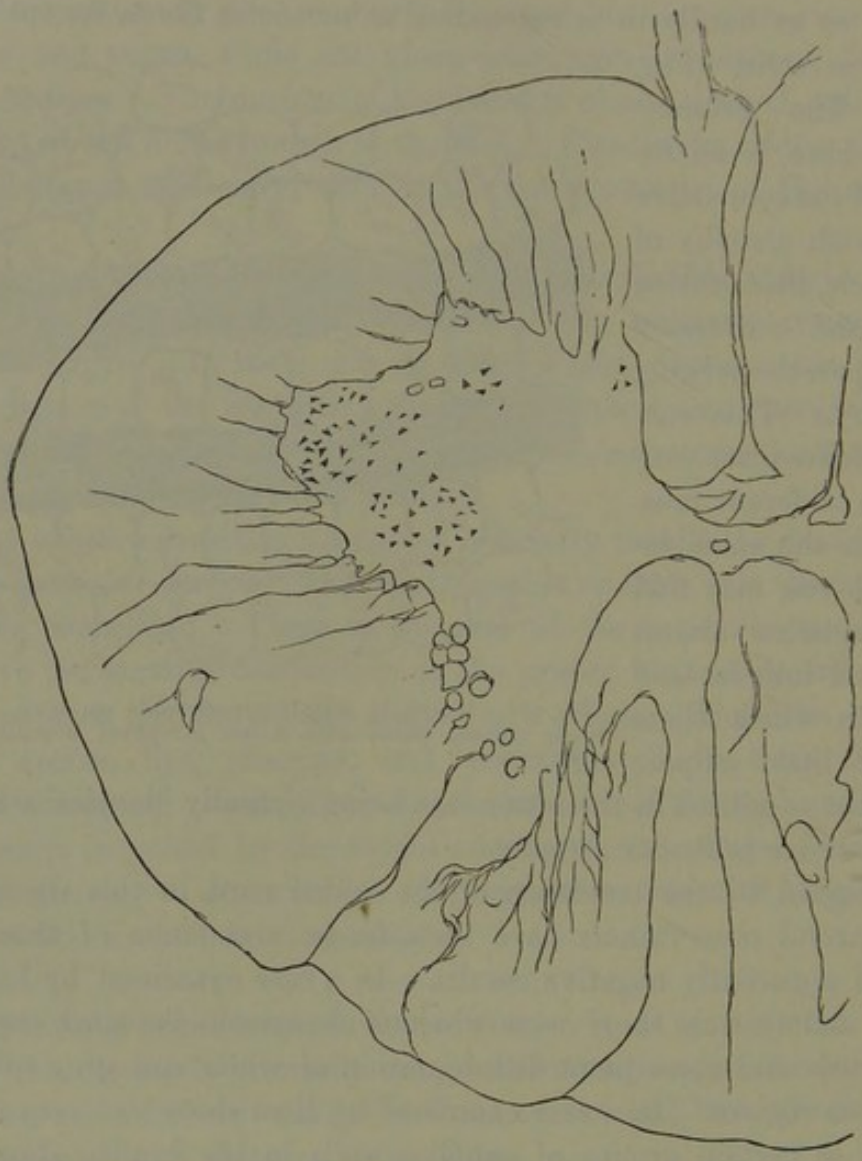


Fig. 205.—Cervical enlargement in a case of pseudo-hypertrophic paralysis.

TUMOURS OF THE CORD AND MEDULLA OBLONGATA.

Tumours actually originating in the cord or medulla are excessively rare; tumours originating in the membranes or elsewhere outside the cord and pressing on the cord are rather more common. Cases of GLIOMA and SARCOMA, and also of FIBROMA of the cord and medulla oblongata, have been observed.

SCROFULOUS TUBERCLES similar to those which are so common in the brain, and will be described hereafter, have been met with in the

cord, but are of very rare occurrence. They have been found most frequently in the lumbar region.

SYPHILITIC GUMMATA are also of occasional occurrence. Like those of the brain, they are mostly superficial and involve the membranes, where they probably originate.

CYSTS occur very rarely in connection with tumours. Apart from these, tubular cavities are sometimes met with (SYRINGOMYELIA). Some of these are due to congenital dilatation of the central canal of the cord, but many of them are of independent origin. These latter are usually situated in the posterior columns and in their deeper parts immediately behind the central canal. Cavities of this kind are caused by extensive loss of substance, but it is often obscure how this has come about, whether by inflammation or otherwise. In this connection, it is interesting to note that Eichhorst found, in experiments on animals in which the cord had been divided or injured, that cavities formed frequently in the posterior columns, and sometimes extended into the central canal. When the syringomyelia is due to dilatation of the central canal the cysts are lined with ciliated epithelium, but even in the other forms this may be the case.

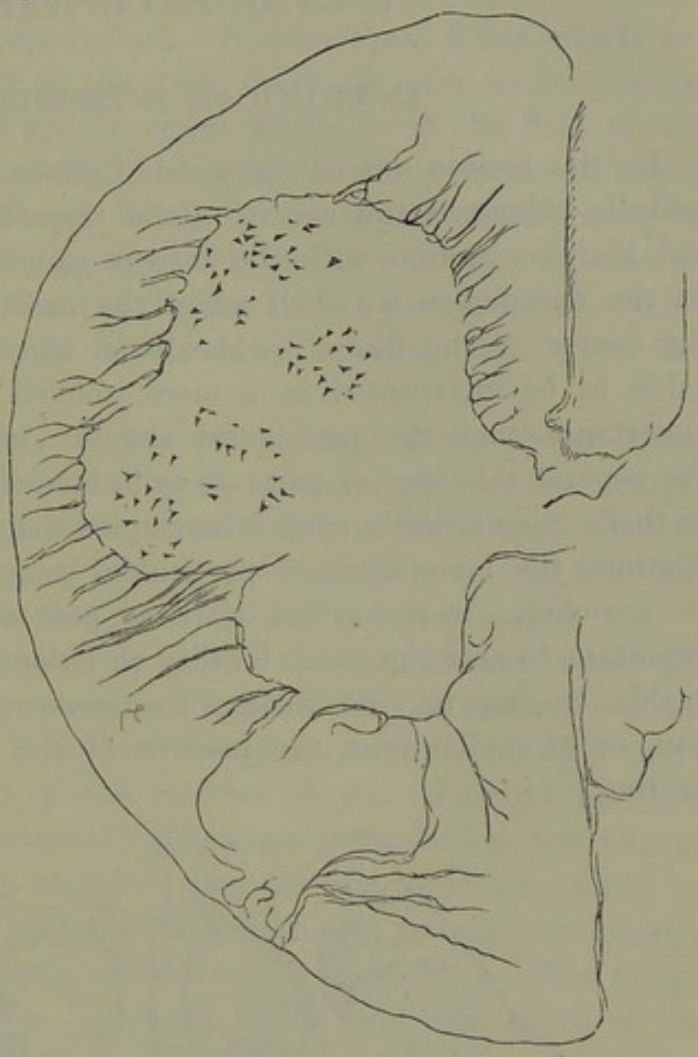


Fig. 206.—Lumbar enlargement in a case of pseudo-hypertrophic paralysis.

C.—THE ENCEPHALON.

ANATOMICAL INTRODUCTION.

In the section introductory to diseases of the spinal cord and medulla oblongata the course of the respective tracts of nerve fibres and their connection with the various ganglionic centres were traced. In the encephalon we shall adopt the same method, premising that the course of the fibres is here even more important, as they are liable to be interrupted in a more isolated fashion. It is of great importance that the pathologist should have an acquaintance with the general relations of parts so as to identify the position of lesions. In this section nothing more is attempted than to indicate these general relations, the more intricate particulars being left to the special works on anatomy. In the actual work of post-mortem examination, it is important to note the exact locality of lesions on the spot. To assist in this, tracings may be made of the figures which accompany this section, or of similar ones, the position of the lesions being entered in shading.



Fig. 207.—Pons varolii. In lower half the transverse section of nerve bundles continued upwards from the cord is seen, the pyramidal tract being in front (or lower in figure). The Roman numerals and letters indicate the nuclei of spinal nerves. (QUAIN.)

In the medulla oblongata, as we have seen, the motor fibres which have been in the lateral columns of the cord come forward and form the anterior pyramids, in which they decussate. The sensory fibres are now behind, and they remain posterior to the motor in all the succeeding

parts. In the PONS VAROLII (Fig. 207) the motor fibres are in front, forming bundles, as shown in lower half of figure, but overlaid by the transverse fibres from the cerebellum. Besides these fibres, which are mainly in the anterior half of the pons, there are grey nuclei (shown in figure) which continue up the series which lie in the floor of the fourth ventricle in the medulla oblongata. In the pons the principal nuclei are those of the sixth and facial, the motor and sensory roots of the fifth, and one of the nuclei of the auditory nerve. It is to be remembered also that the fibres of these nerves in part at least traverse the pons, and are liable to be involved by a lesion, even when the nuclei are not reached.

In the CRURA CEREBRI, or cerebral peduncles, the motor fibres are in front and internal, forming the greater part of the crusta. Sensory fibres occupy about the external fourth of the crusta. Behind the crusta is the locus niger, behind which again is the tegmentum, which contains a rather complex mass of fibres and grey matter.

Above the crura the fibres are continued upwards, the motor still anterior and the sensory posterior in the mass of white substance called the INTERNAL CAPSULE. It is here necessary to be somewhat more minute in the description of the relation of the structures, as these relations are of great importance. When one of the lateral ventricles of the brain is opened, certain masses of grey nervous tissue are seen in its floor. In front there is a long brown prominence, rounded anteriorly, and tailed behind. This is the nucleus caudatus, which is often designated the corpus striatum, although really only one piece of it. Behind the nucleus caudatus is the optic thalamus which is more bulky and rounded. It is to be remembered that in opening the lateral ventricle almost no nerve fibres need to be cut except the commissural ones of the corpus callosum. The great masses of nerve fibres passing upwards are as it were pushed outwards by the lateral ventricle, and we have to cut into its floor in order to reach them. From the accompanying figure, which represents a horizontal section of the brain just below the floor of the lateral ventricle, the relations of parts may be gathered (Fig. 208). Beneath and outside the nucleus caudatus (*NC*), and continuous above and externally with the great central white substance of the hemispheres, the corona radiata, there is a mass of white substance. This is the INTERNAL CAPSULE in which may be distinguished an anterior division *IK'*, a posterior division *IK*, and a middle part, the knee *K*. To the outside of and beneath the internal capsule lies a mass of grey substance (*LN*), which on section has a triangular shape with the

base turned outwards, and is seen to be divided into three pieces (shown on right side). This is the NUCLEUS LENTICULARIS, which is generally

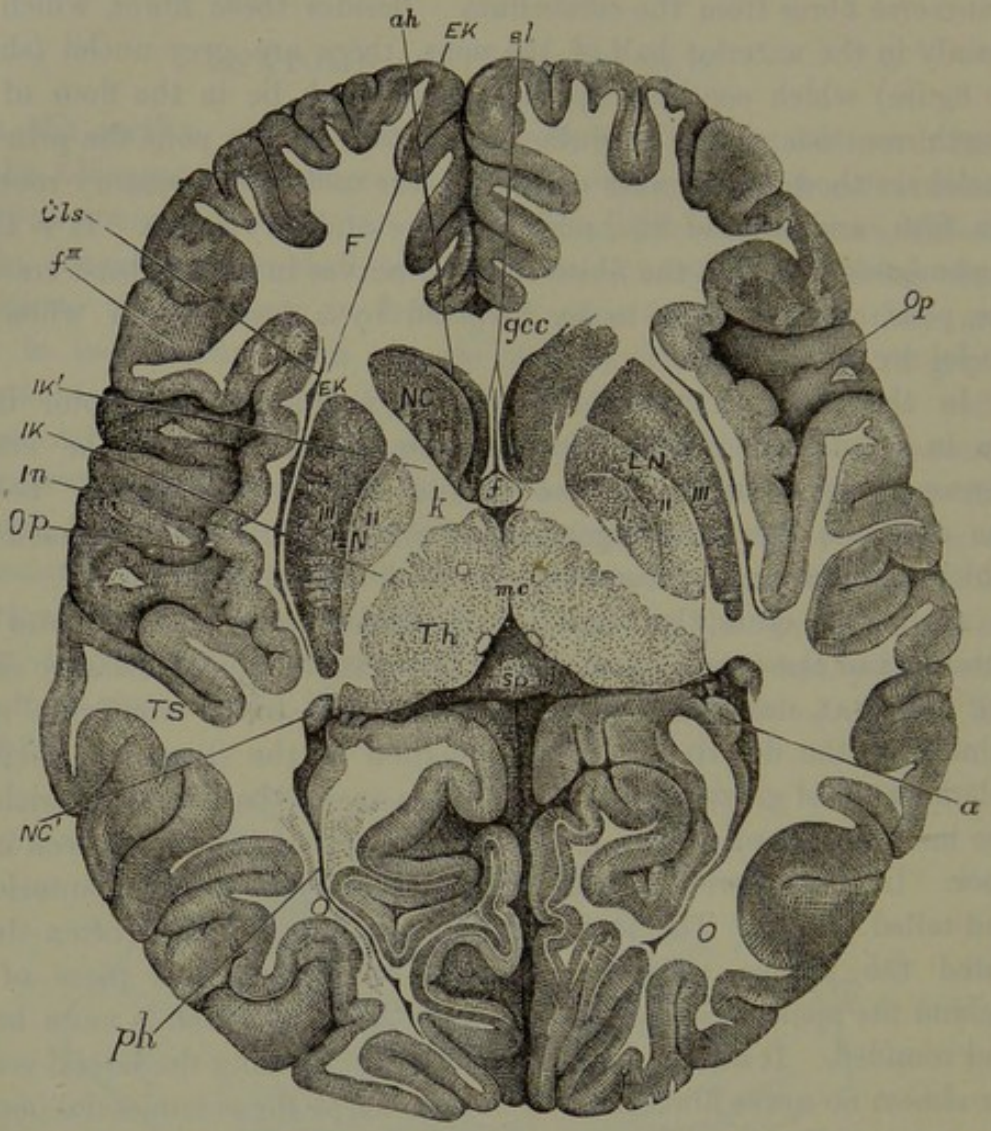


Fig. 208.—Horizontal section of brain of a child nine months old, the right side at a somewhat lower level than the left. *F*, frontal; *TS*, temporo-sphenoidal; and *O*, occipital lobes; *Op*, operculum; *In*, island of Reil; *Cls*, claustrum; f^{III}, third frontal convolution; *Th*, thalamus; *NC*, nucleus caudatus; *NC'*, tail of same; *LN*, nucleus lenticularis; *I*, *II*, *III*, its first, second, and third divisions; *IK*, internal capsule, posterior division; *IK'*, anterior division, and *k*, knee; *ah* and *ph*, anterior and posterior horns of left lateral ventricle; *gcc*, knee of corpus callosum; *sp*, splenium; *mc*, middle commissure; *f*, fornix; *sl*, septum lucidum; *α*, cornu Ammonis. (Ross from FLECHSIG.)

regarded as a part of the corpus striatum and motor in function. The nucleus lenticularis extends a considerable distance from before backwards, and in its posterior parts the internal capsule (*IK'*) lies between it and the optic thalamus, which has now largely taken the place of the nucleus caudatus. Outside the nucleus lenticularis there is a narrow band of white substance (*EK*), called the EXTERNAL CAPSULE, the capsules being named from their relation to the nucleus lenticularis. Outside

the external capsule again and close to the convolutions (here the Island of Reil) there is a narrow band of grey substance (*Cls*), which is fancifully compared to a tape-worm, and is called the nucleus tæniæformis or claustrum. The anterior parts of the internal capsule then contain motor fibres, and the posterior sensory; it is generally said that the anterior two-thirds are motor, and the posterior third sensory.

It is to be remembered that the three nuclei we have referred to, the nucleus caudatus, nucleus lenticularis, and thalamus opticus, receive fibres from and give fibres to the internal capsule. There are fibres passing upwards to the convolutions and others downwards to the lower centres. It has been said by some that all the fibres from the convolutions pass into the basal ganglia, in which case all the fibres of the internal capsule would end or begin in these nuclei, but there is no proper foundation for this view.

Passing upwards, the fibres of the internal capsule are continued into the CORONA RADIATA or centrum ovale, containing the white substance of the hemispheres, and it may be stated generally that in the corona radiata motor fibres are anterior and sensory posterior. But besides these fibres there are multitudes which form communications between one part of the convolutions and another, and altogether the connections here are very complicated.

It will be necessary further to make some general remarks on the CEREBRAL CONVOLUTIONS and their arrangement, which may be studied in Ecker's work, in which the descriptions are very clear.

If the lateral aspect of one of the cerebral hemispheres be examined (see Fig. 209), two great landmarks should first be made out; these are the fissure of Sylvius (*SSS*), and the fissure of Rolando (*RR*). There is no difficulty with the fissure of Sylvius of which the main or transverse arm is perfectly distinct, while its short ascending arm near the front is easy to make out. The fissure of Rolando passes obliquely forward from above downwards through the middle of the lateral aspect of the hemisphere, not reaching the longitudinal fissure above, or the fissure of Sylvius below. This fissure can usually be recognized by the fact that it is bounded by or lies between two convolutions which extend side by side upwards and backwards from the fissure of Sylvius (*A*, *A*, *A* and *B*, *B*).

Having distinguished these two fissures the various lobes of the brain may now be determined. All in front of the fissure of Rolando, and above the fissure of Sylvius, is FRONTAL LOBE. The PARIETAL LOBE lies

behind the fissure of Rolando, and its posterior extremity is bounded by a fissure which is best seen on the inner face of the hemisphere, the parieto-occipital fissure. This fissure, beginning about the edge of the

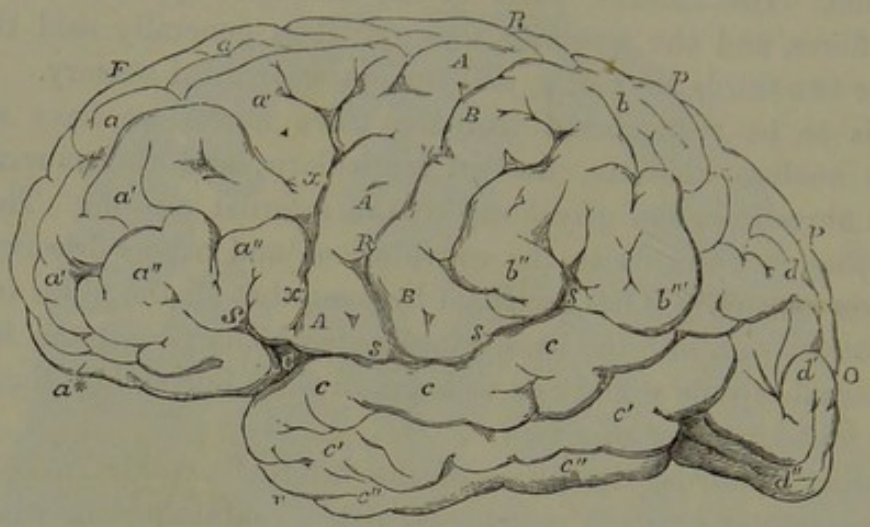


Fig. 209.—Left lateral aspect of cerebrum. Explanation in text. (QUAIN.)

great median fissure, passes downwards and forwards on the inner face of the hemisphere (par. occ. f. Fig. 210). Behind this is the OCCIPITAL LOBE. The remaining lobe is the TEMPORO-SPHENOIDAL which lies below the fissure of Sylvius and extends backwards to meet the occipital lobe from which it is indefinitely distinguished.

Turning now to the principal CONVOLUTIONS in these lobes, the easiest to determine are those bounding the fissure of Rolando, one of which is, of course, in the frontal and the other in the parietal lobe, and so they are called ASCENDING FRONTAL and ASCENDING PARIETAL CONVOLUTIONS respectively. In front of the ascending frontal, the frontal lobe presents three layers of convolutions (*a*, *a'* and *a''*) which lie transversely and pass by their posterior extremities into the ascending frontal. These TRANSVERSE FRONTAL CONVOLUTIONS are distinguished as the first, second, and third, or superior, middle, and inferior. It is not to be supposed that these are single simple convolutions, they are rather layers or strata of convolutions. The inferior (*a''*) is a very important one, and it can generally be easily recognized as it curves round the short ascending branch of the fissure of Sylvius (*s*). After curving round this branch it becomes continuous with the lower end of the ascending frontal. At this point the two convolutions form a somewhat triangular piece, and as this lies over and partially covers the island of Reil, it is often called the OPERCULUM (in the position of *x A* in Fig. 209). In addition to these we have still in the frontal

lobe the SUPRAORBITAL convolutions (a^*) which have no arrangement that needs to be detailed.

In the parietal lobe the ASCENDING PARIETAL CONVOLUTION (B, B) is already known. Another easily recognized one is that which lies immediately above the fissure of Sylvius and is called the SUPRAMARGINAL CONVOLUTION. The posterior portion of this convolution curves round the upper end of the fissure of Sylvius, and as it turns thus round an angle it is often called the *angular gyrus* (b'''), and is important, as Ferrier has supposed it to be the seat of the sense of sight. The rest of the parietal lobe is divided into an upper and a lower portion by a longitudinally placed fissure which is often not very distinct, the intra-parietal fissure, which arises close to the fissure of Sylvius behind the fissure of Rolando to which it at first lies parallel, and then passes backwards. The lobe is thus divided into the SUPERIOR AND INFERIOR PARIETAL LOBULES, the former being continuous in front with the ascending parietal convolution.

In the OCCIPITAL LOBE, looking at the lateral aspect, THREE TRANSVERSE LAYERS of convolutions can be distinguished. These are named as in the frontal lobe, first, second and third, or superior, middle and inferior (d, d', d''). On the under or basal surface there are two further layers which are continuous in front with those of the temporo-sphenoidal lobe and are named in common with them inferior occipito-temporal convolutions.

The TEMPORO-SPHENOIDAL LOBE presents on its lateral surface again THREE TRANSVERSE CONVOLUTIONS, superior, middle, and inferior (c, c', c''); the superior, bounding the fissure of Sylvius and also called INFRA-MARGINAL, is continuous with the angular gyrus. The remaining two sets in the basal surface have been already mentioned as forming with those of the occipital lobe the inferior occipito-temporal convolutions.

On examining the INTERNAL ASPECT of the cerebral hemisphere (Fig. 210) certain convolutions are to be distinguished. The superior frontal convolution and the ascending frontal and parietal convolutions are here partly visible. More distinctly on the internal surface we distinguish in front the MARGINAL CONVOLUTION (*marg. c.*) which is continuous with the superior frontal and lies along the superior longitudinal fissure. Immediately behind this convolution we come to the superior parietal lobule which, on its mesial surface, is called the PRÆCUNEUS or QUADRATE LOBE (see figure). The parieto-occipital fissure is here very marked, and it is joined at an angle by the calcarine fissure (*calc. f.*) in such a way as to demarcate a triangular surface, the CUNEUS (*cuneate l.*). On this

aspect also appear the inferior occipito-temporal convolutions (*i. oc.-temp. c.*). Within this external ring of convolutions we have now a deeper layer. Immediately bordering on the corpus callosum and following the fornix

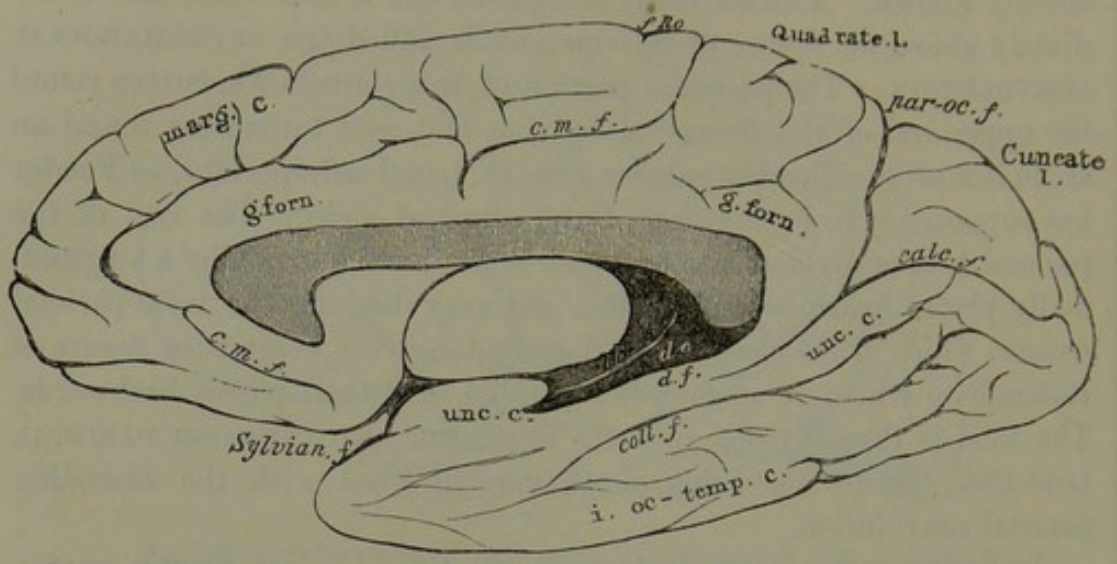


Fig. 210.—Internal aspect of right cerebral hemisphere. Explanation in text. (QUAIN.)

we trace from before backwards the GYRUS FORNICATUS. Having skirted the corpus callosum from before backwards it turns round at its posterior extremity, and passes downwards into the GYRUS HIPPOCAMPI. This gyrus is also continuous with the gyrus cunei and the median occipito-temporal. The gyrus hippocampi passes forward towards the anterior extremity of the temporo-sphenoidal lobe where it terminates in a hook-like curve, the GYRUS UNCINATUS (*unc. c.*).

In the cornu Ammonis of the lateral ventricle there lies a convolution whose surface is turned inwards and forms an elongated rounded projection in the cornu; this is the GYRUS DENTATUS (*d. c.*).

THE CEREBELLUM. There are only a few points which require notice here as to the general arrangements of the parts in the cerebellum. Like the cerebrum it is divisible into two lateral hemispheres, the right and left lobes. These are united by a central piece, which is most marked on the under surface, called the vermiform process. The cerebellum is divided by many fissures which run horizontally and leave narrow convolutions called the FOLIA. One of these fissures, deeper than the rest, and called the great horizontal fissure, divides the cerebellum into an upper and a lower portion. In its internal structure it presents white matter which runs outwards from the peduncles diverging towards the folia and forming a tree-like expansion, the ARBOR VITÆ.

In the midst of the white substance in each hemisphere there is a small grey nucleus, not unlike the olivary body, called the CORPUS DENTATUM.

ARTERIES OF THE BRAIN.—With a view to the identification of the numerous lesions of the arteries in the brain, it will be proper here to refer briefly to the distribution of these vessels. The CIRCLE OF WILLIS gives off at the base three main arteries to the brain, the posterior, middle and anterior cerebral. The POSTERIOR CEREBRAL ARTERY, besides giving certain central branches to be afterwards referred to, is distributed on the surface of the brain, supplying the greater part of the occipital and temporo-sphenoidal lobes with the exception of the upper temporo-sphenoidal convolution. The MIDDLE CEREBRAL ARTERY, or the artery of the fissure of Sylvius, is of great importance as being much more frequently the seat of lesion than the others. Besides its central branches, afterwards considered, it supplies the middle district of the brain all round the fissure of Sylvius, including the parietal lobe, the posterior parts of the frontal lobe, and the superior convolution of the temporo-sphenoidal lobe. The ANTERIOR CEREBRAL ARTERY is distributed to the anterior parts of the frontal lobe. These arteries, with the exception of their central branches, run in the sulci of the convolutions, and divide into successive orders of branches which lie in the pia mater. The larger branches anastomose sparely, but the finer twigs are end-arteries (*Duret*). All the arteries hitherto considered run on the surface of the brain in the soft membranes. The actual nutritive arteries are branches of these, and penetrate from them into the substance of the brain. We may thus distinguish the larger arteries of the surface and the smaller or nutritive arteries.

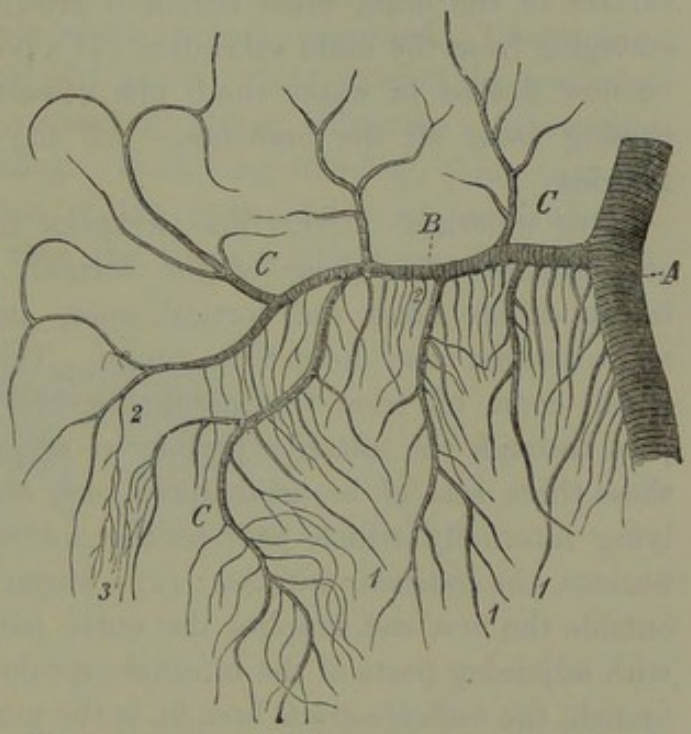


Fig. 211.—Arteries of the brain showing cortical distribution. *A*, a tertiary branch of main artery. *B*, primary twig. *C*, *C*, *C*, secondary twigs. The nutritive arteries are seen to pass off from all these branches as fine hair-like offsets. (Ross after DURET.)

The NUTRITIVE ARTERIES again are divisible into two groups, which may be designated the cortical and central systems.

The NUTRITIVE ARTERIES OF THE CORTEX pass off not merely from the finer twigs of the larger arteries, but also from the larger branches (see Fig. 211). They are fine thread-like vessels which pass down perpendicularly into the brain substance. Some of them are short and supply the grey substance of the convolutions, others are longer and reach the white substance, their territory here extending to the boundaries of that of the central arteries. In stripping the membranes from the surface of the brain these nutritive arteries are seen like fine hairs emerging from the brain substance. If a portion of the soft membranes be now floated in water these fine vessels will be seen like bristles passing from all the branches. All the nutritive arteries are end-arteries.

THE CENTRAL NUTRITIVE ARTERIES have a somewhat different arrangement from those of the cortex. They are long vessels of larger calibre than the cortical ones, and they pass off from the main arteries very near their origin. The most important are those which come off from the middle cerebral just outside its origin and pass through the anterior perforated space to the basal ganglia. Of these three sets of branches have been distinguished: (1) short twigs lying internally which pass to the internal parts of the lenticular nucleus, the *lenticular branches;* (2) a longer and larger vessel which lies outside the first and supplies the outer parts of the lenticular nucleus with adjoining parts of the internal capsule and caudate nucleus. This branch, the *lenticulo-striate* branch, is the most important, as being most frequently the seat of hæmorrhage; (3) the *lenticulo-optic* branch is posterior to the former and supplies the posterior part of the lenticular nucleus and the anterior part of the optic thalamus. The remaining central branches are supplied by the anterior and posterior cerebral arteries. The former sends branches which supply the anterior part of the caudate nucleus, and the latter sends two sets, an internal and an external, to the optic thalamus. All these central arteries are end-arteries.

The arteries of the pons and medulla oblongata are like the cortical arteries in their small size and like the central ones in respect that they come off from large stems, and pass directly into the substance of the part.

SECONDARY DEGENERATION IN THE BRAIN.

We have already seen in the case of the cord and medulla oblongata that when the nerve fibres are cut off from their trophic centres they undergo degeneration. In the brain it is only the pyramidal tract (see p. 436) that is the seat of this secondary change. The trophic centres of the pyramidal tract appear to be in the motor convolutions, and when the fibres are interrupted at any point below this, a secondary degeneration follows. The interruption is most commonly effected by hæmorrhage or softening in the region of the corpus striatum, and it is the fibres which form the internal capsule which are here concerned. Destruction of the internal capsule at any part of its extent, except the posterior fourth or third (which contains sensory fibres), will cause a descending degeneration in parts succeeding. If of long standing, there may be great shrinking of the portion of the pyramidal tract involved (see Fig. 212). It appears also that the fibres which form the internal

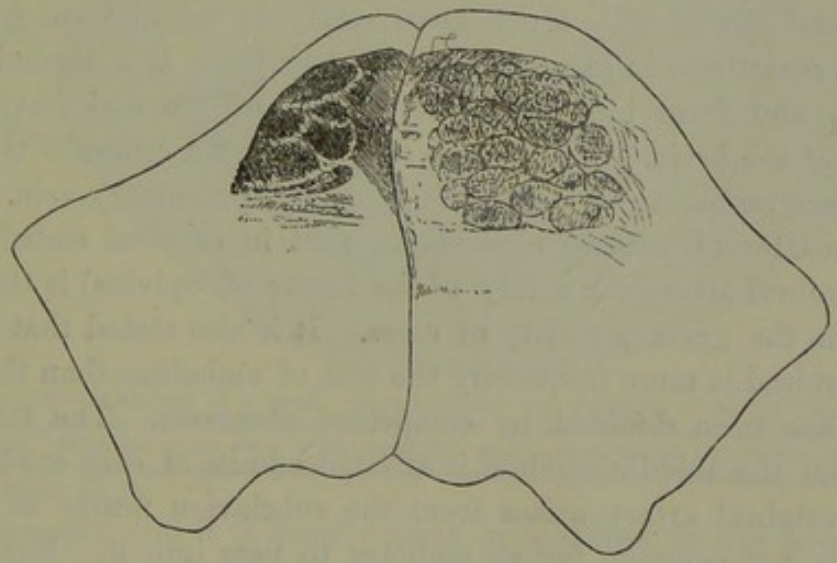


Fig. 212.—Pons in descending sclerosis. The pyramidal tract on the left side is seen to be shrunken and in a state of grey degeneration.

capsule keep nearly the same arrangement from before backwards in the crura, pons and medulla oblongata that they have in the capsule. The destruction may involve the whole internal capsule, or only a limited part of it, and the degeneration will be similar in extent. The posterior part of the internal capsule and the corresponding portions of the crura and pons being sensory, are not liable to descending degeneration.

THROMBOSIS AND EMBOLISM OF THE CEREBRAL VESSELS.

In considering the various conditions included here, it should be borne in mind that the arteries of the circle of Willis anastomose freely. The arteries in the meninges also anastomose, but much less freely, while the nutritive arteries, both those given off to the basal parts of the brain and those of the convolutions, are end-arteries. These facts are of great importance in relation to the effects of occlusion.

EMBOLISM in the arteries of the brain occurs in the great majority of cases in connection with acute endocarditis or valvular disease of the heart from chronic endocarditis. In the former case the embolus is a piece of fibrine broken off from the inflamed aortic or mitral valve; in the latter case it is mostly a piece of calcareous matter from the indurated and calcified curtain. Besides, we may have globular thrombi in the left auricle or ventricle becoming detached, or softening, and so giving rise to plugging. So also may thrombi in the aorta become detached and carried off. Much more rarely do emboli come from the lungs, but sometimes in gangrene of the lungs there is a thrombosis of the veins, and from bits of fibrine carried off we may have septic embolism of the brain. It is conceivable also that a cancer of the lungs may produce embolism by penetrating into the pulmonary vein.

It is matter of general observation that in cerebral embolism the middle cerebral artery (or artery of the fissure of Sylvius) is the vessel plugged in the great majority of cases. It is also stated that the left middle cerebral is more frequently the seat of embolism than the right, but this has been doubted by competent observers. The frequency with which the middle cerebral is affected admits of easy explanation. As the vertebral artery arises from the subclavian nearly at a right angle, it is not common for an embolus to pass into it. But the innominate and the carotid, being nearly in the direct line of the current from the aortic orifice, readily receive any fragment. Then again, the middle cerebral is the direct continuation of the internal carotid and an embolus will more readily sweep into it than diverge forward or backward. It is important here to bear in mind that the middle cerebral supplies the greater part of the basal ganglia, including nearly the whole of the corpus striatum and internal capsule and a part of the thalamus opticus. It also supplies the greater part of the motor convolutions.

THROMBOSIS arises in consequence of some alteration of the walls of the arteries. It is predisposed to by weakness of the heart, but

mere sluggishness of the circulation so induced will hardly cause thrombosis in a healthy artery, although it may do so in the venous sinuses of the dura mater, where the circulation is naturally so much slower. Thrombosis is mostly induced either by ATHEROMA or by SYPHILITIC DISEASE of the arteries. In both cases the internal coat is thickened, and the surface is rough, while the calibre of the artery is already considerably encroached on, as Fig. 213 shows. Atheroma occurs mostly

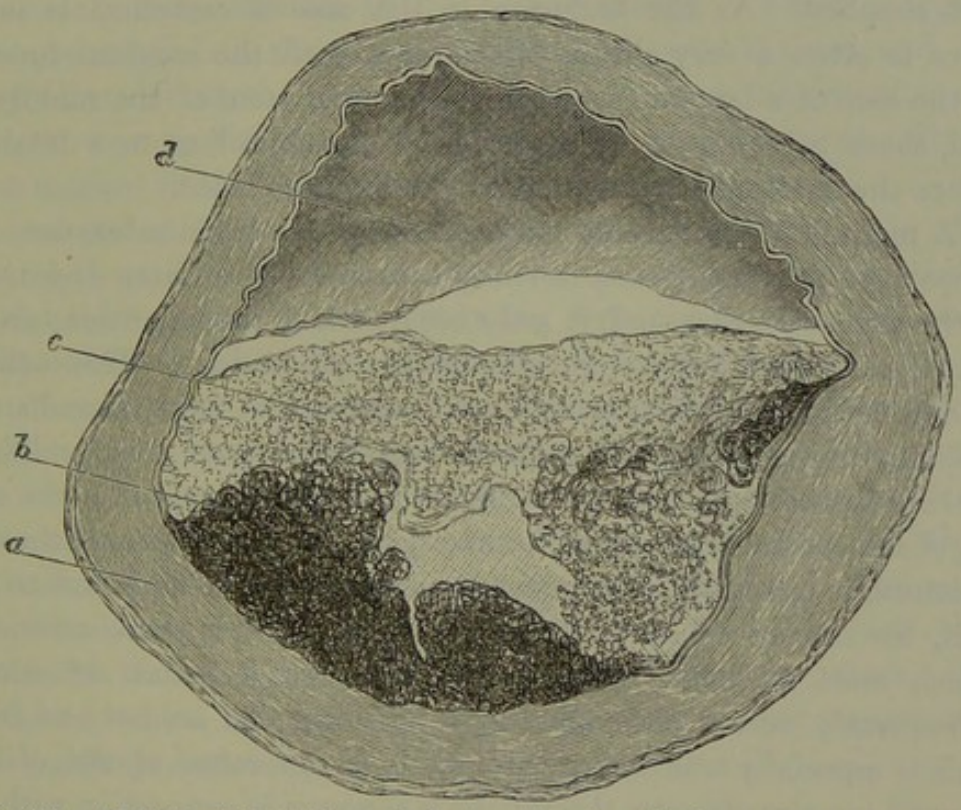


Fig. 213.—Atheroma of a small cerebral artery the eleventh of an inch in diameter, with thrombosis. *b*, atheromatous internal coat; *c*, thrombus on its surface partially organized. Between these two is an irregular clear space, which represents fresh blood which had been insinuated between patch and thrombus. *d*, remaining calibre filled with blood. × 34.

in old persons, and it is usually most pronounced in the larger arteries of the base, where there may be numerous yellow patches. But not infrequently it extends to the finer ramifications, and it is in these that it most readily leads to occlusion by thrombosis. The artery from which the figure is taken, for instance, had an external diameter of the eleventh of an inch. Syphilitic disease of the arteries, on the other hand, occurs most frequently in younger people in connection with gummata, and these may occur at any part of the surface of the brain.

EFFECTS OF OCCLUSION OF ARTERIES IN THE BRAIN.—Here, as in other parts, the effects of occlusion depend chiefly on whether the

arteries concerned are end-arteries or not. The arteries of the circle of Willis anastomose freely, and occlusion of them leads only to a very temporary derangement of the circulation. The larger branches anastomose sparely, and occlusion of them has much more serious effects. The nutritive arteries do not anastomose at all, and occlusion of them has very evil results.

The most direct result of occlusion of arteries is ANÆMIA of the part supplied. As the occlusion in the case of embolism is sudden, there is often a very abrupt interference with the cerebral functions. In the case of a large artery such as the main stem of the middle cerebral, there may be a very extensive anæmia, leading to a fatal issue before the anastomosing circulation can be established.

A more important result is SOFTENING of the brain substance. This as we have previously seen is really a necrosis with fatty degeneration of the nervous tissue, and it only occurs when the conditions are such that the circulation is brought absolutely to a standstill. This is the case when any of the nutritive arteries are obstructed, as these are end-arteries. The nutritive arteries which come off from the first part of the middle cerebral are the most exposed to obstruction from embolism, and hence softening of the central parts of the brain, especially in the region of the corpus striatum, is of somewhat common occurrence. It is important to notice that, for reasons to be afterwards considered, it is these arteries also which most frequently give rise to hæmorrhage. But softening not infrequently occurs although the vessels occluded are not end-arteries. This is especially true where thrombosis is the cause of the occlusion. As we have already seen, thrombosis is common in connection with atheroma. Now this is a disease of old people, in whom the circulation is weak. Under these circumstances occlusion of a small peripheral artery may lead to softening, before the force of the blood has brought about an anastomosing circulation, all the more because many of the neighbouring arteries are also partially obstructed by atheroma. Even in the case of embolism there may be considerable cortical softening if the embolus has broken up and plugged several vessels at the same time, so as to interfere with the establishment of the anastomosing circulation.

Another occasional effect of the occlusion is HÆMORRHAGE. It is seldom that the proper hæmorrhagic infarction is produced here, but it often happens that some blood is mixed with the softened brain substance, producing a yellow or red softening.

OCCLUSION OF ARTERIES IN CHOREA.—The frequent association of

this disease with acute endocarditis has suggested the view that it may have its origin in embolism of the arteries and capillaries of the brain, multiple embolism with softening having been found in some cases, but not in all. According to the observations of Dickinson the most constant changes in chorea are dilatation of the arteries and veins throughout the substance of the brain and spinal cord, exudations or small hæmorrhages, sometimes with blood crystals around the vessels, and in chronic cases sclerosis in the neighbourhood. These changes are most pronounced in the corpora striata and optic thalami, and in the grey substance of the spinal cord, especially near the junction of the posterior cornua with the central parts of the grey substance. They are most marked in the dorsal and cervical regions of the cord.

It seems probable that in chorea there is an irritant present in the blood, and it may be the same irritant as that in acute rheumatism. It attacks the nervous system, producing hyperæmia and exudation from the vessels. While the whole central nervous system is more or less affected there are certain parts specially involved, these parts being what have been called the accessory portions of the nervous system. It may be supposed that the fundamental and simpler parts of the brain and cord are more stable than the accessory parts, and that when attacked by an irritant the latter will give way first. The anatomical distribution of the lesions suggests that this is so, and the symptoms of chorea indicate disorder in "movements which are acquired, and which are probably only learned by a long apprenticeship" (Hughlings Jackson).

Thrombosis of the cerebral sinuses.—These venous channels are somewhat frequently the seat of thrombosis. The coagulation may have its starting point in an inflammation propagated from a neighbouring structure. The most frequent origin of such inflammations is caries of the temporal bone from disease in the ear, but it may follow on injury to the head, inflammations of the skin of the face and scalp, especially erysipelas, and of the bones. In all these cases the thrombosis usually has its starting point towards the base of the skull, and especially in the lateral and petrosal sinuses.

There is, however, another class of cases in which the thrombosis has a more obscure origin, and seems sometimes even spontaneous. The blood simply coagulates in the sinus, and it is usually in the longitudinal sinus that the coagulation begins. In most of these cases the person is in a state of debility, and the thrombus may be regarded as

marasmic in its origin. But there are cases in which there is no obvious weakness of the heart, and the coagulation has no apparent cause. The localization of the thrombosis suggests stagnation of the blood as its cause. The sinuses are rigid tubes incapable of narrowing when the circulation is slow, and they are intersected by bands of connective tissue. The longitudinal sinus also is so situated that, at its middle part at least, the blood passing from the cerebral veins flows upwards to it against the force of gravitation.

The EFFECTS of thrombosis of the sinuses will vary according to the cause. If due to the propagation of inflammation from neighbouring structures, then a suppurative phlebitis may result, with meningitis, and even abscess of the brain. There are, however, cases of abscess of the brain without meningitis, in which the inflammation seems to have extended along the veins either in their interior or in their sheath.

In the other form the results are usually much less serious. The veins which open into the sinus are greatly engorged, and the thrombosis may extend into them. It is here chiefly the longitudinal sinus that is concerned, and the veins which open into it are those of the cerebral hemispheres. These may stand out as prominent worm-like cords filled with dark coagula. In most cases the blood finds its way by other routes, and there may even, after a time, be a re-establishment of the circulation in the sinus. Sometimes, however, the obstruction in the veins is such as to lead to HÆMORRHAGE. This is usually in the form of numerous capillary hæmorrhages, but sometimes there is along with this a large effusion of blood in the substance of the brain and under the soft membranes. The seat of such hæmorrhages is usually the superficial and upper parts of the hemispheres, and they are frequently multiple.

CEREBRAL HÆMORRHAGE.

By this term is meant bleeding in the substance of the brain. The blood may be large or small in quantity but it pushes aside the brain substance, tearing for itself a cavity where it coagulates. With the doubtful exception of certain diseases of the blood, where the hæmorrhage may possibly be by diapedesis, there is always rupture of one or more vessels.

In a previous page reference has been made to the two orders of cerebral arteries, and the differences in the circumstances of hæmorrhages from these are such that we must consider them separately here.

(1) HÆMORRHAGE FROM THE LARGER CEREBRAL ARTERIES.—We have seen that these vessels run in the soft membranes, and it might be supposed that their rupture would give rise to meningeal rather than cerebral hæmorrhage, and so it is usually stated. But this is not the case. The blood nearly always finds its way into the brain substance, where it is found usually in much larger quantity than in the meninges, so that the case has much more the characters of cerebral than of meningeal hæmorrhage. There is usually some blood in the meninges occupying the sulci between the convolutions, and it may even be considerable, extending to the base and perhaps covering the optic commissure; but usually the amount is small, and on account of the large cerebral hæmorrhage is apt to be overlooked. It is very rare indeed for the blood to escape towards the surface and appear in the cavity of the dura mater. Any appearance of blood in the meninges, however, should at once direct attention to the larger cerebral arteries as the probable source of the hæmorrhage.

The explanation of the extension of the blood into the brain substance suggests itself when we consider the circumstances of the parts. When rupture of such an artery occurs the blood tears its way around; it passes into the loose connective tissue, and by and by reaches the surface of the brain. Here the tissue, being soft, tears readily, and the blood rapidly passes inwards. On the other hand the connective tissue on the surface is tough and the blood will tear it with difficulty. The blood may work its way from space to space in the connective tissue, but this takes time and probably needs considerable pressure. There is another circumstance which probably has to do with the blood so constantly finding its way into the brain substance. As we shall see afterwards, a large number of the cases of hæmorrhage in this situation are from rupture of aneurisms. Now an aneurism will probably project more readily towards the surface of the brain where the substance is soft than in other directions, and when such an aneurism ruptures it may do so directly into the brain.

The CAUSES of the rupture of these larger arteries is to be sought for in disease of their walls and increase of the blood-pressure.

The commonest cause is ANEURISM of these arteries, which is of remarkably frequent occurrence. The great majority of the cases of cerebral hæmorrhage occurring before the age of fifty years is due to the rupture of aneurisms of these larger arteries. The aneurisms are mostly thin-walled and therefore prone to rupture. Their most

frequent seat is on the middle cerebral artery or one of its branches in the fissure of Sylvius, but they may occur on any of the arteries of the brain and are not infrequently multiple.

The frequent occurrence of these aneurisms and their serious import suggests an inquiry into the causes of their formation. In the first place the arteries are thin-walled and are placed in a loose tissue, so that they very readily undergo dilatation. Any local injury to the wall may be the starting point to the dilatation. This is often produced by *embolism*. In a large proportion of cases the aneurism is associated with valvular disease of the heart, and an embolus imperfectly obstructing an artery, especially if it be a cretaceous piece broken off from a valve, may readily injure the wall so as to allow of dilatation. Ponfick has found that in a considerable proportion of cases of acute endocarditis there is embolism with either fully formed or incipient aneurisms. When they have an origin such as this the aneurisms will be specially thin-walled and partake of the characters of false aneurisms. This mode of origin also goes far to explain the greater predominance of these aneurisms in the middle cerebral artery, which, as we have seen, is especially liable to embolism. Another occasional cause of cerebral aneurism is *atheroma*. This disease injures the vessel-wall and produces obstruction, and it may lead to aneurism on the one hand by weakening the wall, and on the other by locally increasing the blood-pressure on the peripheral side of the obstruction. Syphilitic disease is also assigned as a cause of aneurism.

The subject of ATHEROMA as a direct cause of cerebral hæmorrhage is a somewhat difficult one. This condition is undoubtedly in many cases associated with cerebral hæmorrhage, but it is difficult to believe that it can be the sole cause. Atheroma produces, as Fig. 213 shows, a thickening of the arterial wall. At the same time, however, it weakens the wall, and if the coats get separated and the blood penetrates behind the atheromatous patch, there may be serious risk of rupture. Besides this, atheroma will, as mentioned above, produce, by obstructing the vessel, an increase of blood-pressure on the proximal side of the patch and also in neighbouring arteries. If there be extensive atheroma the mere rigidity of the arteries may produce an increase of blood-pressure in the smaller arteries. But all these conditions seem scarcely capable by themselves of leading to hæmorrhage, and it is in cases where atheroma is associated with a general increase of blood-pressure that this occurs, especially in chronic Bright's disease.

On the other hand INCREASE OF BLOOD-PRESSURE alone can hardly

lead to hæmorrhage. In chronic Bright's disease there is frequently a constant increase in the arterial tension, and hypertrophy of the left ventricle of the heart. This condition will conduce to hæmorrhage in both orders of arteries in the brain, especially if this disease be associated with atheroma, or with fatty degeneration of the smaller arteries of the brain, which some assert to be common in Bright's disease.

(2) HÆMORRHAGE FROM THE NUTRITIVE ARTERIES.—As these vessels run in the substance of the brain the hæmorrhage will be always cerebral and will rarely extend to the meninges. It might be supposed that as the nutritive vessels are small the hæmorrhage from them would be small, and in many cases it is so; but when bleeding has once begun, the blood tearing the brain substance ruptures other vessels, and there is often a considerable effusion of blood.

Hæmorrhage rarely occurs from the cortical nutritive vessels, but is very common from the central ones. The circumstances of these latter go far to explain this. They arise from large stems, mainly from the middle cerebral immediately after its origin from the internal carotid. It is clear that the blood here will be at a pressure not much less than that of the aorta, and any variations of pressure will tell readily. On the other hand the cortical vessels mostly arise from fine vessels in which the blood pressure has been reduced by successive division and sub-division.

As to the CAUSES of hæmorrhage in these arteries, ANEURISM again plays the most important part. As the arteries are small so are the aneurisms, but they are numerous in the same person. Such aneurisms have been called by Bouchard and Charcot MILIARY ANEURISMS. They occur in every region of the brain, but are most readily detected on the surface of the convolutions, where, on stripping off the pia mater from the convolutions, they may be seen as small red or brown spots. When examined under the microscope they have all the characters of ordinary aneurisms. Most of them are sacculated (Fig. 214), but some are fusiform (Fig. 215). It is stated that the cause of their formation is a sclerosis of the walls of the arteries, involving first a formation of round cells in the external coat with subsequent fibrous transformation. There results an atrophy of the middle coat which seems to be the most direct cause of the dilatation. This diffused sclerosis of the nutritive arteries is mostly met with in old people; in persons above fifty cerebral hæmorrhage is, in the larger proportion of cases, due to rupture of miliary aneurisms.

Although the aneurisms are present in all regions of the brain, rupture seldom occurs except in those of the central arteries. The ex-

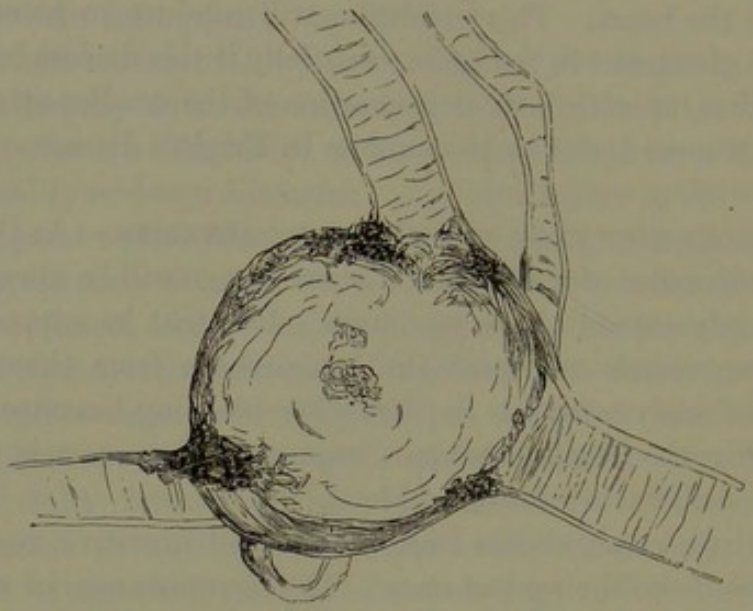


Fig. 214.—Sacculated miliary aneurism of a nutritive artery of the brain. The aneurism is about the twentieth of an inch in diameter. × 27.

planation of this has already been indicated, and it has been mentioned that the lenticulo-striate branch is pre-eminently that from which hæmorrhage occurs.

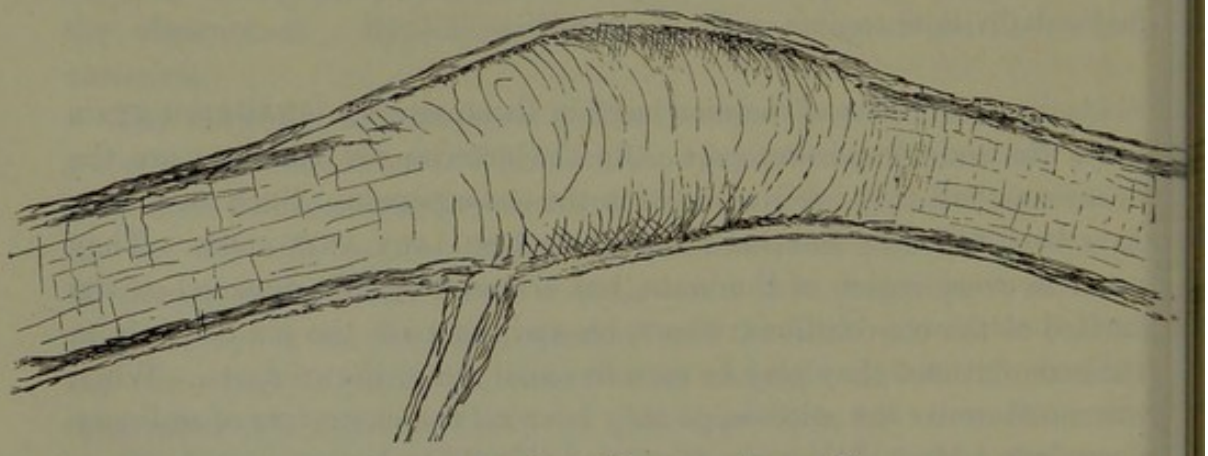


Fig. 215. Fusiform miliary aneurism. × 27.

Atheroma, with increased blood-pressure, is occasionally a cause of hæmorrhage from the nutritive arteries as from the larger ones. Atheroma is not common in small arteries, but as the central nutritive arteries are much larger than the cortical ones, atheroma is commoner in them, and hæmorrhage from this cause is therefore, for a double reason, more frequent in these.

(3) HÆMORRHAGE FROM THE CAPILLARIES.—A certain amount of capillary hæmorrhage generally accompanies all larger bleedings. The explanation of this seems to be that the pressure of the blood produces such obstruction of the vessels around that frequent leakage occurs from the capillaries. In the case of thrombosis of the sinuses and veins also, there is capillary hæmorrhage. Again, embolism may cause capillary hæmorrhage, and, as we have seen, the blood is often mixed with the softened brain tissue. Septic embolism as in ulcerative endocarditis, and pyæmia leads to capillary hæmorrhage. Lastly, we may have leakage from the capillaries in scurvy, purpura, and other morbid states of the blood.

In capillary hæmorrhages the collections of blood are generally small in size forming a congeries of red puncta. But if very frequent and closely set they may run together and form a considerable effusion.

APPEARANCES OF THE BRAIN IN HÆMORRHAGE.—The appearances presented when a person dies soon after the occurrence of hæmorrhage are sufficiently characteristic. The effused blood increases the contents of the skull, and in order to its accommodation there must be some displacement and crushing of the remaining brain substance. If the hæmorrhage be at all extensive we find on opening the skull that the corresponding hemisphere is bulged outwards and perhaps projects beyond the middle line. The convolutions are more or less flattened, and there is a certain dryness and glazing of the surface which indicates that all available fluid has been absorbed to make room for the addition made to the contents of the skull. These are all indications of increased pressure within the skull, and during life this increase of pressure causes symptoms referrible to the brain as a whole or to parts removed from the seat of hæmorrhage. It sometimes happens that the appearance of blood in the membranes suggests the existence of hæmorrhage before the brain is laid open, and this will be especially the case when rupture of an aneurism, or thrombosis in the sinuses has been the cause. On cutting into the brain substance the appearances will vary to some extent according to the cause and extent of the hæmorrhage. If there are numerous small hæmorrhages closely set there will be much softening of the brain, and the brain substance will be mixed with blood. If the hæmorrhage be large the blood will be more pure. In any case the blood produces softening in the parts around, which may be stained with the blood-colouring matter. As already mentioned there are usually red spots from capillary hæmor-

rhage around the clot. The clot itself is mixed with the debris of brain substance, and the internal wall of the cavity in which it lies has an irregular character.

If the patient die almost immediately the clot is exactly like an ordinary gelatinous coagulum. But if he survive a day or two it has already drawn together somewhat and become firmer and more of a brown colour. This is sometimes peculiarly manifest at the peripheral parts of the clot, so that a kind of capsule may be formed of condensed fibrine.

ORGANIZATION OF THE CLOT. The APOPLECTIC CYST.—The further organization of the coagulum is a slow process, and proceeds very much in the same way as organization of clots inside or outside of vessels. An inflammatory process is set up in the neighbourhood, and this results in the production of connective tissue which by and by encapsules the clot. The clot in the meanwhile softens; its pigment is dissolved out, and frequently deposited in the crystalline (see figure 216) or granular form in the softened material or in the capsule, often giving the parts a rosy or rusty colour. The blood being frequently mixed with brain substance and both these constituents being degenerated, various appearances are presented; sometimes the capsule contains material of an atheromatous aspect.

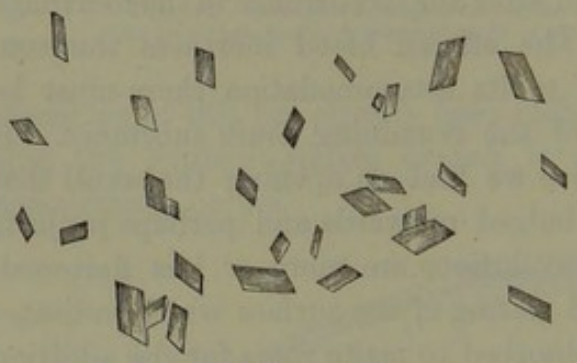


Fig. 216.—Crystals of hæmatoidin from a cerebral hæmorrhage. The crystals form oblique rhombic pillars of a reddish brown colour. × 350.

Through time, however, the contents tend more and more to absorption, and being replaced by clear fluid a cyst is the result, the so-called APOPLECTIC CYST. This cyst is not merely a simple sac containing fluid, but it is generally intersected by connective-tissue trabeculæ so as to appear to be filled with a net-work. Very often some crystalline or granular pigment is met with in the wall of the cyst. It is to be remarked that cysts which in their later stages are indistinguishable from those now under consideration may have their origin in softening of the brain, especially as a result of embolism. It will be seen that the apoplectic cyst may be compared in its origin with a cicatrix; it arises by the formation of connective tissue and fills the place of tissue lost, and it is only because, being situated in the midst of the brain

substance, it does not readily contract that we have a cyst rather than a cicatrix. If the hæmorrhage has been near the surface of a ventricle or of the brain itself we may have a cicatrix instead of a cyst; or a cyst by thickening of the trabeculæ and gradual drawing together of the parts may be converted into a cicatrix. In the case of cicatrices occurring thus on the surface of the brain the soft membranes are depressed and puckered and firmly adherent to them. The cicatrices like the cysts often present some remains of blood-colouring matter.

SOFTENING OF THE BRAIN (*RAMOLISSEMENT*).

This subject has already been several times considered incidentally. We have seen that localized softenings occur in connection with embolism and thrombosis of the cerebral arteries, and in addition to this there is softening in connection with inflammation, sometimes going on to the formation of abscess. Lastly, there is a softening to be referred to in studying tubercular meningitis. We have here to consider the character of the changes which occur in the brain substance in the simple softenings, apart from those of inflammation or tubercular meningitis.

As these softenings occur mainly in connection with the occlusion of arteries the affected piece of brain substance is limited to the distribution of the artery concerned. In the case of embolism it will nearly always be situated in the region supplied by the middle cerebral artery, and especially in the central parts, the more direct central nutritive arteries being much more frequently the seat of embolism than the cortical ones.

Softenings have often been distinguished according to the colour presented by the affected brain substance, so that WHITE, YELLOW and RED softenings have been described. For the most part the colour depends on the blood mixed with the nervous tissue, and the amount and condition of the former can hardly be regarded as a chief characteristic of the softening, and the colour is therefore not of primary importance.

We have seen already that softening of the brain substance is really due to a NECROSIS. The result of the death of the nervous structures is their disintegration. The nerve fibres very rapidly break up; the myeline of the medullary sheath coagulates and escapes from the primitive sheath, and afterwards breaks up into fine fat granules. The ganglion cells are more resistant, but they also become granular and gradually disappear. The cells of the neuroglia and the nuclei of the walls of the

vessels undergo a change which appears at first sight to be a fatty degeneration, but which very probably has, to some extent, a different significance. These structures become filled with finely divided fat, so that the neuroglia cells are converted into characteristic COMPOUND GRANULAR CORPUSCLES and the nuclei of the vessels are converted into aggregates of fat granules at intervals along the vessels (Fig. 217). So far as

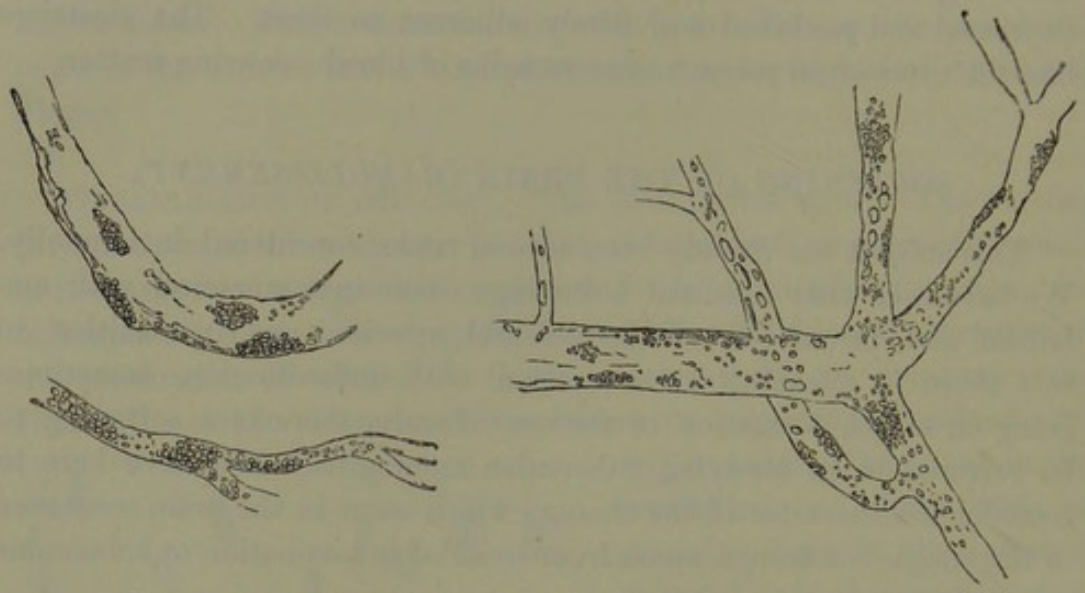


Fig. 217.—Fatty degeneration of the vessels in cerebral softening. (PAGET.)

the neuroglia cells are concerned it is probable that they pick up the fat arising from the disintegrated myeline. It is not so clear that the nuclei of the blood-vessels do this, and there is here, more probably, a fatty degeneration of them. Besides the neuroglia cells there may be present in the part amœboid cells, or these may pass into it after the occurrence of the necrosis, and these also take up the granular fat. In this way there are, frequently, large numbers of compound granular corpuscles which are very conspicuous when a piece of the softened tissue is examined in the fresh state under the microscope.

In some cases, as already mentioned, the softened brain substance is largely mixed with blood, especially in embolic softening. At first the blood gives a red colour to the softening. But as time goes on the colouring matter is dissolved out of the red corpuscles and diffused throughout the softened structures, as well as to some extent in the brain substance around. In that case the colour becomes less intense and merges into yellow, or the colour may be reddish yellow from the outset. It will be seen from this that red and yellow softening run together, and that the latter is often merely a later stage of the former. At the time when the softening occurs the vessels are often filled with

blood, which soon coagulates. The fibrine disintegrates as the colouring matter is dissolved out from the corpuscles. Sometimes the dissolved colouring matter is deposited in the granular or even in the crystalline form inside or outside the vessels. If there is very little blood in the vessels of the softened part then the colour is white or grey. This is mostly seen when death has occurred very soon after the occlusion of an artery.

The ultimate disposal of the necrosed piece of brain substance occurs on principles already considered. The softened brain substance has ultimately the characters of a fatty emulsion, which is gradually absorbed. A chronic inflammation occurs around, just as in the case of a hæmorrhage, and in a similar fashion connective tissue is produced, taking the form of a cyst or a cicatrix, according to circumstances. The resulting cyst or cicatrix is not always to be distinguished from that of a cerebral hæmorrhage. Usually the latter presents more distinct pigmentation, but the former may also present pigment granules and crystals.

INFLAMMATIONS OF THE BRAIN.

These embrace a very extensive and varied set of conditions, some of which have little in common. Thus there are localized inflammations of an acute kind, going on sometimes to the formation of abscesses; chronic localized inflammations; inflammations diffused throughout the brain; inflammations extending to the brain substance from the membranes, etc.

(1) Acute localized encephalitis.—We have already seen that, around and in the midst of hæmorrhagic foci and cerebral softenings, there are inflammatory manifestations, evidenced by the presence of leucocytes, which take up fat granules. The inflammatory process does not go on to suppuration, but results in the formation of connective tissue, constituting a cyst or a cicatrix.

When the brain is injured traumatically—lacerated, for example, by a blow on the head or directly wounded by a protruding piece of fractured bone—then there is usually a more intense inflammation, which may go on to suppuration, especially when the brain communicates with an external wound. The brain may be considerably lacerated without any external wound or fracture of the skull, especially by falls on the head. In that case, when the head lights on the ground, the soft brain

is, as it were, propelled against the dense skull which has been suddenly arrested, the laceration being brought about by *contre coup*. In all these cases the mere injury to the brain induces a certain amount of inflammation, resulting in an aggregation of leucocytes. Usually the ultimate result is the formation of a cicatrix or a sclerosis of the portion of brain substance, but there may be suppuration, in which the membranes of the brain take part.

Inflammation of the brain may result in ABSCESS, but almost alone in septic cases. An injury to the brain communicating with a septic wound may have this result. More frequently the primary disease is caries of the bones of the skull, and especially of the temporal bone. The great majority of cases of abscess of the brain are connected with suppuration of the middle ear, very often of prolonged duration dating, it may be, from a scarlatina years before. There is most danger of abscess when caries exists in the petrous portion of the temporal bone; but even without caries an abscess may form. The abscess is due to a septic inflammation extending directly from the affected parts inwards. Some of the veins from the temporal bone pass inwards to the lateral sinus, and a septic process may be propagated along the sheath of these veins to the dura mater. This explains cases in which abscess of the brain is associated with inflammation of the dura mater, and is localized in the neighbourhood of the temporal bone. But, in some cases, the path of propagation is more obscure, and an abscess is present in the midst of the brain substance, separated from the temporal bone by sound tissue. Abscesses sometimes occur by propagation from the nose, the antrum of Highmore, and the orbit.

In the early stages of abscess there is softening of the brain substance, which is infiltrated with leucocytes. But the conditions hardly offer themselves to observation in this stage. The fully-formed abscess is generally of old standing, and has been of slow growth. It contains thick yellow pus, generally with a very offensive smell. The pus corpuscles are usually œdematous and fatty, and altogether ill preserved. The abscess may be surrounded by softened brain substance, but most usually there is a dense capsule surrounding it so that it can be enucleated by tearing away the capsule. The capsule is composed of inflammatory tissue, partly in the state of granulation tissue, but partly as connective tissue. This capsule, to a certain extent, represents sclerosed brain substance, but outside the capsule the

brain substance is frequently softened so as to allow of its enucleation. Abscesses may burst into the ventricles of the brain, or on to its surface.

(2) CHRONIC LOCALIZED ENCEPHALITIS.—The processes of chronic inflammation here are similar to those in the spinal cord, and the result here, as there, is SCLEROSIS. In the case of the brain there is hardly anything of the systematic sclerosis so frequent in the cord. There is, however, one form of disease which affects both brain and spinal cord, and which presents some analogies with the systematic scleroses of the cord.

DISSEMINATED SCLEROSIS, or SCLEROSIS IN PATCHES, is characterized by the occurrence of patches of chronic inflammation scattered over the cord, or the brain, or both. These patches have all the characters of sclerosis; in the white substance they are grey, and in both white and grey substance they produce induration and shrinking. Under the microscope the sclerosed white substance shows loss of the medullary sheaths of the fibres, while the axis cylinders, according to Charcot, are largely retained. In the grey substance, the ganglion cells are shrunken sometimes with pigmentation. At the peripheral parts of the patch there may be evidences of more active inflammation, in the form of abundant round cells along with compound granular corpuscles.

The distribution of the patches is somewhat irregular. They are found of various sizes in the cord, medulla oblongata, pons, peduncles, corona radiata, convolutions, cerebellum. In such various situations the sclerosis leads to very various functional disturbances. The great frequency of motor tremors, however, suggests some tendency to localization. Erb has pointed out that when tremors exist, patches are specially present on the peduncular parts (pons, medulla, peduncles). If patches are seated there, the motor impulses will be imperfectly conducted but not absolutely interrupted, as the axis cylinders are preserved.

(3) DIFFUSED ENCEPHALITIS.—This term may be applied to conditions in which there is a general irritation of the brain, presumably by some irritant circulating in the blood. It may be held to include a considerable number of varied conditions. As the irritant, being in the blood, will attack all parts equally, we may expect to find evidences of irritation in the spinal cord as well as in the brain.

In the DELIRIUM OF FEVERS it may be presumed that the brain is irritated by the morbid condition of the blood. According to Popoff, there are visible evidences of this in the case of typhoid fever in the presence of abundant leucocytes. These are stated to be particularly abundant around the vessels, and evidently spreading out from these. The leucocytes were frequently found in the spaces around the ganglion cells (pericellular lymph spaces), and even, in some cases, in the substance of the ganglion cells. These conditions indicate the presence of an irritation of the brain.

Then Middleton has pointed out that in delirium tremens, tubercular meningitis, uræmia, fracture of the skull with injury to the brain, erysipelas, etc., the brain substance is over-run with leucocytes, the appearances being very similar to those which will be described as occurring in hydrophobia. In all cases where irritation of the nervous centres is evidenced during life, these signs of irritation may be looked for in the brain after death.

CONDITION OF THE BRAIN IN GENERAL PARALYSIS OF THE INSANE (*Dementia paralytica*).—The condition of excitement with which many cases of insanity begin, suggests irritation of the cerebral centres; but it is very difficult to determine the exact relation of the conditions here, especially as the cortex of the brain is very intricate in its structure and difficult to disentangle. In general paralysis the disease is usually in an advanced stage before the death of the patient, but it begins with acute symptoms, such as epileptic attacks and acute mania, and death sometimes occurs at this period. Meyer has recorded the results of observation in twenty cases of this kind, in which the disease began with headache and went on to maniacal outbreaks which he compares with the delirium of fever. He asserts that death occurs more frequently in this stage than is generally supposed, but that the cases are very often not recognized as such.

In these cases, after death there was the appearance of a general swelling of the brain, the convolutions being more voluminous, and the sulci smaller, while the grey substance presented a lively red appearance, frequently mottled and with multiple minute softenings. On microscopic examination the blood-vessels in the cortical substance were found engorged with blood, and around them leucocytes in abnormal quantity. Leucocytes were also abundantly present in parts removed from the vessels. This condition was seen mainly in the cortex, but also spreading to the white medullary substance. The vessels themselves had

undergone changes; in the most acute periods the principal change was fatty degeneration of the wall, visible chiefly in the capillaries. There were also minute hæmorrhages, the blood often getting through the internal and middle coats, but accumulating inside the external so as to form a kind of dissecting aneurism. These minute dissecting aneurisms may be best detected (according to Rindfleisch) by carefully separating out the vessels from the surface inwards under a stream of water.

In the more CHRONIC PERIODS of the disease the appearances are those rather of degenerative than of active processes, but the degenerative are presumably secondary to the inflammatory, the disease having very much the characters of an interstitial cerebritis with loss of the proper nervous tissue as a consequence, a cirrhosis of the brain.

The appearances of the brain as a whole are very suggestive of such a condition, especially if, as mostly happens, the case has been of some duration. The appearances are prominently those of ATROPHY OF THE BRAIN. On removing the calvarium the dura mater is commonly found wrinkled over the frontal lobes, evidently from shrinking, but not necessarily of these lobes, because the position of the head causing the brain to gravitate backwards would probably make the shrinking tell anteriorly whatever its locality. On removing the dura mater a very manifest œdema of the membranes of the brain presents itself. There is also distension of the ventricles, frequently very great, so that the brain substance lying between the fluid in the ventricles and the superficial œdema of the membranes is greatly shrunken. The œdema of the membranes is most visible in the sulci which gape and are filled up with œdematous connective tissue. The fluid is chiefly in the membranes over the parietal and occipital lobes, perhaps from gravitation. The surface of the ventricles is beset with little prominent granulations which are often very marked. It has been pointed out by Crichton Browne that the pia mater is adherent to the surface of the convolutions, so that on attempting to remove it bits of brain substance come away with it. These adhesions may be taken as indications of the inflammatory nature of the disease, and their locality affords some evidence of the localization of the lesions. Crichton Browne states that the adhesions occur mainly in the anterior three-fourths of the brain, affecting the frontal lobe chiefly in its anterior and posterior thirds, and the parietal in all its convolutions.

The brain as a whole is greatly reduced in weight. Taking the normal weight of the brain, including membranes, etc., as fifty ounces for the adult male, and forty-five for the female, the weight in general

paralysis often falls to thirty-five ounces. The loss of weight does not affect the brain uniformly; it is mainly the cerebral hemispheres that are affected, the basal ganglia and peduncular parts being much less so, and the cerebellum not at all.

Besides these evidences of atrophy of the brain, the membranes show irregular thickenings. The pia mater presents milky opacities or more obvious patches of thickening. The dura mater is usually also affected, so frequently that at one time it was supposed to be the primary seat of disease. It is commonly adherent to the calvarium, so that it is often difficult to remove the latter, and it is necessary to remove bone and dura mater together. That membrane presents patches of thickening, opacities, and even flat bony developments. Not infrequently there are extravasations of blood of smaller or larger size accompanied by appearances which we shall have to describe under pachymeningitis chronica hæmorrhagica. The calvarium itself sometimes presents thickening, which is usually diffuse, and may be chiefly due to the shrinking of the brain; sometimes there are also local prominences or actual exostoses. Sometimes also the diploe is converted into dense bone, so that the calvarium is much heavier than normal—so-called sclerosis of the bone.

All these appearances are due to inflammation and shrinking of the brain substance, the dropsy of the ventricles and œdema of the membranes occurring in order to fill up the space formerly occupied by the brain, the cranium being a cavity of fixed size and the dropsy being *ex vacuo*.

The appearances under the microscope are chiefly those of diffused sclerosis and atrophy of the brain substance. We have already seen that there is sclerosis of the posterior columns of the cord, and this may even be an early condition. In the brain there are often traces of the earlier acute condition in the form of little clumps of pigment around the vessels, the remains of former extravasations. But the appearances are more those of degeneration. The ganglion cells are shrunken and frequently pigmented; the blood-vessels show sometimes fatty degeneration, sometimes a homogeneous glancing appearance (colloid); and they are frequently obstructed by glancing masses which are partly calcareous and partly colloid. These appearances are not to be regarded as in any way peculiar to this disease, they are simply evidences of the profound atrophy of the brain, and may occur to a limited extent in old persons where there has been only a senile atrophy.

HYDROPHOBIA.—This is a disease in which there is every indication of irritation of certain centres, and of a greatly increased reflex irritability. The centres irritated here are less those of the cerebral hemispheres than of the spinal cord and medulla oblongata, although delirium is also occasionally present. The symptoms point mainly to the medulla oblongata; there are various spasms of the muscles of deglutition and respiration which occur to some extent spontaneously, but are also evoked by slight sensory stimulation. The mere sight of water gives rise to the idea of swallowing it, and brings on a violent spasm of the muscles of deglutition. A breath of cold air on the surface of the body causes a violent respiratory spasm or gasp. The centres in the cord are also irritated, as shown by the tendency to spasm of the muscles generally.

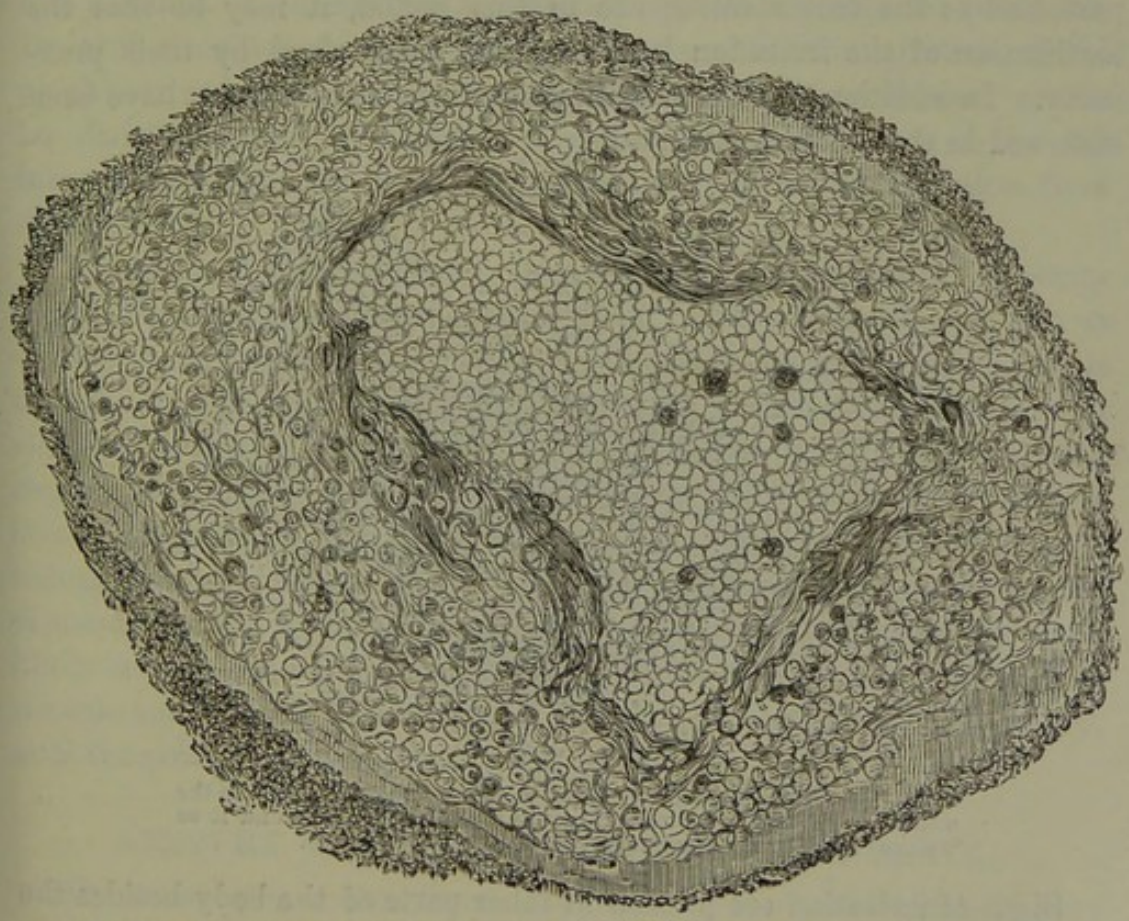


Fig. 218.—A blood-vessel from the medulla oblongata in a case of hydrophobia. Large numbers of round cells are seen in its sheath. × 350.

In this disease an irritating virus is present in the blood and induces these conditions of the nervous system. After death most manifest signs of irritation are visible on microscopic examination. They are to be found most characteristically in the medulla oblongata and next to

that in the spinal cord, but are not absent in the other parts of the nervous system. The most prominent condition is an accumulation of leucocytes around the vessels in the substance of the cord and medulla oblongata. There may be just a few leucocytes in the sheath, but from this there are all gradations up to a condition in which the vessel is clothed with a mantle consisting of many layers of leucocytes (Fig. 218). The leucocytes are also present elsewhere, and sometimes in such quantities as to have induced one observer to speak of the collections as miliary abscesses. This name is, however, objectionable, as there is no solution of the tissue such as is involved in the idea of an abscess. The leucocytes find their way into the pericellular spaces and are found keeping company with the ganglion cells in these situations. In the medulla oblongata the main nutritive vessels are towards the posterior part, and as the motor nuclei are in this region, it may be that the localization of the irritation here is partly determined by their proximity. In addition to these conditions minute hæmorrhages have been observed in the medulla and cord.

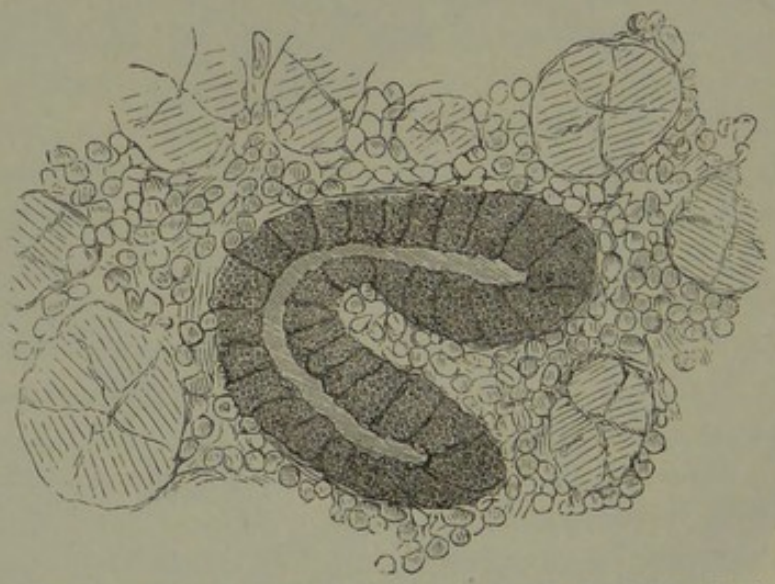


Fig. 219.—From the salivary gland in a case of hydrophobia. In the middle is portion of a duct; abundant round cells surround it as well as the glandular structures, shown in outline. × 350.

Signs of irritation are present in other parts of the body besides the nervous system. The salivary glands have been found to present abundant leucocytes between the glandular elements (Fig. 219). In the kidneys also there are signs of irritation in the form of dilatation of vessels and hæmorrhage.

It is clear then that here an intense irritant is circulating in the blood, and the intensity of it may be judged from the fact that all

these very marked appearances occur within two or three days of the onset of the nervous symptoms.

TETANUS.—In this disease we have another example of an intense irritation of the spinal cord and medulla oblongata. There is here violent spasm of the muscles, but those under the control of the medulla oblongata are not so specially involved as in hydrophobia, although the person frequently dies from spasm of the muscles of respiration.

Here again there are signs of irritation discoverable in the spinal cord and medulla oblongata, although they are very different from those in hydrophobia. In tetanus the most prominent and constant appearance suggests the exudation of fluid from the vessels. The fluid sometimes collects around the vessels and, as in hardened specimens the albumen is coagulated, a granular appearance may be produced. In other cases it looks as if the fluid produced a disintegration of the neighbouring nervous tissue, the appearance being that of the "granular disintegration" of Lockhart Clarke. The localization of the disintegration around the vessels suggests its origin in an exudation from them.

The cause of the irritation in tetanus is not at all clear. It seems likely, however, that here also there is an irritant in the blood, just as there is in hydrophobia. In both of these diseases the temperature is elevated, and, especially in the case of tetanus, reaches sometimes a most startling height (110° F.). It is difficult to account for this extreme rise of temperature by the muscular spasm, though the possibility of this explanation is not to be absolutely denied. It seems more probable, however, that an irritant acting to some extent generally on the tissues is the cause of the elevation of temperature. This is the more likely because tetanus has been known to occur in epidemics, and because if a case survives eight days there is considerable probability of recovery, as if the poison ran its course in that period.

ATROPHY AND DEGENERATIONS OF THE BRAIN.

There are cases of CONGENITAL ATROPHY of the brain which is very commonly partial. It may be of one cerebral hemisphere or of the cerebellum. An interesting case of the latter kind has been recorded by Fraser in which there were striking symptoms of ataxia due to a congenital smallness of the CEREBELLUM. From the existence of similar symptoms in another member of the same family it was inferred that she also was the subject of a similar affection.

The brain frequently atrophies in old age—SENILE ATROPHY. There is usually a general shrinking of the brain substance, but this may be greater in some parts than in others. The loss of substance is made up partly by thickening and œdema of the soft membranes, such as have been already described as occurring in general paralysis, and partly by thickening of the skull.

Of the more definite DEGENERATIVE CHANGES it is not necessary to give here a detailed account, as they have mostly been incidentally referred to.

The WHITE SUBSTANCE of the brain undergoes a process of atrophy under various circumstances—in softening of the brain, in sclerosis, etc. It also presents a condition which Lockhart Clarke has designated GRANULAR DISINTEGRATION. This occurs in the neighbourhood of blood-vessels, and is probably due to exudation from them. The white substance degenerates into an indefinite granular material.

The GANGLION CELLS are frequently the seat of atrophy and degeneration. They may undergo a SIMPLE ATROPHY, shrinking and losing their processes. But very commonly the atrophy is accompanied by pigmentation, and so a PIGMENTARY DEGENERATION is the result. Virchow was the first to describe a CALCIFICATION of the ganglion cells. This condition seems to be of frequent occurrence when these cells are suddenly deprived of vitality. It was found by Virchow originally in cases of commotio cerebri, but has since been seen in softening of the brain, in acute poliomyelitis anterior, etc. The ganglion cells, having died and having undergone coagulation-necrosis, become infiltrated with lime like other dead structures. A HYALINE or COLLOID degeneration of the ganglion cells has also been described, especially in cases of insanity.

SYPHILIS OF THE BRAIN AND ITS MEMBRANES.

Syphilitic lesions affecting the encephalon are of considerable frequency, and hence of great importance. For convenience of description we shall divide the lesions into three, although it is to be understood that these are often coincident in the same case. We shall consider, first, the syphilitic gumma; next, syphilitic disease of the cerebral arteries; and, lastly, syphilitic inflammations. In this description the brain and its membranes will be considered together, inasmuch as the lesions, being almost entirely of the surface, frequently involve both brain substance and membranes.

The GUMMA occurs either as a greyish tumour of soft consistence and transparent gelatinous appearance, or as a yellow mass of hard consistence and opaque cheesy appearance. These two forms are not absolutely separate in their occurrence, and it is probable that the cheesy form is due to metamorphosis of the grey transparent. In correspondence with this the grey form presents, under the microscope, masses of well-formed round cells, often with some admixture of the tissue in which the tumour is growing; in fact the tumour consists of fresh granulation-tissue like other recent gummata. It is never distinctly circumscribed, but merges at its margins into the surrounding tissues, in which masses of round cells may be found for some distance outside the tumour. The grey tumour may be interspersed with yellow cheesy parts, which are clearly older.

The yellow cheesy form is more frequently a defined tumour, and has commonly a peripheral zone of grey tissue. This form presents a very miscellaneous structure, the cheesy part consisting of shrunken cells, fatty debris, fat crystals, masses of blood-pigment, with, it may be, some remains of the original tissue in the form of irregular fibres, etc.

These tumours are met with chiefly in the dura mater or in the soft membranes. In the DURA MATER we sometimes see tumours of considerable size, as large as a pigeon's or even a hen's egg. The tumour grows in the substance of the dura mater, and is nearly always of the yellow caseous form; it is distinctly defined, and the dura mater around it is greatly thickened. These tumours occur in all regions of the dura mater, but they attain to the largest size commonly in the duplicatures, such as the falx cerebri. They press on the brain within and the skull without, but their chief effects are in the latter direction. They produce erosion of the internal surface of the skull, so-called DRY CARIES.

Of even greater importance than these are the gummata of the SOFT MEMBRANES, because they have a much greater effect on the brain itself. It may here be said that the great majority of gummata of the brain itself are at the surface, and really originate in the soft membranes, the pia mater or the arachnoid. Tumours of this kind occurring on the convexity present the appearance of great matting and thickening of the entire membranes, the dura mater being adherent over the place so that it cannot be separated. In the midst of the matted tissue is found the tumour or tumours, recognized by their yellow cheesy appearance. The tumour is seen on section to involve the brain substance

which is partly replaced by its tissue. Around the tumour the brain substance is softened, and this softening may extend widely outside the growth. When seated over the convexity, the tumour will, of course, involve the grey substance of the surface of the convolutions.

When the growth occurs at the base of the brain, the dura mater is less commonly affected, and we more frequently have the grey transparent form of gumma. The tumour is peculiarly prone to occur about the optic chiasma, the crura cerebri, and the pons. Here also it grows into the brain substance, working it up, and it may in like manner attack the cerebral nerves as they issue from the brain. The nerves most frequently affected are the optic, and those issuing from the peduncles and pons (the third, fourth, and fifth).

It has been already stated that inflammation and thickening of the membranes occur around the gummata, but sometimes a condition exists which may be designated a GUMMATOUS MENINGITIS. The gummatous tissue is formed more diffusely in the form of a grey gelatinous layer, covering a considerable surface at the base or on the convexity. In the former case there may be some resemblance to tubercular meningitis. In the latter, the whole membranes are thickened and matted together by gummatous tissue, and the brain substance beneath is softened. If under treatment, or otherwise, the proper gummatous tissue disappears, then the thickened membranes may present the appearance of an old simple inflammation.

Gummata of the brain substance proper are of the rarest occurrence, if we exclude those which have some connection with the surface, and may have originated from the soft membranes. Of the very few cases recorded, there are even some where the conditions were ambiguous.

SYPHILITIC DISEASE OF THE BLOOD-VESSELS, although not confined to those of the brain, is most frequent and most characteristic in them (see p. 361). The condition somewhat resembles atheroma, but presents certain distinct differences. The lesion may occur in the vessels near a gumma, but also independently and at a distance. It is noted that at a certain spot the vessel has become more opaque and greyish white in colour. Its wall in the affected part is firmer, so that instead of the vessel being flattened as usual it preserves a cylindrical shape. The part also feels hard and resistant. On section it is seen that the calibre of the vessel is greatly reduced by a new-formation in its wall. This new-formation has a greyish or whitish colour, and is of dense, almost cartilaginous, consistence. The reduction of the calibre varies, but it may go on to

nearly complete occlusion. The narrowed portion may become the seat of a thrombus which may complete the obstruction. The new-formation has its seat in the internal coat of the artery, and (according to Heubner, whose description in Ziemssen's *Handbuch* is here followed) especially between the elastic lamina and the endothelial layer. There is first a germination of the endothelial cells, which form a firm connective tissue containing spindle and stellate cells. There is also a formation of granulation-tissue in the wall, as in the gumma. This new-formation extends along the vessel as well as inwards, and involves communicating branches. It is clear that this disease must often by narrowing, with or without thrombosis, lead to complete, or nearly complete, occlusion of the artery, the natural result being softening of the brain in the region of distribution. Heubner has pointed out that the disease most frequently affects the carotid and its branches, especially the middle cerebral, so that this softening is most commonly in the same region as that from embolism. It has been noted above that softening of the brain occurs around gummata, and in that case it is largely the result of this disease in the arteries.

This form of disease of the arteries is to be distinguished from atheroma, chiefly from its occurrence in connection with other manifestations of syphilis. It also occurs in younger persons, and may be in single patches, while atheroma is prone to affect many vessels.

INFLAMMATION OF THE MEMBRANES in syphilis occurs mainly in connection with gummata. Cases have been recorded of inflammation without gummata and their occurrence is not to be denied, but there is often the possibility of gummata having previously existed, and been removed perhaps by treatment.

In connection with the symptoms due to syphilitic lesions of the brain it is important to remember the LOCALIZATION OF THESE LESIONS. The gummata and resulting inflammations of the convexity, occurring as they do on the surface, will, at first, irritate the surface of the convolutions. If a motor part be affected then there will be muscular spasm, often progressing, and ending perhaps in general convulsions of a quasi-epileptic character. Any sort of local spasm may be produced according to the particular part irritated. If the lesion be over a sensory part there will be subjective sensory impressions. We have already seen that the brain substance commonly gets involved in the gumma, and that outside it there is also softening of the brain. This destruction of

brain substance involves loss of function, namely, paralysis or loss of sensation; but there will still be irritation of the marginal parts, and though paralyses and anæsthesiæ may develop, the signs of irritation generally remain prominent. At the base the gumma is very apt to involve motor tracts. The motor fibres of the pons and peduncles are anterior, and are therefore more exposed to the inroads of the tumour. But these paralyses are apt to be complicated by the lesion extending to the cerebral nerves which issue here, mainly the optic, third, fourth, and fifth, and so we have very complex conditions brought about, such as crossed paralysis, etc. Again, the syphilitic disease of the arteries occurs most frequently in the carotid and middle cerebral, and the resulting softening is usually most manifest in the region of the corpus striatum and motor convolutions. In this way a hemiplegia may be produced which imitates that from embolism. It will be seen that a great variety of symptoms may be produced from syphilitic lesions of the brain and its membranes.

TUMOURS OF THE BRAIN.

Tumours are of very frequent occurrence in the brain substance, and are of great importance in a practical point of view. In examination of the brain particular attention should be directed to the exact locality of the tumour, and the extent to which the brain substance is involved in it.

A tumour nearly always induces inflammation of the brain substance around it. If it be of rapid growth there is softening, but if slow in growth then there is sclerosis from chronic inflammation. In the latter case the tumour will often at its margin merge gradually into condensed connective tissue. The tumours very often lead to the occurrence of hydrocephalus, which will come up for consideration afterwards. They also lead usually to optic neuritis when they have induced considerable increase of the intracranial pressure. The neuritis is localized in the intraocular termination of the nerve, where it gives rise to the characteristic "choked disc" or "engorged papilla."

THE SCROFULOUS TUBERCLE is the commonest tumour of the brain. It occurs most frequently in young persons and is often multiple. We have seen that tubercles occur in the form of minute round tumours, but here in the brain substance we have solid tumours of a size increasing up to that of a hen's egg. These massive

tumours are of course composed of myriads of tubercles, with the products of their degeneration. The greater part of the tumour is made up of a firm caseous mass, which resembles very closely in appearance a scrofulous gland. Sometimes the cheesy mass is directly continuous with the brain substance, but usually there is a transparent grey zone outside it, and this gradually merges in the brain substance around. This grey zone, when it exists, indicates that the tumour has been growing up till death, and is often distinctly composed of tubercles of characteristic form. Sometimes there are no rounded tubercles in it, and it forms simply a cellular zone. The grey tissue gradually merges in the brain substance, and both it and the brain substance show inflammatory conditions characterized by the presence of multitudes of round cells. The solitary tubercles are met with in all parts of the brain and spinal cord, but are peculiarly frequent in the cerebrum and cerebellum. In these they show a preference for the cortical substance, but in the case of the latter they may grow to such a size as to replace almost the entire substance of one lobe.

The GLIOMA is also a somewhat frequent tumour. It sometimes grows to a large size and is usually of slow growth. In its general



Fig. 220. From a glioma of the brain. The coarse fibrous structure with a few cells is shown. × 350.

appearance it resembles brain substance, and as it commonly replaces a piece of brain and merges into the brain substance at its

margin, it may be difficult to make out its limits accurately, and it may appear as an enlargement of a part of the brain. Two forms of glioma have been distinguished, a *hard* and a *soft*. The variations in consistence depend largely on the character of the matrix of the tumour. It may be composed chiefly of stiff thick fibres (as in Fig. 220), in which case the consistence will be dense, or of a delicate network, when the tissue is soft. The cells are of small size and mostly round, and they present considerable variations in abundance. In the softer forms the cells are generally numerous. Sometimes there is an excessive development of blood-vessels, in which case there is a tendency to hæmorrhage. If death occur from the hæmorrhage the appearances may resemble those of ordinary cerebral hæmorrhage, the tumour broken up by the clot resembling the broken-up brain substance. The substance of the glioma not infrequently undergoes fatty degeneration and a cheesy appearance is produced. When hæmorrhage occurs the clot may also assume a cheesy appearance. In this way very varied and peculiar appearances may be produced.

The MYXOMA occasionally occurs in the brain, but is more frequent on the peripheral nerves. It is a soft tumour of a transparent glancing appearance, and by still further softening may become cystic.

SARCOMAS are of considerable frequency, and are of various structure. There are sarcomas allied to the glioma and others to the myxoma, and so we have glio-sarcomas and myxo-sarcomas, the difference being mainly in the character of the intercellular substance. In the myxo-sarcoma the cells are round, and the tumour very soft. In the glio-sarcoma the cells may be round or spindle-shaped, and the tumour soft or hard.

CANCERS will hardly occur in the brain, except by extension through the skull from the skin.

PAPILLOMA sometimes occurs as an outgrowth on the surface of the ventricles.

OSTEOMAS are very rare, but true bony tumours have been found, one occupying almost the entire cerebellum.

THE LIPOMA is excessively rare.

CYSTS may arise from the myxoma, or may possibly originate more independently. Dermoid cysts have been observed.

PARASITES.

The CYSTICERCUS of the tænia solium has occasionally its seat in the brain, mostly in the cortical portions, but it may be in any situation.

It forms a small round structure enclosed in a connective-tissue capsule. Inside this the proper stratified membrane of the parasite, with the head and other structures, are to be found. Sometimes the parasite is dead and calcified. As a rule it produces little disturbance, and is often found by accident after death. If situated in the peduncular portions it may produce serious symptoms, but even here its slow growth and small size generally allow of accommodation. Sometimes several cysticerci, as many as 10 to 20, have been found.

The ECHINOCOCCUS sometimes develops in the brain, but has usually been found by accident on post-mortem examination.

C.—THE MEMBRANES AND CAVITIES OF THE BRAIN AND SPINAL CORD.

INTRODUCTORY CONSIDERATIONS.—The dura mater is a dense connective-tissue membrane which is more intimately connected with the bone than with the brain and spinal cord, forming something like a periosteum to the bone. It is generally said that the dura mater is lined with arachnoid membrane, one layer of arachnoid covering the brain and cord and another the dura mater. It is thus customary to speak of the arachnoid sac as of the pleural sac, and of a visceral and a parietal layer. But these analogies are contradicted by pathological experience. There is no fine membrane lining the dura mater, and the arachnoid membrane covering the brain has almost nothing in common with the dura mater in its diseases. We are accustomed to acute inflammations of the pleural and other serous sacs, in which the whole sac, including both visceral and parietal layers, takes part, but there is hardly such a thing as an arachnitis involving surface of brain and internal surface of dura mater. On the other hand the arachnoid and the pia mater go together in their inflammations, and it is better to speak of the dura mater as one membrane and the pia-arachnoid as another. It will be proper also to speak of the arachnoid cavity as the cavity of the dura mater or subdural space, just as we speak of the subarachnoid space.

The SUBARACHNOID SPACE contains the cerebro-spinal fluid, which appears to circulate somewhat freely on the surface of the brain and

spinal cord. It is important to notice the connections of the subarachnoid space, as it, with its connections, forms a large communicating system of lymph spaces, and may be almost compared with a serous cavity. The subarachnoid space, lying between pia mater and arachnoid, is intersected by trabeculæ. The pia mater and arachnoid become incorporated over the summits of the convolutions, so that it is only in the sulci that there is any space. The pia mater is prolonged into the lateral ventricles, forming the supporting structure of the choroid plexus, and the subarachnoid tissue is also continued, so that the ventricles communicate here with the subarachnoid space. There is a still freer communication by means of the foramen of Majendie at the fourth ventricle. The subarachnoid space and the ventricles of the brain with the central canal of the spinal cord thus form a continuous system of lymph spaces, and the cerebro-spinal fluid circulates in them. In addition to this, the subarachnoid space communicates with lymph spaces around the vessels and ganglion cells, the perivascular and periganglionic spaces. It is important to observe that the subarachnoid space does not communicate with the subdural space.

MENINGEAL HÆMORRHAGE.

The HÆMATOMA OF THE DURA MATER is a condition concerning which considerable differences of opinion exist. It presents itself mostly in the form of a somewhat massive blood-clot covering the internal surface of the dura mater and compressing the brain substance. When the clot is more particularly examined it is seen to be not exactly free on the surface of the dura mater, but covered with a delicate membrane, which is continued beyond the clot on the surface of the dura mater as a thin soft layer. This membrane generally has a brownish colour, evidently from the blood-colouring matter, and it presents in its substance, as well as between the membrane and the dura mater, numerous smaller hæmorrhages. This condition is of somewhat frequent occurrence, particularly among the insane.

There are two views as to its true nature, and it is quite possible that there may be actually two diseases. According to one view, a hæmorrhage into the cavity of the dura mater is the primary condition. It is undoubted that a hæmorrhage may lead to a condition resembling that described. In a case of aneurism of one of the larger cerebral vessels, where bleeding had occurred into the subdural space some time before the fatal cerebral hæmorrhage, the

author found a layer of soft tissue covering the dura mater and having much of the characters described above. In this and similar cases the coagulum on the surface of the dura mater becomes organized in the usual way, and vessels pass from the dura mater into the rudimentary tissue thus produced. These thin-walled vessels are specially apt to bleed for reasons to be presently referred to, and so there is hæmorrhage in the new-formed tissue and under it.

But many cases have a more spontaneous origin, and agree with the description which Virchow has given of HÆMORRHAGIC PACHYMENINGITIS. This disease begins in an inflammation of the dura mater, characterized by hyperæmia. The inflammation being chronic, the result is the formation of a soft membrane on the internal surface of the dura mater, owing to an inflammatory transformation of its internal layer. In its structure this membrane somewhat resembles mucous tissue, containing stellate and spindle-shaped cells in a matrix which gives a precipitate with acetic acid. In it there are large thin-walled blood-vessels in large numbers. The false membrane is easily lifted from the dura mater with forceps, and as this is being done numerous red threads are seen to stretch from it to the dura mater: these are the blood-vessels.

An explanation of the large size and tendency to rupture of these vessels has been suggested by Rindfleisch. To begin with, there is hyperæmia of the dura mater with relaxation of the arteries. The normal capillaries being in a dense tissue will not dilate much, but the blood in them will be at a high pressure. The new-formed vessels, however, are delicate and lie in a soft tissue, and they communicate with the capillaries of the dura mater in which the blood-pressure is excessive. They are therefore very liable to dilatation, and although they have the structure of capillaries they are mostly three or four times as wide as ordinary ones. These vessels often rupture, so that there is frequent hæmorrhage into the soft membrane. But sometimes a more considerable hæmorrhage occurs, and the blood accumulating dissects up the membrane from the dura mater, rupturing fresh vessels as it advances. In this way a large flat clot as thick as the hand may be formed, the proper hæmatoma. It will be observed that this clot is still covered with the membrane, and it is quite unusual to find the blood escaping into the cavity of the dura mater.

If a fatal hæmorrhage does not occur, the new-formed membrane undergoes organization in the way of other inflammatory structures. It becomes more cellular and finally develops into connective tissue which

coalesces with that of the dura mater. The disease, however, is apt to recur, and a fresh soft layer is formed which goes through the same stages, so that there may be several layers in different stages of transformation on the surface of the dura mater, the innermost layer having the characters described above.

This condition occurs chiefly over the convexity of the brain, and is stated to be mainly in the domain of the middle meningeal artery. An acute suppurative inflammation very rarely develops in connection with the hæmatoma.

HÆMORRHAGE IN THE SOFT MEMBRANES is of comparatively trivial consequence. We have seen that in the case of rupture of aneurisms of the larger cerebral arteries blood passes into the subarachnoid space, but usually for a short distance only, the many septa apparently preventing the extension of the blood, which finds much freer access towards the brain. There may be hæmorrhage also in consequence of injuries, whether accompanied by definite wounds or fractures, or only by violent shaking of the brain. Hæmorrhages have also been observed in splenic fever and ulcerative endocarditis.

INFLAMMATIONS OF THE MEMBRANES.

The INFLAMMATIONS OF THE DURA MATER are not very important if we exclude the hæmorrhagic form described above. ACUTE SUPPURATIVE INFLAMMATION is always secondary, occurring in connection with wounds of the head, disease of the bones, especially caries, and thrombosis of the sinuses. The dura mater is softened and infiltrated with pus and portions of it often slough.

SIMPLE ACUTE MENINGITIS.—This name is applied to non-specific inflammations of the pia-arachnoid. If it be desired to distinguish it from inflammation of the dura mater it may be named LEPTOMENINGITIS. Some irritant obtains access to the membranes, and as it is carried by the circulating cerebro-spinal fluid the inflammation is usually of a spreading character. The cases are frequently traumatic and the irritant is septic in nature; they may be due to extension from disease of the bones, and in these cases the meningitis may be associated with abscess of the brain. There are, however, cases in which the disease has its starting point in a simple blow with commotio cerebri without any external wound, and there are even

some in which no cause is discoverable, but these form rare exceptions.

In the milder cases there may be simply a serous exudation in the subarachnoid space, constituting an inflammatory œdema. But in most instances the case goes on till pus, or pus with fibrine, is exuded. The first appearances are visible in the neighbourhood of the veins, in the sulci between the convolutions. Very often there is a white or yellow band visible on either side of the vein, and this consists of accumulated leucocytes, it may be with fibrine. As the exudation increases the veins become buried in it, and the whole subarachnoid space becomes filled. The spaces being filled out the pia-arachnoid forms a bulky solid layer which may be separated from the surface of the brain, and form a mould of the convolutions on its under surface. The inflammation extends in some measure along the perivascular spaces into the superficial parts of the brain substance. This is important in relation to the symptoms, which are often those of irritation of the cortex of the brain.

The inflammation usually begins in a particular locality, generally some part of the convexity, and here the arachnoid and the dura mater are sometimes united by fibrinous exudation. It spreads from this, generally confining itself to the convexity, but sometimes it extends to the base, or to the spinal cord, or even into the ventricles.

Simple chronic meningitis of the brain and spinal cord is usually secondary. There are thickenings and adhesions of these membranes in different forms of insanity, in diseases of the bones, in the various scleroses of the cord, especially posterior sclerosis. It is important to remember that a chronic inflammation of the membranes of the cord may be propagated from the peripheral nerves along their sheaths.

Epidemic cerebro-spinal meningitis.—As the name implies, this is a disease which, like the acute fevers and hydrophobia, depends on a virus introduced into the body. The morbid poison shows a special affinity for the meninges of the brain and spinal cord, although other organs are also in a minor degree affected.

The soft membranes present evidences of acute inflammation at first in the form of serous exudation with few leucocytes and red corpuscles. This condition is only seen in cases which have died very early after the onset of the disease, and soon the exudation takes on a purulent

character as in simple meningitis. The exudation is here also in the subarachnoid space, and penetrates along the sheath of the nutritive arteries into the nervous tissue beneath. There is very seldom any exudation on the surface of the arachnoid, and the dura mater hardly ever takes part in the disease. The exudation is most marked in the sulci between the convolutions of the convexity, in the fissure of Sylvius, on the surface of the pons, and upper surface of the cerebellum. In the spinal cord it is most abundant in the lumbar region, and is almost confined to the posterior surface where it often surrounds the posterior roots.

The disease is fatal in over 50 per cent. of the cases, but when recovery occurs it is usually complete. Sometimes, however, there is permanent damage to the nervous structures, as evidenced by deafness, etc.

TUBERCULAR MENINGITIS (*Basal meningitis, Hydrocephalus acutus*).—This disease, as the name implies, depends on the presence in the meninges of the tubercular virus. In the large majority of cases the disease is simply part of a GENERAL TUBERCULOSIS, the virus being in the blood. There are disseminated tubercles in other organs, as the lungs, liver, kidneys, but the affection of the meninges produces such pronounced symptoms that it monopolizes the attention especially of the clinical observer. The meninges are affected more frequently in the general tuberculosis of children than in that of adults; it thus seems as if the soft membranes in children were more adapted to the growth of the virus. Hence *water in the head* is counted rather a disease of children. But tubercular meningitis is more frequent in the adult than is usually supposed, and many obscure head cases are found post mortem to be cases of general tuberculosis with, it may be, a very limited meningitis.

When not connected with general tuberculosis, tubercular meningitis is for the most part connected with solitary tubercles in the brain, although this is by no means a frequent association.

The virus reaching the meninges by the blood, lodges in the lymph spaces of the membranes, and produces inflammation and tubercles in the walls of the finer arteries of the pia mater, and in the subarachnoid space. These conditions are peculiarly localized in the basal parts of the brain, although extending sometimes to the lateral aspects and to the spinal cord. It may be that this is related to the fact that the arteries are distributed from the base, or, more probably, that the

cerebro-spinal fluid stagnates here more than elsewhere, and allows of the growth of the virus.

The APPEARANCE OF THE BRAIN on post-mortem examination is somewhat as follows. On removing the dura mater, the cerebral hemispheres are generally seen to be fuller than usual, and the surface of the arachnoid is somewhat dry and glazed. This is due to the pressure from the ventricles, which are distended with fluid, usually clear serum, but sometimes slightly turbid with pus. The amount of fluid is sometimes very great, and this prominent feature gave rise to the name ACUTE HYDROCEPHALUS being applied to this disease. In the neighbourhood of the lateral ventricles, and especially posteriorly, the brain substance is soft and almost diffluent (white softening). On exposing the base of the brain, the appearances of inflammation in the membranes are to be looked for. These are often somewhat obscure, and in appearance trivial. In the slighter cases they consist merely of a turbidity or opacity over the pons and optic chiasma. The subarachnoid space is occupied by a serous exudation with some pus, giving often a greenish colour. But usually the exudation is much more abundant and covers the basal structures, extending to the surface of the cerebellum, and up the fissure of Sylvius, where it often reaches the lateral aspects of the hemispheres. The concentration of the exudation at the base is of great importance, and the covering-in of the optic chiasma is often the most direct and sometimes the only prominent sign of the existence of the disease.

The evidences of inflammation are much more prominent to the naked eye than the tubercles. These are often only distinctly visible on microscopic examination, as they are so much buried in the exudation and attached to such small arteries. On opening up the fissure of Sylvius, however, where the exudation generally glues the opposed surfaces of the brain together, it is usually possible to see the little white tubercles, often no larger than pin's heads. If a piece of the soft membrane be removed, however, even from a part where the exudation is very abundant, and examined with a low power under the microscope, the tubercles are readily seen as spindle-shaped prominences on the small arteries (see Fig. 221). These are seated in the adventitia, and are often somewhat ill-defined at their periphery on account of the inflammatory exudation.

The exudation, and perhaps the tubercles also, extend along the sheaths of the nutritive vessels into the substance of the brain and spinal cord, as well as into the cerebral nerves. The superficial parts of

the brain substance in particular are hyperæmic, and not infrequently the seat of small hæmorrhages.

The dropsy of the ventricles, which is such a prominent feature in this disease, will be considered afterwards in the section on hydro-

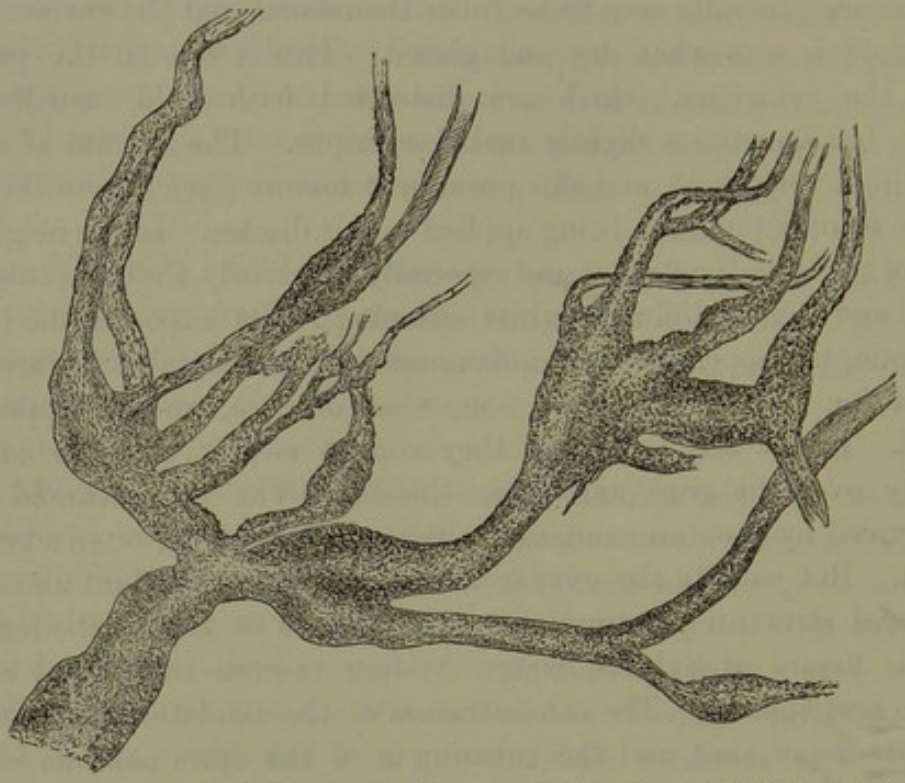


Fig. 221.—Arteries of the pia mater in a case of tubercular meningitis. The frequent spindle-shaped swellings indicate the position of the tubercles. × 16.

cephalus. The WHITE SOFTENING of the parts around the ventricles has given rise to some discussion as to its cause. It may extend somewhat deeply into the brain substance, involving fornix, septum lucidum, corpus callosum, and even the thalamus opticus and corpus striatum, and it is sometimes so extreme as to reduce the tissue to the consistence of thick cream. It is clear from the comparative absence of symptoms that this extreme softening does not exist during life. Probably the fluid in the ventricles macerates and loosens out the brain tissue without interrupting the functions, and after death a more pronounced softening occurs. The condition is not an inflammatory one, and it occurs mainly where the fluid gravitates, namely, in the brain substance around the posterior parts of the ventricle.

ACCUMULATION OF THE CEREBRO-SPINAL FLUID IN THE MEMBRANES AND CAVITIES.

It has been already pointed out that the subarachnoid space, with the ventricles and central canal of the spinal cord, form a single system of lymph spaces which intercommunicate. The lymph in these spaces may accumulate, and so lead to various forms of œdema and dropsy of the brain. In this connection it is important to remember that the skull is a closed cavity, and any increase in the fluid in these spaces implies a decrease in the quantity of blood in the vessels or of the brain substance itself.

There may be a GENERAL ŒDEMA of the membranes and spaces, perhaps including the perivascular spaces in the brain substance. This may take place in Bright's disease, and may occur along with an œdema of other parts, or develop in a more isolated manner. The pressure of the fluid in this case has been supposed by some to be the cause of the symptoms usually called uræmic.

Then there is an ŒDEMA EX VACUO. When the brain shrinks, as we have seen in GENERAL PARALYSIS, or when it undergoes a more simple atrophy as in SENILE ATROPHY, there is a serious loss of substance. The latter condition may be extreme in very old persons, although the brain does not usually atrophy in proportion to other tissues. The loss of substance thus produced must be compensated, and there are two ways in which this may be done, the one is by thickening of the cranium and the other by augmentation of the cerebro-spinal fluid. Thickening of the cranium takes place only to a limited extent, and the space is chiefly filled up by fluid. The ventricles dilate greatly (*hydrocephalus*), and the subarachnoid space is highly œdematous. It is to be particularly observed that there is seldom any excess of fluid in the subdural space, but that the soft membranes, especially between the atrophied convolutions, are highly œdematous.

HYDROCEPHALUS.—This name is applied to dropsy of the ventricles of the brain, and we have now to consider the condition as it occurs apart from œdema of the membranes. More strictly, dropsy of the ventricles is hydrocephalus internus, while a massive collection of fluid externally is hydrocephalus externus. But as the latter hardly occurs except as an œdema, the name hydrocephalus is usually limited to the former. In a similar sense the term hydrorhachis is used for the spinal cord, hydrorhachis interna being a dropsy of the central canal and hydro-

rhachis externa a dropsical accumulation in the subarachnoid spaces. We shall consider first some of the more easily explainable cases of hydrocephalus.

ACQUIRED HYDROCEPHALUS.—Apart from the form *ex vacuo*, hydrocephalus as met with in the adult is mostly related to a definite disturbance of the circulation in the brain. The ventricles are supplied with fluid chiefly through the choroid plexus, and any obstruction to the veins here is liable to lead, on principles already considered, to an excessive exudation. It seems also as if the choroid plexus, with its villi, acted as a drain to the ventricles, the fluid passing into its lymph spaces, and so either into the veins or outwards to the subarachnoid space. If the veins are obstructed they can no longer aid in absorption, but on the contrary their obstruction causes, as we have just seen, excessive transudation from the capillaries. Again, if the lymphatic vessels and spaces are filled up, this will interfere with the absorption, so that dropsy may arise in this way. We have therefore two classes of cases, one in which the veins, and another in which the lymph spaces are obstructed.

The veins of the choroid plexus gather themselves into the great VEINS OF GALEN, which pass outwards between the corpus callosum and corpora quadrigemina to open into the straight sinuses. In cases of obstruction of these veins there may be a rapid accumulation of fluid in the ventricles, and death may even result from the sudden increase of intracranial pressure. These veins may be obstructed by pressure from without, especially by tumours of the cerebellum, or by thrombi occupying their calibre. In most cases the thrombus originates in the sinuses, and grows into the veins of Galen, but Newman has recorded a case in which these veins alone seemed to be the seat of thrombosis.

In TUBERCULAR MENINGITIS hydrocephalus is nearly constant, but it is rather difficult of explanation. Tubercles are generally found on the vessels of the choroid plexus, but the exudation in the ventricles is rarely inflammatory in character, consisting of a clear pellucid fluid with little albumen, and a specific gravity of about 1010. The explanation is probably to be found in the exudation outside the ventricles. This is generally abundant where the velum interpositum issues from the ventricles just in front of the cerebellum, and here, besides filling up the lymph spaces, it is liable to cause pressure on the veins of Galen as they pass through the comparatively narrow isthmus. This is the more likely to produce hyperæmia and exudation from the veins that the

arteries reach the plexus by a different route, and are not so liable to be pressed on.

CHRONIC HYDROCEPHALUS.—This name is given to a condition which is very frequently CONGENITAL; if not congenital, it sets in at an early period after birth. The explanation of the enormous accumulation of fluid which occurs here is very obscure. As a rule, no mechanical cause is discoverable obstructing the venous circulation, although there are cases of solitary tubercle obstructing veins in children and producing what is really an acquired hydrocephalus. It is said that chronic hydrocephalus often goes along with rickets, and it has been suggested that as a rickety skull is more yielding than a normal one, too little pressure is exercised on the brain, and the accumulation of fluid is allowed. This is not, however, a sufficient explanation, especially of the severe congenital cases. The probability is that the disease depends on a congenital defect in the apparatus for the secretion and absorption of the cerebro-spinal fluid.

The dropsy affects mainly the lateral ventricles, but may extend to the others. Sometimes the ventricle of the septum lucidum is obviously distended as it lies between the two lateral ventricles. The convolutions are flattened out, and as the accumulation increases they may be completely unfolded, the brain forming a smooth globe over the greatly distended ventricles. If the disease has begun early in fœtal life, the brain may be deficient in some of its parts. The distension may be so great as to cause thinning of the covering brain substance to an extraordinary degree, leaving little between the pia mater and the fluid. The surface of the ventricles (ependyma) is usually somewhat thickened, giving a kind of leathery membranous lining to the cavity. In this respect the condition differs markedly from that in acute hydrocephalus, although in the chronic form there may be considerable softening of the brain substance outside the ependyma. In some very rare cases the corpus callosum and its pia-arachnoid have given way, the fluid coming thus to the surface and filling the cavity of the dura mater. In that case the hemispheres are folded aside, and the central parts of the brain are exposed, the brain being as a whole pressed down towards the base.

With this great enlargement of the ventricles the head is greatly enlarged, and as the bones are more yielding in some parts than others, an alteration in shape occurs. The fontanelles and sutures are enlarged and their closure greatly delayed. The frontal bone is pushed forward so that the forehead rises perpendicularly, or overhangs the eyebrows; the parietals bulge laterally, and the occipital bones are pushed back-

wards. The head in this way becomes greatly increased in circumference, while it is usually much flattened at the vertex. The bones of the face, even though they are of normal size, look dwarfed beside the enlarged cranium, and have a pinched look. The eyeballs are rendered prominent by the pressure on the roof of the orbit, and enlarged veins are generally seen beneath the thin skin of the head.

Although there is this great thinning of the brain substance, it is remarkable how the functions may be retained. A child in this condition may remain very intelligent, and when recovery occurs may pass through life with no permanent defect in the functions of the brain. The yielding of the skull seems to prevent any such excess of pressure as to seriously damage the brain, which has a remarkable power of accommodating itself to alterations in position of its parts. If recovery takes place, the skull to some extent collapses, the fontanelles and sutures close, often with the formation of additional centres of ossification, forming Wormian bones in the sutures. But the fontanelles are late in closing, and the cranium retains somewhat of the hydrocephalic shape during life.

HYDRENCEPHALOCELE.—This condition is somewhat allied to hydrocephalus. There is here, however, a congenital defect in the cranial bones, and the sac of fluid protrudes externally. It may be only the membranes that protrude in the form of a sac filled with fluid (meningocele), or there may be also a layer of brain substance. Sometimes the external sac becomes separated from the structures inside and forms an independent sac. The usual situations of these tumours are the root of the nose, the occipital region, and (more rarely) the sagittal suture.

SPINA BIFIDA.—This condition is associated with or depends on hydrorhachis, but there is in addition a congenital defect in the spinal column, by reason of which a sac containing cerebro-spinal fluid is protruded externally. It thus forms a rounded tumour in the middle line of the back, situated, in the great majority of cases, in the lumbar or lumbo-sacral region, but occasionally at other levels.

The spina bifida seems to have its origin in a fœtal HYDRORHACHIS. The cerebro-spinal fluid accumulates either in the central canal or in the subarachnoid space, and a protrusion of the dropsical structures from the spinal canal takes place. It should be stated here that a hydrorhachis may occur after birth or even in the fœtus, without spina bifida, the central canal being distended, and sometimes forming

distinct cysts, or the subarachnoid space being in a dropsical condition.

When spina bifida arises from a hydrorhachis interna, the spinal cord is usually split posteriorly, so that the central canal is laid open and communicates with the surface of the cord. Sometimes instead of this there is great thinning of the cord which is spread over the dropsical cavity. The protruded sac in the case of hydrorhachis interna will consist of the pia-arachnoid and the dura mater. In the other form, when the origin is in hydrorhachis externa, the pia mater will be absent from the sac. But the membranes are often so matted as to be unrecognizable, and, on the other hand, the dura mater is often thinned and perforated.

The sac is generally protruded through the deficient arches of the vertebræ. But the arches, although completely formed, may not have united posteriorly, and there are even cases in which the protrusion is through the space between two arches. Outside the vertebræ the sac acquires a covering of skin, which is sometimes considerably thinned so that rupture may occur. The external tumour is usually sessile, in which case it communicates by a rather large aperture with the spinal canal. In other cases there is a narrow neck, and the tumour may be pendulous.

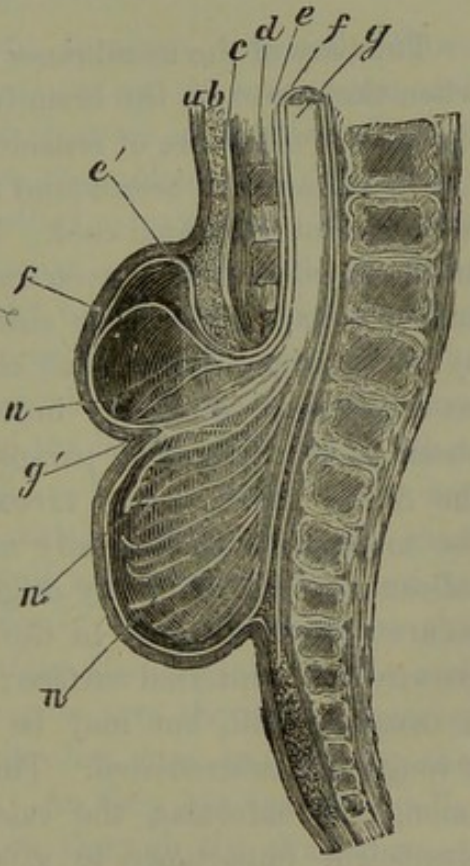


Fig. 222.—Section of a spina bifida of the lumbar region. *a*, *b*, cutis and subcutaneous tissue; *c*, fascia; *d*, spinous processes; *e*, dura mater, which passes into sac and becomes attached to the skin at *e'*; *f*, arachnoid, which passes into sac forming its internal lining; *g*, spinal cord, which also enters the sac and becomes attached to the skin *g'*, where it had a small opening; the attachment forms a dimple in the sac; *n*, *n*, spinal nerves which pass from the cord round to the anterior aspect of the sac so as to reach their normal places of issue from the spinal canal. (Virchow.)

The CONDITION OF THE CORD is of great importance in these cases. When the protrusion is in the sacral region, the filum terminale is often attached inside the sac giving it a central dimpling externally, and the spinal cord extends down into the sacrum as at the earlier months of fœtal life, as if held down by its attachment externally. When dropsy of the central canal has been the primary condition, we have already seen that the cord is usually split, but it may be largely

destroyed for some distance. Whatever the origin of the dropsy, the spinal cord is usually carried to some extent into the sac (Fig. 222), being apparently dragged inwards, either entirely or in some of its strands. The cord is mostly in that case firmly united to the wall of the sac. The nerves may issue from the cord within the sac, and in the case where the filum terminale is in the sac, the sacral nerves traverse the sac before passing to the intervertebral foramina.

TUMOURS OF THE MENINGES.

Tumours of the membranes of the brain are of importance especially when they press on the brain inside or on the nerves as they issue from the skull. They are of considerable variety.

FIBROMAS have been found arising from the dura mater both of the brain and of the spinal cord. In the latter case they are liable to press on the cord and may even interrupt it. In a case observed by the author a hard fibroma the size of a marble produced serious mischief by pressing on the cervical cord. The CHONDROMA has occasionally been observed, especially in the dura mater of the cord. In a dog observed by the author, paraplegia was produced by such a tumour in the dorsal region. The LIPOMA is a very rare form of tumour in the meninges; that already mentioned on the surface of the corpus callosum (p. 185) probably originated in the pia mater. The PSAMMOMA occurs not infrequently in the dura mater, where it forms a rounded growth on its internal surface; sometimes it is multiple. The tumour is usually small, but may be as large as a walnut, and its surface is rough and tuberculated. This form of tumour is sometimes classified among the sarcomas, the calcareous particles being regarded as of insufficient importance to give the name to the tumour; but the structure, apart from the lime deposits, is often that rather of a fibroma. The psammoma also occurs as a small soft tumour in the choroid plexus and in the pineal gland. In the latter case there may be a tumour of considerable size, whose structure is like that of the normal gland, and so the condition is sometimes designated HYPERPLASIA OF THE PINEAL GLAND. The OSTEOMA hardly occurs in the membranes as a distinct tumour, but it is common to find flat pieces of bone in the dura mater, especially in the falx and tentorium, and even in the arachnoid.

The PACCHIONIAN BODIES sometimes give origin to tumours which may grow to considerable dimensions. These bodies consist of papillæ

which spring from the arachnoid and project in various directions; some of them present towards the skull, where, after thinning the dura mater they cause pits; others project into the longitudinal sinus. Cleland has described two tumours of a papillary character which grew from the dura mater and pressed on the brain substance. Although one of these was situated in the falx, which does not normally present pacchionian bodies, yet the structure of the tumours conformed to that of these bodies. In that on the falx there were calcareous masses like those which characterize the psammoma. The tumours measured respectively two inches and one and a-half in diameter.

SARCOMAS are exceedingly important tumours, especially those of the dura mater. Most of these tumours are soft in consistence and contain chiefly round cells. Sometimes there is a distinct alveolar structure, and the cells have a distinct resemblance to epithelium, so that the tumours have been often described as CANCERS. There are even tumours remarkably like epitheliomas sometimes observed in the dura mater, but they are probably to be regarded rather as endotheliomas. The sarcomas generally present great malignancy. On the one hand they extend and involve neighbouring parts of the dura mater as well as the soft membranes and the brain; and on the other hand they press outwards to the skull, and may, after destroying the bone, work through to the external surface. These tumours have mostly their seat at the base of the skull and often lead to serious nervous lesions. They may involve directly such structures as the pons or medulla oblongata, the sarcomatous tissue growing into and replacing the proper structure; they also grow into the cranial nerves. By involving the bone and enlarging it, they may impinge on the foramina by which the nerves take exit. As they are seated usually at the base, they generally when they work through the skull present at the pharynx or nares.

Of the remaining tumours, the SYPHILITIC have been already considered (p. 469). Tubercular growths hardly ever occur except by propagation from disease of the vertebræ. DERMOID CYSTS of the dura mater have been observed in a few cases.

The ECHINOCOCCUS sometimes develops in the neighbourhood of the spinal canal, in the muscles or in the vertebræ. By enlarging it may extend into the canal, pushing the dura mater before it and compressing the cord. It has even been found to have its seat inside the dura mater. A few cases of CYSTICERCUS in the subarachnoid space have been described.

DISEASES OF THE ORGANS OF RESPIRATION.

A.—THE AIR PASSAGES.

WE have here to study the diseases of the nasal passages, the larynx, trachea, and bronchi. As these parts have much that is common in structure, their lesions have much similarity. This applies especially to the larynx, trachea, and bronchi, which are of essentially similar structure.

THE NASAL PASSAGES.

CONGENITAL MALFORMATIONS.—Such deformities as absence of the nose and its cavities, stenosis, and so on, are usually parts of a general malformation, and are not of importance in a practical aspect. In clefts of the lip and palate, the nasal cavities are in communication to a greater or less extent with the mouth. This communication renders the mucous membrane of the nares liable to inflammation. Normally, the nasal passages are protected against any irritation except that of the air passing through them, and the mucous membrane is correspondingly sensitive. We know how the accidental passage of a piece of solid food into the nares causes great irritation, and we shall afterwards see that the existence of a foreign body in the nares is a frequent cause of prolonged catarrh. In cases of cleft palate the food and secretions of the mouth readily pass into the nares and, although a certain tolerance may be established, persons so affected are peculiarly liable to catarrh of the nares.

ACUTE CATARRH.—This is by far the commonest disease of the nares, being usually called cold in the head. It is an inflammation of the

nasal mucous membrane, but it is exceedingly difficult to be certain as to what the cause of the inflammation is. We shall see as we go on that the mucous membranes of the air passages are much more liable to inflammations than those of the alimentary canal, and we can understand that an exposure to cold air which would not produce any catarrh of the mouth might do so in the nares. Moreover, the fact that the nares are the nearest part of the air passages to the air, and are therefore most exposed to the action of the cold, is an indication that such exposure has probably something to do with it. But mere inhalation of cold air is not enough to produce catarrh, as everyone who is liable to cold in the head will admit. There must be, as a predisposing cause, some peculiar sensitiveness of the mucous membrane. It is exceedingly difficult to explain how, at one time, a person is able to brave any amount of exposure without any risk of catarrh, while at another time a slight draught, or no perceptible exposure at all, will bring it on. Such circumstances as these, taken along with the fact that the catarrh has a definite course, usually of a week's duration, has induced some to suppose that the disease is really due to specific organisms. In this view it is necessary to suppose that these organisms are abundantly present in the air, and that they take, as it were, advantage of the mucous membrane when, at any time, it is in a specially predisposed state. This predisposition may be induced by cold applied either directly to the mucous membrane or to some other part of the body, but other predisposing causes may exist. For instance, when a person is sitting before a warm fire the arteries of the skin and mucous membranes generally are relaxed, and there is an active hyperæmia. At such a time a slight exposure to cold may induce catarrh, apparently by rendering the mucous membrane less able to resist. Much could be said in favour of this view of the causation of catarrh of the nares. There is apparent confirmation of it in the fact that nasal catarrh is known to occur as the result of irritation by known specific viruses. In measles the catarrh seems referrible to the specific virus. In hay asthma the irritation of the pollen of grasses is believed to be the cause of the catarrh. Again, it is commonly stated that nasal catarrh is communicable from person to person, and it is hardly conceivable that this could occur unless the disease had, as a part of its cause, some specific materies morbi. It will be seen that the causation of nasal catarrh offers many difficulties, and that no very settled result can be stated.

The catarrh begins with an inflammatory hyperæmia of the mucous

membrane. This may, of itself, lead to swelling so great as partially to obstruct the passages, giving the feeling of a "stuffed nose." The inflammation soon passes on to exudation. This finds its way for the most part to the surface, but in its passage it increases the swelling of the mucous membrane. The exudation is the usual one of inflammation, namely the blood-plasma with leucocytes. At first this is mixed with mucus, but as it increases in amount it rapidly assumes a serous character, and we know that a great abundance of serous fluid may be discharged from the nostrils. As time goes on the leucocytes increase in the exudation, and it may assume a semi-purulent character. Sometimes red corpuscles are present, giving the discharge a greenish-yellow colour. As the inflammation passes off the mucous character of the exudation returns and the leucocytes diminish. As a general rule the mucous membrane returns to its normal condition as the inflammation subsides. Sometimes a chronic catarrh remains, but this is seldom the case unless there be some permanent cause of irritation present. It is to be remembered that there are various cavities in direct communication with the nares, of which the principal are the FRONTAL SINUSES and the ANTRUM OF HIGHMORE, and that these frequently take part in the acute catarrh. It will be observed that in all stages of the catarrh there is more or less swelling of the mucous membrane, and that this leads to the obstruction of the passages which is such a marked symptom. This swelling is temporary in the acute disease, but in chronic catarrh it is apt to give way to a more permanent thickening.

CHRONIC NASAL CATARRH.—There is thickening of the mucous membrane and continuous exudation which is usually more or less purulent and may be strongly decomposing. In these cases there is nearly always a permanent source of irritation. It may be a foreign body in the nose, and this is always to be suspected, especially in children, when the one nostril is concerned. It is frequently a scrofulous (tubercular) or syphilitic manifestation, but in both of these conditions it is frequently associated with deeper lesions.

Chronic catarrh frequently leads to ulceration of the mucous membrane. In ordinary cases the ulcers are superficial, and when the cause is removed (as a foreign body) then the ulcers heal rapidly. In scrofulous and syphilitic cases the ulceration very often extends. It passes down through the mucous membrane to perichondrium or periosteum, and we are apt to have necrosis or caries as the result. In this way there may be considerable alteration of the nasal passages, abnor-

mal communications with the mouth, falling in of the nose and so on. When the bones are affected the discharge from them is added to that from the mucous membrane, and it is in such cases that a strong odour of decomposition is frequently developed (OZÆNA). With or without ulceration we commonly find thickening of the mucous membrane from the usual new-formation of connective tissue in chronic inflammation. In this way the nares are considerably obstructed. The finer ramifications of the olfactory nerve are injured by these tissue changes, and thus a chronic catarrh, even if recovered from, often leaves behind loss or impairment of the sense of smell.

TUMOURS.—The most frequent tumours of the nares are the MUCOUS POLYPI. Like other mucous polypi they occur very commonly as a result of chronic catarrh, but they appear occasionally without any such cause. They are usually in the form of rounded projections having a comparatively narrow base or neck, the growth becoming more pedunculated as it enlarges. They often produce much obstruction of the passages. In structure some of them present simply the constituents of the inflamed mucous membrane, connective tissue with rather wide serous spaces, and covered with cylindrical ciliated epithelium. (If the epithelium be examined in fluid immediately after removal, the ciliary motion will be seen.) The connective tissue is usually so infiltrated with serous fluid as to give an œdematous appearance to the polypus, and sometimes a more definite cystic formation occurs. In some cases there is in the tumour great new-formation of mucous gland tissue, so that the growth is truly a MUCOUS ADENOMA. In such tumours again cysts may arise from dilatation of the glands with mucus. In the other form also cystic formation may occur from dilatation of normal glands contained in the tumour. The polypi are not infrequently multiple. PAPILLOMATA occur in the nares, and may be of considerable size.

Other tumours are not common in the nares, but FIBROMAS and SARCOMAS, originating mostly in the periosteum or perichondrium, may produce serious obstruction and deformities of the nasal structures. The sarcomas especially often dislocate the nasal bones, and involve the neighbouring structures in their substance. In this way they sometimes penetrate into the antrum, or involve the hard palate and alveoli. CANCERS rarely occur in the nares as primary tumours, but may involve them by extension from neighbouring parts.

THE LARYNX AND TRACHEA.

There are many disadvantages in dividing the subject of diseases of the respiratory passages, especially in separating the lesions of the bronchi from those of the trachea, because they are so often continuous. But the points in favour of such a division counterbalance its disadvantages, it being understood that the respective inflammatory conditions especially run into one another.

MALFORMATIONS.—Entire ABSENCE of the larynx and trachea occurs only in acephalic monsters which are incapable of living. There are, further, cases of COMMUNICATION BETWEEN THE TRACHEA AND ŒSOPHAGUS; generally in these cases the pharynx ends in a cul-de-sac and the œsophagus opens into the trachea. Then we meet with cases of IMPERFECT CLOSURE of the original BRANCHIAL ARCHES. All that remains is usually a slight fissure in the skin, leading into a fistula which has mostly a blind end, but sometimes opens by a small aperture into the pharynx or trachea. The aperture in the neck is small and is situated about an inch above the sterno-clavicular articulation, usually on one or both sides, more rarely in the middle line. The aperture is usually slightly elevated, and sometimes it yields a drop of fluid. Again, INDIVIDUAL CARTILAGES, as the epiglottis, or one or more of the rings of the trachea may be ABSENT, or there may be one or more rings supernumerary. The trachea may divide into three main bronchi instead of two, and in that case two stems pass to the right lung and one to the left. Occasionally the larynx is CONGENITALLY NARROW, or it may fail to undergo the usual changes at puberty, especially in cases of castration before puberty or of non-descent of the testes. Lastly, the trachea has been observed to the left of the œsophagus or even behind it.

CROUP AND DIPHTHERIA.—It is well known that much has been written on the question whether these two diseases are identical or not. Without in the meantime entering on that subject, it may be said that in using the terms here it is intended to refer to the conditions which are designated clinically as croup and diphtheria, and that the distinction sometimes made between croupous and diphtheritic inflammation is not made use of.

In DIPHTHERIA we have a disease which is undoubtedly infectious, its communicability from person to person being associated with the fact that it depends on the existence of micrococci in the

mucous membrane. These organisms have been found not only in the mucous membrane, but, having penetrated into the blood, they have been observed in the blood-vessels and tubules of the kidneys. The organism is one of comparatively large size, and appears to be of an allied form to that which is to be found in decomposing animal juices. It occurs in the form of multitudes of minute globular bacteria aggregated into colonies, and capable of self-propagation in the tissues. Now this organism either in itself or by its products is an irritant to mucous membranes, and produces violent inflammations.

The inflammations differ somewhat in the fauces and nares on the one hand and the larynx and trachea on the other. In both cases a catarrh is the first sign of inflammation. The mucous membrane is hyperæmic, and there is increased mucous secretion. In the case of the FAUCES AND NARES this is succeeded by the formation of a false membrane, which does not lie free on the surface but involves the superficial layers of the mucous membrane as well. The irritant in fact has caused a partial necrosis of the mucous membrane which by and by sloughs and leaves an ulcer. The necrosis here may be regarded as an instance of coagulation-necrosis, the dead tissue undergoing the change already described and becoming converted into something like a fibrinous clot. It is probable that along with the coagulated tissue there is actually fibrine produced in the usual way in the meshes of the tissue. The false membrane is therefore composed of fibrine and necrosed and coagulated mucous membrane. When the slough separates or is removed there is apt to be a second formation of false membrane.

While this is the process in the fauces and nares, that in the LARYNX AND TRACHEA is a somewhat different one. The disease usually begins in the former structures, its most frequent primary seat being the fauces, whence it occasionally extends into the nares, and more frequently into the pharynx and larynx. In the larynx, after the catarrhal stage, there is also the production of a false membrane, but this does not adhere to the mucous membrane, nor is there usually any necrosis. The false membrane is a whitish layer which is loosely connected with the mucous membrane and is readily raised by the accumulation of mucus under it. There are undoubted inflammatory changes in the mucous membrane in the form of infiltration with round cells, but the only actual loss of substance is the shedding of the epithelium of the surface. The epithelium always undergoes necrosis before the formation of the false membrane.

Differences of opinion exist as to the nature of this false membrane in

the larynx and trachea. By Wagner it has been asserted that it arises from the epithelium, being the product of what may be regarded as a coagulation necrosis of it. It is not to be denied that the epithelium may undergo this process, but it does not seem possible that this can be the source of the whole membrane. We know that the membrane is often removed and reproduced, and that it may be produced in such quantity as to fill up the larynx completely. The thin layer of epithelium is quite inadequate to such a result, and we must believe that fibrine is actually deposited on the inflamed surface. The removal of the epithelium leaves the surface incapable of preventing the disintegration of the leucocytes. The false membrane is therefore to be regarded as an inflammatory exudation, and in its histological characters it agrees with this. It consists of a fibrinous network, often very coarse in its texture, and with inflammatory cells in various abundance in it.

Croup is a name given to membranous sore throats in which the exudation is mainly or entirely in the larynx and trachea. The name was first applied before the eminently contagious diphtheria was distinguished, and it was commonly understood to be a peculiarly violent inflammation of the air passages. There seems to be no doubt that, now-a-days at least, the great majority of cases of croup are really cases of diphtheria in which the disease is mainly or entirely in the larynx and trachea.

We have seen that in the larynx diphtheria produces an inflammation in which, after the shedding of the epithelium, a fibrinous exudation occurs. It is asserted by some that the diphtheritic poison is the only agent capable of producing this form of inflammation. Looking at the matter from a purely pathological point of view apart from clinical experience, it certainly seems possible that other irritants may produce similar results. Croup has been produced artificially in rabbits by the injection of ammonia into the trachea (*Weigert*). In these cases the irritant first kills the epithelium, and then fibrine is deposited. If croup occurs in man apart from diphtheria, the irritant must be strong enough to destroy the surface epithelium. Apart from the action of minute organisms, such an irritant must be of rare occurrence, but the possibility of its existence is not to be denied. We shall see afterwards that in rare cases we meet with a bronchial croup where there can be no question of diphtheria, and so we may have laryngeal and tracheal croup of a simple inflammatory kind. In such cases there will be no signs of general disease, but all the symptoms will be referrible to the local inflammation and obstruction of the larynx. It should be added

that laryngeal croup has been met with in small-pox, measles, pyæmia, etc., but here it is to be ascribed to the action of organisms, as in diphtheria.

CATARRH OF THE LARYNX AND TRACHEA.—We have seen that ACUTE CATARRH forms the first stage in croup; it is the result of the action of the specific poison. Similarly we have acute catarrh in measles and small-pox, there being here a specific eruption similar to that on the skin, along with acute catarrh. In typhoid fever and other infectious diseases we may also have acute catarrh. It occurs also as an independent affection, just as nasal catarrh does, and in this case, although usually slight, it may assume a very severe character. Lastly, a catarrh may be set up by the inhalation of irritating chemical fumes.

There is, as in other inflammations, hyperæmia and exudation. The mucous membrane is red as seen during life, but on post-mortem examination the redness has usually disappeared entirely, the vessels emptying apparently by the shrinking of the tissue. The exudation is originally mucous in character, and is not generally very abundant. After a time, as in the case of nasal catarrh, it usually assumes a more purulent character. The swelling of the mucous membrane is not usually great, and there is not commonly any serious obstruction. On the other hand, in children a slight catarrh may bring on a sudden suffocative attack due not so much to the swelling as to spasm of the muscles. As an unusual complication of acute laryngitis may be mentioned œdema glottidis, the condition next to be described.

ŒDEMA GLOTTIDIS.—This name is applied to a comparatively sudden œdematous swelling, causing often a serious or even fatal obstruction of the larynx. The œdema is in most cases an inflammatory exudation, but it occurs in Bright's disease as part of a general œdema. It may be part of a simple inflammation of the larynx, or from diphtheria, or the pustular inflammation of small-pox. Or the inflammation may be propagated from the pharynx and fauces, or from the inflamed perichondrium. The condition is not an œdema of the mucous membrane itself; that would produce a very moderate swelling, but it is an inflammation and œdema extending to the submucous tissue. Now, in most parts of the larynx there is little or no submucous tissue, the mucous membrane being bound down to the perichondrium. There are some parts, however, where the tissue

is looser, and these are chiefly the base of the epiglottis, and, to a less extent, the whole epiglottis, the ventricular bands, and most of all, the aryteno-epiglottic folds. The epiglottis is swollen, especially at its base; the aryteno-epiglottic folds are usually much tumefied, appearing as rounded tumours projecting backwards from the base of the epiglottis. These rounded swellings form indeed the most prominent appearances. The ligaments passing from the epiglottis to the tongue are also sometimes swollen. Examined from above, the tumefied aryteno-epiglottic folds conceal the parts beneath, but on laying open the larynx after death it is found that the ventricular bands (false cords) are tumefied, although the true cords are usually very little affected. The œdema may affect the submucous tissue in the trachea for some distance below the glottis. If the swollen parts be cut into a fluid exudes, which is usually sero-purulent and sometimes almost purulent. Occasionally there is blood in it.

Chronic Catarrh.—This is a common result of repeated attacks of acute catarrh, but may occur spontaneously. It is chiefly characterized, like other chronic inflammations, by new-formation of tissue; the mucous membrane is thickened, and its surface is irregular. The increase is mainly of connective tissue which, having the usual characters of that resulting from inflammation, gives rigidity to the parts. The movable structures of the larynx are thus rendered more or less stiff, and hoarseness is the result. Not infrequently flat superficial ulcers or erosions form, and these have their seats most commonly at the posterior commissure. The racemose glands of the larynx may undergo special enlargement so as to appear as rounded prominences. They sometimes ulcerate, and so give rise to small crater-shaped ulcers, which are chiefly to be seen on the epiglottis and aryteno-epiglottic ligaments. The thickening and contraction of the connective tissue are sometimes so great as to produce very great stenosis of the larynx, so that tracheotomy is needed to permit of respiration. Sometimes mucous polypi form on the surface, and add to the irregularity.

Subglottic Inflammation.—This disease, which is not of very frequent occurrence, is an inflammation of the mucous membrane beneath the glottis. It may be acute in its onset but it generally passes into a chronic stage. It has been observed as a sequel to erysipelas and typhus fever, and may have origin apparently in inflammation of the perichondrium. In acute cases there may be considerable œdematous

swelling. In the chronic form there is thickening of the mucous membrane as in ordinary chronic laryngitis. The inflammation is often just beneath the cords and so may produce fixation of them, but it may occur further down, and is not infrequently in patches interrupted by normal mucous membrane.

Inflammation of the Perichondrium.—This disease is rarely a primary one, being induced chiefly by syphilitic and tubercular inflammations, especially when there is deep ulceration extending down to the perichondrium. It occurs occasionally as a sequel of typhoid and also probably of typhus fever. It has usually a somewhat chronic course, but may be acute, and in either case it ends in the formation of pus under the perichondrium. The pus accumulating under the perichondrium cuts off the cartilage from its source of nutrition, and just as in periostitis, this is usually followed by necrosis of the cartilage. The destruction of the cartilage may be a slow process and there may be a kind of caries followed by necrosis. The disease is generally confined to one cartilage at the outset, the cricoid being most frequently attacked, but it may extend to others. When suppuration has occurred the inflammation spreads to structures around, and we may have burrowing of the pus under the mucous membrane for some distance, or even outside the larynx among the structures of the neck.

The pus after a time obtains an exit, usually by perforating the mucous membrane, but sometimes it finds its way to the surface of the body. The necrosed cartilage is, by degrees, separated from the living and not infrequently it finds exit by the fistula which the pus has formed. It is usually discharged into the larynx, and cases have occurred in which the dead piece of cartilage has obstructed the glottis. Or, after being discharged into the larynx it may drop down into the trachea or bronchi to be afterwards coughed up. On the other hand it is sometimes discharged through the skin. In connection with these processes and often with the primary disease, there is usually great thickening and deformity of the larynx. If the patient survive the discharge of the cartilage, its loss leads to still greater deformity. The larynx may collapse, or, by a more chronic process, the inflammation may cause great contraction and obstruction of the larynx. When the cartilage is discharged it is generally found calcified or ossified, and it may be a question how far the calcification preceded the inflammation. Dietrich has suggested that, in the case of the cricoid, ossification may sometimes be the primary condition, and that the inflammation may be

induced by the pressure of the hardened cartilage against the vertebral column.

SYPHILIS.—This disease produces very frequent and sometimes very serious lesions in the larynx. These lesions are almost entirely inflammatory, and they vary from a slight catarrh to a prolonged inflammation accompanied by great thickening with stenosis and deep ulceration. The slighter inflammations are earlier manifestations of syphilis, and like these in general they may entirely disappear. Those occurring later on are usually prolonged and slow in their progress. The mucous membrane and submucous tissue are infiltrated and thickened, ulcers develop, first as a general rule in the epiglottis, but they are prone to extend deeply and widely so as to destroy large portions of the epiglottis or the whole of it. We have already seen that the ulceration may lead to perichondritis and necrosis of the cartilage with still wider results. With all this there is great new-formation of connective tissue with corresponding deformity, and if the ulcers heal the contraction of the cicatricial tissue leads to great deformity and not infrequently to such obstruction of the glottis as to require tracheotomy. These inflammatory manifestations are not usually associated with the formation of proper gummata, although the granulation tissue may be produced at first in small nodules and is hardly of normal character, partaking of the tendency to regressive changes which the gummata show. Sometimes with the slighter inflammations there may be polypoid projections consisting of thickened mucous membrane and epithelium, forming the so-called CONDYLOMATA.

LARYNGEAL PHTHISIS.—This is nearly always secondary to pulmonary phthisis, and is a true tubercular disease. It is not impossible that the tubercular virus may attack the laryngeal mucous membrane primarily, or it may attack it simultaneously with the lung, but as a matter of fact the lung is in almost every case diseased, and the probability is that in most cases the virus is carried from the diseased lung in the sputum. There are some cases in which the laryngeal symptoms are more pronounced than the pulmonary, and clinical observers describe them as cases of laryngeal rather than of pulmonary phthisis. The larynx has been found affected in about 30 per cent. of cases of pulmonary phthisis examined after death.

In cases of phthisis pulmonalis the mucous membrane is frequently pale from anæmia, but although this may be important as showing a

tendency to laryngeal disease it is not to be regarded as really due to existing tuberculosis, especially as it occurs in ordinary anæmias. The first result of the actual tubercular disease is thickening of the mucous membrane. This is due to chronic inflammation, and is caused chiefly by exudation of serous fluid and inflammatory cells with tubercles, so that it is mainly an œdematous thickening. It is most marked in the epiglottis and aryteno-epiglottic folds, these latter often showing themselves as rounded prominences. In this stage microscopic examination shows the presence of tubercles with their characteristic structure along with inflammatory cells. The tubercles are in the mucous membrane and the submucous tissue, the epithelium being as yet intact.

To the thickening succeeds ulceration, the ulcers being at first small and superficial. These ulcers result from the caseation and softening of superficial tubercles. By coalescence larger ulcers form out of the smaller ones, and there is a continual tendency to spreading. As a rule there are many ulcers, and between them is thickened mucous membrane which at the borders of the ulcers sometimes presents irregular projections like papillary outgrowths. The ulcers are at first superficial, but as the disease progresses considerable destruction of tissue may result. The vocal cords are not infrequently destroyed, and so there is loss of voice, but the voice may be lost from the rigidity of the structures caused by thickening from chronic inflammation. Again, perichondritis not infrequently follows, with suppuration, and this causes still further inflammatory manifestations.

Ulceration not uncommonly exists in the trachea and bronchi as well as in the larynx. There are many ulcers, and it is not uncommon to find the cartilaginous rings of the trachea extensively exposed. With these ulcerations of the trachea there will be swelling of the remaining mucous membrane and sometimes a perichondritis with necrosis.

The lymphatic glands in the neck are affected secondarily to the larynx, they are the seat of scrofulous processes such as we have already described, and their enlargment may, in some cases, aid in the exact diagnosis of the disease in the larynx.

Tumours.—The most frequent form of tumour of the larynx is the Papilloma. This tumour is often preceded by catarrhal conditions, and is particularly common in persons who, from the nature of their profession, use the voice frequently. But it often occurs without either of these predisposing conditions. The tumours most frequently grow

from the vocal cords, where the epithelium is flat. They consist, like other papillomas, of a basis of connective tissue forming numerous conical projections covered with epithelium (see Fig. 223). The epi-

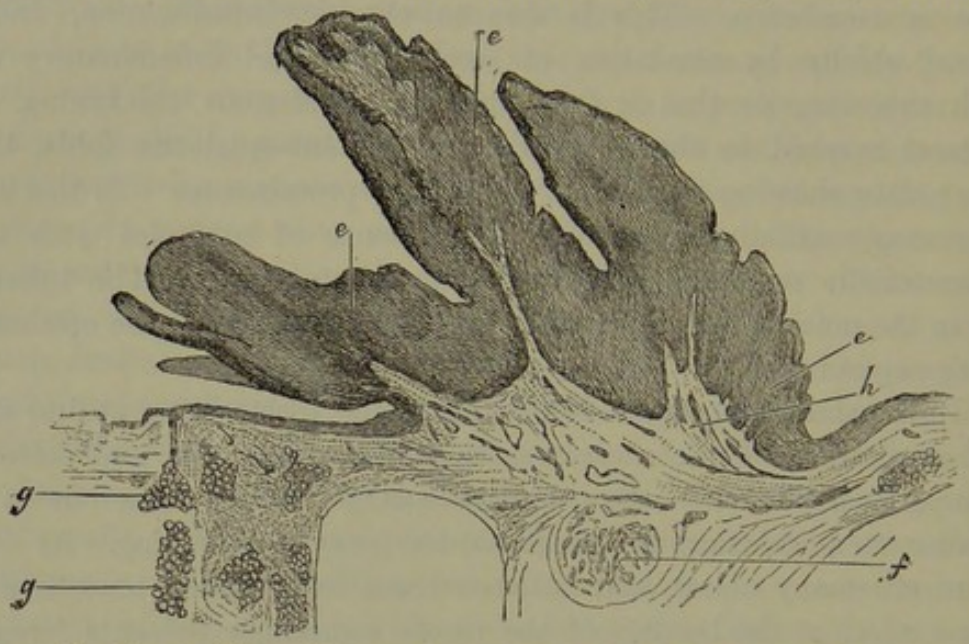


Fig. 223.—Papilloma of larynx. *e*, *e*, greatly thickened epithelium; *h*, connective tissue; *g*, mucous glands; *f*, a gland at base of tumour atrophied by its pressure. ×20. (Cornil and Ranvier.)

thelium may be thick, and the connective tissue dense, so that the tumour is like a hard wart, or the epithelium may be thin and the connective tissue soft, sometimes richly infiltrated with round cells, and so the growth is soft like a soft wart or condyloma. The growth may occupy a small surface of the cord, being partially pedunculated, but it often has a considerable base, forming a shaggy, irregular outgrowth. Sometimes, after extirpation, these tumours take on a sarcomatous character, or even develop a cancerous growth.

A kind of false papilloma occurs, as we have already seen, in some cases of tubercular or syphilitic ulceration of the larynx. Sometimes, also, the surface of an epithelioma has a papillary character.

Next to the papillomas the FIBROMAS are the commonest tumours in the larynx. Morell Mackenzie has found in one hundred cases of non-malignant tumours, sixty-seven papillomas and sixteen fibromas. They are tumours of slow growth, mostly seated on the cords or at the base of the epiglottis. They consist of firm or soft connective tissue, those of firm consistence being the commoner. They are usually more or less pedunculated, and their surface is generally smooth, although it may be irregular or even furnished with papillæ. They are usually small tumours from the size of a split pea to that of an acorn.

MUCOUS POLYPI occasionally occur, taking origin in the mucous glands. They very commonly undergo transformation into cysts, and their most frequent seats are the epiglottis and the ventricles of Morgagni.

Other forms of simple tumours are uncommon, but cases of LIPOMA, MYXOMA, and ANGIOMA have been met with. CARTILAGINOUS TUMOURS formed by outgrowth from the normal cartilages have been found. They are usually multiple and sessile. They may project considerably into the larynx, and being covered with mucous membrane may be mistaken for one of the commoner tumours mentioned above. As these tumours are firmly connected with the cartilage beneath, they cannot be removed by forceps, and so it is important to distinguish them from the others.

SARCOMAS of the larynx are of occasional occurrence. They are usually of the spindle-celled form, but may be round-celled. They may grow to a considerable size, and are, of course, prone to recur unless the whole larynx be removed along with the tumour.

CANCER of the larynx develops in the form of flat-celled EPITHELIOMA. It is not infrequently a primary tumour, growing usually from the ventricular bands, but also originating in other parts. An epithelioma may also extend from a neighbouring part, particularly from the tongue. There is first an infiltration of a limited part which extends in area, involving more and more in an indiscriminate advance. Very commonly there is an abundant papillary growth on the surface so that there is a resemblance to the cauliflower cancer or to the papilloma. The central parts of the growth undergo ulceration while the disease is extending circumferentially. In this way great destruction of tissue may result, and the parts present great deformity.

Tumours are of very rare occurrence in the trachea, but we may have similar growths to those in the larynx.

THE BRONCHIAL TUBES.

The diseases of the bronchi stand in close relation on the one hand to those of the larynx and trachea, and on the other to those of the lungs, and it is impossible to draw an absolute line of distinction on either side. The affections of the larger and middle bronchi are essentially like those of the larynx and trachea, and this is consistent with the fact that in structure they are similar. As we pass down the bronchial tree, however, the structure changes considerably. The car-

tilaginous plates become irregular and smaller, and finally disappear; the elastic tissue becomes more completely incorporated with the mucous membrane, so as to form a single layer which becomes thinner as the tube diminishes in calibre; the bronchial glands altogether disappear in the finer tubes. The bronchial tube thus becomes more simple in structure, and approximates to that of the lung alveoli. So it happens that in their diseases the finer bronchi are more allied to the lungs, and are often involved with them. We shall afterwards see that in acute catarrhal inflammation of the lung the disease often begins in a capillary bronchitis, and is sometimes described under that name.

Bronchiectasis.—By this name is meant dilatation of bronchial tubes, a condition of somewhat frequent occurrence, but depending on a considerable variety of circumstances. The normal bronchial tube offers resistance to the dilating force of the air, chiefly by virtue of its elastic or dense walls, and the support which it receives from the pulmonary tissue around. If the walls be weakened or the support of the pulmonary parenchyma withdrawn, or if the distensile force of the air or other contents be considerably increased, then we may have bronchiectasis. It will be seen that one or other of these predisposing conditions may occur under very various circumstances. A prolonged catarrh may cause atrophy of the elastic tissue of the bronchial wall, and so reduce the resistance. On the other hand, obliteration of the finer bronchi and lung alveoli in a district will cause the pressure of the air in inspiration to act especially on the bronchial tubes, the dilatation being here similar in its origin to compensatory emphysema. Lastly, we may have the bronchi dilated from accumulation of secretion. This will occur chiefly when a small bronchus has been obstructed, and the condition may be compared to a retention cyst.

The various forms of bronchiectasis may be divided into two, namely, cylindrical and sacculated dilatations. The former occurs mainly where the causal condition has been more or less of a general one, such as a prolonged bronchitis. The bronchi, especially the middle-sized ones, are unduly wide, and their walls are thinned. The dilatation may be quite regular, but very often there are little bulgings or pouches. In the sacculated form there has usually been a more local agent at work. The most typical sacculated dilatations are found in fibroid phthisis, under which heading they will be treated of more fully. They may be produced also by any cause which induces shrinking of the lung tissue. The wall of the bronchus is thinned, but

it still presents a distinct membrane lining the sac. When cavities in the lung have a distinct lining membrane, they are generally of this origin, and they are especially so when the membrane is surrounded by lung tissue which approaches to the normal condition. As the secretion stagnates in the sacculated dilatation, and may decompose, there may be ulceration of its internal wall.

Bronchial Catarrh or Ordinary Bronchitis. This is an inflammation affecting the larger and middle-sized tubes, but not extending to any considerable degree into the finer ones. As to the conditions giving rise to it, much that has been said under nasal catarrh is again applicable here. It is to be added, however, that in many persons there is a special proclivity to recurrent attacks of bronchitis. This may be due to an inherited weakness in this direction, but is perhaps more frequently occasioned by an acute bronchitis which has left the bronchi considerably altered in structure, has rendered them, in fact, the least resistant part of the body. In such persons cold may set up a bronchitis, or it may be set up by disorder of the stomach, or by some other trivial cause. Valvular disease of the heart frequently gives rise to bronchitis, but we shall consider this when the results of cardiac disease in regard to the lung are under review.

In the slighter forms of bronchitis the larger bronchi and the trachea are mainly affected. In fact, it frequently happens that along with a slight laryngitis there is a tracheitis and a bronchitis of the larger stems, without the name bronchitis being given. In the more definite cases of bronchial catarrh it is the middle-sized tubes that are chiefly involved.

In order to appreciate the changes which occur in bronchitis it is necessary to refer to some points in the structure of the tubes. The mucous membrane is covered with epithelium whose superficial layer is cylindrical and ciliated. Beneath the epithelium there is a basement membrane which is separate from the proper mucosa under it. The mucosa is composed of connective tissue and presents externally a muscular layer, chiefly of circular fibres, but with some longitudinal ones. Outside this we have the sub-mucosa or adventitia which is continuous with and really forms a part of the general interstitial connective tissue of the lung. In this loose adventitia the cartilages are embedded, and there are abundant serous and lymphatic spaces, which are in communication with those throughout the lung, the perivascular and others.

According to the careful description of Hamilton acute bronchitis is

accompanied first by great congestion, chiefly of the vessels in the proper mucosa. Œdema of the basement membrane follows, and this structure becomes greatly thickened. The superficial layer of columnar epithelium is shed, but vigorous germination of the deeper layers occurs, abundant embryonic cells being produced. At the same time there is great infiltration of the mucosa, muscular layer, and adventitia, with round cells of inflammation. This infiltration may be very great, and as the adventitia communicates with the general interstitial tissue of the lungs, there may be a wide distribution of these cells, which pass on by the lymphatic channels to the lymphatic glands.

If the disease becomes chronic the inflammatory infiltration of the layers beneath the basement membrane continues, and there is the usual new-formation of connective tissue producing an induration of the tissue. As in other productive inflammations the new-formed tissue often causes atrophy of the proper structures. In many cases the muscular coat is to some extent atrophied although sometimes it is hypertrophied. The mucous glands are often considerably destroyed, and even the cartilages may be partially atrophied. These alterations in the walls of the tubes no doubt weaken them, and as they occur especially in long continued cases of bronchitis, we can understand how in such cases the bronchial tubes sometimes undergo dilatation. Dilatation of bronchial tubes is not however a very prominent feature of ordinary bronchitis.

THE EXUDATION in bronchitis is important as it forms THE SPUTUM, and gives its characters to the latter. In the normal condition the mucous glands secrete enough mucus to keep the membrane moist, the secretion consisting of a glairy fluid containing a few leucocytes which are here called mucus corpuscles. The fluid owes its glairy or sticky character to the fact that it contains mucin, a chemical substance allied to albumen and secreted by the mucous glands. This normal secretion catches and holds the minute particles forming the dust which we inhale with the air, and the vibratile cilia of the epithelium acting towards the outlets carry mucus and dust outwards, to be swallowed or expectorated. In bronchitis there is at first very little increase of the secretion, and what there is is chiefly concentrated mucus, tough and scanty. As the disease progresses it becomes more abundant but less tough and less transparent, and this is brought about by the increase of the inflammatory exudation consisting of serous fluid and inflammatory cells. The degree of toughness depends on the proportion of mucin,

and the degree of opacity on the quantity of cells. As the disease advances the leucocytes go on increasing, and so the fluid on the surface of the mucous membrane becomes more and more opaque.

The SPUTUM COCTUM, or ripe sputum met with at the acme of the disease, is yellowish white or greenish and opaque. It is not homogeneous, but has more opaque and less opaque portions according as it has got mixed and coated with mucus from less affected parts of the tubes. The sputum as seen in a vessel appears at first sight like pus, but it is much more tenacious. Under the microscope it also resembles pus, the field being crowded with multitudes of leucocytes. But the tenacity of the fluid is often shown by the manner in which the plastic leucocytes are altered in shape, being drawn out into oval or more elongated forms according as the tough mucus is drawn out. On adding acetic acid the usual development of nuclei occurs in the cells, and the intermediate fluid becomes markedly opaque from the precipitation of the mucin which can be seen now in fine granules. With acetic acid the sputum assumes to the naked eye a whitish opaque, and almost membranous character.

In chronic bronchitis the sputum is often very abundant, and is usually sero-mucous with comparatively few leucocytes, and hence transparent. There is a comparatively rich serous exudation with very little increase in the secretion of mucus. The sputum is not so tough as in more acute cases, and is often very frothy. In some very chronic cases there is a very abundant cellular exudation—the sputum is almost like pus and has not the toughness of the sputum coctum. Large quantities of pus may thus be expectorated. In these cases it may be supposed that leucocytes are present in the walls and outside the bronchi as well as in the expectoration, and it is in them that we may look especially for dilatation of the tubes.

FIBRINOUS BRONCHITIS. This name, as well as that of PLASTIC BRONCHITIS or BRONCHIAL CROUP, is given to a condition of very rare occurrence and of rather obscure pathology, but yet of great interest. We have seen that in laryngeal and tracheal croup the fibrinous exudation sometimes extends down into the bronchial tubes, and that casts of these are formed occasionally. Taking the other end of the bronchial tree we find that in acute pneumonia the fibrinous exudation which forms in the lung alveoli commonly extends some distance into the finer bronchi, and so we find casts in them. But there are cases in which fibrinous casts form in the bronchial tubes

independently, without any disease of the trachea on the one hand or of the lung proper on the other. These cases are somewhat chronic in character, and the expectoration of casts occurs at intervals during months or even years. The casts are of a whitish grey colour and represent the bronchi of, it may be, a single lobe, with their ramifications, as we can see very beautifully by floating them out in water. Sometimes the fine ends of the casts are swollen out as if they had come from the alveoli. The casts sometimes present on section a stratified arrangement as if the fibrine had been deposited in layers. They show under the microscope fibrine with leucocytes.

The exact pathology and the source of this exudation are somewhat obscure. In some cases where death has occurred shortly after the expectoration of the casts, or where they have been found in situ, there has been little perceptible alteration of the mucous membrane. This has led some to suppose that the fibrine comes from the lung alveoli, and in many cases the lung tissue is considerably altered, for there may be phthisis, or pneumonia, or collapse. But it is not apparent to what extent these may be secondary to the bronchitis. A possible indication of the pathology may be afforded by the fact that in a considerable proportion of the cases there has been hæmorrhage from the lungs.

B.—THE LUNGS.

In examining the lungs after death we seldom meet with them in a perfectly normal condition. They may be abnormally adherent to the wall of the thorax, or unduly pigmented, or there may be cicatrices in them, or œdema, and so on. The explanation of this is perhaps that the lungs are peculiarly exposed to deleterious influences in two directions. The air passing into them is apt to carry irritating materials with it, and the blood circulating so richly through their tissue is liable to variations in its constitution and degree of pressure. We have already seen, for instance, that organic disease of the heart has serious effects on the pulmonary circulation, but apart from that, simple weakness of the heart may, as we shall afterwards see, have important effects on the lung. It must not be forgotten also that there is no organ of the body whose tissue is so intimately related to its blood-vessels as the lungs. These organs are little more than a congeries of

blood-vessels with a sufficient supporting stroma. Any deleterious substance circulating in the blood, therefore, is very prone to affect the lungs, especially if there be any special weakness in this direction. We have abundant illustration of this in the frequency of lung complications in the acute fevers.

There are one or two points in the anatomical relations of the lung which should be kept in mind. It is supplied with two different sets of blood-vessels, the pulmonary artery on the one hand, and the bronchial artery on the other. We should remember the distribution of these, and not confuse effects due to obstruction of the one with those due to obstruction of the other. Then we speak of diseases affecting the respiratory surface on the one hand, and the supporting structures on the other; that is to say, there are some diseases which affect the surfaces of the finer bronchi and of the alveoli, while others involve the walls of the alveoli and of the bronchi. It is true that these two are generally involved together, but in different cases the one or the other is primarily concerned, and usually retains the lead. It is obvious that to a certain extent the determining cause of the disease will have something to do with this. An agent which acts by being carried into the lungs with the air will mostly affect the surface of the alveoli and bronchi in the first place, whereas an agent arriving by the blood will be more apt to attack the walls. We shall see, however, that to this there are important exceptions, because, on the one hand, the capillary vessels have such a close relation to the surface of the alveoli, and, on the other hand, substances arriving from without very readily penetrate into the substance of the lung. A more important consideration arising from the anatomical relations has reference to the distribution of a lesion in larger or smaller districts of the lung. When a disease is caused by something arriving by the blood then we should expect it to be distributed over a large extent of lung tissue or over the whole; the disease will occupy whole lobes. If it arrives by the bronchial tubes, we should expect it to extend to the proper lung tissue more irregularly, here and there an extension corresponding with a particular minute bronchus; the disease at first involves lobules. In this way we may distinguish roughly diseases which are lobar as due to alterations in the blood, and those that are lobular as related to the bronchial stem.

MALFORMATIONS OF THE LUNG.

These are not frequent, and are of minor importance. Apart from absence or exceeding smallness of one or both lungs, which occurs as part of general malformations, there are cases where single lobes have been wanting, and their place taken by cicatricial tissue. These have probably their origin in obliteration of a bronchus in early fœtal life. Again, the lungs may be normal in form, but very small in size. In such cases the whole body, and especially the circulatory system, will remain ill-developed.

It is not uncommon to meet with abnormal lobulation of the lungs, the regular lobes being divided by the formation of deep fissures. Rokitansky has described a case in which an accessory lobe existed between the base of the left lung and the diaphragm, and quite separate from the lung. It had no bronchus, however.

ATELECTASIS AND COLLAPSE OF THE LUNG.

These names designate conditions in which the lung alveoli and finer bronchi contain no air, but are in a condition similar to that of the fœtal lung before inflation, the internal surfaces of the alveoli being applied to each other. It may be a survival of the fœtal state, or it may be subsequently produced by the alveoli being, in some way, emptied of their air. As this condition occurs under a considerable variety of circumstances we shall give no general description, but refer to the individual forms.

Atelectasis is frequently found in new-born children, being, indeed, a survival of the fœtal state. The lungs have to a greater or less extent remained uninflated. The non-inflation may be due to some obstruction in the bronchi, by meconium or mucus, but in most cases it is merely due to the weakness of the respiratory efforts. The new-born child usually cries lustily, and in the deep inspiratory gasps between the cries the lungs are fully inflated. But if the child be weak or has not cried freely, certain parts of the lungs are apt to remain devoid of air. The atelectasis of the new-born is most frequent in the lower lobe, and in the posterior parts of this lobe. It may be only in small areas in the midst of the inflated lung tissue, or the greater part of a lobe, or the whole lobe may be affected. In any case the non-inflated part usually shows by its shape that it is the district supplied

by one or more bronchi. The atelectasis shows itself by the smaller volume of the part. If it is in the midst of inflated lung it is depressed below the surface. Like the fœtal lung, it is redder than the normal, firmer to the touch, and non-crepitant when handled. It is important to distinguish this condition from condensation of the lung, for which it is liable to be mistaken. In both the lung is devoid of air, but in the case of condensation it is so because the air spaces are filled up with solid material, usually inflammatory exudation. The atelectatic portion is capable of inflation by blowing air into the lung by the bronchi, at least it is so at the outset, while the condensed part is not inflatable.

There is no doubt that a lung which was partly atelectatic immediately after birth may subsequently become perfectly inflated. On the other hand there is reason to believe that, if the atelectasis persist long, the lung becomes incapable of inflation. If the child survive, the applied walls of the lung alveoli adhere and an actual obliteration of the latter occurs. The part gradually atrophies, and it has been supposed that cicatrices sometimes seen in the adult lung and without any obvious cause may have this origin.

The question arises here whether, after inflation of the lung, portions or the whole may again collapse. We shall see immediately that collapse occurs in the adult, and there is no reason to suppose that it does not occur in the new-born infant. There are undoubted cases of children who have lived over twenty-fours and have cried, in whose bodies the lungs have been found with only one island here and there of inflated lung.

Collapse of the Lung is of frequent occurrence. In some cases it is due to direct compression of the lung ; the air is simply squeezed out of it. Usually this arises from the presence of fluid or air in the pleural cavity. In that case the collapse is not unlikely to be only partial, that is to say, the air vesicles are only partly emptied and readily recover. But if the exudation is great and remains long, then the lung may be pressed upwards and backwards and come to form merely a red fleshy layer flattened against the chest wall. This condition is often called carnification, and in it the tissue appears darkly pigmented, the absence of blood and the packing together of the lung tissue exaggerating the existing carbonaceous pigmentation. The cause mentioned above is by far the most frequent in producing collapse by pressure, but there are others. Curvature of the spine sometimes causes such a narrowing of a part of the

chest that the lung is squeezed or collapsed. Aneurisms or tumours may also compress the lung, but they more frequently cause collapse by obstructing the bronchi. Even distension of the abdomen, by pressing the diaphragm upwards and limiting the chest space, may cause a partial collapse. A great distension of the pericardium may have a similar effect.

A very important cause of collapse is obstruction of bronchi. To a limited extent collapse is exceedingly frequent in bronchitis, much more frequent than is usually supposed. The collapse very often appears in the form of small wedge-shaped depressions at the edges of the lungs, and may be almost concealed by neighbouring emphysematous lung. But sometimes, especially in children, the collapse may be much more extensive. The mode in which this collapse occurs has been well described by Gairdner. If a pellet of mucus obstructs a bronchus it generally does so at a bifurcation. The bronchus is partially obstructed, and the pellet of mucus being movable, acts to a certain extent like a valve; it is pushed out into the larger tube during expiration, and being drawn back against the bifurcation in inspiration stops the tube. In this way the escape of air during expiration is allowed, but the entrance of air during inspiration prevented. The respiratory movements will thus act, to a certain extent, like an air pump, and the portion of lung tissue concerned will be gradually emptied of air.

There is another way in which collapse probably occurs when a bronchus is obstructed. It is to be remembered that the lung tissue is elastic, and that left to themselves the alveoli collapse and their walls apply themselves together. If a bronchus be obstructed, therefore, and communication with the external air withdrawn, the absorption of oxygen will soon reduce the bulk of the contained air, and cause a reduction of its elastic pressure. The elasticity of the lung tissue, again, will cause pressure to be exercised on the air, and absorption of the gases of the air will be thus promoted. It has been proved that such absorption actually occurs, first of the oxygen, then of the carbonic acid, the nitrogen being slowest of absorption. The lung of course collapses as the air is absorbed.

It has just been stated that collapse from bronchial obstruction is most common in the bronchitis of children, but it is necessary to observe that in children, in whom the form called capillary bronchitis is common, it is often accompanied by a condition which is apt to be mistaken for collapse, namely, lobular condensation. The catarrhal process in the bronchi readily passes in children to the lung alveoli, and the catarrhal products

fill these up, causing condensation of a portion of the tissue which has a wedge-shaped configuration similar to that of the collapsed portion. Of course, these two conditions may co-exist in the same lung, or we may even have a combination of them, the collapsed lung becoming the seat of catarrh, and so passing into the condition of condensation.

HYPERTROPHY OF THE LUNG.

A case occurred recently to the author which distinctly manifested the characters of COMPENSATORY HYPERTROPHY of the lung. The left lung was of very small dimensions, especially the upper lobe, which appeared merely as a membranous structure in which dilated bronchi would be felt. There was no pigment in this lobe, and not a trace of lung parenchyma. The lower lobe contained the ordinary carbonaceous pigment in limited amount, but was greatly reduced in size.

The right lung was of very unusual volume, extending across the middle line, so that its edge reached beyond the left nipple. The enlargement seemed to be due to an addition of lung tissue at the anterior parts. The supra-clavicular part of the apex of the lung had the normal form and size, and its anterior border indicated the position of the normal anterior margin. What should have been the anterior margin was indicated by this. Beyond this, however, a bulky piece of lung extended into the other half of the chest. This part of the lung had not the appearances of emphysema, at least in any considerable degree. The right ventricle of the heart was greatly enlarged, and the pulmonary artery showed a remarkable thickening of its wall, there being scarcely any difference between it and the aorta.

The absence of pulmonary tissue in the upper lobe of the left lung indicated that the collapse had been of long standing, while the entire absence of pigment showed that if not congenital it had occurred in very early life. The enlargement of the right lung was thus compensatory, dating from a period when the organ was in a state of growth. The compensation seems to have been somewhat effective, as the person lived to the age of 46, and it was only during the later months of his life that he suffered from serious dyspnœa, followed by signs of venous engorgement. The remarkable thickening of the pulmonary artery without any appearance of atheroma, also seems to point to a compensatory hypertrophy of the right ventricle during the period of growth, the vessel in its growth accommodating itself to the increased blood-pressure. It may be added that the left pulmonary artery had only about a third of the calibre of the right, but the main bronchus was of equal size on the two sides.

PULMONARY EMPHYSEMA.

This name includes two distinct lesions, in one of which air escapes into the connective tissue of the lungs and distends the connective tissue spaces, while in the other the alveoli are over-distended and various other changes result, but the air does not escape from its natural chambers. It will be seen that the first form is comparable with surgical or cutaneous emphysema, while the second is essentially different. The one form is called interlobular or interstitial emphysema: the other, which is much commoner, is named vesicular emphysema or simply emphysema.

Interlobular Emphysema occurs when the air vesicles are ruptured and the air escapes into the interstitial tissue. The air vesicles may be actually torn open by a broken rib coming against the lung, or by the lung being directly wounded. On the other hand it occasionally happens that the air vesicles rupture from acute over-distension. We shall see afterwards that over-distension usually produces the other form of emphysema, but, if very acute and very extreme, it may lead to an actual rupture of the air vesicles. A sudden obstruction of a considerable bronchus, causing imperfect inflation of a portion of lung, may cause such serious over-distension of other parts as to lead to actual rupture of the air vesicles. More commonly it is the result of very violent expiratory efforts generally with, but sometimes without, obstruction of the air passages. It has been met with in hooping-cough, in diphtheria, and in violent coughing from the inhalation of irritating material. The violent efforts with closed glottis cause such compression of the air in the alveoli, that at some place the vesicles rupture. As seen after death the air appears in the form of minute rows of bead-like bubbles, visible through the pleura. These rows of beads demarcate the lobules. Occasionally there are larger bullæ, which have been known to rupture externally, and so lead to pneumothorax. The air sometimes travels along the connective tissue for some distance, just as we find in the case of subcutaneous emphysema. It may pass to the root of the lung, and from there up along the trachea and out to the subcutaneous tissue of the neck, and so lead to a surgical emphysema. This has led in some cases to a mistake in diagnosis, as Virchow has pointed out. Interlobular emphysema sometimes occurs in diphtheria, and may lead to subcutaneous emphysema in the way just mentioned. But if tracheotomy has been performed, it may be thought that the emphysema has taken origin in the wound.

VESICULAR EMPHYSEMA.—In this condition the air vesicles are over-distended, and, by partial atrophy of their walls, to some extent coalesced, but without any actual tearing of them. It will be clear that the distension must be frequently repeated or permanent, and we have to consider to what it may be due. Of course the distensile force is in the air within the air vesicles, and it may be exercised either in inspiration or expiration.

When the glottis is closed, and EXPIRATION violently performed, then the air in the vesicles will be at an increased pressure. The expiratory effort is produced by the muscles causing the movable walls of the chest to be pressed against the lung. The contraction of the abdominal muscles presses the diaphragm upwards, while the ribs are depressed. The lung is thus compressed, but at the same time it is supported by the structures which compress it, and the same force that increases the pressure helps the lung tissue to resist it by increasing the support. When the glottis is closed, the whole lung may be regarded as one cavity, and the pressure will be universally diffused. It may be expected, therefore, that if any part of the lung be insufficiently supported, the distensile force will tell especially there. The question therefore arises, Are there any parts where the lung is not fully supported by the chest walls? If a deep breath be taken, the glottis closed, and the act of expiration vigorously performed for a few seconds, we find in our own feelings indications that the lungs are over-distended, mainly at the anterior parts and the parts above the clavicles. We can easily understand how this should be. The anterior part of the chest, by reason of the flexibility of the costal cartilages, is more movable than the rest of it, and the anterior edges of the lungs, as we can see in an animal whose chest is laid open while artificial respiration is carried on, have very free play. Then, above the clavicle the lung is obviously less supported than where the chest has bony walls. We shall see afterwards that these, with one or two other parts, are those in which emphysema, when due to frequent expiratory efforts, occurs most typically.

It will be obvious that if the lung tissue has lost in elasticity, the permanent dilatation of the air vesicles will occur more easily, and will readily extend to parts more fully supported than those mentioned. In the form to be afterwards referred to under the name of Senile Emphysema, there is a loss of elasticity from the atrophy of old age. But there seems to be in some cases a general loss of elasticity, and it appears as if such a condition were hereditary to some extent. It

is true that frequent over-distension will cause atrophy of the elastic tissue of itself, but it is quite apparent that in many individuals there is, to begin with, less elastic tissue, or it is less resistant, and so we have a predisposition to emphysema, sometimes inherited.

We have still to inquire under what circumstances frequent or violent expiratory efforts are made with closed glottis. Coughing implies such efforts, and it is in diseases where coughing is a prominent feature that we are to look for emphysema from this cause. It is met with pre-eminently in bronchitis. It also occurs in hooping-cough, occasionally in croup, and even in the violent expiratory efforts of parturition, although in the last two cases interlobular emphysema is more likely to occur from the sudden and violent nature of the distension. As chronic bronchitis is peculiarly a disease of more advanced life, we may expect that a preliminary atrophy of the lung tissue, implying a loss of elastic tissue, plays an important part in the production of emphysema in a large number of cases.

We turn now to cases in which the air vesicles are over-distended during INSPIRATION. A large number of cases of what is called COMPENSATORY or VICARIOUS EMPHYSEMA belong to this class. If a part of the lung does not distend fully in inspiration, there must either be a falling in of the chest to a corresponding extent, or else an over-distension of another part of the lung in order to fill up the space. To what extent one or other or both of these will occur is determined by circumstances, chiefly by the situation of the insufficiently distended part and the time occupied in the occurrence of the lesion. There are many different circumstances under which compensatory emphysema may occur. If a portion of the lung is collapsed, the neighbouring part often undergoes emphysematous distension. It occurs thus in bronchitis, and the wedges of collapse, already referred to, are often fringed with emphysema. We see it also around cicatrices in phthisis, or along with bronchiectasis in fibroid phthisis. Emphysema occurs sometimes to a remarkable extent in connection with general adhesions of the lung, and the emphysema is often very marked at the anterior parts. In order to explain this it is to be remembered that the lungs have a considerable play in the thorax. They come well forward in inspiration and retreat during expiration. We see this in the opened thorax during artificial respiration, but in the closed thorax the greater mobility of the anterior wall of the thorax and the elevation of the sternum produce a similar shifting of the lung. But now if one lung is

bound down by firm general adhesions, this play of the lung is prevented, and the distension of the lung as a whole is hindered. There may be as a result deficient movement of that side of the chest as a whole. The sternum will continue to rise during inspiration, however, and, in order to fill up the space, one of two things will happen —either the other lung, if not also adherent, will be over-distended and project beyond the middle line, or else an emphysema will occur at the anterior parts of the adherent lung; this latter is very frequently seen.

It is sometimes stated that emphysema occurs in cases of condensation of the lungs, as in pneumonia and especially in phthisis. We have here to do with conditions in which the air vesicles are filled up with solid material and air does not get in; the finer bronchi are at the same time plugged. The air vesicles are not necessarily distended with the material, but, being plugged, they do not expand during inspiration. For this reason the chest in phthisis is often immobile in its upper part, and it may even fall in somewhat even without the formation and collapse of a cavity. On the other hand, this deficient expansion may lead to a compensatory emphysema.

There is still another way in which it is asserted emphysema occurs in the inspiratory phase. If the bronchi be partially obstructed, the more powerful inspiratory muscles may be able to overcome the obstruction while the expiratory forces, which normally depend mainly on the elasticity of the lung, may do so much less efficiently. At each inspiration, therefore, the air vesicles are over-distended, and are only partially relieved in expiration, so that there is an almost continuous condition of dilatation, which readily passes into emphysema. This applies chiefly to the case of bronchitis, and especially where the smaller bronchi are partially obstructed by swelling of the mucous membrane. This view does not now meet with very general acceptance, especially as in bronchitis the coughing gives frequent violent expiratory acts.

We have next to consider the ANATOMICAL CHANGES which occur in the lung tissue in emphysema. We have to do with air spaces of irregular shape and separated by partial partitions, and as the distensile force acts from within, its tendency is to distend equally and so render the spaces globular. The ultimate bronchial tubes terminate in the elongated passages called from their shape infundibula. From these passages open by wide apertures the air vesicles, which therefore cluster around the infundibula and are mere pouches out from them. The distensile force will act first on the infundibulum with its system of air

vesicles, causing distension. The tendency will be to render the outline more globular and the cavity simpler. The partitions separating the alveoli atrophy, and the infundibulum expands into a simpler cavity (*a a* in Fig. 224). Thus while more space is occupied there is less res-

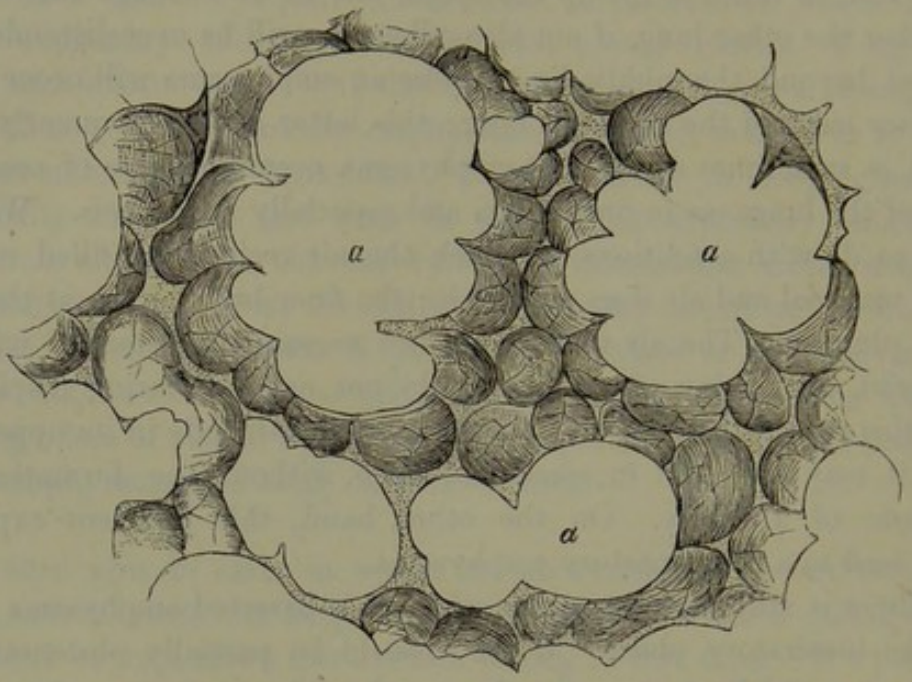


Fig. 224.—Section of the lung in emphysema, early stage. The infundibula, *a*, *a*, *a*, are dilated. × 100. (RINDFLEISCH.)

piratory surface. The infundibulum continues to expand and meets with other infundibula undergoing a similar process. By mutual pressure the adjoining tissue atrophies, and the two communicate by such rounded apertures as are shown in Fig. 225. The larger cavity tends to become simpler by atrophy of all partitions and septa, and so the process goes on by coalescence of neighbouring spaces and atrophy of the partitions. The enlarged air spaces thus produced are of various sizes, up to considerable vesicles or bullæ. With this atrophy there is great loss of tissue and of blood-vessels. Before the actual destruction of the blood-vessels the pressure seems to cause obstruction of them so that they are not able to be injected and appear as white cords. It is stated that this obstruction is effected by the formation of white thrombi. The epithelium for the most part persists in the distended air spaces, but it is frequently in a state of fatty degeneration. It may happen that, as in Fig. 225, the wall of the alveolus has atrophied except the epithelium, and the actual apertures are formed by its being shed. Of most importance is the atrophy of the elastic tissue, because on this account the lung tissue will be prevented from collapsing as it normally does.

The changes in the lungs visible to the naked eye are in accordance with these alterations in the finer structure. In the first place the

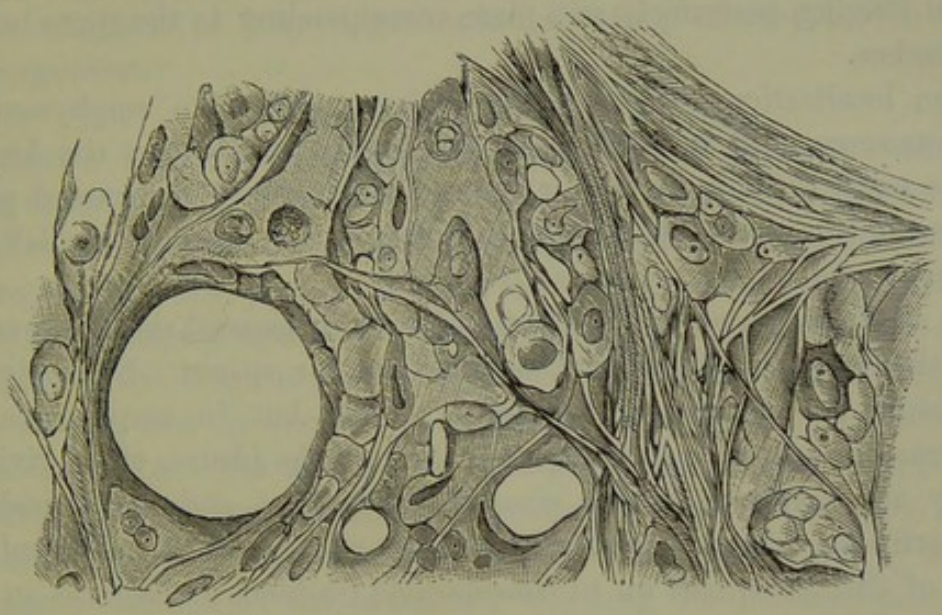


Fig. 225.—Emphysema of lung, portion of the wall of an alveolus. There are several rounded apertures. In some parts, and especially at right hand corner, an aperture seems to be forming by the separation of epithelium which has come to form the entire thickness of the alveolar wall. × 600. (THIERFELDER.)

changes described cause the affected lung tissue to take up more room, and there will, therefore, be enlargement of the lung varying in extent and situation according to circumstances. If the emphysema be at all extensive the lungs as a whole appear more bulky, and when the chest is laid open they may appear as if bulging out at the aperture. This appearance is not altogether due to the enlargement, but to a certain extent it is related to the fact that as the elastic tissue is largely lost the lungs do not retract in the normal fashion. The increase of bulk is usually most manifest at the anterior margins which, in bronchitis at least, are the most frequent seats of the lesion. The margins are unduly voluminous and the edges rounded. It not infrequently happens that certain portions of the anterior margins undergo special enlargement, a projecting piece of lung becoming by its increase in bulk partially isolated. The tongue-shaped projection at the edge of the left lung corresponding with the lower part of the heart, often presents considerable elongation and partial separation.

Another locality where emphysema is often very manifest is the base. Here there are frequently rounded prominences projecting against the diaphragm, and the diaphragmatic surface of the lung as a whole may be convex instead of concave. This is especially the case in the left lung where the diaphragm is not supported by a solid organ as it is on the right

side by the liver. Again the enlargement is very frequent at the apices. It has been pointed out by Jenner that the right lung often presents a special bulging posteriorly at a place corresponding to the space behind the trachea.

The localization will be more various where the emphysema is compensatory, and in that case will depend greatly on the locality of the cause. Thus we see it around cicatrices or contracted pieces of lung, but in nearly all cases there is a tendency to affect especially the anterior parts.

In all these places, with increase of bulk in general there is, even to the naked eye, a visible enlargement of the air spaces. Normally, the individual air vesicles are scarcely visible, but in emphysema the abnormal air spaces are plainly seen through the pleura, often giving a frothy appearance from the size of the vesicles and the delicacy of the partitions. Beyond this we may have all degrees of visible enlargement of the air spaces up to considerable bladders as large as an egg. The emphysematous portion is unduly pale, and gives a soft downy feeling to the touch. On cutting into it there is often a creaking, crisp sound, and if the vesicles are large they collapse markedly.

We have still to consider some of the EFFECTS OF EMPHYSEMA on other parts. The lungs are permanently increased in bulk, and the capacity of the chest is correspondingly increased. The chest is kept more or less in the condition of deep inspiration, the diaphragm depressed and flattened, the shoulders elevated, the sternum pushed forwards and outwards, and the chest more or less barrel-shaped. The heart is depressed along with the diaphragm and placed more horizontally, while it is overlaid by the edges of the lung. The liver is pushed downwards by the flattened diaphragm. The emphysema has a serious effect on the circulation. We have seen that there is obstruction and destruction of the blood-vessels in the lung, and this reacting on the pulmonary artery causes engorgement of the right ventricle. The right ventricle is induced to hypertrophy by reason of the increased strain thrown on it, and by more vigorous efforts it may to a great extent compensate for the obstruction and send enough blood through the reduced channels. But the compensation may, as the disease advances, be insufficient, and so we have insufficient aëration of the blood and dilatation of the right ventricle without corresponding hypertrophy. On this follow all the serious results of venous engorgement already referred to. The dilatation of the heart is more apt to ensue

if, from imperfect nutrition of the heart, the muscular fibre undergoes fatty degeneration, and as a matter of fact the actual fatal result is often traceable to fatty degeneration allowing of very severe venous engorgement.

Senile Emphysema is primarily an atrophy of the lung tissue along with atrophy of the other tissues of the body. The lung in this form does not become more voluminous, but rather retracts and becomes softer and more pliable. On opening the chest the lungs are found much reduced in bulk and collapsed against the posterior wall of the chest. The normal weight of the lungs is about 44½ ounces in the male and 35 ounces in the female, but in senile emphysema they may be only two-thirds of this weight. The air vesicles undergo changes similar in appearance to those in ordinary vesicular emphysema; their walls atrophy and the infundibula coalesce so as to form larger cavities, but this is by a simple process of atrophy. On examining the lung the increased size of the air spaces may be invisible at first, but if the lung be distended, or if after laying it open by incision it be floated in water, the large vesicles become visible. Of course old people are subject to bronchitis, and senile atrophy may strongly predispose to the more ordinary form of emphysema.

DISORDERS OF THE CIRCULATION IN THE LUNGS.

It is to be remembered that the pulmonary arteries are thin-walled, and that their muscular coat is comparatively inefficient. Any increase of blood-pressure, therefore, will tell with full force on the pulmonary circulation. The capillaries are abundant and closely set, and are capable of great distension. Their dilatation will cause them to project into the air vesicles, and it is not improbable that they sometimes interfere seriously with the inflation of the air vesicles.

Active Hyperæmia.—This is a condition which we have few opportunities of actually observing, but which is to be inferred as existing under certain circumstances. It has been a matter of question whether an increase in the strength of the cardiac contractions is capable by itself of producing active congestion of the lungs. But, to take a simple example, the feeling of breathlessness which one experiences in going up a hill, accompanied as it is with severe palpitation and a feeling of oppression in the chest, is probably due to an active hyperæmia of the lungs from this cause. The exertion of the body

sends more blood to the right ventricle and also stimulates the heart to increased exertion. A larger amount of blood is forced into the pulmonary artery, and at a greater pressure. Thus the feeling of oppression and breathlessness may be due to the overloading of the vessels, and perhaps to some extent to the insufficient inflation of the alveoli. In some persons this condition is brought about by very slight exertion, their hearts being peculiarly excitable; or it may occur without any exertion at all. In persons with damaged hearts, in whom the pulmonary circulation is already somewhat engorged, a very slight increase in the force of the heart may bring on a further hyperæmia such as to lead to severe dyspnœa. Thus we know that persons suffering from mitral disease find great difficulty even in ascending a stair.

An acute hyperæmia sometimes develops as a COLLATERAL HYPERÆMIA. Cases have been recorded in which a person while heated has drunk large quantities of cold water, and has immediately been attacked by great dyspnœa, which has even been fatal. Hertz has related a case in which a workman, while much heated, went into a vault and drank a quantity of water which he had cooled with ice. He was immediately seized with the most intense dyspnœa, and soon began to expectorate a bright red sputum. In this case there was evidently an acute hyperæmia, which would probably have proved fatal but for timely venesection. The exact mode of occurrence of such severe hyperæmia has been made the subject of experimental investigation. Quantities of ice-cold water have been introduced into the stomach in animals, while the blood-pressure was registered by a kymograph connected with the carotid. The result was an immediate and very marked increase of blood-pressure. The cause of increase in pressure was not the absorption into the blood of an excess of fluid, because an equal quantity of warm water injected directly into the veins produced no such rise. The explanation is that the cold water reduces the temperature not only in the stomach but in the organs around. The result of this application of cold is contraction of arteries, and as in this neighbourhood there are a large number of arteries—those of the stomach itself, the splenic, the hepatic, and the mesenterics, with their numerous fine ramifications in the mesentery and intestine—their sudden contraction at once raises the blood-pressure, and this acts most readily backwards on the lungs. On similar grounds, we may explain the breathlessness which one experiences in plunging into cold water. Here the arteries of the skin contract, and the risk of pulmonary congestion is greater if the cutaneous arteries

have been peculiarly relaxed, as when the person has been much heated beforehand.

A simple active hyperæmia of the lungs seldom gives rise to œdema. We have already seen this to be the case in regard to active hyperæmia in general, and it especially applies here. In the case which we have cited from Hertz there was curvature of the spine, and some contraction of the thorax, and this may have had to do with the severity of the hyperæmia and the occurrence of œdema as evidenced by the râles in the chest and the expectoration.

PASSIVE HYPERÆMIA AND PULMONARY ŒDEMA.—Passive hyperæmia is of much more frequent occurrence than that just considered. In the regular course of post-mortem examinations, we very frequently find that the dependent parts of the lungs present a dark blue colour due to the vessels being over-filled with blood. This condition is commonly called HYPOSTATIC ENGORGEMENT, and to a certain extent it is really of post-mortem occurrence, the blood gravitating to the dependent parts of the lungs. In many cases, however, it has existed, at least partly, during life, especially when it is associated, as it commonly is, with œdema. This condition arises most frequently in persons whose hearts are weakened by debilitating diseases, and it frequently develops not long before death. In a large number of cases of all kinds of debilitating diseases we find just before death the chest full of râles and the breathing much obstructed, and it is in these cases that we find hyperæmia and œdema after death. Or the engorgement and œdema may occur in the midst of a debilitating disease, such as typhus fever, when they are regarded as of very serious import. Sometimes an œdema develops with remarkable suddenness, and seriously endangers life.

It has been stated above that the hyperæmia and œdema in these cases are connected with weakening of the heart, but it is not easy to see how this should produce such results, especially when they are of sudden occurrence. When the blood is already deteriorated, as in typhus fever, and when by reason of the weakness of the heart the circulation is very sluggish in the capillaries of the lung, we can understand the occurrence of engorgement and œdema, just as in these diseases we may have gangrene of the toes. Here the absence of the proper renewal of the blood causes the vessels to lose their natural vigour and allow of transudation. In the more ordinary cases of hypostatic œdema occurring just before death, we have also, as a consequence of some debilitating disease, not only weakness of the heart, but deterioration of

the blood, and these together may account for the occurrence of the engorgement and œdema.

But there are some cases in which œdema occurs suddenly, and without any previous anæmia or morbid condition of the blood. Some of these are cases of Bright's disease, and the œdema here is of similar import to that of the skin in that disease. There are cases, however, chiefly of heart disease, in which a sudden œdema occurs and is sometimes fatal. These cases can hardly be accounted for by a simple weakening of the heart as a whole, or else we should have œdema in cases of syncope in which there is simple failure of the heart. An endeavour has been made to account for it by supposing increase of blood-pressure in the pulmonary circulation. It has been shown by Cohnheim, from experiments on animals, that in order to produce pulmonary œdema the blood-pressure must be enormously increased, much more than is ever likely to happen from simple mechanical interruption to the circulation in the ordinary way. This author has found, however, that if the left ventricle be paralysed while the right keeps beating vigorously, we may have such an increase of blood-pressure as to cause œdema of the lungs. The weakened left ventricle does not empty itself, and acts as an obstruction to the return of blood from the lungs, and the obstruction is so great that the right ventricle cannot overcome it. It might be objected to this that if the left ventricle is thus paralysed the systemic circulation will be at a standstill, and very little blood will find its way to the right ventricle. But we have to consider that in such patients there is urgent dyspnœa with violent inspiratory efforts which have the effect of sucking the blood into the chest. The diastole of the right heart also acts in the way of drawing blood towards it. These cases then of sudden œdema may be accounted for by weakening of the left ventricle while the right remains vigorous. Any special overstraining of the left ventricle may cause sudden paralysis of it. It is not improbable also that immediately before death the pulsations of the left ventricle may, in many cases, cease before those of the right, and that the ordinary œdema at the end of debilitating diseases may have partly a similar origin.

When the lungs are examined after death in cases of passive hyperæmia, they present a dark blue colour which is often limited to the posterior parts and those towards the base. If œdema co-exists, as it so often does, the tissue is bulkier and more solid. If the lung be divided with the knife and the organ squeezed, a frothy fluid mixed with blood issues from the cut surface, If the œdema exists without much hyper-

æmia the lung is pale, but bulky and heavy, and a watery fluid exudes from the cut surface. The condition of hyperæmia with œdema is sometimes called SPLENIZATION, because the tissue is like that of the spleen in its naked-eye characters. Examined minutely it is found that the capillaries are distended and the air vesicles filled with serous fluid in which leucocytes and red corpuscles are present.

If this condition persists, it usually passes gradually into an inflammatory condition. Fibrine is exuded into the air vesicles, but it is mixed with serous fluid, and does not give that extreme solidification to the lung which we find in acute pneumonia. The lung is more solid than in splenization however, and the colour is not so deep. In some cases we find a close approximation to actual hepatization, and there may even be breaking down of the inflammatory products, as in the later stages of a pneumonia, so that on squeezing the lung a grumous fluid exudes from the cut surface.

PASSIVE HYPERÆMIA OF THE LUNGS FROM HEART DISEASE.—This subject has to a large extent been treated of in previous paragraphs, but some special points remain to be considered. In mitral disease especially, there is a constant obstruction to the return of blood from the lungs, which, in many cases, is largely compensated by hypertrophy of the right ventricle, but even when it is so the pulmonary circulation will be constantly at an increased pressure, and there will be, consequently, a more or less permanent passive hyperæmia. This passive hyperæmia has various secondary results. The most prominent of these during life is bronchitis, a more or less persistent catarrh of the bronchial mucous membrane. Another result is the condition designated BROWN INDURATION. In this, as in other cases of prolonged passive hyperæmia, the connective tissue of the lung is thickened and increased in density, so much so that the condition was described by Rokitansky as an inflammatory hypertrophy of the connective tissue. At the same time the capillaries are distended and rendered tortuous. This condition of the capillaries is rendered obvious by separating a piece of lung tissue by a ligature, placing it in nitric acid, and then in spirit. Sections will show the enlarged and varicose capillaries as a brownish-red network. The larger vessels are also dilated and their supporting connective tissue hypertrophied. The dilated capillaries are apt to allow of the leakage of blood corpuscles into the interior of the alveoli, and these give the sputum a bloody appearance. Hæmorrhage occurs also into

the connective tissue, and the result is a pigmentation, the colouring matter existing in the form of granules contained in the connective tissue corpuscles. The blood in some of the capillaries may stagnate altogether, and in that case the capillaries will come to be represented by a network of brown pigment.

The general appearance of the lung corresponds to the finer characters. As a whole the lung is more consistent, and does not retract so fully as usual when the chest is laid open. The colour is brownish, but it varies considerably both in different cases and in different parts of the same lung. There may be a general brownish colour, or there may be lighter and darker pieces, according as local hæmorrhages have occurred more or less recently.

We must remember that the hæmorrhagic infarction occurs mainly in cases of heart disease, but has a different origin as appears in the next section.

The Hæmorrhagic Infarction.—This condition has already been the subject of study when treating of embolism at p. 37. We there saw that the pulmonary artery and its branches are end-arteries, and that obstruction of one of them is likely to produce the hæmorrhagic infarction. We saw, however, that two circumstances render this result less uniform in the lungs; in the first place, the wide capillaries may act as anastomosing vessels, and so the circulation may be kept up sufficiently to prevent diapedesis; and, in the second place, the bronchial artery keeps the lung tissue, to a certain extent, nourished. We saw that when the infarction occurs it is likely to form at the periphery of the lung, especially towards the edges where the lung substance is covered on more than one side with pleura. The infarction forms by the blood taking a backward course from the veins into the capillaries. The capillaries become engorged, and the red corpuscles pass through their walls into the lung alveoli, which they fill to the exclusion of the air.

But the hæmorrhagic infarction appears to form sometimes as a result rather of thrombosis than of embolism of the pulmonary artery. In cases, especially of mitral disease, there may be, from the great obstruction of the circulation in the lungs, an actual stasis in the capillaries, and if the stasis extends backwards to the pulmonary artery, it may induce coagulation there. If thrombosis occurs in the pulmonary artery, then the blood in the corresponding veins will take a backward course as before, and the previous engorgement of

the vessels from the mitral disease will render this all the more likely; the capillaries will be distended, and diapedesis will result. A hæmorrhagic infarction occurring in this way will closely resemble one having an embolic origin, and the thrombus may be itself hardly distinguishable from an embolus. The infarction will, like the other, have a wedge-shape, with its blunt end towards the surface. It may be added that this mode of origin is much less common than the other, but that an embolus is often increased in size by thrombosis, and may not obstruct till added to by thrombosis.

The appearances of the hæmorrhagic infarction are such as result from distension of the air spaces with blood. If quite recent it is of a dark blue colour, dense to the feeling, and more or less wedge-shaped, with the apex inwards. It may present all varieties of size

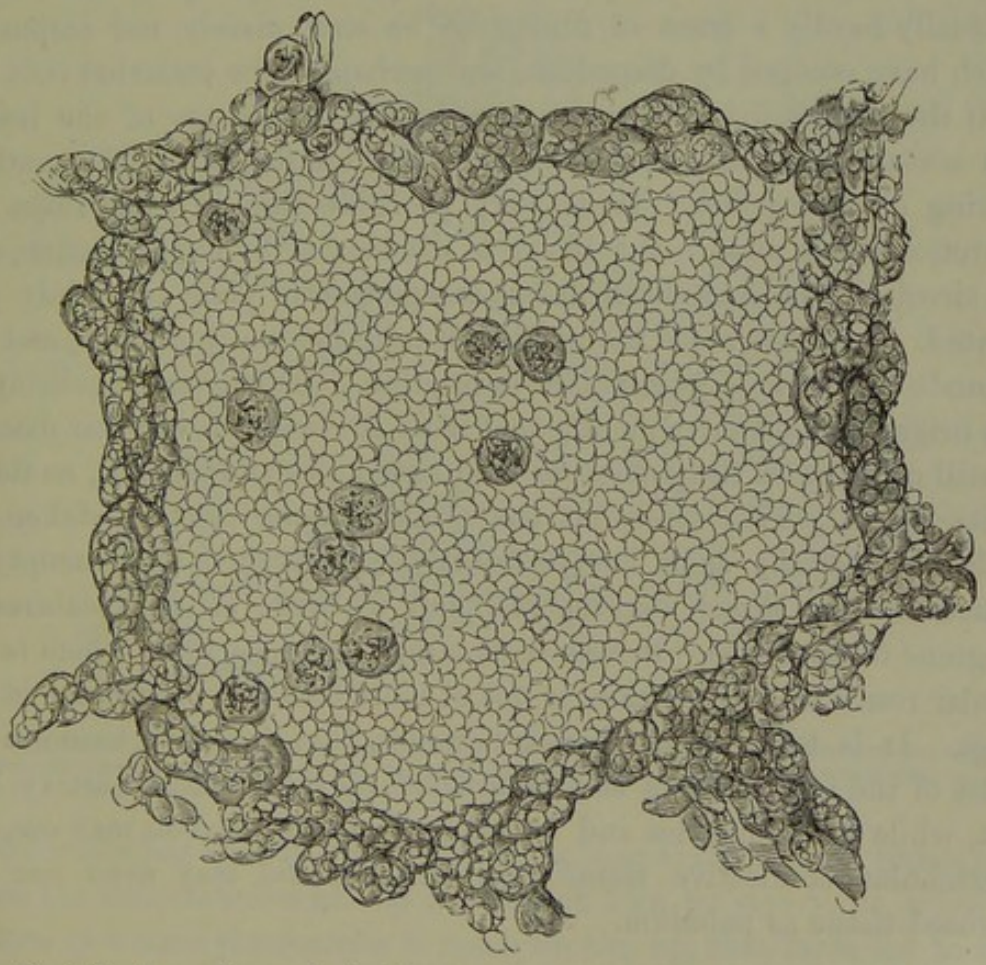


Fig. 226.—From a hæmorrhagic infarction of the lung. The alveolus is filled with red blood corpuscles, with one or two large catarrhal cells. In the wall of the alveolus the capillaries are greatly distended with blood. × 350.

up to half the lung. As the infarction is mostly peripheral it may be often recognized by the dark colour seen through the pleura, but

it is more easily discovered by handling the lung when the solid mass is readily detected. At first it looks on section like a recent blood clot, and has almost a similar smooth surface, but as time goes on the colour merges into brown, and the appearance may come to resemble that of red hepatization. As blood fills the air spaces the piece of lung is more bulky than that surrounding it. The infarction, therefore, is often seen as a rounded bulging beneath the pleura, or when the lung is divided it stands at a higher level than the surrounding tissue. The pleura over the infarction is usually covered with a layer of fibrinous exudation of a yellow colour, and the pleural cavity contains fluid, often in considerable quantity.

Under the microscope, as shown in figure 226, we have simply an enormous aggregation of red corpuscles in the lung alveoli and finer bronchial tubes, with distension of the pulmonary capillaries. There is usually hardly a trace of fibrine to be seen, merely red corpuscles which have escaped by diapedesis, and perhaps a few catarrhal cells.

If the patient live for some time after the occurrence of the infarction certain changes occur in it, but there are few actual observations bearing on this point. It is very probable that in some cases the infarction clears away; the blood is discharged by expectoration, and the circulation is re-established, but the portion of lung is unduly pigmented. In other cases the portion of lung gradually shrinks, and the ultimate result is a pigmented induration. Indurations, probably of this origin, are not infrequently met with in cases of valvular disease. In still other cases the portion of lung tissue dies and sloughs, so that a cavity forms. This condition has probably been often mistaken for phthisis, especially as it has probably been preceded by hæmoptysis. Sometimes the slough decomposes, and we have all the features of gangrene of the lungs. It may seem strange that necrosis, which is the regular result in other organs, is not of more constant occurrence in the lungs. It is to be remembered, however, that the lung tissue in the midst of the infarction is still nourished by the bronchial artery, and that, while the capillaries and actual walls of the alveoli may die, the interlobular connective tissue may survive, and may even use the necrosed tissue as pabulum.

Embolism of the Pulmonary Artery has been referred to in its relations to the hæmorrhagic infarction, but we have already seen that it by no means uniformly leads to that result. If the main artery of a lung be obstructed the infarction cannot occur, because by

the obstruction of the artery the lung is deprived of blood. But even when smaller branches are occluded the infarction may be absent. Cases of sudden death after parturition occur from embolic obstruction of the lungs without any infarction. The suddenness of death in some of these cases seems to indicate that it is not due entirely to the obstruction in the lungs and consequent non-aëration of the blood. It seems rather due in great measure to the fact that, as the blood is prevented from reaching the left ventricle in sufficient amount, the brain and medulla oblongata are deprived of their proper nourishment. In such cases the right ventricle will be found dilated, while the lungs are pale and probably over-inflated by the violent but ineffectual respiratory efforts. These sudden deaths after confinement used to be explained as cases of shock before Virchow pointed out their true significance.



Fig. 227.—Oil or fat embolism of the lung. The fat occupies the smaller arteries and extends into the capillaries, which, towards the right, form a network injected with oil. × 90. (THIERFELDER.)

Reference has already been made to the special form of OIL EMBOLISM. When the subcutaneous fat has been much torn by injury, or when in fracture of a bone the marrow is much broken up, then fat is apt to find its way into the veins, and this is especially the case when the open mouths of the veins in the broken bone come in contact with the fluid fat rendered free by the tearing of the adipose tissue. The fat is carried by the veins to the right heart and thence to the lungs. It

floats in the blood as larger or smaller drops, and it may obstruct branches of the pulmonary artery of not inconsiderable size, and frequently produces extensive injection of the capillaries (see Fig. 227). If the obstruction be extensive, even though the capillaries are the vessels mainly affected, then serious results may follow. We may have diapedesis and condensation, but in a scattered irregular form. When the lungs are laid open by incision, the fat drops may sometimes be detected with the naked eye by their glancing character as they have issued on the cut surface.

Pulmonary Hæmorrhage.—We have still to refer to certain forms besides the hæmorrhagic infarction. The hæmorrhage which occurs in heart disease, and which leads on to brown induration, has been considered already. That which so frequently occurs in phthisis will be taken up afterwards. Then there is hæmorrhage in consequence of tearing of the lung by a broken rib or otherwise. It is asserted also that there may be rupture of a branch of the pulmonary artery from fatty degeneration of its walls, as we may have hæmorrhage in the brain from atheroma, but this is excessively rare.

In the case of tearing or rupture there is a massive hæmorrhage, and the blood forms a cavity for itself just as it does in a cerebral hæmorrhage. To such conditions some would apply the name pulmonary apoplexy, but as this is more frequently used to designate the hæmorrhagic infarction, it is perhaps better to discontinue its use. According to Rokitansky, blood thus effused may become encapsuled and subsequently become infiltrated with lime salts like a foreign body.

When the hæmorrhage is from the bronchial mucous membrane or the lung alveoli, then it appears in the sputum. To some extent, however, the blood remains in the air-passages, and if it be in considerable quantity it may even be carried in considerable quantity into the lung alveoli. The blood, in this case, is mixed with air, and there is no such condensation as that which occurs in the hæmorrhagic infarction. In the lung alveoli the blood acting as a foreign body irritates the tissue and a catarrhal inflammation may result. In such cases large catarrhal cells may occupy the alveoli wherever the blood has penetrated, and these cells may be deeply stained with the colouring matter of the blood.

It is stated that blood insufflated in large quantities may even cause necrosis of the lung tissue in which it lies, and so give rise to a condition like that of the infarction. This may, perhaps, occur when

the lung is already seriously damaged, as in phthisis pulmonalis, but hardly in an otherwise healthy lung. It is also possible that blood may be drawn into cavities and form fibrinous plugs there.

INFLAMMATIONS OF THE LUNGS.

ACUTE PNEUMONIA.—This is a disease essentially of the lung alveoli, and as the most prominent feature is the exudation of fibrine into the alveoli, it is frequently called croupous pneumonia. Its causation is somewhat obscure. In considering the causation of inflammations in general we have already referred to the fact that an irritant, such as carbolic acid, conveyed by the blood to the lungs may produce pneumonia. The fact that the disease affects whole lobes of the lung is also in favour of the view that the irritant is conveyed by the blood. Many physicians regard it as belonging to the group of zymotic diseases, and in favour of this is the fact that, while usually endemic, it sometimes assumes an epidemic prevalence. Lately Koch and others have asserted that a bacillus is present in the lung tissue. Koch finds it in the alveoli, but only in places where the disease is advancing, the condition in this respect resembling that in erysipelas.

The disease is an acute inflammation, and as the lung alveoli possess merely a single layer of pavement epithelium the inflammation resembles that of serous rather than of mucous membranes. As in the former we have here a fibrinous exudation, and though this occurs primarily and mainly in the alveoli, the fibrine, as we shall see, generally extends to the finer bronchi, forming casts of them.

Pneumonia has been divided into three stages, a preliminary one of engorgement, a second one of hepatization, which is divided into two divisions, red and grey hepatization, and lastly the stage of resolution. By separating the second stage into its two divisions we shall have four stages, under which arrangement it will be considered here, namely, engorgement, red hepatization, grey hepatization, and finally purulent infiltration and resolution.

In the first stage, that of ENGORGEMENT, the lung-capillaries are highly injected, and there is an exudation of serous fluid into the air vesicles. To the naked eye the affected portion of lung is of a dark red colour, to the touch it is inelastic, and the finger applied to the surface leaves a pit behind. On section a reddish serum flows out, and the tissue does not crepitate under the knife so much as in the natural state. Though heavier than usual, the diseased portion of lung still contains some air

and therefore usually floats in water. This state, from the resemblance of the cut surface of the diseased lung to the spleen, has been called SPLENIZATION. So far as the merely anatomical condition is concerned the lung is very much in the same state as in passive hyperæmia and œdema, such as we see in the ordinary hypostatic engorgement, and we have seen that the same term splenization is applied there. In the present case, however, the splenization is not localized in the dependent parts as in the other, but it affects a definite region of lung, generally the lower lobe as a whole, along with, perhaps, a portion of the upper. The hyperæmia and œdema are, of course, inflammatory in character, and the serum is the inflammatory exudation. Like other inflammatory exudations, this fluid contains leucocytes and also red blood corpuscles, sometimes in large numbers. As the alveoli are filled with serous fluid, the air bubbling in and out among it during respiration produces the fine crepitation which is the characteristic auscultatory sign of this stage.

In the second stage, that of RED HEPATIZATION, we have fibrine exuded from the overfilled capillary vessels. In consequence a coagulum (Fig. 228) comes to occupy the lumen of the vesicles and infundibula, instead of the mixture of serous fluid and air which is present in the first stage. But the coagulum is not entirely composed of the fibrine effused from the vessels; it contains, in addition, abundant leucocytes and red corpuscles which are often so abundant as almost to conceal the fibrine. The fibrine may be detected as a coarse network with interlacing fibres (Fig. 229). The capillaries of the lung are in much the same state of over-distension as in the first stage, and the lung-parenchyma is likewise little altered. The red corpuscles are present in the alveoli in very varying proportion. They are never entirely absent, but in general form the minority of the total cells present; in some cases they are equal to the white ones, in some more abundant. In very rare cases they are so abundant that the exudation has more the character of an ordinary clot than of a fibrinous exudation. In these latter cases, which may be described as hæmorrhagic pneumonia, the lung itself has a deep red colour. These are mostly very severe cases, and imply a previous state of debility in the patient, very commonly referrible to alcoholic excess. In accordance with this exudation of red blood corpuscles we have in this and in the preceding stage, the rusty



Fig. 228.—Cast of small bronchus infundibula and air vesicles in pneumonia. × 40. (CORNIL and RANVIER.)

tinge of the sputum which is characteristic of pneumonia. The appearance of the lung in this stage is somewhat different from that in the first.

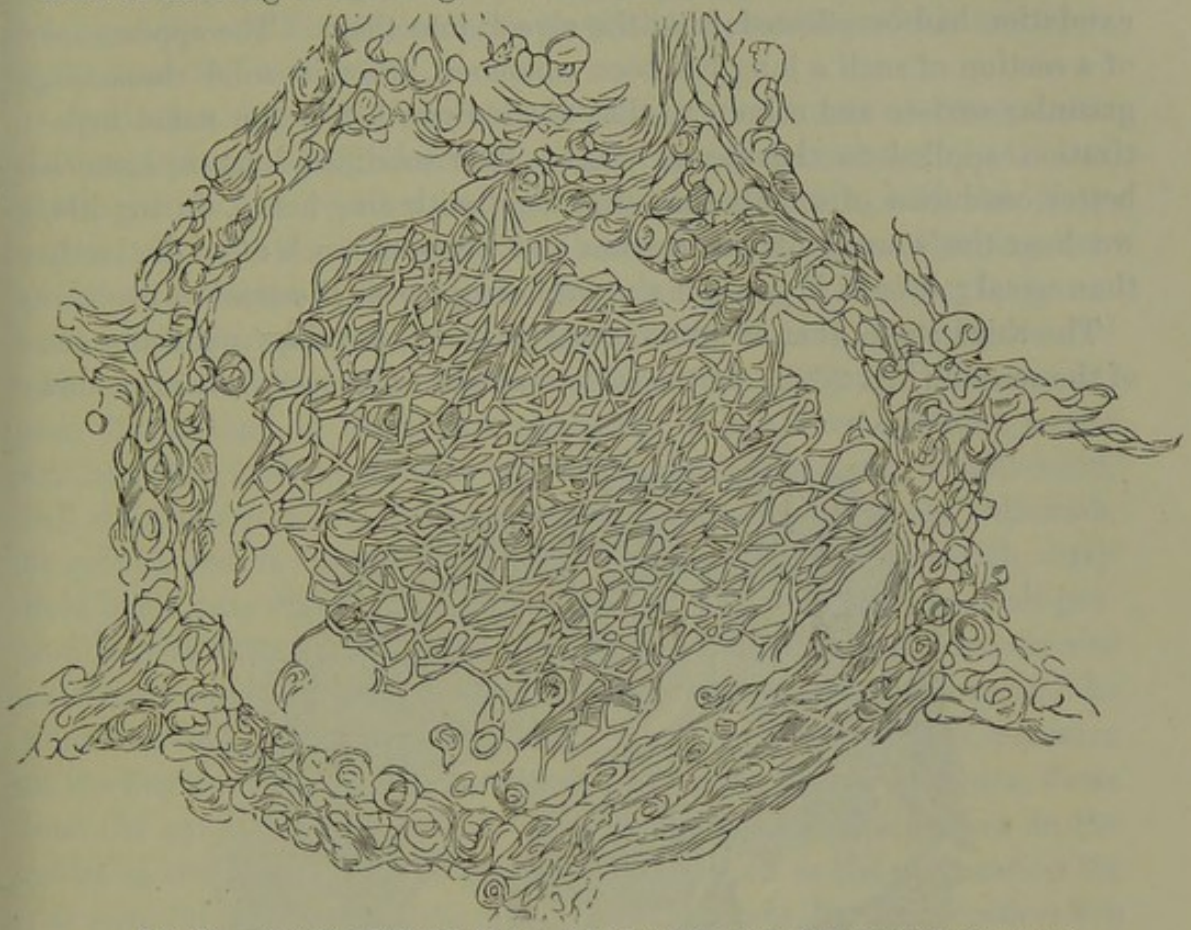


Fig. 229.—Alveolus filled with fibrine and a few leucocytes, from a case of pneumonia in stage of red hepatization. ×350.

It retains its red colour, both from the continuance of the congestion of the capillaries and from the red corpuscles in the exudation. But it is now much firmer and heavier—it does not crepitate under the knife or finger, and it sinks in water—no air being any longer contained in the vesicles. On section from a sound part into a hepatized part, it is observed that the latter remains on a level while the sound part sinks away so that the diseased part appears enlarged. Even on external examination the affected part of the lung looks bulky. On more close examination, the cut surface has not the homogeneous velvety appearance of the lung in splenization, but a coarse granular appearance, and this will be more readily seen on tearing the tissue and examining the torn surface with a lens. The red granulations thus brought out are undoubtedly the plugs of fibrine with corpuscles which fill the air vesicles. If you stroke a surface so cut with the blade of the knife you may succeed in getting one or two casts of the vesicles and infundibula which, under the microscope, have the appearance shown in figure 228.

If the bronchial tubes be cut open with scissors, the finer ones will generally be found to contain fine casts of soft fibrine, as if the exudation had overflowed from the alveoli into them. The appearance of a section of such a lung has been compared, from its solid character, granular surface and colour, to that of the liver, hence the name hepatization applied to the second stage. The solidified lung is a much better conductor of sounds than that filled with air; hence, during life, we hear the sounds of the trachea and bronchi much more distinctly than usual; it is as if you put the stethoscope over the trachea itself.

The third stage, that of GREY HEPATIZATION, develops naturally out of the second (Fig. 230). In the earlier periods red corpuscles are exuded

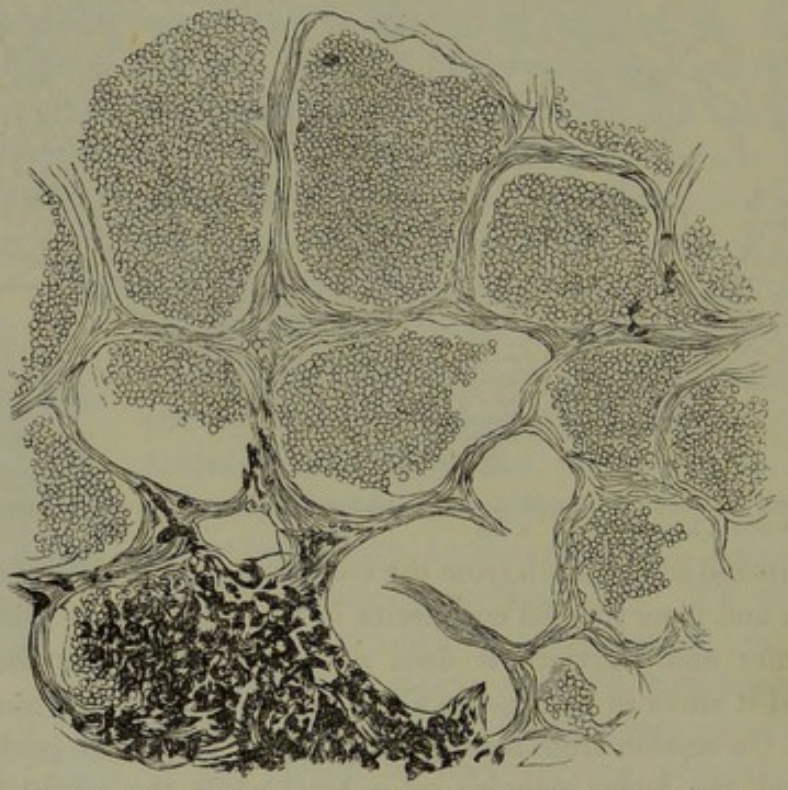


Fig. 230.—Section of lung in grey hepatization. The alveoli filled with plugs in which are multitudes of round cells. In the stroma the usual carbonaceous pigmentation of the lung is seen at lower part of figure. × 90.

largely, but except in cases of a hæmorrhagic kind the white very much preponderate in the later periods. The leucocytes swarming into the alveoli cover up the red corpuscles. The additional material in the vesicles also causes pressure to be exercised on the capillaries, which are thereby emptied. In this way we have, instead of the previous hyperæmia, an anæmia of the tissue. In accordance with the much less abundance of red blood, and the presence of an additional number of colourless cells, the colour of the tissue is changed. It retains the firm

character, and the granular appearance of the previous stage, but the colour is grey. The pigment of the lung intermixed with the white colour of the multitudinous cells gives the appearance which has been aptly described as marbled.

In the last stage, that of RESOLUTION and PURULENT INFILTRATION, the lung returns to its normal condition. In some cases the cells and fibrine in the air vesicles undergo fatty degeneration, and the plugs soften. The fat is partly absorbed, but to a large extent the degenerated corpuscles are expectorated. In other cases the leucocytes go on accumulating in the air vesicles, and as the fibrine degenerates and softens the alveoli come to contain what is virtually pus. The appearance of the lung in these two conditions is not very different, as the emulsion-like fatty material is not unlike pus. The lung is still solid, still sinks in water, but its firmness is gone, its surface is pale, yellowish, or greyish red, it has lost the granular appearance, and a greyish, dirty fluid oozes out, which makes the surface so slippery that a small portion is with difficulty lifted or held in the fingers. The tissue is also extremely soft, and tears under the mere pressure of the fingers. In removing such a lung from the body, unless care is exercised, pressure of the fingers may rupture the tissue, and as the pus or emulsion flows into the cavity it may give rise to the appearance of abscesses in the midst of the lung. This stage may be looked on as the preparation for the removal of the exudation, which takes place by the degeneration and absorption of the young cells, and by their expectoration. The exudation must have very thoroughly softened before it can make its way through the narrow neck of the infundibulum into the bronchus. After the infundibula and vesicles are emptied the blood returns in full force into the capillaries. Instead of the anæmia we have indeed a hyperæmia, for the tissue has been weakened by the inflammation, and is less able to resist the blood-pressure than formerly. It should be remembered in practice that the lungs of a pneumonic patient take some time to recover from the effects of the inflammation, and great exertion during convalescence should be warned against, till the tissue has recovered its tone.

While the above is the most common termination of Pneumonia sometimes it does not issue so fortunately. The purulent infiltration may involve the lung tissue, and by its sloughing an abscess may be formed. In this way we may have one or several ABSCESSES of various sizes, or several may coalesce into one of larger dimensions. In the

wall of the abscess a considerable vessel may rupture, and so we may have profuse hæmorrhage. The abscess may subsequently burst into a bronchus or the pleura, in the latter case producing empyema and perhaps pneumothorax.

Another unfortunate result which sometimes occurs is GANGRENE of the lung. This is mostly met with in the hæmorrhagic form and in drunkards, but it may occur where there is a bronchiectatic cavity with decomposing contents.

There are some cases of pneumonia which end in PHTHISIS PULMONALIS, and that either in the indurative or caseous form. This outcome is rare, and only occurs in persons predisposed to phthisis. Another rare result is CHRONIC PNEUMONIA, whose description follows below. It is more common than the termination in phthisis, and is probably mistaken for the latter not infrequently.

The PLEURA always takes part more or less in the inflammation of the lung. The pleural surface of the inflamed portion of lung is coated with a white fibrinous exudation, which is sometimes of considerable thickness. There is rarely any considerable serous exudation in the pleura, probably because the lung distended with the solid exudation fills the cavity, and by its pressure prevents the accumulation of fluid. Sometimes the pleural exudation takes on a purulent character, and an empyema may remain after the resolution of the pneumonia. In some cases the inflammation extends to the pericardium, on the surface of which there may be a slight fibrinous exudation.

Pneumonia is an acute febrile disease, and so produces secondary changes in the organs of the body, generally comparable with those in acute specific fevers. There is commonly, but not always, enlargement of the spleen. The liver is usually enlarged, and shows parenchymatous infiltration.

CHRONIC PNEUMONIA.—This name is one whose significance is somewhat ambiguous, and it will be necessary in the first place to define the meaning attached to it here. We include those conditions in which the lung tissue is the seat of a simple chronic inflammation, without anything of a tubercular or otherwise specific nature. The simplest cases are those in which an acute pneumonia, instead of resolving, passes into a chronic condition. In addition to that we may have a chronic inflammation set up by the inhalation of irritating particles, as among potters, stone-hewers, etc. In old persons ordinary pneumonia

is apt to be chronic, and it may therefore be said that senile pneumonia is included under the present head. To a certain extent the same is true of pneumonia in drunkards, and in debilitated persons, especially when it affects the apex of the lung.

The chronic inflammation here, as in other organs, is chiefly characterized by a new-formation of connective tissue, so that INDURATION of the lung is the result. In this view of it the terms chronic interstitial pneumonia, cirrhosis, sclerosis, fibroid phthisis, are sometimes used as being virtually of the same meaning as chronic pneumonia. But here it is necessary to distinguish very carefully. We shall see afterwards that there is a form of phthisis pulmonalis in which a great new formation of connective tissue occurs, but the inflammation in that case is due to the tubercular virus. In the disease at present under consideration there is no such irritant present, and the inflammation is simple. The proper tubercular fibroid phthisis is a much commoner condition than the simple chronic induration.

The appearances presented by the lung in cases of acute pneumonia which have had a prolonged course and have become chronic are not



Fig. 231.—Chronic pneumonia. The connective tissue is greatly increased, and the alveoli (a, a, a,) are represented by contracted spaces lined with well-formed epithelium. The epithelium here is much more distinct than in the normal alveoli. × 350.

unlike those of the lung in the stage of grey hepatization. The disease is generally confined to one lung, and may affect only a portion of it.

The lung is bulky and dense, and feels solid to the touch. When cut into, the solid lung has usually a grey colour, although sometimes with a tint of red, but it has a smoother cut surface than that in hepatization, and the tissue is also tougher. To this condition the name iron-grey induration may be aptly applied.

Under the microscope the conditions are such as are indicated in Fig. 231. The walls of the alveoli are greatly thickened by fibrous tissue, which largely encroaches on the alveoli, the epithelium of which is preserved, and sometimes occupies their interior. When it is considered that the lung as a whole is not reduced in bulk, and that the alveoli are in great part empty, then the overgrowth of connective tissue will be understood to be very great. Along with the interstitial new-formation there is commonly thickening and adhesion of the pleura. In the condition hitherto described, there is no considerable obliteration of the air vesicles except in so far as they are encroached on from without.

If the disease progresses however, the new-formed connective tissue takes on a cicatricial character and by its contraction destroys and contorts the proper lung tissue. Just as in the case of cirrhosis of the liver, there is here an atrophy of the normal structure and a tendency in the organ to shrink. This leads to dilatation of the bronchi on principles already enunciated, so that BRONCHIECTASIS is a prominent feature in advanced cases of this kind. The bronchial secretion may stagnate in the dilated bronchi and decompose; the irritation of the decomposing juices sometimes causes ulceration, and ragged cavities may thus form, so that the condition closely resembles that of phthisis.

ACUTE CATARRHAL PNEUMONIA (*Broncho-pneumonia, Capillary Bronchitis*).—This disease occurs most frequently in children, and is in them, as in adults, associated with catarrh of the finer bronchi. So close is the connection between the pulmonary catarrh and that of the bronchi that the disease may very properly be called BRONCHO-PNEUMONIA. The bronchi are first affected, and so it may be said that the pneumonia springs out of a CAPILLARY BRONCHITIS, the tubes affected being those of the finest calibre. In a large proportion of cases the bronchitis originates in measles, or it may occur in diphtheria, or small-pox, or hooping cough. In adults it may follow typhoid or other infectious fever, or it may be the result of the inhalation of irritating gases, or of the presence of decomposing material or foreign

bodies. It is to be noted that an ordinary bronchial catarrh, such as was described in the section on bronchitis, seldom goes on to a catarrhal pneumonia, but that for the most part the latter is due to the existence of some special irritant such as the virus of measles or decomposing juices in the bronchial tubes.

We have already seen that the presence of blood in the alveoli may cause it, and this is a good instance of the action of a foreign substance in its production. In this regard it is interesting that a catarrhal pneumonia may be produced in animals by division of the pneumogastric nerves. The pneumonia here seems due to stagnation of the secretion which is no longer expelled, and to the irritation which this produces.

As the disease begins in the bronchial tubes and is propagated to the lung tissue, it follows in its distribution the arrangement of the bronchial tubes; that is to say, it occurs in a LOBULAR form. Although the disease is thus primarily lobular, it is clear that it will often occur in several neighbouring lobules, and so a considerable tract of lung may be involved. This will be more particularly the case when it is due to the insufflation of irritating substances, which may be distributed in almost all the lobules of the lung.

As the disease begins in a catarrh of the finer bronchi, there is often COLLAPSE of the corresponding portion of lung before any actual inflammatory processes occur in it. The obstruction of the tubes with tough secretion sufficiently accounts for this collapse. It is a lobular collapse, and as seen from the surface areas of larger or smaller size are depressed and of a bluish red colour. These are mostly to be found in the first instance at the posterior and inferior parts of the lung. In other parts, and especially in the upper lobes, we may have emphysema. With or without a previous stage of collapse, the inflammation by and by extends to the lung alveoli. There is a rich production of catarrhal cells, which fill the alveoli and cause condensation of the lung. The affected pieces of lung tissue are firm and pale, and again present more or less of the lobular arrangement. This condensation of the lung tissue may be more or less extensive, and as it springs very often out of collapse there may be various gradations visible in the same lung.

The inflammatory products in the air vesicles may after a time undergo fatty degeneration, break down, and be discharged, some part of them being probably absorbed by the lymphatics. In some cases, however, the result is not in every part of the lung so fortunate. For

one thing, the collapse may never go on to a proper condensation, and when recovery takes place the collapsed portion remains uninflated. Or, again, the catarrh may become chronic, and, being associated with an interstitial inflammation, result in a permanent induration, the alveoli being encroached on by the growing connective tissue, as in the case of chronic pneumonia. In this way, the person, though recovering, emerges from the disease with a damaged lung; according to the extent of the permanent damage will be the shrinking of the lung and possible displacement of organs. Again, phthisis pulmonalis may develop out of an acute catarrhal pneumonia, but this is fortunately an unusual result.

The inflammatory products in this disease deserve particular notice. In the acute capillary bronchitis we have a muco-purulent material produced, and on section of the lung little yellow drops appear on the cut surface. In the alveoli themselves the secretion is more apt to contain large cells of epithelial origin and character, but here also pus corpuscles or leucocytes often predominate largely. These leucocytes are very often not by any means confined to the surface of the mucous membrane and the alveoli, but are often present abundantly in the connective tissue around the bronchi and between the lobules. In fact the lung tissue may be largely over-run by leucocytes, and the characters of an ACUTE INTERSTITIAL PNEUMONIA may be added to those of catarrhal inflammation.

It has already been mentioned that the disease begins in the bronchi, and it has been asserted by Buhl that, throughout, the inflammation remains confined to the bronchi, the inflammatory products found in the alveoli being simply insufflated from the bronchi. This view, however, can hardly be maintained, as evidence of acute changes can actually be observed in the epithelium of the alveoli.

GANGRENE OF THE LUNGS.

In this condition necrosis of a definite piece of lung tissue occurs. The necrosis is always accompanied or followed by decomposition, and the irritating character of the decomposing material plays an important part in the processes concerned. The gangrene may itself arise by the action of decomposing material. If a foreign substance, such as a piece of solid food, gets into the bronchi, it may induce a bronchitis with putrescence of the secretion, and the irritation of the putrid juices may induce gangrene of the lung. Similarly, putrid juices inspired from ulcers and wounds of the mouth and air-passages, or perforation of

abscesses or ulcers into the trachea or bronchi may set it up. Again, the juices in cavities, especially in those arising by dilatation of bronchi, may stagnate and decompose, and lead to gangrene. Wounds and contusions may cause necrosis directly. Sometimes the lung tissue dies in severe cases of typhoid fever or other zymotic diseases. We have also seen that gangrene may occasionally follow the hæmorrhagic infarction or acute pneumonia, and that it is a constant feature of the metastatic abscess. Lastly, there are some cases in which the cause of the gangrene is obscure, but these cases, as well as those with more definite cause, are somewhat common in persons given to alcoholic excess.

It is customary to divide gangrene of the lung into a circumscribed and a diffuse form. In both the lung tissue dies and decomposes, ultimately becoming separated, if the patient survive, as a shreddy slough, which occupies the cavity formed by the loss of tissue. In the diffuse form there are gangrenous patches throughout the lung, or a considerable portion of it, and there is much less probability of the effects becoming limited by reactive inflammation in the neighbourhood. The diffuse form not infrequently develops from the circumscribed, the decomposing juices from the slough causing still further necrosis.

The various changes which occur around a gangrenous piece of lung, and in more distant parts of the organ, are related to the irritating character of the slough. These changes are mainly inflammatory. The immediately neighbouring lung tissue is acutely inflamed, and there is thus a zone of condensation around having the usual features of acute pneumonia, often with a specially hæmorrhagic character. In this inflammatory zone the gangrene may advance. On the other hand the slough may be detached by the inflammatory process, and through time, a more chronic inflammation having occurred, the slough may be separated from the lung tissue by a layer of granulation tissue which produces pus abundantly into the interior of the cavity. If the slough be small enough the cavity may, after the discharge of the slough, ultimately contract and form a cicatrix, but in the case of larger sloughs a suppurating cavity may long remain.

The effect on the bronchial mucous membrane is of importance. The decomposing juices from the slough and from the inflamed lung tissue find their way into the bronchial tubes, where they set up an acute inflammation of a highly suppurative character. A rich secretion of putrid pus is the result. This secretion carried to the bronchi in other parts of the lung may set up gangrene in numerous small isolated patches, and in this way multiple small abscesses may occur. If the

gangrene be near the surface an acute pleurisy is the result with fibrinous exudation. Sometimes the cavity opens into the pleura, and we have a suppurative pleurisy, perhaps with pneumothorax. An occasional complication of gangrene is hæmorrhage. As the slough separates from the living tissue the more resistant tissues retain their connection longest. The bronchi and larger vessels sometimes remain as rigid trabeculæ in the midst of the soft slough. The arteries remain longest in connection, but they are usually filled with thrombi and obliterated. Occasionally, however, the gangrene advances around an artery which is still pervious, and in that case hæmorrhage of a serious or even fatal character may result. Sometimes the gangrene leads to a definite septicæmia, or metastatic inflammations result, having their seats especially in the brain. In these cases the decomposing material gets into the pulmonary veins, having first caused thrombosis of them.

A peculiar feature in gangrene of the lung is the very abundant and highly putrid sputum. The decomposing juices from the slough set up, wherever they are carried, acute suppurative inflammations, and the abundant inflammatory products also undergo decomposition. The bronchial tubes being weakened by the severe inflammation often undergo dilatation, and the material stagnates in them all the more, and decomposes. So it happens that in the cavity itself, and in the dilated bronchi there are usually large quantities of putrid secretion. This is expectorated at intervals, and sometimes so abundantly that it pours out of nose and mouth. The sputum is extraordinarily fœtid, and if allowed to stand deposits triple phosphates, crystals of margarin, etc. It also contains abundant pus corpuscles, many of them broken down by decomposition, pieces of lung tissue, and bacteria isolated and in colonies. Sometimes the sputum contains also spirilla.

PHTHISIS PULMONALIS.

Under this designation are included conditions in which there is disease of the lungs, accompanied by destruction of the lung tissue and wasting of the body. The disease is usually progressive, but it presents all degrees of acuteness and the greatest variety in its duration. When we look at the lung removed from a case of phthisis, and observe the various appearances, the cavities, the solidifications, the indurations, the yellow caseous appearances, and so on, we seem to see nothing but inextricable confusion. And when we subject the phthisical lung to microscopic examination, the confusion is hardly reduced. We see evidences

of inflammation affecting bronchi, alveoli, and interstitial tissue; we see the inflammatory products undergoing processes of degeneration and organization; we see tubercles, also variously modified; but the interrelation of the various conditions is by no means apparent. It is clear that there is some serious disturbing cause present, but the connection of the various phenomena with this cause is not clear.

In accordance with our usual method it will be proper here to inquire what is the CAUSE of phthisis pulmonalis. We shall put aside in the meantime the true tubercles which are of almost constant occurrence in most forms of phthisis, and looking merely at the anatomical changes in the lung tissue we shall find them comprised under the two processes —namely, inflammation and necrosis. The inflammation manifests itself in the interstitial connective tissue, in the alveoli, and in the bronchi; and the necrosis involves inflammatory products and lung tissue. We shall see afterwards that in different cases the different structures of the lungs are involved to a varying degree, but in a large proportion we have both catarrhal and interstitial inflammations to some extent. Now, we have seen that inflammations arise as the result of the action of some irritant and that necrosis frequently goes along with inflammation if the irritant, be a severe one. We have to inquire here what may be the nature of the irritant, and what may be the cause of the necrosis which is such a frequent concurrent.

There are some cases of phthisis which owe their origin to syphilis. The syphilitic virus, here, as in other organs, gives rise mainly to an interstitial inflammation. Along with this we find, in some cases, at intervals that more pronounced new-formation of granulation tissue which is designated the gumma. In the gumma we have caseous necrosis, so that in this disease we may have, as in ordinary phthisis, the combination of inflammation and necrosis. But syphilitic phthisis is a rare disease, and in the vast majority of cases of phthisis, syphilis has nothing to do with it.

There can now be little doubt that in the ordinary forms of phthisis there is a virus present, and that this is related to the micro-organism already referred to and described at p. 164. It is not to be asserted that the existence of this organism explains everything. We must presume a previous state of susceptibility in the individual, but when this exists the virus takes possession, and all the progressive lesions are apt to follow.

It may be well here to refer briefly to the various phases through which the VIEWS AS TO THE PATHOLOGY OF PHTHISIS have gone since the time of Lænnec, especially as many of the terms in common use in connection with the disease are related to some of these views.

Lænnec believed that there was a particular tubercular matter which was liable to be deposited in the lungs or elsewhere. It might be deposited in isolated places, forming miliary tubercles, or infiltrated into a considerable portion of lung, forming infiltrated tubercle. In both cases the deposit usually begins as a grey transparent structure, which, however, is prone to change into a yellow or whitish material which is drier and harder. This yellow material was called yellow or crude tubercle, whether occurring in the isolated or in the infiltrated form. All cases were regarded as tubercular in which there were either isolated nodules or extensive infiltrations, whether these were grey or yellow.

By and by it came to be seen, however, that many of the conditions in phthisis are simply inflammatory. The minute histological characters of what we now call the tubercle were discriminated, and the essentially inflammatory processes were sought to be separated from the tubercular. It was shown that the existence of caseous material is no evidence of tuberculosis, since the ordinary products of inflammation and other new-formations, such as tumours, may undergo this change, which, in its essence, is really a necrosis with degeneration of the structures concerned. In phthisis, then, the process is largely an inflammatory one, with the special tendency in the products of inflammation to undergo a caseous metamorphosis. In this way arose Virchow's designation CASEOUS PNEUMONIA—namely, an inflammation with a caseous tendency in its products, just as scrofulous disease of the glands is an adenitis with a similar tendency.

When the lungs in phthisis were more particularly examined, however, it was found that the condition is not such a purely inflammatory one as Virchow's position would indicate. In all stages of the disease tubercles are to be found alongside the inflammatory products. The tubercles undergo changes similar to these, and it is often difficult to discriminate between the two, especially when caseous metamorphosis has occurred. But in nearly all cases where the disease is advancing proper tubercles are to be found along with the inflammatory conditions.

The more modern position brings us back more nearly to that of Lænnec. Again we regard phthisis as a tubercular disease, but not merely in the general sense of Lænnec. We are to observe carefully

the inflammatory processes and distinguish their effects on the lung tissue. Our position differs also from Lænnec's in respect that he regarded a particular state of the constitution as the essential cause of the tuberculosis. It is not to be denied that the lungs must be in a state of susceptibility before they can be affected by the tubercular virus, but the same may be said concerning any form of tuberculosis, and indeed concerning ordinary inflammatory processes. We know that different persons, or the same person at different times, are very variously susceptible to catarrhs, and to inflammations of all sorts.

We are to regard phthisis pulmonalis as a LOCAL TUBERCULOSIS, in which chronic inflammatory processes and the actual formation of tubercles play their parts, and both lead on to necrosis and ulceration.

It is necessary here to observe that phthisis pulmonalis has nothing to do with acute miliary tuberculosis of the lungs. This condition is merely part of a general tuberculosis in which the virus is in the blood. Phthisis may indeed give origin to general tuberculosis by the virus getting into the blood in sufficient quantity, but it does so very rarely, and the great majority of cases of general tuberculosis are not even associated with phthisis pulmonalis.

We have still to consider the CONDITIONS of the lungs WHICH PREDISPOSE to the occurrence of phthisis, and the path by which the tubercular virus finds access to the lungs. All authors seem agreed that phthisis is in many cases hereditary. That is to say, persons are born with a condition of lungs which renders them peculiarly susceptible to the changes which are to be described below. Taking the view that these changes are due to the tubercular virus it seems that persons are born with constitutions peculiarly incapable of resisting the action of the virus. It need hardly be said that this is perfectly consistent with what we know concerning other diseases. There are families in which diphtheria and scarlet fever make the most serious ravages, and there are others which they never attack. There are persons who are attacked by every form of fever in turn, there are others equally exposed who take none. But, besides an inherited liability, there is an acquired tendency to phthisis. This occurs principally in persons placed in circumstances in which the general health is reduced, and where especially the respiratory functions do not get justice. Persons living in close dwellings, especially when at their work, in factories and otherwise, they are in the habit of breathing vitiated air, in which, it may be, finely divided dust is abundantly suspended,

frequently acquire a tendency to phthisis although originally free from it.

We have now to inquire as to the PATH OF ENTRANCE of the irritant to the lungs. In the study of the lesions met with we shall find that they all start at the finer bronchi. A catarrh of the finest bronchial tubes, usually occurring in a number of these simultaneously, is the starting point of a variety of lesions, which, however, for a considerable time remain related to the bronchi in their distribution. This is a sufficient indication that the agent finds access to the lungs by the inspired air.

Before leaving the etiology of phthisis, we may consider its almost uniform LOCALIZATION AT THE APEX of the lungs, at least at the outset. The cause of this localization is generally regarded as obscure, but as has been hinted it has probably to do with the fact that the apices of the lungs are the least expansile portions. The first rib even in women is very little raised in inspiration, and in persons with weak respiratory movements the air is apt to stagnate at the apex. This view receives some confirmation from the fact that phthisis so frequently improves when the patients go to reside in high altitudes where the rarefied air requires more vigorous respiratory efforts. In such persons the size of the chest as a whole generally undergoes an increase. If the localization of the disease at the apices is due to imperfect expansion of the lungs, then this will fall in perfectly with the view that the disease originates in a virus inhaled from without. If the air stagnates the virus will remain lying in the lung and will have time to develop and begin its disastrous effects. Koch found that the bacillus is of slow development, at least at first, so that the absence of disturbance will greatly favour its growth.

ANATOMICAL CHANGES IN PHTHISIS.—In studying the changes in the lung it will be necessary to give descriptions of the various processes separately, and to a certain extent these processes are separable, but at the same time it will be understood that many of them go together and by their simultaneous occurrence frequently mask each other. It may be said in general that the disease, beginning in the finer bronchi, tends to spread in one of two directions, or in both of them at once, namely, from the bronchus to the surrounding connective tissue and on into the general connective tissue of the lungs, or else along the bronchus to the lung alveoli. In both cases we find tubercles developed in all stages of the

process, and in both there is inflammation, but of different kinds according to the structures involved. In the case of the connective tissue the inflammation produces new-formation of connective tissue and consequent induration. In the case of the alveoli it is a catarrh, although the alveolar wall may be at the same time involved. It is exceedingly difficult to say what determines the one or the other mode of extension, but it is probable that it depends on individual peculiarities. Some persons are peculiarly liable to catarrh of the alveoli, and some are not. It is important to observe that the tubercles which occur in both cases partake, to a considerable extent, in the peculiarities of the inflammations. In the case of extension to the connective tissue the tubercles tend to undergo fibrous transformation. In the other case they are liable rather to caseous metamorphosis. As the morbid changes begin in the bronchial tubes we shall begin our description by the processes met with there.

Condition of the bronchi.—The most constant primary change is catarrh, but it is a much more chronic catarrh than that of ordinary bronchitis. Whether catarrh occurs without the formation of tubercles or not, it is impossible to say, but certainly tubercles are to be found at a comparatively early period. The catarrhal products sometimes dry-in and become caseous, especially when the phthisis passes on to catarrh of the alveoli. This change may also occur in the other form of extension, and we may find a bronchus plugged with a white mass and surrounded by indurated connective tissue. The catarrh is not infrequently accompanied by ulceration of the bronchial mucous membrane, and little cavities

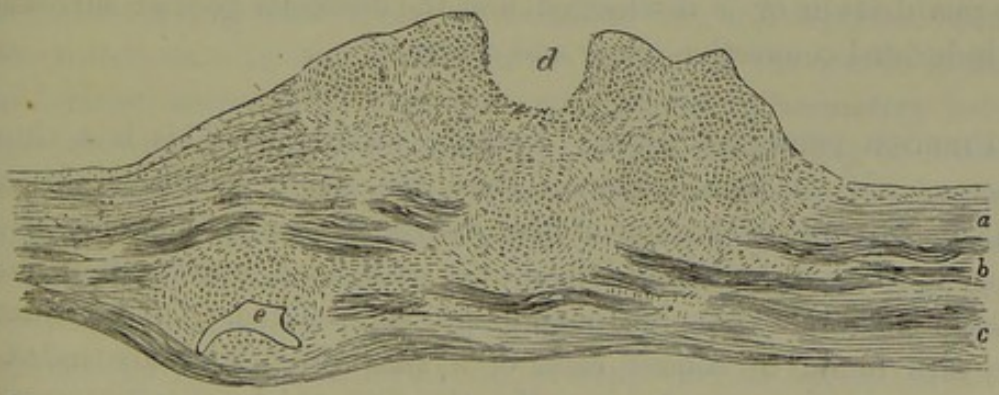


Fig. 232.—Tubercular ulcer of bronchus ; *a*, mucous membrane ; *b*, muscular coat. At *d* there is a small ulcer on the summit of a swelling. In the latter are several tubercles indicated by the concentric shading. The muscular coat is broken up by the tubercles. × 60. (Rindfleisch.)

frequently arise in this way, the cavity appearing to the naked eye to form a sacculated dilatation of a small bronchial tube. These ulcers are surrounded by inflamed and indurated connective tissue, in the midst

of which numerous tubercles are to be found (see Fig. 232). The ulcer here is essentially like the tubercular ulcer of the intestine or the urino-genital canals. We shall next consider the appearances presented when the irritation extends from the bronchi to the surrounding connective tissue, in which case the resulting inflammation may be designated PERIBRONCHITIS.

ACUTE PERIBRONCHITIS.—In some very rapid cases the peribronchitis is acute, and may even be PURULENT. Suppuration occurs in the bronchial wall as well as in the surrounding tissue, and, these structures being broken up, a kind of acute abscess is formed. Some of these abscesses may be near the surface and by rapidly undermining the pleura cause it to slough. By the separation of the sloughs the cavity of the abscess may come to communicate with the pleural cavity and so pneumothorax may result. The peribronchitis, however, is very rarely the only prominent condition. Along with it there is inflammation of the alveoli, but here too it is an acute inflammation, and the products are small round cells rather than the larger epithelioid elements of catarrhal inflammation. This inflammatory condition of the alveoli existing in the neighbourhood of the suppurating bronchi assists in the formation of the abscesses. Sometimes there is even a gangrenous condition developed, and actual sloughing of pieces of lung tissue occurs. Acute cases such as these bespeak a peculiar virulence of the morbid agent or a peculiar susceptibility of the patient. They usually pass rapidly on to a fatal issue with high fever. In some cases recovery takes place, the pus dries-in or is discharged, and the abscesses become surrounded by indurated connective tissue and contract.

FIBROUS PERIBRONCHITIS. FIBROID PHTHISIS.—This is a chronic process, and is more common than the acute condition just described. In an early stage of this disease the lung, especially in the upper lobes, may be found dotted over with hard masses, often nearly black in colour. These are small in size and isolated. On examination they are found to consist each of a small bronchus surrounded by indurated and pigmented connective tissue in which tubercles are to be found. The disease has begun in a set of bronchi of nearly the same size and has produced similar results in all. The appearances of inflammation here are similar to those in other parts. The mucous membrane and the connective tissue outside are infiltrated with round cells, which as usual develop dense connective tissue. Sometimes there are tuber-

cular ulcers of the bronchi having the characters already described. It has been stated above that these nodules are often nearly black in colour. This colouration is derived from the blood-pigment, and may be an indication of the existence of minute hæmorrhages, or else of occlusion of the vessels by the contracting tissue and staining of the tissue with the colouring matter dissolved out from the blood left in the obstructed vessels. It is to be noted that in this stage considerable hæmorrhage may take place into the bronchi. The hæmorrhage from each spot may be trifling, but from many together a severe hæmoptysis may occur. Some cases of hæmoptysis before any clinical signs of phthisis have manifested themselves are of this kind. The blood may to some extent come from the tubercular ulcers, but apparently this is not necessary. In many cases this tendency to pigmentation is manifest throughout the disease, and the extensive formations of connective tissue which occur are frequently of a slaty colour.

The new formation of connective tissue may limit itself for a considerable time to the neighbourhood of the bronchial tubes, and the nodules may enlarge. But as a rule it slowly extends outwards to the interstitial tissue of the lungs generally. An extensive new formation of dense connective tissue thus occurs throughout the lungs. The normal connective tissue of the lungs lies mainly around the bronchi and vessels, and between the lobules, and it forms one system with the subpleural layer, the tissue in these three situations being in intimate connection by means of the lymphatics. Hamilton has pointed out very instructively how foreign material such as dust when inhaled and conveyed into the lung tissue is carried about the lung and deposited in these three situations. In similar fashion the irritant in the condition under consideration seems to be conveyed and produces inflammatory induration everywhere. The new-formed connective tissue may be found in different stages of development, according to the particular part examined. We may find mainly round cells, spindle cells, or a dense tissue like that of the cicatrix, in which only small spindle cells are to be found. In all these stages tubercles can be seen, and they also, as they undergo fibroid transformation, present various appearances. In the later stage the tubercles are represented merely by a concentric arrangement of the dense connective tissue at intervals, this concentric appearance being sometimes emphasized by the existence of pigment.

If the lung be examined when this disease is fully developed, there will be found, to begin with, a very firm adhesion of the pleura over the diseased part. The pleura often undergoes a very remarkable thickening

reaching sometimes half an inch, and the thickened portion may form a kind of hard cap at the apex of the lung. When cut into there are trabeculæ of firm tissue traversing the lung, and frequently retaining something of the interlobular arrangement in respect that the trabeculæ tend to pass towards the root of the lung. The lung tissue which remains in the midst of these masses of connective tissue is often emphysematous, but the dilated alveoli present also thickening of their walls.

Besides all this there are commonly CAVITIES, and sometimes these are of very large dimensions. The cavities have as a rule the characters of BRONCHIECTASIS. The bronchiectatic cavity has a distinct lining membrane which may limit it from surrounding lung tissue. This lining membrane is sometimes directly continuous with the bronchial membrane, and the cavity may be obviously continuous with the bronchus, having sometimes an elongated shape with sacculated dilatations. But the cavities are often much more than mere dilatations of the bronchi. We may find almost the entire upper lobe forming one cavity with a distinct lining membrane, and with partial septa radiating from the neighbourhood of the root of the lung.

The occurrence of emphysema and cavities in this form of phthisis merits more particular consideration. The EMPHYSEMA is largely compensatory. By the formation and contraction of the connective tissue large numbers of alveoli are destroyed and the remaining ones dilate to fill up the space. The CAVITIES are obviously formed in connection with the bronchial tubes. To a certain extent the dilatation is compensatory like the emphysema, and the inflammatory infiltration of the wall may allow more readily of dilatation. It is to be remembered also that tubercular ulceration often accompanies the process, and where this exists dilatation will more readily occur; besides that, a gap caused by ulceration may, as we have seen, have much the appearance of a dilatation. There is another way in which dilatation of the bronchi occurs, and this has been well described by Hamilton. There are agents at work which may directly pull out the bronchial wall. We have seen that there is usually thickening and adhesion of the pleura on the one hand, and the peribronchial induration on the other. Between these there is the indurated interlobular connective tissue, which by its contraction tends to approximate the two. As the pleura is fixed to the chest wall by firm adhesions there is a dragging in of this wall, producing the flattening of the apex which is sometimes so very marked in this

disease. But the bronchial wall is also drawn outwards, at first unequally, so that the cavity is an irregular one.

There is still another method by which cavities form in this disease; it has been already referred to and compared to that of the formation of the retention-cyst. The peribronchial connective tissue may contract concentrically and obstruct small bronchial tubes, or the obstruction may be assisted by the drying-in of the catarrhal products in the lumen of the tube. If a small tube be thus obstructed the secretion may accumulate behind and cause dilatation of the tube, this occurring the more readily that these fine tubes are thin-walled. In this way we may have sacculated dilatations of the tubes, and the communications with the bronchi from which they took origin may even be obscured or cut off. In cavities thus formed the lining membrane is very commonly directly in contact with sound lung tissue, and although the wall is composed largely of round-celled tissue of an inflammatory kind, yet here, as in other bronchiectatic cavities, ciliated epithelial cells are usually to be found. The cavity frequently contains pus, and if it be near the surface and of rapid formation it may so undermine the pleura as to cause necrosis and render pneumothorax imminent.

It is to be remembered that, although these processes may occur by themselves, and in their aggravated form warrant the special designation of fibroid phthisis or cirrhosis of the lung, yet many of them occur along with the changes next to be described. This applies especially to the peribronchitis and the induration of the connective tissue around the individual lobules, as distinguished from an induration of the general connective tissue of the lungs.

Catarrhal or caseous form.—We have now to consider the other mode of extension, namely from the finer bronchi along to the alveoli. In studying acute catarrhal pneumonia we have seen that the disease begins with a capillary bronchitis which runs into a proper pneumonia. In the present case there is a similar extension, so that the condition is sometimes called chronic catarrhal pneumonia, or broncho-pneumonia. But there are certain important differences which from the first should be borne in mind. In the first place the affection of the finer bronchi is not a simple catarrh, but is accompanied by the formation of tubercles. These tubercles form most readily, according to Rindfleisch, just where the bronchial tubes pass into the lung alveoli, attacking the projecting angles at the points where bronchi give place to infundibula. Another distinction is that, as the

tubercles are in the connective tissue forming the bronchial wall, so there is always some inflammatory infiltration of the wall with more or less peribronchitis. In like manner, when the disease passes into the alveoli it does not, like the acute catarrhal pneumonia, confine itself to the surface, but here again we have it extending into the alveolar wall and producing thickening and induration there. Lastly, there is a marked tendency for the products of inflammation to undergo caseous necrosis. This process occurs not only in the material accumulated in the alveoli, but also in the alveolar wall and the wall of the bronchus. So characteristic is this condition in many cases that as we have seen the name CASEOUS PNEUMONIA has been sometimes applied.

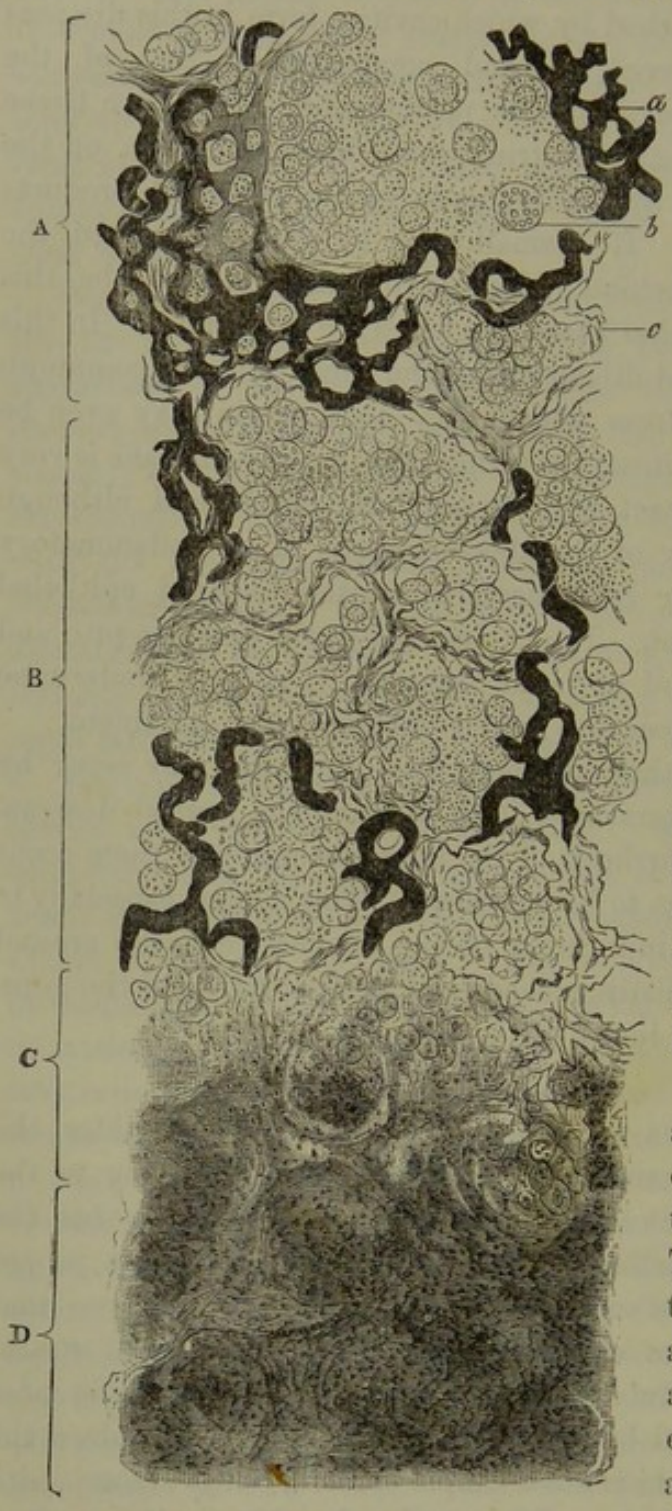


Fig. 233.—Lung in caseous form of phthisis ; the capillaries injected (shown black). At *A* there are catarrhal cells (*b*) in alveoli, and the capillaries are well filled. At *B*, the capillaries are less injected. At *C*, caseous necrosis has begun; and at *D*, it is complete, the structure being here quite obscured in a general granular opacity. × 350. (HAMILTON.)

The disease beginning in a catarrh with infiltration of the bronchus passes on to catarrh of the alveoli. The inflammation leads to the filling up of the alveoli with cells which are mostly of the large epithelioid character, such as are shown in Fig. 233. With these may be mingled small round cells such as exist in ordinary acute pneumonia, but there

is rarely a filling up of the alveoli with small round cells and fibrine such as we see in hepatization, although in very acute cases this may occur. The alveolar wall, as has already been noticed, is infiltrated with inflammatory round cells, and it is very often difficult to distinguish the exact boundaries of the alveoli, the swollen wall being ill-defined from the products inside. The result of all this is a condensation of the lung tissue, and according to the extent of the affected areas will there be larger or smaller solidifications of the lung. These will always in their distribution bear a relation to the bronchial stems, having usually in this early stage a distinctly lobular arrangement, like bunches of fruit in clusters.

These condensations will have a grey colour, but soon caseous necrosis occurs, and it is rare to find many of them purely grey. The caseous necrosis has been ascribed to the infiltration of the alveolar wall, causing compression of the blood-vessels, and consequent anæmia, resulting in degeneration and death. It is true that in a caseating condensation the vessels do become obstructed, as may be proved by injection (see Fig. 233), but this is just as likely to be the result of the necrosis as the cause. In the swelling and induration of connective tissue produced in ordinary inflammations we never have such obstruction of the vessels or a caseous process. Moreover, the inflammatory infiltration is derived from the blood, and it seems strange that the blood-vessels should yield material to such an extent as to cause their own obstruction. The process of caseation so characteristic of the condition we are describing must be set down to a different cause. It is analogous to the caseation of syphilitic and tubercular formations, and due to the virulence of the agent which produces the primary changes. In the present case the caseous necrosis attacks indiscriminately the whole structures concerned. Beginning in the central parts of each small condensation, it involves the products within the alveoli, the altered alveolar wall, the tubercles, and the fine bronchus. The caseous area presents under the microscope a finely granular homogeneous appearance as in Fig. 233 *D*, in which it is very often impossible to recognize any structure at all. Sometimes the outlines of the alveoli can be made out, but even these may be obscured. As seen with the naked eye, the caseous condition is recognized by the opaque yellow or white appearance presented, this usually beginning in the central parts of the grey condensations.

As confirmatory of the view that the caseous necrosis is due directly to the action of the original irritant, it is to be noted that in very acute

cases necrosis may occur almost directly and without caseation. An acute condensation takes place not unlike that of pneumonia but with the lobular distribution, and goes straight on to sloughing of the lung tissue, perhaps with a purulent peribronchitis.

The caseous material is of course dead, and in any further changes it is merely passive. In some cases, which unfortunately are not very common, the disease makes pauses. The caseous mass becomes encapsuled and dries-in more and more. By and by it becomes infiltrated with lime salts, and may thus be converted into a putty-like material, or condensed into a stony mass, which may lie for years in the lung tissue.

More frequently the caseous material softens and partially liquefies, so that a CAVITY forms. It may be that, as Hamilton suggests, this may be due to a chemical change analogous to that which occurs in the ripening of cheese, in which, according to M. Duclaux, certain insoluble albuminates become soluble in water. The softening affects the whole caseous material, and the piece of lung concerned breaks down and liquefies, so that a small cavity results. The broken-down caseous material forms a grumous turbid fluid, in which the more resisting

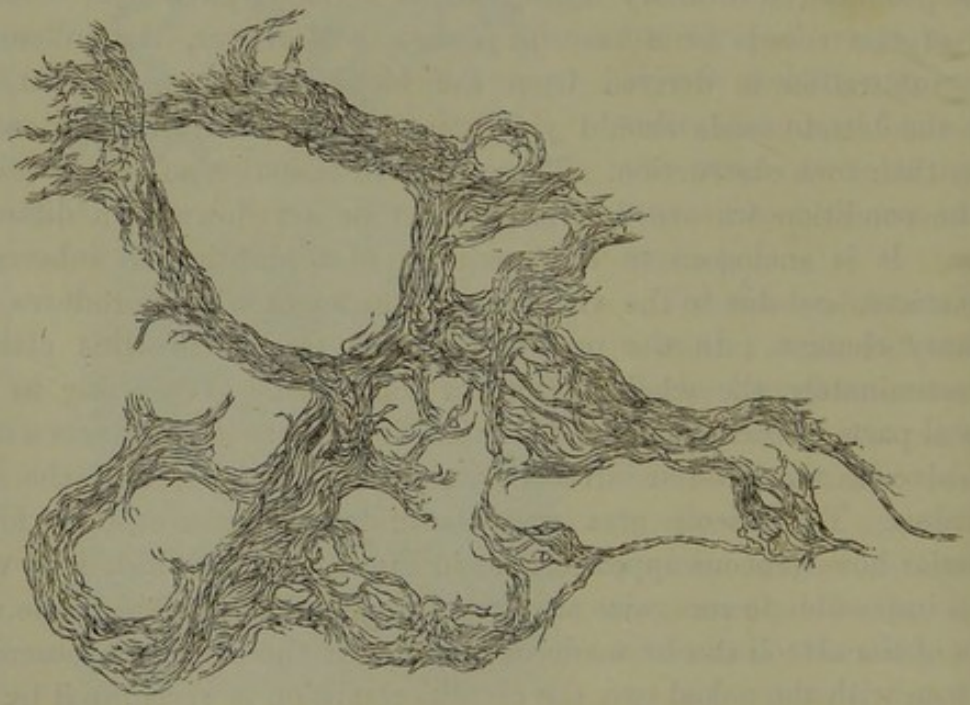


Fig. 234.—Lung tissue from the sputum in phthisis. The sputum was digested in caustic soda according to Fenwick's method, and then subjected to microscopic examination. × 350.

elastic tissue of the lung may be found still retaining to some extent the form of the alveoli. This elastic tissue may be frequently recog-

nised in the sputum of such patients by proper methods of search (see Fig. 234). At first the cavity formed is small, but by extension of the process and coalescence of neighbouring softenings, larger cavities result. These cavities are very irregular, and their walls at first ragged and ill-defined. After all the caseous material has been cleared out there may be a smoothing of the walls of the cavities by the formation of connective tissue, but there is not the regular lining membrane of the bronchiectatic cavity, nor the same relation to the bronchi. The cavity sooner or later opens into one or more bronchi, and its contents are discharged. When the caseous material is cleared out the wall assumes an inflammatory character and secretes pus more or less abundantly. In the walls of such cavities, and in the mucous membrane of the bronchi with which they are in communication, tubercular ulcers may usually be distinguished.

It may be well here to consider the GENERAL APPEARANCES presented by the lung on post-mortem examination of an advanced case of the kind we are considering. The lung will be found firmly adherent over the upper lobe or more extensively. There will not, however, be the same thickening of the pleura as is met with so commonly in the indurative form. In removing the lung, it will generally be found that there are cavities at the apices, often of very large size, and in separating the lung from the pleura there is great risk of opening into some of these cavities. If the lung after removal be divided from apex to base, various appearances will be presented, many of which are sometimes difficult of interpretation. There are cavities filled mostly with a grumous yellow material. These are exceedingly irregular in shape, and traversed by partial septa or by completely isolated trabeculæ. These trabeculæ represent branches of the pulmonary artery which have survived the general necrosis, and although the arteries are mostly obstructed, some of them remain partially pervious, and we may find aneurismal dilatations on these. The cavities have frequently no proper lining membrane, but if they are large and of some duration there is a red layer having the appearance of granulation tissue. Looking away from the cavities, the lung tissue is found condensed and frequently caseous. In the immediate neighbourhood of the cavities the condensation is probably continuous, and is frequently accompanied with great induration of the lung tissue. But farther off, and especially in the lower lobe, there are usually more isolated patches of condensation. These on section very commonly

have a circular form, or they present the appearance already mentioned of clusters of fruit. By the coalescence of these we may have more continuous condensations, but at the marginal parts there are usually indications of the lobular extension of the lesion. The condensed portions are usually very firm, and in each we find the opaque appearance of the caseous necrosis. In the central parts there may be softening and incipient cavities. After examining the cut surface, the bronchial tubes may be opened up with the scissors. Those which pass towards the cavities are nearly always the seat of tubercular ulceration. The mucous membrane is irregularly destroyed, and the ulcers have commonly a rather ragged appearance, but are usually superficial. The ulceration is very often prolonged into the main bronchus of the affected lung, and even to the lower part of the trachea. In the larynx there is also frequently ulceration as already described, but it is not usually continuous with that in the bronchi or lower trachea, there being mostly an interval between in which the mucous membrane of the trachea is normal or only red from inflammation.

It is to be understood that these appearances will vary greatly according to circumstances, the chief cause of variation being the different degrees in which, along with the caseous catarrhal pneumonia, there is induration of the connective tissue of the lung. We have seen how this induration so often starts from the bronchi, but after the extension of the catarrh to the alveoli we may have a very pronounced inflammation of the connective tissue, causing induration of the alveolar wall and extending to the general connective tissue. This will cause the condensation to have a much firmer character to begin with, and if the induration predominate over the caseous catarrh we may have the features of fibrous phthisis becoming pronounced in the older parts of the lesion, while the more recent parts show rather those of lobular broncho-pneumonia.

It may be useful here, before leaving the subject, to refer to the various MODES IN WHICH CAVITIES FORM AND EXTEND. We have seen that in the indurative form or fibrous phthisis, cavities form by dilatation of the bronchial tubes, tubercular ulceration often playing an important part in the process. Then we have cavities formed by the softening of the caseous material. Around such softening there is frequently a reactive inflammation, resulting in the formation of granulation tissue which finally forms the lining of the cavities. Such cavities commonly enlarge by the coalescence of neighbouring soften-

ings, and in their walls also tubercular ulceration often progresses. Then there is the more direct destruction of the lung tissue occurring in very acute cases, associated, as we have seen, with purulent peribronchitis, acute inflammation of the alveoli, and such a rapid necrosis of the tissue as to approach to the characters of gangrene of the lung.

The SPUTUM in phthisis pulmonalis is variously composed. In the earlier stages the expectoration has the usual characters of that in catarrh, consisting of mucus, with more or less abundant leucocytes. In the sputum in this early stage are often found large epithelioid cells with one or more nuclei such as we find in the lung alveoli in the catarrhal form of phthisis. These cells frequently present fatty degeneration. Considerable weight has sometimes been attached to the presence of such cells as evidence of the existence of the disease in its early stage, and their discovery may be useful in this regard; but as they may exist in simple catarrhs their diagnostic value may be overrated. The sputum in phthisis often contains ELASTIC TISSUE from the breaking down of the lung. In very rapid cases we may find this by a simple examination of the sputum, but the search is often a difficult one because the thick mucus and pus hold the pieces of lung tissue suspended and isolated. By Fenwick's method of digestion in soda solution, pieces of lung tissue, such as that shown in Fig. 234, will frequently be found in the deposit. This method is also applicable to the sputum in gangrene of the lungs. The TUBERCULAR BACILLUS is usually to be found in the sputum, especially in advanced cases. The characters are shown in Fig. 56, p. 164, and have been described already.

The sputum often contains blood in phthisis, and it will be proper here to inquire as to the source of HÆMORRHAGE. Bleeding sometimes occurs in early stages before cavities have formed, arising from the mucous membrane of the finer bronchial tubes. We have already seen that this frequently occurs in the early stages of the indurative form of phthisis, and we saw reason to believe that it is sometimes related to tubercular ulceration of these bronchi, although the hyperæmia coincident with the process probably plays the principal part. In the other form of phthisis the finer bronchi are also the source of the early hæmorrhage, and here, too, the inflammatory hyperæmia appears to be the principal cause, although it may be complicated with tubercular ulceration as well. In late stages after cavities have formed hæmorrhage may occur from their walls. In the process of extension of cavities, whether by

caseous necrosis or tubercular ulceration, the more resisting walls of the pulmonary arteries are able to persist longer than the rest of the tissues, and these form prominent elongated projections on the walls of the cavities or isolated cylindrical trabeculæ traversing them. The calibre of the artery is frequently obliterated, and the structure consists of granulation tissue in which some remains of elastic tissue may be found. But sometimes the calibre persists, at least partially. At the same time the wall is infiltrated and consists essentially of soft granulation tissue. This soft tissue frequently allows of dilatation of the artery, and we have ANEURISMS whose walls are similarly soft and friable. Rupture of the softened wall of the artery or aneurism would occur more readily were it not that the blood-pressure is already reduced by the narrowing of the calibre, but it does occur not infrequently, and it appears that in a large proportion of cases the blood comes from aneurisms. The resulting hæmorrhage is commonly very severe, and often fatal, either by obstruction of the air passages with the blood or from the general collapse resulting from loss of blood.

The condition of the PLEURA in phthisis has already several times been incidentally referred to. As the pulmonary layer of the pleura or at least the subpleural tissue is part of the system of the interstitial connective tissue, it takes part in the inflammatory new-formation in the indurative form of phthisis, and we have seen that it is sometimes greatly thickened. In the other form of phthisis when the disease approaches the pleura there is always inflammation with new-formation of connective tissue, and adhesion of the two layers. This adhesion occurs in the way that will be described in considering the diseases of the pleura, and consists of an actual coalescence of the two layers with communication of the blood-vessels. The adhesion is often so firm that it is easier to strip off the parietal pleura from the internal surface of the thorax than to separate the layers. Sometimes it happens that the inflammatory condition extends beyond the parietal pleura and causes adhesion of this layer to the periosteum of the ribs and intercostal tissue. In that case the separation of the lung from the chest wall is very difficult, and sometimes cannot be accomplished without cutting.

Cavities in the lung very often come close up to the pleura and undermine it. If the cavity be at all large it cuts off a portion of pleura from its vascular supply from the lung. But, as a general rule, adhesion has already taken place between the two layers of pleura, and, the vessels being in communication, the portion over the cavity is kept supplied with blood

from the parietal layer. We may even suppose that the blood passing from the branches of the bronchial artery out into the parietal pleura may be conveyed along over the cavity and return in part to nourish the visceral layer. But if a cavity comes to the surface at a place where vascular adhesion has not taken place, then NECROSIS OF THE PLEURA will probably result. The portion of pleura is of a dead-white colour, and by and by it becomes abruptly demarcated from the neighbouring parts. The line of demarcation becomes more and more distinct, and an actual separation often occurs, the result of which is communication between the cavity and the pleural sac, leading to PNEUMOTHORAX. This is nearly always the manner in which pneumothorax occurs. It will happen mostly in acute cases where the cavities form rapidly without affording time for the formation of vascular adhesions. More especially is this the case where cavities form by purulent peribronchitis with or without sloughing of the lung tissue. It will be seen that the occurrence of the pneumothorax depends on the absence of adhesions, hence it happens that it so frequently occurs in the lung which is least advanced in the disease, because in that lung adhesions are less likely to be present. The pneumothorax, being associated with the passage into the sac of foreign material from the pulmonary cavity, generally results in an ACUTE PLEURISY, so that the layers of the pleura may be glued together by recent fibrinous exudation. It very frequently happens in a case of pneumothorax that there are several places in which necrosis of the pleura exists, one of these having given way, but the others being in a condition in which they might readily have done so.

The BRONCHIAL GLANDS are nearly always more or less affected in phthisis. They are frequently enlarged and caseous, exactly like scrofulous glands. Like them they contain tubercles. These caseous glands are sometimes found in a state of softening. Not infrequently the caseous material becomes impregnated with lime salts, and we may find the gland represented by a capsule filled with a material like mortar, or more nearly of a stony consistence. In the indurative form of phthisis the tubercles in the glands undergo the fibrous transformation like those in the lung tissue, and we meet with dense hard pigmented glands with an almost cicatricial appearance.

We have already noted the existence of tubercular ulceration of the mucous membrane of the bronchi, and of the trachea and larynx. These are to be explained by the passage of the virulent material

from the breaking-down lung substance, over the structures concerned and its action on them. Of similar import is the ULCERATION OF THE INTESTINES, which occurs in the later stages of about two-thirds of the cases of phthisis. The material from the cavities is partly swallowed, and, containing the virus, it produces a tuberculosis in the parts of the intestine which afford a fitting soil. These ulcers are most common in the caseating form of phthisis, and we may associate this with the fact that the debris of the lung is much greater in that form.

Besides the tuberculosis of the bronchial glands and intestine we find sometimes a TUBERCULOSIS OF THE URINO-GENITAL ORGANS, but this is comparatively rare. Then we sometimes find miliary tubercles in the LIVER and KIDNEYS, scattered through these organs as in acute general tuberculosis. There are usually, however, but few tubercles compared with what we find in the latter disease. When tubercles exist scattered throughout the liver or in the kidney, we must regard that as evidence that the virus has got into the blood, although present only in small quantity there.

ACUTE MILIARY TUBERCULOSIS.

This condition we have already seen to be that in which the tubercular virus is contained in the blood, apparently in considerable abundance, giving origin to miliary tubercles in many organs. The lungs are affected in almost all cases. Acute miliary tuberculosis is very common in children, being nearly always the fundamental condition in acute hydrocephalus, but it also occurs in adults. If the patient die in the earlier stages the lungs are found beset from apex to base with minute tubercles which are often very closely placed. The tubercles may be so small as to be only distinguishable as such with the microscope, but they present the typical structure of miliary tubercles. In the early stages this, with general hyperæmia of the lungs, is all that can be seen. But if the case be one of rather longer duration we find around the individual tubercles processes which can be strictly compared with those in phthisis pulmonalis. The air vesicles are filled with catarrhal cells and the alveolar walls infiltrated with inflammatory round cells. The tubercles appear larger, but this is because each of them is surrounded by a zone of condensed lung tissue which cannot with the naked eye be distinguished from the tubercle. By and by caseous necrosis occurs, beginning in the centres of the tubercles. As

in the case of phthisis the caseous process extends to the lung tissue and inflammatory products, and the whole is involved in an indiscriminate necrosis. The caseous material may also soften, and numerous minute cavities form, but the patient rarely survives till this has occurred to any considerable extent.

The disease of animals, called by the Germans PERLSUCHT, presents many analogies to tuberculosis, and, according to the observations of Koch, it depends on the same form of organism. This relation is expressed in the term BOVINE TUBERCULOSIS which is sometimes applied to it. We have already seen that cases of what looks like general tuberculosis occur which are probably actual cases of bovine tuberculosis transmitted to the human subject. There are also cases in which the lung is the seat of a more local destructive process which may be mistaken for ordinary phthisis, especially as there may be considerable cavities produced. This subject has received notice, however, at an earlier part of this work (see p. 167).

SYPHILITIC DISEASE OF THE LUNGS.

This is somewhat rare, at least in the adult, although more frequent in the newly born. We have here similar lesions to those in other organs, consisting of inflammatory changes with the occasional formation of gummata. The inflammation affects mainly, but not alone, the connective tissue, so that a condition sometimes ensues like that of fibrous phthisis. In syphilis, however, the virus coming by the blood is more generally diffused, and we have not that relation to the bronchi which we saw in ordinary phthisis. An extensive tract of lung is involved, and we have a rich formation of connective tissue so that the alveoli are compressed, while they also contain catarrhal products. In this way is produced what is called a WHITE PNEUMONIA. If gummata occur they are as usual surrounded by a connective-tissue formation, so that cicatricial depressions and corresponding deformities of the lung may result. The gummata are often distinguishable by the caseous necrosis which they present, and if the caseous material soften we may have cavities resembling those in ordinary phthisis.

TUMOURS OF THE LUNGS.

Tumours of the lungs are much more frequently secondary than primary growths, but there are some forms of primary tumour. Little

pieces of bone have been met with in the interstitial connective tissue, also little cartilaginous tumours in connection with the cartilages of the bronchi.

Secondary tumours of various kinds are met with. We have most frequently LYMPHO-SARCOMAS originating in the bronchial glands and extending into the lung. The new-formation follows the connective tissue of the lung, and we find it penetrating in a radiating manner from the root, often burying the bronchial tubes in a sheath of new-formed tissue and partially or completely obstructing them. Other forms of sarcoma originating in the mediastinum may spread in a similar fashion. Secondary tumours may arise by embolism, the tumour having its origin in something conveyed to the lungs by the pulmonary artery, and being thus metastatic.

SARCOMAS, as we know, sometimes penetrate directly into the veins, and portions being carried to the right heart are caught in the branches of the pulmonary artery or capillaries. The secondary tumours in the

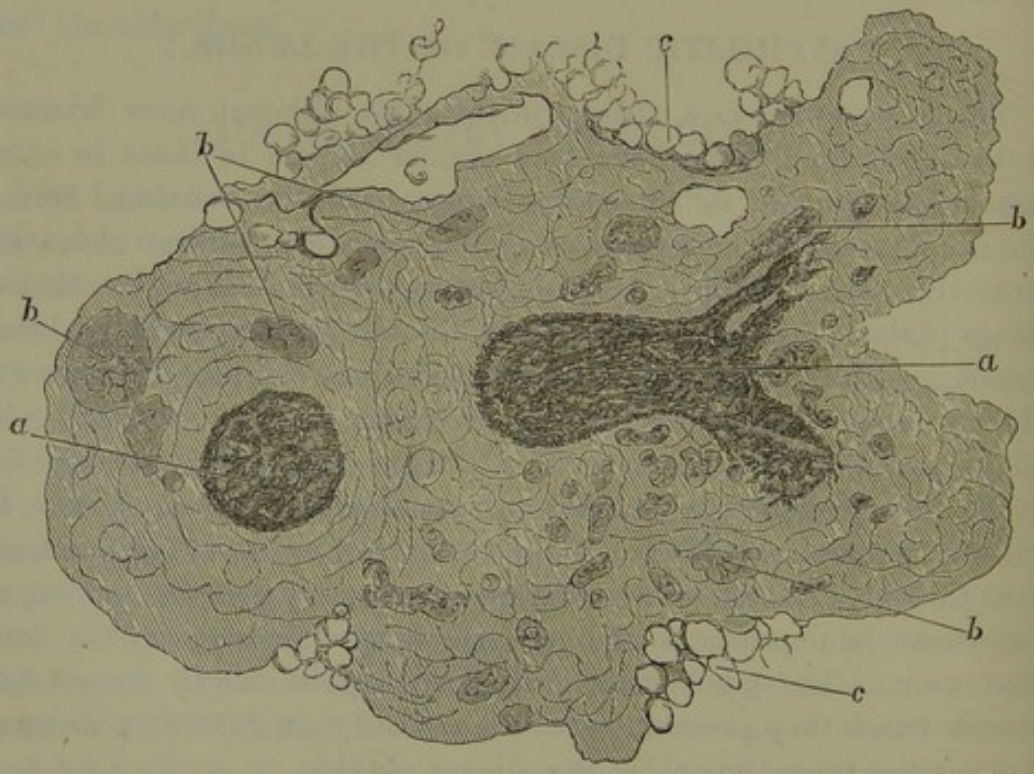


Fig. 235.—Embolic cancer of lung. Two branches of the pulmonary artery (*a*, *a*) are obstructed. Around them are various spaces (*b*, *b*) filled with epithelial cells. *c*, *c*, normal lung alveoli. × 16.

lung are multiple and they repeat exactly the structure of the primary one. Thus we have giant-celled, round-celled, and spindle-celled sarcomas. A tolerably frequent form is the pigmented sarcoma. The

ENCHONDROMA also not infrequently undergoes secondary development, like the sarcoma, by penetrating into veins, and the embolic origin of these secondary tumours has been directly demonstrated.

CANCERS, as we have seen, do not readily penetrate into the veins directly. Finding an easier path by the lymphatics they nearly always first develop in the lymphatic glands. After a time the cancerous tissue may penetrate from the lymphatic sinuses in the gland into the veins, or they may possibly in a few cases penetrate directly into the latter, and the material is carried on to the lungs. As the cancer is usually arrested for a considerable time at the lymphatic glands, it happens that in all forms of cancer secondary tumours in the lungs are of late development. As the secondary tumours are in the lymphatic glands we may regard these in the lungs as of a tertiary order. Further, the material which produces these tumours often passes to



Fig. 236.—Embolic cancer of lung. One of the spaces filled with epithelial cells (*b* in preceding figure) under a high power. There is a larger space with two branches into which the epithelial cells have extended. × 90.

some extent through the wide capillaries of the lung and on into the systemic arteries so that we may have tertiary tumours occurring at the same time in a variety of organs. The tumours in the lung are multiple and they repeat the structure of the primary tumour whatever be the variety of cancer which has formed it.

That these tertiary cancers form by embolism was readily seen in a case which occurred to the author, and which may here be briefly

related. It illustrates as well the tendency, which tumours even of this order show, of the cancerous masses to penetrate into existing spaces and canals. The primary tumour was a cancer of the stomach, and secondary growths had occurred in the prevertebral glands. One of these glands was adherent to the vena cava, and several radicles of this vein emerged from the midst of cancerous glands. Actual cancerous thrombi of some of these veins were detected by the naked eye, and under the microscope it was seen that the cancerous masses had partially penetrated into the venous radicles in the glands. In the lungs the finer branches of the pulmonary artery were found frequently obstructed (see Fig. 235). The obstructing material was not entirely cancerous in structure. There was often a round-cell formation with now and again a distinctly cancerous appearance. In most cases the obstruction was complete. Outside the obstructed arteries there were spaces and canals filled with cancerous growths, as shown in Figs. 235 and 236. These were obviously the lymphatic channels of the sheath of the vessels into which the cancerous formation had penetrated.

INHALATION OF FOREIGN SUBSTANCES.

The lungs of all adults have more or less of a grey colour from the existence of a black pigment in the lung tissue. This pigment is absent from the lungs of children, and is undoubtedly the dust of the air inhaled with the respired air. It need hardly be said that the air of all confined spaces, such as rooms, is loaded with finely divided particles. This is particularly the case in cities where coal is burnt extensively, and it attains its maximum in the black fogs of such cities as London and Glasgow. The particles of dust inhaled with the air are for the most part caught by the mucus with which the surface of the bronchial tubes is moistened, and as the ciliated epithelium plays in the direction towards the larynx, the dust-laden mucus is carried upwards to the larynx where it is either expectorated or swallowed. No doubt when the air is unusually laden with dust the mucous secretion is increased, and those who live in cities know that when the weather is thick a considerable mass of black mucus is brought up from the larynx in the morning, the busy cilia having swept it thither during the hours of sleep. But some of the dust penetrates beyond the reach of those scavengers and passes into the lung alveoli, where it lodges. From the lung alveoli it penetrates into the lung tissue. It is to be remembered that the structure of the alveolus is somewhat like that of a serous

membrane. There is a single layer of epithelium, and some have even described stomata or pseudo-stomata as existing. At any rate the dust particles penetrate through or between the epithelial cells and emerge into the lymph spaces of the alveolar wall. Having entered the lymphatic system of the lung, the dust is carried into all the communicating channels of that system, and is partially deposited and retained as it goes by the connective-tissue cells. In this way a kind of pigmentation of the entire lymphatic system of the lung is obtained which for demonstration may serve the purposes of an injection of that system. In this conveyance of the dust particles the leucocytes which are always present in the lymphatic spaces probably play an important part. The parts pigmented are, the walls of the alveoli, the interstitial connective tissue especially that around the pulmonary artery and the bronchi, and the subpleural tissue, which is often definitely demarcated from the pleura proper by the pigmentation. The pigment is also carried to the bronchial glands at the root of the lung which are more or less blackened. This pigment is a carbonaceous material consisting mostly of round particles, and is to a great extent the soot of coal.

Persons who live in a very dusty atmosphere are liable to a very excessive pigmentation of the lungs to which the name ANTHRACOSIS is applied. This is seen most typically in THE COAL MINER'S LUNG. Here the path by which the dust gets in, and its permanent locality, are the same as those indicated above, but the amount is greatly increased. The material also is essentially the same. It is sometimes asserted that in the coal miner's lung the pigment consists of coal dust, each minute particle having the irregular crystalline character of a piece of broken coal. But this is not entirely the case. The particles are largely spherical and smooth, and these consist of the soot from the lamps that are burnt in the mines with imperfect combustion. The pigment in this case, as in the ordinary pigmentation of the lungs, is in the lymphatics and follows the distribution of the connective tissue. It is often seen in excessive quantity around the branches of the pulmonary artery where it occupies the perivascular lymphatic spaces. It is not present in the proper walls of the bronchi, but exists to some extent in the lymphatic spaces of their adventitia. The interlobular and subpleural connective tissue is deeply pigmented.

The inhaled dust seems a comparatively innocuous substance. In the bronchial tubes and in the alveoli it may induce, or be associated with, a catarrh, and in that case the inflammatory products

contain abundant pigment giving rise to the well-known black spit of miners. The pigment is found abundantly in cells as in Fig. 237.

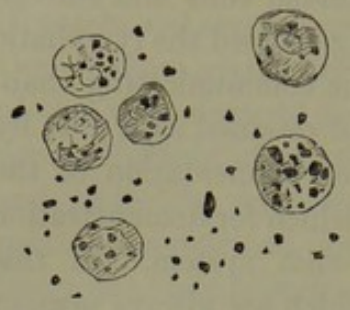


Fig. 237.—Part of the contents of a lung alveolus in anthracosis. Black particles are seen, some angular, and others rounded. The large catarrhal cells contain many particles. × 350.

But in the lung tissue itself there is usually little disturbance, and even in severe cases of anthracosis there may be merely a moderate induration of the connective tissue. It is to be noted that in persons whose lungs are the seat of excessive pigment, a catarrh is often associated with a recurrence of the "black spit," although the persons may have left the pit for years. In that case the black spit will not occur unless the inflammation involves the connective tissue as well as the epithelial layers of the bronchi and alveoli, and it is to be presumed that the pigment passes out of the lungs in the same way as it has passed into them, namely, from the connective tissue, into the alveoli and thence outwards. As mentioned above there is no pigmentation of the bronchial mucous membrane, and it does not seem probable that pigment will penetrate from without through the bronchial wall into the interior of the tube. This indicates that in catarrhs the connective tissue is active, and that the pigment is conveyed by leucocytes into the alveoli or bronchi.

There are some persons exposed to the inhalation of particles of a more irritating nature. It has long been known that masons are peculiarly liable to bronchitis and phthisis. The particles of sandstone are inhaled just as are the particles of dust. From their shape and the sharp angles which the particles of rock crystal present, they are much more irritating than the dust particles. They irritate the bronchial mucous membrane. When they pass into the interstitial tissue of the lungs they irritate it, and in this case there is frequently a very marked induration of the connective tissue. This induration, along with the bronchitis, may go on to the formation of cavities by bronchiectasis. The indurations in this disease often have special centres of greatest intensity in the form of hard nodules, in the centres of which a collection of glistening particles may be found.

Other kinds of dust may be inhaled, and give rise to inflammatory conditions in the lungs. They seem to irritate more or less according to the mechanical qualities of the particles. Particles which are hard, heavy, and angular, like the siliceous particles of sandstone, or like the

steel dust to which file-cutters are exposed, irritate more than those which are light and rounded like those in the miner's lung. The colour of the inhaled dust communicates itself to the lung, and so we have various pigmentations, but in all the forms there is a tendency to the occurrence of black pigment along with the other coloured substances.

C.—THE PLEURA.

PLEURISY.—The pleural sac in its structure and in many of its relations is comparable to the pericardial and peritoneal sacs, and much that has already been stated above regarding inflammation of the pericardium is applicable to inflammation of the pleura. There are two circumstances, however, that place the pleura in its pathological relations in a somewhat different position from the pericardium, and these are its connections with the lung on the one hand and with the peritoneum on the other. In studying diseases of the lung we have seen that whenever any form of inflammation comes to the surface of the lung it causes inflammatory changes in the pleura; there is acute pleurisy in acute pneumonia, and chronic pleurisy is a nearly constant accompaniment of phthisis pulmonalis. On the other hand, the pleura seems to have intimate connections with the peritoneum, as there are lymphatic channels passing through the diaphragm which form communications between the two sacs. These channels are doubtless intricate and narrow, so that the diaphragm acts to a certain extent as a barrier between the two sacs, but it is not sufficient to prevent the passage, for instance, of the tubercular virus from the one to the other. A tubercular peritonitis is nearly always accompanied by a tubercular pleurisy, perhaps limited to the lower parts of the sac. Similarly a septic peritonitis has usually a dependent pleurisy. Tumours of the peritoneum also frequently lead to similar formations in the pleura.

In the above cases the pleurisy is secondary to inflammation in some other part, but there are also cases of primary pleurisy. Persons take pleurisy from catching cold, as it is said, whatever be the exact mode in which the cold produces its effects. There is very often a localized pleurisy occurring in a limited area, just where the pleura is most

directly exposed to the effects of cold, namely, in the left lower lateral region. In this position the chest is not covered by any considerable mass of muscles, as the fleshy masses of the latissimus dorsi and pectoralis major passing upwards to the arm leave, as it were, an unprotected space covered by the comparatively thin origins of the serratus magnus and external oblique muscle of the abdomen. This part is also removed from the centre of heat in the heart, and on the left side instead of the liver there is the hollow stomach. On the right side the liver is a source of heat, and renders the corresponding part on this side less exposed to cold than that on the left, but still more exposed than most other parts of the chest. It is probable that, in these localities especially, cold, acting directly on the chest wall, may cause an inflammation of the pleura by depressing the temperature. But cold may produce a general pleurisy just as it is said to produce a general pneumonia, the fact of the general character of the inflammation indicating that some irritant is present in the fluid which exists in the pleural sac.

It is here proper to state that a considerable number of cases appearing to be simple pleurisy are really cases of tubercular pleurisy. The tubercular virus sometimes finds its way into the pleura independently of neighbouring organs, being apparently carried by the blood to the pleural sac. The lymphatic system of the lungs is not in direct communication with that of the pleura, and so it does not usually happen that a tubercular pleurisy develops from phthisis pulmonalis except in its later stages. The true tubercular pleurisy develops independently of lung disease, although it may be present along with tuberculosis of the lungs in acute miliary tuberculosis, where the virus is undoubtedly conveyed by the blood. Tubercular pleurisy is usually an acute disease, and is often associated with tubercular pericarditis or, more rarely, with tubercular peritonitis.

In its ANATOMICAL DETAILS acute pleurisy is closely analogous to acute pericarditis. There is hyperæmia, soon followed by a thin fibrinous deposit. This fibrinous exudation, forming a soft yellow layer, often attains to a considerable thickness, forming shaggy projections from the pleural surface especially in the region of the lower lobe. Serous fluid is also exuded, sometimes in considerable abundance. If the fluid in the pleura is not too abundant the two surfaces of the membrane come in contact, and there is adhesion of the two layers of fibrine. This adhesion prevents further deposition of fibrine, which is often very thin over the upper lobe.

If the inflammation goes on there is a new-formation of vascular granulation tissue which may come to replace the fibrine. If two such surfaces are in contact, by absorption of the serous fluid or otherwise, coalescence occurs and complete union of the surfaces, the granulation tissue afterwards developing into connective tissue. We have already seen that the fluid accumulated in the pleural sac frequently compresses the lung greatly, producing collapse of it.

An ordinary pleurisy may go on to suppuration (EMPYEMA) if the inflammation be very acute, or it may be suppurative from the outset. In the latter case there has usually been some specially virulent irritant present in the pleura, as where a metastatic abscess in the lung has approached the pleura, or where the pleurisy is one of the phenomena of septicæmia. In these cases the disease is generally rapidly fatal, and we may find remains of the fibrinous exudation mixed with abundant pus. Where the suppuration has come on in the course of a simple pleurisy the disease is often greatly prolonged, and the pleura undergoes great thickening, being converted into a bulky layer of granulation tissue like the wall of an abscess. The granulation tissue may undergo partial transformations into connective tissue with occasional adhesion, and as the lung has been compressed by the exudation we may have drawing together of the chest to an extreme degree should the pus be discharged or partially absorbed.

Reference has already been made to TUBERCULAR PLEURISY. The tubercles occur in the form of comparatively small white nodules which are present in the substance of the pleura, but near the surface. They are very commonly hidden by fibrinous exudation, and are therefore most easily seen on separating the lobes, the contact of which has prevented any thick fibrinous deposit. The pleurisy is usually prolonged, and we have at once fibrinous exudation with a certain amount of serum and chronic thickening of the membrane.

PLEURAL ADHESIONS.—We have already seen that an acute pleurisy may result in adhesion of the sac, the process of adhesion resulting from coalescence of the surfaces which have become like granulation tissue from the inflammation. Such adhesion will not occur so long as fibrine is present on the surface, and is to be carefully distinguished from the mere gluing which may occur in the earlier stages from the adhesion of the fibrinous exudation on opposed surfaces. But we have also seen that in the frequent chronic pleurisy of phthisis a similar

adhesion occurs, and the method of its occurrence is similar. Without any fibrinous or serous exudation (hence called dry pleurisy) the surfaces come to have the characters of granulation tissue and coalescence with vascular communication occurs.

HYDROTHORAX is a dropsy of the pleural sac. The serous exudation of acute pleurisy is not to be placed in this category, which only includes cases in which the transudation is increased without inflammation. Most frequently it is part of a general dropsy, as in Bright's disease, cardiac disease, or anæmia. Malignant tumours, especially secondary cancers, produce hydrothorax just as they produce accumulation in the peritoneal sac. As cancers spread along the lymphatic spaces it may possibly be that the dropsy results from obstruction of these.

PNEUMOTHORAX has been referred to in connection with phthisis pulmonalis, and the mode of origin there indicated is that in the great majority of cases. Of the remainder there are some in which it is due to empyema—the visceral pleura has softened and the lung has become ulcerated so as to communicate with the pleura, or to gangrene of the lung, or to metastatic abscesses, or to the bursting of emphysematous vesicles, or to a traumatic cause. The air in the pleural cavity is usually at a high pressure and the cavity is much distended, so that when the chest is opened the air rushes out with some force. The pleural cavity as exposed presents a remarkably empty appearance, the lung being compressed except where there are adhesions, which may form tense bridges across from parietal to visceral layer or may limit the pneumothorax considerably. If the patient live there is nearly always an acute suppurative pleurisy, so that the condition may be designated PYO-PNEUMOTHORAX.

Experimental observation seems to show that the air may be absorbed, and this is confirmed by actual clinical observation. In the great majority of cases, however, the pneumothorax being followed by suppurative pleurisy, the aperture does not close and the condition persists till death, which is not generally long delayed.

TUMOURS of the pleura are rarely primary, but osteomas and lipomas have been seen. Cases have also been described of primary cancer of the pleura in which the tumour appeared to take origin in the endothelium of the sac or of its lymphatics.

SECONDARY TUMOURS are not infrequent. A sarcoma of the mediastinum, originating in the bronchial glands, may result in an eruption of secondary tumours in the pleura, or a cancer originating in connection with the bronchi at the root of the lung may have a similar consequence. In cancer of the mamma the secondary tumours sometimes involve the chest wall and are propagated to the pleura where they produce an eruption, and may pass on to the lungs. Cancers of the peritoneum also frequently cause cancer of the pleura. In all these cases the tumours form pale soft masses which are usually flat and sessile, but may show considerable prominence. As already mentioned, the cancers are usually associated with dropsical exudation.

DISEASES OF THE ALIMENTARY CANAL.

INTRODUCTORY OBSERVATIONS.

IN studying the diseases of the alimentary canal certain facts as to its structure and functions are to be borne in mind. The canal is lined throughout by a mucous membrane, which consists of loose connective tissue covered with epithelium in one or several layers. In the mucous membrane and to some extent beneath it are glands which in different parts have different structures, but everywhere secrete materials that pass into the calibre of the canal. In addition to these there are in many parts closed follicles of a lymphatic structure which usually lie near the surface and frequently take part in changes going on there. Beneath the mucous membrane is the submucous tissue which, for the most part, is loose, and so allows the mucous membrane to go into folds or be stretched out flat according to the state of dilatation or contraction of the canal. Outside this there is a muscular coat, generally in two layers, by means of which movements and variations in calibre are effected. In most parts of the intestinal canal there is a serous coat outside of all.

In the diseases of the alimentary canal it is chiefly the mucous membrane that we have to deal with, the subjacent structures being usually subordinate to and affected secondarily to it. The serous coat, it is true, is often affected independently; its diseases, however, do not belong specially to the alimentary canal, but to the peritoneum as a whole. The mucous membrane on account of its exposure to a variety of influences derived from the varying contents of the canal is specially liable to inflammations, and the great majority of the diseases to be considered here are inflammatory ones.

It will be necessary for convenience to subdivide the alimentary canal into different sections and to consider each of these separately.

A.—THE MOUTH.

As the mouth is exposed in an especial manner to external influences, so its mucous membrane possesses an epithelium in many layers, and it is not nearly so liable to inflammations as most other parts of the alimentary canal.

INFLAMMATIONS OF THE MOUTH.

CATARRH.—If we leave out of view the catarrhs of the fauces and pharynx which we consider afterwards, SIMPLE CATARRH of the mouth is exceedingly rare as a primary disease. It is not infrequent, however, as a secondary affection, arising from the irritation of carious teeth, from the use of mercury, the presence of ulcers, etc. It is also of frequent occurrence in the acute fevers, especially typhus, scarlet fever, small-pox and measles. In these fevers there is also a catarrh of the stomach, and the inflammation in both seems due to the action of the poison in the blood.

The mucous membrane is swollen and red and there is greatly increased desquamation of the epithelium, especially inside the cheeks and on the tongue. The desquamated epithelium is mixed with leucocytes serous exudation and mucus in varying proportions, and on that account it has varying characters. On the tongue there is usually much epithelium which lies on the surface, and so a tolerably thick layer is formed mostly of a whitish or yellowish colour (furred tongue). On the cheeks and gums there is more fluid and less epithelium. In the midst of the epithelium and leucocytes bacteria and leptothrix threads are to be found. If the patient is feverish and lies with the mouth open, the catarrhal products dry-in and form a dirty brownish coating of the tongue and gums which goes under the name of SORDES.

Sometimes the inflammation centres especially around the mucous glands, and they may form prominent nodules or vesicles. To this form the name FOLLICULAR STOMATITIS has been given, and it is frequently seen in children during dentition or after measles, and is often associated with catarrh of the stomach or intestine. The vesicles or small prominences frequently burst and leave multiple small ulcers covered by a dirty exudation.

Catarrh of the mouth rarely assumes a phlegmonous character, in this respect contrasting with inflammation of the fauces.

THRUSH or APHTHOUS STOMATITIS or SOOR.—This condition has already been mentioned as connected with the presence of a fungus. It occurs in the mouths of young unhealthy children, but is also occasionally seen in emaciated adults, as in diabetes. The normal secretion of the mouth is alkaline, but in this disease it becomes acid, which may perhaps be the reason that the fungus develops. If the mouth be examined it will be found beset with small white spots, which look like little bits of white curd on the surface of the mucous membrane. These patches are, however, adherent, and in removing them the mucous membrane beneath will be found red and bleeding. The white patch consists of epithelium united into a membrane by a fungus, the oidium albicans (Fig. 238). It consists of branching threads composed of elongated cells placed end to end and sometimes losing themselves in masses of spores. The aphthous patches frequently extend from the mouth downwards to the pharynx and œsophagus.

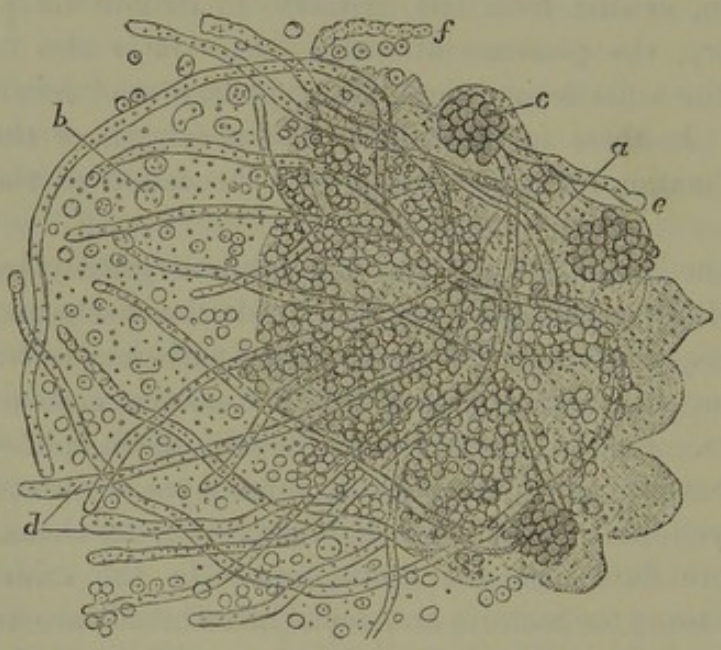


Fig. 238.—Oidium albicans or thrush-fungus. The constituents of the fungus are associated with flat epithelium. ×450. (KÜCHENMEISTER.)

The condition of the mucous membrane in certain SPECIAL FORMS OF INFLAMMATION deserves particular mention. In SMALL-POX, besides a general catarrh there are vesicles or pustules analogous to those on the skin. We have first whitish patches consisting of raised and desquamating epithelium. The epithelium is soon discharged and superficial ulcers result. In SCURVY there is great swelling and œdema of the mucous membrane of the gums around the teeth. The gums bleed and, apparently as a consequence of this, ulcers form at the edges of the teeth and may extend down to the bone which may undergo necrosis. Very often the teeth are loosened. As a consequence of the USE OF

MERCURY we sometimes have a considerable stomatitis. It occurs after the medicinal use of mercury and also among workmen who employ it in their occupations. The mucous membrane is swelled, especially that of the gums and cheeks, and there is severe salivation. Ulcers frequently form, especially on the internal surface of the cheeks and lips, and on the edges of the tongue. They may be in the form of flat excoriations or deeper ulcers with a membranous covering.

GANGRENOUS STOMATITIS or CANCRUM ORIS or NOMA.—This disease, which is fortunately a rare one, occurs in badly nourished children, particularly when reduced by severe illness such as scarlet fever or measles. It presents itself first as a diffuse swelling of the cheek which is seen to be tense, red, and glistening, with one spot in the centre usually redder than the rest. On examining the inside of the mouth there is already an excavated ulcer opposite the red spot on the cheek, and the gums opposite may also be ulcerated. As the disease progresses more and more of the mucous membrane of the mouth is ulcerated away. At the same time the red spot on the cheek gets black in the centre, and afterwards extends in area. By and by a slough of various sizes separates and a communication forms through the cheek with the inside of the mouth. If the patient survive still further destruction occurs, the necrosis passing on to the surrounding skin of the jaws, even to the ear and eyelids. There may be necrosis of the jaws. Not infrequently this disease is associated with a gangrenous pneumonia and there are general symptoms of septic poisoning.

The exact nature of this disease is not known, but it must be suspected from the rapid necrosis that a specific virus has to do with it.

INFLAMMATION OF THE TONGUE deserves a brief special notice. We have seen that the tongue takes part in most of the inflammations of the mucous membrane, but sometimes it becomes the seat of a special inflammation of its substance, a true GLOSSITIS. This may occur as a result of wounds or irritations from without, or in the course of such diseases as erysipelas and small-pox. The tongue swells greatly in consequence of the inflammatory infiltration of the interstitial connective tissue, and this sometimes, though rarely, goes on to the formation of abscesses. The muscular fibres are swelled, pale and brittle. Usually the inflammation ends in resolution, but sometimes it becomes chronic, and there may be great increase of connective tissue with permanent induration of the tongue.

INFECTIVE TUMOURS OF THE MOUTH.

SYPHILIS.—We have various syphilitic lesions in the mouth, from slight inflammation to deep ulceration. It is not uncommon to meet with a PRIMARY CHANCRE on the lips. In that case there is a prominent tumour which has, in more than one case, been taken for an epithelioma. On microscopic examination the tumour is found to consist of immense aggregations of round cells (Fig. 239).

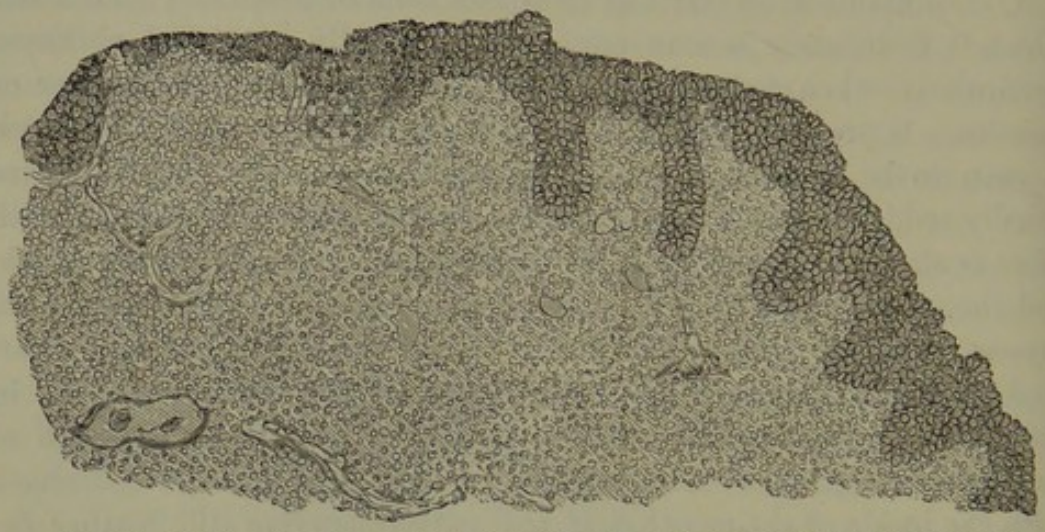


Fig. 239.—Section of a chancre of the lip which was excised under the belief that it was an epithelioma. There are multitudes of round cells beneath the epithelium, which is encroached on towards the left. × 90.

The catarrh which accompanies the secondary stage is often very slight, but it may be accompanied by superficial ulceration of considerable extent. FLAT CONDYLOMATA are particularly frequent in the mouth, and they often break down and form superficial ulcers, especially on the lower lip and angle of the mouth. The deeper ulcers arise in connection with GUMMATA, which form in the substance of the mucous membrane, and may lead to very serious loss of substance. If healing occurs a cicatrix forms, but cicatrices sometimes occur without ulceration having taken place, the gumma itself giving place to a cicatrix. The gummata not infrequently have their seat deep in the substance of the tongue, and the resulting cicatrices, with or without ulceration, may produce very marked deformity of this organ.

LUPUS not infrequently extends from the neighbouring skin into the mouth and may produce considerable destruction. LEPROSY also affects the mucous membrane of the mouth sometimes. GLANDERS occasionally manifests itself here. TUBERCULAR ULCERS are exceedingly rare.

TUMOURS OF THE MOUTH.

These are of somewhat frequent occurrence and considerable variety. We meet rarely with fibromas, lipomas, and enchondromas. Rather more common are ADENOID TUMOURS of the lips. These take origin in the mucous glands of the lips, and frequently become converted into mucous or colloid cysts. They form prominent rounded tumours sometimes as large as a hazel-nut and are readily enucleated. VASCULAR TUMOURS, mostly congenital nævi, are not infrequent on the lips, forming either flat elevations or, more rarely, prominent tumours with limited base. Vascular tumours are also met with on the tongue. WARTS occur on the lips, especially at the edges. In that situation they are mostly hard, while those on the proper mucous membrane are soft. Not infrequently the wart ulcerates, and, it is said, may give origin to a cancerous tumour. Warty outgrowths also occur on the tongue. The papillæ of the tongue sometimes undergo great elongation, especially their epithelial layers, and we may have a condition as of hairs on the tongue.

SARCOMAS rarely develop in the mouth itself, although they have been met with in the tongue. On the other hand it is not uncommon to find a sarcoma of the jaws growing from the periosteum and projecting into the mouth. This applies especially to the form of tumour called EPULIS. This name is given generally to tumours which arise from the alveolar processes of the jaws, growing mainly from the periosteum. These are mostly sarcomas and composed of spindle-cells, but they nearly always contain giant-cells, and sometimes these are in large numbers. Osseous trabeculæ pass into them frequently from the bone beneath. As these tumours grow they push the mucous membrane of the gums before them and so form red prominences of a rounded form, behind, in front of, or between the teeth, and generally hard to the feel. The teeth are often considerably displaced by them as they grow, especially when they assume large dimensions as sometimes happens.

CANCERS of the mouth are nearly all of the epithelial variety. They are of very frequent occurrence on the lips and are also common on the tongue. On the lips epithelioma is almost confined to the male sex, and has its seat in the great majority of cases in the lower lip. This is frequently ascribed to the fact that in men the lip is more frequently exposed to irritation by smoking short pipes and in shaving. On the

tongue the epithelioma usually forms at the edge, and it is often said that the irritation of the sharp edge of a carious tooth has been the starting point. The epithelioma begins in a limited infiltration of the lip or tongue, but as a rule ulceration soon occurs, and the tumour presents itself as a flat or excavated ulcer with infiltrated edges. By ulceration great destruction may take place of the lips and skin around, or of the tongue. Secondary epitheliomatous formation frequently occurs in the submaxillary lymphatic glands, and may extend to the glands of the neck.

Macroglossia is a condition in which the tongue is greatly increased in bulk, the enlargement being nearly always congenital. Even at birth the tongue may be too large for the mouth and project beyond the lips. Afterwards it may increase still more, and as the child grows it may displace the alveolar processes considerably. For the most part there is no hypertrophy here except of the interstitial connective tissue, but evidences of new-formation of muscular tissue have been observed. As a rule, the lymph spaces of the hypertrophied connective tissue are greatly enlarged, and there is even a formation of cavernous tissue the spaces in which are filled with lymph. In this way we may speak of lymphangioma cavernosum as taking part in the condition. It will be observed that the condition here somewhat resembles that in elephantiasis, there being in both cases a great new formation of succulent connective tissue with wide lymph spaces. The resemblance is further indicated in the fact that the lips frequently hypertrophy as well.

Ranula is a name applied to cysts which form beneath the tongue. These mostly arise as retention-cysts from closure of Wharton's duct (duct of the submaxillary gland) or the duct of the sublingual gland, but they may take origin in the mucous glands. Before the occurrence of the cyst there is usually some inflammation of the floor of the mouth very often connected with affections of the teeth. According to the observations of Recklinghausen referred to at p. 206, the cyst arises by dilatation of the duct, while the gland structure persists and furnishes the material by whose accumulation the cyst forms (see Fig. 81, p. 206).

AFFECTIONS OF THE TEETH.

In studying the diseases of the teeth we have to remember what are their constituent and related structures. The hard part of the tooth

consists of enamel, dentine, and cement. The ENAMEL, containing very little organic matter (only about 2 or 3 per cent.), is for the most part passive, and even presents great mechanical resistance to destructive processes. In its original formation it is a superadded structure, and for this reason also it takes little part in the morbid changes which occur in the teeth. The DENTINE, consisting of tubules with a hard matrix, possesses a much larger proportion of organic matter (28 per cent.), and is much more directly involved in morbid processes. The CEMENT, which covers those parts of the tooth which are devoid of enamel, consists of true bone, and is liable to changes of a similar nature to those of bone.

Turning to the soft parts, the PULP fills the cavity of the tooth and has an outline parallel to that of the tooth as a whole. The pulp is a soft, highly vascular tissue, and is concerned in the nutrition of the dentine. It is also richly supplied with nerves whose filaments pass in part into the dentinal tubules. The pulp is so sensitive that in popular language it is called "the nerve." In the original formation of the tooth the dentine is produced by the structure which is afterwards represented by the pulp, and through life the latter retains to a considerable extent its formative power. As we shall see afterwards, it is concerned in the formation of the secondary dentine.

The tooth is fitted accurately into the alveolus by means of the cement on the one hand and the DENTAL PERIOSTEUM or periodontal membrane on the other. This membrane, lying between the cement and the bone of the jaw, forms a kind of double periosteum, and is, from its position, very liable to the action of mechanical forces, being placed between two rigid structures, one of which (the tooth) is peculiarly exposed to mechanical interference. It is continuous at the apex of the root with the pulp, and at the neck with the mucous membrane of the gums on the one hand and the periosteum of the jaw on the other. We shall see afterwards that inflammations are apt to extend from the pulp to the dental periosteum, and from the latter to the gums and maxillary periosteum.

CARIES.—This name is applied to a condition which is not quite analogous to caries of bone, except in so far as in both there is destruction of the dense calcified structure. Caries of bone is related to inflammatory processes, but caries of the teeth has no such origin. It consists of a softening, usually progressive, of the enamel and dentine and their subsequent disintegration. The process appears

to begin very commonly in places where the enamel shows normally rather deep furrows, and is therefore thinner and more easily destroyed than elsewhere. When the caries reaches the dentine it advances more freely, so that the enamel may to some extent be undermined. The lime salts are first absorbed, and then the organic basis is broken down. The caries advances in the direction of the dentinal tubules, as shown in Fig. 240.

Various views have been held as to the nature of the process. At one time it was regarded as inflammatory, but this view may be set aside, chiefly on the ground that a process exactly similar occurs in teeth which have been drawn and re-inserted, as well as in artificial teeth made of the ivory of the hippopotamus. The caries consists, in fact, of a gradual solution of the lime salts, and for this solution we must infer the existence of an acid. The secretion of the mouth is naturally alkaline, but in carious teeth an acid reaction has been detected. The acidity is often connected with derangements of the stomach, but it may have a more local origin, as when the secretion of the gums is abnormal, or perhaps when food is undergoing acid fermentation in contact with the teeth. It may be that before the teeth yield to an undue acidity they have already an abnormally weak power of resistance, and this may be related to personal peculiarities, inherited or otherwise.

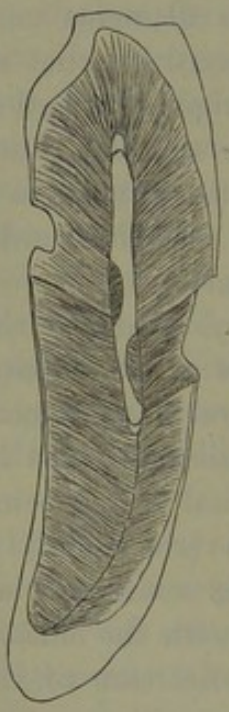


Fig 240.—Section of tooth with caries. There are two cavities, one on each side, and in the pulp cavity a new-formation of secondary dentine. The secondary dentine is not exactly on the same level as the cavities, but at the extremities of the dentinal tubules leading from these. (After SALTER.)

At the advancing margin of the caries a widening of the dentinal tubes is visible, and in these widened tubes, as well as in the carious cavity, bacteria and leptothrix threads are to be found. By some the process has been ascribed to the action of these organisms, and especially by Klebs, but these views stand in need of confirmation.

INFLAMMATION frequently follows on caries, and the pulp is usually involved. It is almost certainly attacked if the caries causes penetration into the pulp, but even before this takes place there is frequently some inflammation. This sometimes expresses itself in a new-formation of SECONDARY DENTINE inside the tooth around the point to which the caries is advancing (see Fig. 240). In this way the carious cavity may be shut off

from the cavity of the pulp, and so a more serious inflammation warded off. Very frequently, however, a more acute inflammation of the pulp occurs, with redness, swelling, great pain, not infrequently also with complete necrosis of the pulp, and, in consequence, of the whole tooth.

The inflammation often extends to structures around the tooth. The root-membrane or dental periosteum, which covers the root portion of the tooth, is the structure most directly attacked. This membrane is, as we have seen, intimately connected towards the neck of the tooth with the submucous tissue of the gums, and the periosteum of the alveolar process of the jaw. Inflammations of these structures, especially of the gums, very frequently ensue, resulting in the well-known GUM-BOIL, which often goes on to suppuration and abscess, forming the so-called PARULIS. The abscess usually bursts into the mouth, but it may produce extensive swelling of the gum, and lead even to penetration outwards, resulting in a fistulous opening in the skin.

The result may be even more serious if the periosteum of the jaw becomes inflamed, resulting, it may be, in suppuration which is apt to be chronic. With the periostitis there is usually new-formation of bone, causing thickening of the jaw.

It is to be added that these inflammations of the root-membrane and periosteum of the jaw sometimes occur apart from caries, as a result, for instance, of poisoning with phosphorus or mercury, and in scurvy. In that case the inflammation is not limited to the neighbourhood of one tooth, but extends probably to a series.

The cement, which, it must be remembered, is composed of bony tissue, sometimes undergoes a hypertrophy to which the name EXOSTOSIS or OSTEOMA is often given. This is scarcely a true bony tumour, but originates rather in a chronic inflammation of the cement, leading to a considerable new-formation of bony tissue. In this way are formed prominent tuberous outgrowths from the roots of the teeth, which may be localized to one part of the fang, or cover a considerable portion of it, or even the whole root portion of the tooth. In the latter case it is as if the root were enlarged by rough accretions on its surface. These so-called exostoses sometimes offer serious resistance to the extraction of the teeth.

Another form of tumour connected with the teeth is that which Virchow has called the ODONTOMA. This tumour arises in connection with teeth retained in the alveoli by faulty development. The tumours are composed of dentine and enamel, and are of small size and rare occurrence.

B.—THE SOFT PALATE, PHARYNX, AND TONSILS.

Introductory Observations.—In studying the diseases of these parts there are two circumstances to be taken into account very carefully: the one concerns the structure of the mucous membrane, and the other the circumstances as to its exposure to influences from without.

The mucous membrane here differs from that of the mouth proper chiefly in respect that in addition to the ordinary mucous glands there are numerous lymphatic follicles. The distinction between these two is not always correctly appreciated. The mucous glands are racemose glands with proper ducts, opening on the surface of the mucous membrane. The follicular glands, as they are often called in rather a confusing way, are strictly comparable with the closed follicles of the intestine. In the pharynx, soft palate, and root of the tongue they occur in the form of isolated rounded masses of lymphatic tissue, like the solitary follicles of the intestine. In the tonsils we have aggregations of these follicles not unlike Peyer's patches. The prominence of these follicles in the tonsils causes the mucous membrane to be thrown into folds, and so we have comparatively deep recesses, which are sometimes called crypts, and in which secretions may accumulate, especially if their depth is exaggerated by diseased conditions.

The other circumstance alluded to is that from their exposed condition these parts are peculiarly prone to irritation from agents coming to them by the inspired air. The mucous membrane of the mouth generally seems peculiarly resistant to external irritations, but here, where there is the transition, as it were, from the mucous membrane exposed to external influences to that protected from them, these inflammatory manifestations occur with peculiar frequency. Almost all the diseases we have to treat of here are forms of inflammation, and it is usual to describe these under the general designation of Angina.

INFLAMMATIONS OF THE FAUCES.

Acute catarrhal angina.—This forms the most ordinary sore throat, and occurs either from "cold," especially at seasons of the year when sudden changes of temperature are prevalent, or as a local symptom of a general disease such as measles, scarlet fever, small-pox. It may be said regarding scarlet fever, small-pox, and diphtheria that the

throat affection in them begins with an acute catarrh, but that, especially in scarlet fever and diphtheria, it nearly always goes on to something more serious. In the simple catarrh there is redness and swelling of the mucous membrane with a mucous exudation which covers the surface and may have a tough consistence. Sometimes vesicles form on the mucous membrane.

CHRONIC CATARRH very frequently follows on the acute form, especially when there have been repeated attacks. The conditions are somewhat different in different cases, and rather complicated classifications have been introduced. As in other chronic inflammations there is here, for the most part, thickening of the mucous membrane, but there are different ways in which this may, to some extent, localize itself. There may be a general hypertrophy of the superficial layers of the mucous membrane, and, as the blood-vessels remain congested, it is a rather succulent swelling. This causes what is called the relaxed throat. The appearances are most pronounced in the case of the uvula, which becomes elongated, sometimes to a very marked extent. At other times the swelling is not so uniform, but with some general thickening there is an occasional localized prominence causing the mucous membrane to assume a granular appearance. This form occurs mostly among clergymen, singers, actors and others whose occupation requires them to use their voices for prolonged periods with a loud tone. It is not by any means certain what the exact structure of the prominent granulations in this disease is, but it seems likely that there are really two conditions included under the name. In one of them the mucous glands are involved and may be seen discharging a milky fluid. In the other the enlargement is not connected with the mucous glands, but is usually supposed to depend on enlargement of the closed follicles, although Stoerk has recently stated that it really consists of a hypertrophy of the epithelium. The condition is often called follicular pharyngitis from the view that the closed follicles are mainly concerned. Ulcers may form in connection with these swellings and they are called follicular ulcers.

ACUTE PHLEGMONOUS INFLAMMATION OF THE FAUCES frequently results in the formation of ABSCESSES. It is a condition of somewhat common occurrence. Here there is not merely a surface catarrh, but the mucous membrane and submucous tissue are involved in an acute inflammation of a very intense kind which usually goes on to suppura-

tion. The disease very commonly begins on one side and frequently involves the tonsil, sometimes extending thence to the posterior wall of the pharynx. The swelling and redness are very great from hyperæmia and œdema of the whole structures, and the patient may have difficulty in opening the mouth. If it goes on to suppuration the pus often collects and forms an abscess which bursts into the throat. In some cases the acute inflammation extends downwards to the base of the epiglottis and the case becomes dangerous because of the possible supervention of œdema glottidis. It should be added that the name QUINCY is applied to this disease as well as to a more local inflammation of the tonsils alone.

The causes of the inflammation are frequently obscure. It seems as if some intense irritant were acting on the fauces, and the fact that severe sore-throats often occur in a number of persons about the same time would point to the existence of a virus of some kind. The occurrence of a similar inflammation in scarlet fever is also confirmatory of the supposition that the disease owes its origin to a virus. It sometimes happens that the inflammation, after attacking one side, passes round and involves the other, and this looks like an irritant which propagates itself.

DIPHTHERIA.—The changes which occur in this disease have already been referred to in considering its manifestations in the air passages. It usually begins in the fauces and has its centre there. The characteristic phenomenon here is the formation of a fibrinous exudation. In order to that there must be the necrosis of the epithelium on the surface. As we have seen there is usually in the fauces a deeper necrosis involving the mucous membrane to a greater or less depth. Besides the exudation and necrosis there are other signs of inflammation, chiefly in the presence of leucocytes infiltrating the mucous membrane and passing into the exudation.

It sometimes happens that the mucous membrane is not involved in the exudation, so that when the exudation is removed there is no loss of substance. As a rule, however, there is necrosis of the mucous membrane, and this in all degrees till we come to the so-called gangrenous form. In this form, as the exudation separates, it carries with it portions of tissue, and as these only by degrees become detached from the living tissue, it looks as if exudation and dead tissue were together sloughs of the mucous membrane. These sloughs frequently look more serious than they are, but there may be considerable loss of substance, and ulcers of some depth and size may be left.

The disposition of the patches of exudation is very various. Sometimes they are mainly on the tonsils, sometimes on the soft palate and uvula. Extension to the posterior nares on the one hand and to the larynx on the other is very frequent, the latter, as we have seen, being particularly common.

Acute Tonsillitis is, as we have seen, occasionally a part of a general phlegmonous inflammation of the fauces. Occurring more independently it is accompanied by considerable swelling, consisting of an inflammatory infiltration of the lymphatic follicles of the tonsils. Sometimes it goes on to suppuration, but rarely does so when the tonsils alone are affected. The swelling in many cases does not fully subside, and gives rise to a more or less permanent enlargement such as we have next to consider.

Chronic Tonsillitis mainly shows itself in the form of hypertrophy of the tonsils. Certain persons, especially in youth, are prone to repeated subacute inflammations of the tonsils, and as these recur the tonsils acquire a permanent enlargement. This consists anatomically in a true hypertrophy of the lymphatic follicles, although there is sometimes also an increase of the interstitial connective tissue. For this reason the tonsils are rarely much indurated, the soft lymphatic tissue existing so abundantly as to make the structure as a whole somewhat soft. The hypertrophy appears to be not always the result of chronic inflammation, or at least it is frequently altogether out of proportion in amount to the inflammation. The greatest degree of hypertrophy is met with in children, and they are not so liable to acute tonsillitis as youths. There are cases even of congenital hypertrophy of the tonsils, and there are still more frequent cases of a gradual enlargement without any apparent attacks of inflammation. In this way the tonsils may acquire very large dimensions, reaching the size of a hen's egg on some occasions.

Syphilitic Disease of the Fauces.—This manifests itself in multifarious ways. A persistent catarrh having the ordinary characters of subacute simple catarrh is very common. Mucous tubercles or condylomata are tolerably frequent, especially in the pillars of the fauces and in the soft palate. In the tertiary stage, with or without the formation of gummata, there may be ulceration of the mucous membrane. Not infrequently the ulceration extends very deeply and causes destruction of the uvula and palate. It may extend to the epiglottis and so further.

It is frequently accompanied by considerable thickening and cicatricial contraction, so that it may lead to great deformity and sometimes to stenosis of the pharynx.

TUBERCULAR ULCERS.—These are of very rare occurrence here, although so common in the larynx. The disease is associated with phthisis pulmonalis, and is really due to an extension upwards of tubercular ulceration of the larynx. It occurs in the form of superficial ulcers, originally of a circular form.

The TUMOURS OF THE FAUCES are not so different from those of the mouth as to call for very special remark, and they are altogether of much less frequent occurrence. We meet with papillary excrescences, cysts, sarcomas, and epitheliomas.

C.—THE ŒSOPHAGUS.

The diseases of this part of the alimentary canal are important from a practical point of view, chiefly because of the natural narrowness of the tube. The mucous membrane of the œsophagus is covered by a thick layer of stratified flat epithelium, and the mucous glands are comparatively few.

DILATATION OF THE ŒSOPHAGUS.—Of this somewhat frequent condition two forms may be distinguished. Besides a local dilatation about to be mentioned, we have a GENERAL DILATATION of the tube as a result of obstruction at any part of its course. The obstruction is mostly low down in the œsophagus and may be even at the cardiac end of the stomach; or the stomach and œsophagus may be simultaneously dilated by obstruction of the pyloric end of the stomach. With the dilatation in these cases there may be considerable thickening of the muscular coat, although this is not always present.

Contrasted with this general dilatation is the PARTIAL DILATATION or DIVERTICULUM. The mode of origin of these diverticula is sometimes obscure. There are some which seem to owe their origin to an imperfect closure of the communication between the œsophagus and the trachea during fœtal life. If this closure be

delayed, then the wall of the œsophagus may remain bulged out in front and from this beginning a larger diverticulum may arise. More commonly, however, the diverticula form on the posterior wall at the lower part of the pharynx or upper part of the œsophagus. It is probable that for the most part these originate by a piece of hard food lodging in a fold of the mucous membrane, and being gradually pushed outwards, carrying the wall of the tube with it. As the sac enlarges, it hangs downwards with its mouth presenting upwards, and so it is always ready to receive the food in its passage downwards. It is probable that in most of these cases there is a separation of the fibres of the muscular coat of the œsophagus or pharynx, and that the mucous membrane is pushed, as it were, through the muscular coat. It is consistent with this view that the diverticula are most common at the junction of pharynx and œsophagus, where the circular muscular coat is thinnest. If the sac is of any considerable size and filled with food, it will press on the œsophagus below its mouth, and of itself produce an obstruction. In this way the food is prevented passing down the œsophagus and goes readily into the sac. We have therefore, for the most part, a continually increasing enlargement of the diverticulum which may reach the dimensions of a child's head or larger. It contains the remains of the decomposing food, with more or less mucus which is sometimes present in considerable masses. If the diverticulum is moderate in size its wall may still contain some muscular fibre, although, from what has been already mentioned, it will appear that the muscular coat is mostly absent except just at the neck.

Besides the two modes of origin already mentioned a third has been distinguished. The lymphatic glands at the root of the lung sometimes, after enlarging, undergo softening and cicatricial contraction. If a gland, under these circumstances, has acquired adhesion to the œsophagus, it may in its contraction drag the wall of the latter outwards. In this way the œsophagus may acquire a funnel-shaped pouch which is liable to enlargement by the food being pushed against it. As it is mostly the bronchial glands that are concerned here, such diverticula are usually found near the bifurcation of the trachea, and they sometimes perforate into the trachea, forming fistulous openings. They have also been observed to perforate into neighbouring cavities such as the pericardium or pleura, producing serious inflammations of these.

Obstruction of the Œsophagus.—This condition may arise as a consequence of pressure from without, by tumours, aneurisms, abscesses.

But it is much more frequent from disease in the tube itself. Ulcers of various kinds, by the cicatricial contraction incident to attempts at healing, may induce obstruction, as, for example, ulcers from swallowing strong acids, syphilitic ulcers, etc. Still more frequent are obstructions from tumours of the œsophagus, and especially cancers, which we shall have to refer to immediately, As we have already seen, obstructions of the œsophagus frequently give rise to dilatations with hypertrophy of the muscular coat above the seat of constriction. Sometimes the dilatation becomes more partial, so that with a general dilatation there is a partial diverticulum.

INFLAMMATIONS of the œsophagus are of comparatively little moment. The mucous membrane is formed so as to resist the action of irritants, and unless the action be peculiarly strong we have not considerable inflammation. When strong acids or alkalies, or substances at a high temperature, are swallowed, they may cause superficial necrosis and considerable inflammation of the mucous membrane. The small-pox eruption may extend into the œsophagus, producing inflammation there.

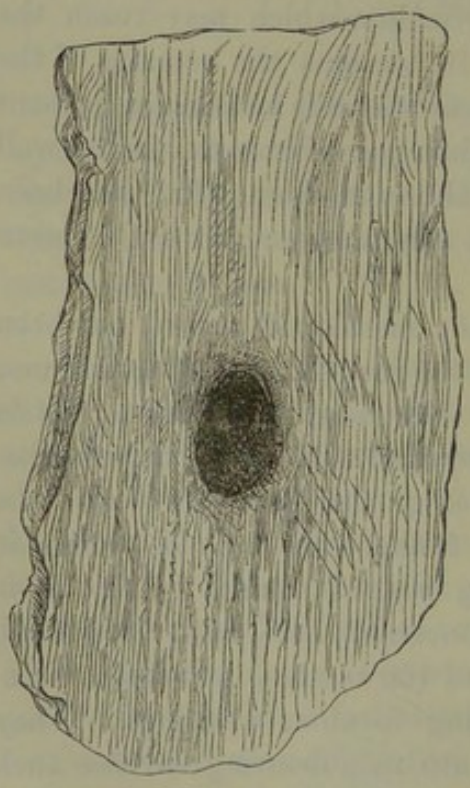


Fig. 241.—Perforating ulcer in lower part of œsophagus. The ulcer penetrated the main bronchus of the left lung.

Strong acids or alkalies when swallowed usually produce much more serious results in the stomach than in the œsophagus, as they pass rapidly over the surface of the latter. Acids produce whitish, yellowish, or brownish sloughs of the epithelium, sometimes penetrating to the mucous membrane itself. Caustic alkalies, on the other hand, dissolve the epithelium, producing a greyish gelatinous material which lies on the surface. If they penetrate to the mucous membrane they reduce it to a soft, brownish, half-diffluent substance. If recovery occurs, there are at first ulcers with more or less violent inflammation, and afterwards healing with contraction of the ulcers and possibly considerable narrowing of the tube.

Small-pox pustules in the œsophagus are very similar to those in the

mouth, and, like them, they readily lose their epithelial covering and become converted into ulcers. They are accompanied by signs of inflammation of the mucous membrane generally.

PERFORATING ULCERS OF THE ŒSOPHAGUS.—A few cases have been observed of round ulcers in the lower part of the œsophagus similar to those which will be described as of common occurrence in the stomach. Figure 241 represents an ulcer of this kind which perforated into the left main bronchus, causing gangrene of the lung on account of the food passing in. There have been cases also in which the ulcer has penetrated into the aorta.

TUMOURS OF THE ŒSOPHAGUS.—Simple tissue tumours are rare. We meet with LIPOMAS and FIBROMAS, and the author has described a case of MYOMA (Fig. 242) in which a tumour $4\frac{3}{4}$ inches long and 2 inches in thickness was attached by a comparatively narrow neck, and produced death by obstructing the tube. Polypoid tumours of a similar form are met with having a fibrous structure.

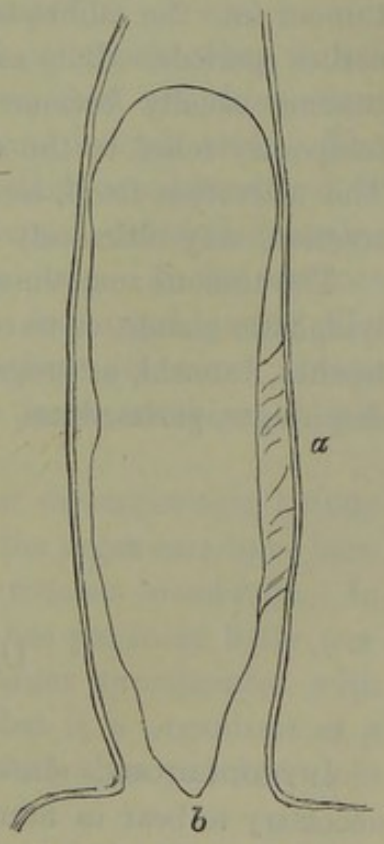


Fig. 242.—Polypoid myoma of œsophagus in section, and semi-diagrammatic. The tumour was attached by a band-like pedicle *a*. It caused considerable distension of the œsophagus, and obstructed the tube. *b* cardiac orifice of stomach. Half the natural size.

CANCER of the œsophagus is by far the most important form of tumour met with. The cancer is nearly always in the form of flat-celled epithelioma, and in its histological details closely conforms to cancer of the lip. The masses of epithelial cells infiltrate the spaces in the underlying connective tissue, and the tumour also projects somewhat into the calibre of the tube. Here also there is a great tendency to ulceration, the mechanical action of the food in swallowing doubtless contributing to this result.

The tumour begins at a limited part of the mucous membrane, but it has a special tendency to extend round the tube in the form of a ring. There has been considerable discussion as to the most common situation of the tumour, and the result of the comparison of various statistics seems to be that the most frequent seat is the lower third. Scarcely less frequent than this is the

middle third, and especially the place corresponding with the bifurcation of the trachea. In the upper third epithelioma is comparatively infrequent.

This form of tumour frequently leads to obstruction of the œsophagus, and it produces this result in more ways than one. On examining the œsophagus after death the seat of the tumour is often indicated externally by a narrowing of the tube, which is also more rigid here than elsewhere. The infiltration of the walls of the œsophagus, by irritating the connective tissue, causes a chronic inflammation with the usual new-formation of connective tissue, which contracts and narrows the tube. Besides this, the mere rigidity of the tube preventing its dilatation when the morsel is being swallowed, may produce during life a feeling of obstruction at the point concerned. The projection of the tumour into the calibre is another element, which tells especially in the earlier periods. But as ulceration occurs, this projection of the tumour usually becomes inconsiderable, and there may even be a temporary relief to the stricture by partial destruction of the tumour. The ulceration itself, however, by inducing still further cicatricial contraction, may ultimately confirm the obstruction.

The tumour sometimes extends from the œsophagus to neighbouring lymphatic glands, or to surrounding structures, and so we may have the trachea, bronchi, or lungs involved in it. Sometimes it extends to the diaphragm, pericardium, vertebræ, etc.

D.—THE STOMACH.

Introductory.—In considering the diseases of the stomach, it is necessary to bear in mind certain points in regard to its structure and functions. The innumerable glands which exist in the mucous membrane are regularly engaged in the formation of the gastric juice for the purposes of digestion. The diseases of the stomach very readily interfere with the function of these glands, so that the secretion of gastric juice is insufficient in quantity or deteriorated in quality. In that case the food is apt to lie in the stomach undigested, and it very commonly undergoes various forms of decomposition. The products of decomposition acting on the mucous membrane still further interfere

with the process of secretion, and by their irritative action keep up or induce a condition of catarrh of the stomach. Gases also develop in the process of decomposition, and these, by distending the organ, interfere with its proper peristaltic movements, and so hinder the passage of the food through the pylorus.

But it is not merely local diseases, such as inflammations and tumours, which interfere with the secretion of the gastric juice. Changes characterized by cloudy swelling and fatty degeneration are met with in the glandular epithelium in numerous infective diseases, small-pox, typhus, septicæmia, as also in poisoning with phosphorus, etc. In these cases the secretion of the gastric juice may be almost at a standstill, and if food be introduced it is apt to lie in the stomach; by its mere presence, and by the action of the products of decomposition, it may produce still further structural changes.

The forms of decomposition which the food undergoes when it lies undigested in the stomach are various, but the chief are those characterized by the development of acetic, lactic, and butyric acids. The agents in these changes are micro-organisms which are introduced in abundance with the food and propagate in the stomach, unless their multiplication is hindered by the action of the gastric juice. In the contents of the stomach, when at any time they are discharged during life, swarms of bacteria are found, and in addition there are nearly always proliferating spores of fungi and sometimes large numbers of sarcinæ.

It has been mentioned that the products of decomposition irritate the mucous membrane, but in addition to that the organisms have been found in some cases to enter the glands and mucous membrane. In cases observed the action of such organisms has produced little pustules in the mucous membrane, or even larger prominences with necrosis and ulceration. It may be inferred that it is organisms of a special kind or in a peculiar state of activity which thus penetrate into the mucous membrane.

Stagnation of the food in the stomach and its decomposition will occur, as we have already mentioned, when anything interferes with proper digestion. But it will occur still more when by stricture of the pylorus there is a mechanical obstacle to the passage from the stomach. In such cases the gastric juice may be secreted nearly in the normal way, or it may not, and so according to circumstances there will be greater or less decomposition of the food.

Besides the mere local effects induced by the products of decom-

position, it is to be remembered that the mucous membrane of the stomach is actively engaged in absorption, and that these products may to some extent be taken into the blood. It is probable that much of the headache and other nervous symptoms occurring in dyspepsia is due to the existence in the blood of small quantities of these poisonous agents and their action on the nervous system. Some of these symptoms may be reflex, but to a certain extent they are more probably direct.

When the food remains in the stomach and accumulates there, it is usually got rid of after a time by vomiting. This action is produced by irritation of a centre in the medulla oblongata, and the muscles employed are mainly those used in respiration, but in different combinations. The centre may be irritated directly, as by introducing apomorphia or tartar emetic into the blood, or by disease of the brain itself. But in the case we are considering it is irritated by reflex stimulation, the stimulation taking origin in centripetal fibres in the stomach itself. The occurrence of vomiting is dependent on the nature and amount of the irritation applied and on the sensitiveness of the centre in the individual.

Post-mortem Changes.—After death any remains of food lying in the stomach are apt to decompose rapidly, especially as the gastric juice in most cases is not secreted in the normal way up to the period of death, and so the decomposition is not interfered with. The decomposing juices therefore act readily on the mucous membrane, and the decomposition may even extend to the latter. The principal changes produced are ALTERATIONS IN COLOUR, resulting from chemical changes in the colouring matter of the blood. The colouring matter may become diffused out of the blood-vessels and stain the mucous membrane of a generally red hue, the colour being specially pronounced in the neighbourhood of the larger vessels. There is often a greenish colour developed by the decomposition of the blood. Lastly, the colour may be almost black or slaty, but in many cases this deep colour is not altogether post-mortem, depending rather on a true pigmentation from chronic catarrh of the mucous membrane.

Softening of the stomach is also a post-mortem change. It is really a digestion of the coats of the stomach by the gastric juice. As a rule in persons near death the gastric juice is not secreted normally, but if the person die somewhat suddenly then there may be a considerable amount of active gastric juice in the stomach at the time of death.

When the mucous membrane of the stomach dies, the gastric juice in such cases begins to digest it, and so a softening occurs which may extend beyond the mucous membrane. As already hinted, this condition occurs mostly in persons who die suddenly, especially if the body is kept in a warm place, and it is more frequent in children than in adults. In the slightest degree the mucous membrane alone is softened, and it can be removed from the surface of the muscular coat with the finger as a soft paste. Penetrating deeper, the muscular coat and even the serous coat may be half liquefied, so that on handling the stomach it may be perforated. The stomach may even rupture in the body, and the contents pass outwards producing softening in neighbouring parts. In some cases the diaphragm has been softened in this way, and the stomach contents have passed partly into the pleural cavity.

These changes, both the ordinary alterations from decomposition and the softening of the coats by digestion, occur in those parts of the stomach where the contents have been lying after death. This is generally the neighbourhood of the fundus. As the contents are usually fluid, it is often seen that the changes stop short at a definite level and the unaltered mucous membrane rapidly emerges from the altered part. The pyloric portion of the stomach, as it usually lies highest, is least frequently affected, and this is important, as that part of the stomach is the most frequent seat of disease.

It will be understood that many of the pathological changes of the stomach will be obscured by the occurrence of these post-mortem changes.

DILATATION AND HYPERTROPHY OF THE STOMACH.

These conditions mostly result from obstruction to the passage of food through the pylorus from contraction of that orifice. It is also stated that sometimes a simple weakness of the muscular coat allows of passive distension. Obstruction of the pylorus causing an accumulation of the stomach contents leads in the first instance to a simple distension of the organ. The distension tells chiefly on the parts which are free to swell out. The lesser curvature is fixed by its attachments, and it usually retains nearly its normal position except that its middle part is somewhat dragged downwards (see Fig. 243). The greater curvature, on the other hand, is carried downwards, and the stomach may virtually fill the entire abdomen, reaching as far as the symphysis pubis in some

cases. Sometimes the pylorus is depressed and the duodenum correspondingly displaced.

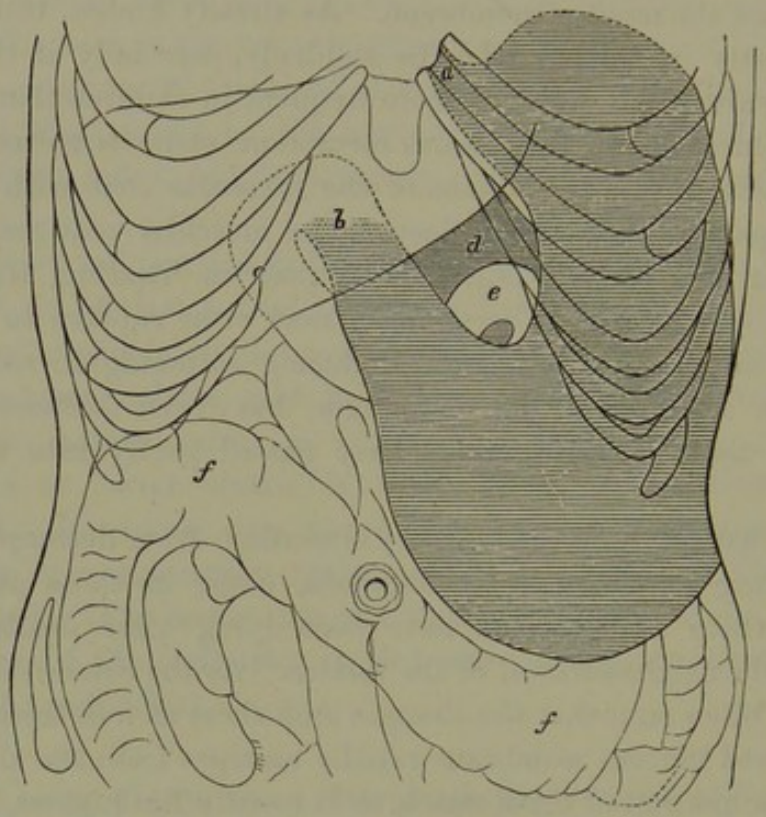


Fig. 243.—Dilatation of the stomach, shown diagrammatically. The stomach is shaded, *a* being cardiac, and *b*, pyloric orifice. The greater curvature is much depressed, while the lesser curvature fixed at its two extremities forms a sharp curve, in the bend of which are visible the first loop of the jejunum (*e*), and the region of the pancreas (*d*); *f f*, transverse colon depressed; in the midst of it the position of the umbilicus is indicated. (After PENZOLDT.)

It may be anticipated that when there is obstruction of the pylorus there will be an effort on the part of the muscular coat to overcome it, just as in the hypertrophy of the heart from obstruction of the aortic orifice, or the similar hypertrophy of the urinary bladder. But the muscular coat of the stomach has a somewhat different function to that of the heart or bladder. In the latter there is a simultaneous contraction of the entire muscle with a view to the emptying of the viscus. In the stomach, however, the contraction is vermicular, and its object is as much to move the contents about inside the stomach as to empty them into the duodenum. In the actual propulsion of the contents into the duodenum it is the pyloric portion of the stomach that is engaged, and here also the material is carried forward by a vermicular movement. Hence the hypertrophy of the muscular coat in obstruction of the pylorus does not occur uniformly in the stomach, but localizes itself in the

pyloric portion, sometimes even with a special thickening just at the orifice, forming a tight sphincter. In these cases, when the wall of the stomach is divided the progressive thickening of the rigid muscular coat can often be distinguished as the pylorus is approached. Along with hypertrophy of the muscle there is very often thickening of the connective tissue in the mucous membrane and submucous tissue, as well as of that between the muscular bundles.

INFLAMMATIONS OF THE STOMACH.—GASTRITIS.

ACUTE INFLAMMATIONS may be produced by the action of irritant poisons which have been swallowed, the inflammation here being accompanied by sloughing. Acute spontaneous inflammation is rare except in the milder forms which constitute catarrh, and we have very rarely, in the stomach, conditions comparable with the phlegmonous angina of the fauces, or the dysenteric inflammation of the intestine. Such PHLEGMONOUS INFLAMMATIONS are met with occasionally in severe infective diseases, and particularly in puerperal fever. There is great swelling and redness of the mucous membrane, terminating in a diffuse purulent infiltration of the wall of the stomach. Sometimes abscesses have been formed in the wall of the stomach which have burst into its cavity.

CATARRH OF THE STOMACH, on the other hand, is a condition of very frequent occurrence and is met with in the acute and chronic forms.

ACUTE CATARRH.—This is induced for the most part by the direct action of irritants on the mucous membrane, mainly by the use of irritating foods or drinks. We have already seen that, when food remains in the stomach undigested, it undergoes decomposition, and the irritating products may induce an acute catarrh. The mere prolonged stay of food in the stomach probably induces it, as when by exposure to cold the secretion of the gastric juice and the peristaltic action necessary to the process of digestion are interfered with.

It is seldom that the stomach can be examined after death in this condition, but from observations of Beaumont on his patient with a gastric fistula, as well as from experiments on animals, the appearances of the mucous membrane have been tolerably well made out. There is intense redness with swelling of the mucous membrane, which is covered by a layer of mucus or muco-pus, sometimes slightly mixed with blood. The appearances are most marked towards the pylorus, and sometimes confined to that region.

Under the microscope the blood-vessels in the mucous membrane, and especially in the submucous tissue, are found enormously distended, and the epithelial cells, both those of the surface and of the glands, enlarged and granular.

Chronic Catarrh.—This often remains after one or more attacks of the acute form. It is also present in cases of passive hyperæmia of the stomach, which so frequently occurs in consequence of disease of the heart and liver. Cancer of the stomach is also accompanied by chronic catarrh in most cases.

If the catarrh is prolonged there usually occurs a considerable new-formation of connective tissue, as in other chronic inflammations. There is thus a thickening which affects mucosa, submucosa, and muscular coat, and causes the surface of the mucous membrane to assume an irregularly folded or warty appearance, which has given rise to the designation *état mamelonné*. The mucous membrane also presents, in many cases, dark spots or a general deep colour from the presence of pigment granules in the tissue. The pigment is derived from the blood, and indicates the occurrence of hæmorrhages, probably by diapedesis. The increase of the connective tissue produces atrophy of the glands which are also considerably distorted.

It sometimes happens that the increase of connective tissue is specially great, and the wall of the stomach may be converted into a thick hard resistant structure. As all these processes occur mainly in the pyloric portion of the stomach, considerable narrowing of the orifice may result. The rigidity of the wall and the narrowing of the orifice induce more forcible muscular contractions, and the muscular coat therefore hypertrophies. In the interstitial tissue of the muscular coat there is also thickening, and the fleshy muscular bundles are separated by trabeculæ of connective tissue. The resulting appearance is often very characteristic, the hypertrophied connective tissue dividing the hypertrophied muscular bundles into divisions, which on section are somewhat like the pieces of a fan. This thickened and indurated condition may closely resemble scirrhus of the stomach, especially as a similar appearance is presented by the muscular coat in that disease.

Occasionally mucous polypi develop in connection with chronic catarrh, and these may develop into mucous cysts.

THE SIMPLE PERFORATING ULCER.

This peculiar form of ulcer is met with only in the stomach, first part of the duodenum, and lower part of œsophagus. It is also called, sometimes, the ROUND and the CHRONIC ULCER. It is clear from the localities in which it occurs that its peculiarities are due to the action of the gastric juice, but the more detailed consideration of its mode of origin will be better taken up after the appearances of the ulcer have been described.

The ulcer is usually round or oval in shape, and presents the appearance as if a conical piece of the wall of the stomach had been punched out from within, its edges being perfectly defined without any considerable thickening of the neighbouring mucous membrane, and the floor of the ulcer perfectly clean, (see Fig. 242, in which an ulcer of the œsophagus having all the characters of that of the stomach is represented). The superficial extent and depth of the ulcer vary considerably. The commonest size is about that of a shilling, but this may be exceeded considerably, and Cruveilhier has described an ulcer which was $6\frac{1}{2}$ inches long and $3\frac{1}{2}$ inches broad. In the smaller ulcers the floor is formed of the coats of the stomach, probably with some new-formed connective tissue. In the larger and deeper ones the tissue of neighbouring organs may be exposed, such as the pancreas or liver. The floor of the ulcer does not present any of the usual appearances of a granulating wound, but is clean and smooth, the actual tissue of the part being exposed, perhaps with some induration from new-formation of connective tissue.

The situation of the ulcer is mostly in the neighbourhood of the lesser curvature, and nearer the pyloric than the cardiac orifice. It is more frequent on the posterior than the anterior wall. It is not uncommon to find more than one ulcer present in the same case. Though the ulcer is much more common in the stomach, yet the duodenal situation has been observed in a considerable number of cases, the œsophageal being, however, exceedingly rare. The ulcer in these situations has exactly the same characters as that in the stomach.

The ulcer presents a tendency to penetrate more and more deeply, from which circumstance it is named the PERFORATING ulcer. It does not appear to extend laterally to any considerable degree; it is probable that at the very first the ulcer assumes its full superficial dimensions. Eating into the wall of the stomach it may penetrate through the entire coats, and sundry accidents are liable to ensue.

One of the commonest of these accidents is HÆMORRHAGE. The ulcer penetrates one or more vessels at its base. The vessels may be small and the hæmorrhage not very considerable, but sometimes a considerable artery is laid open, and a serious, even a fatal hæmorrhage results. From the commoner situations of the ulcers the arteries most frequently penetrated are these—the coronary artery or one of its branches, the gastro-epiploic, the pancreatic, and the splenic. Sometimes the open mouth of the vessel can be seen after death in the floor of the ulcer.

PERFORATION is another result of the penetration of the ulcer, but a much less frequent one than hæmorrhage. For the most part, by the time the ulcer has eaten through the wall of the stomach, the latter has already acquired adhesion to some neighbouring structure, and so actual rupture of the stomach and escape of its contents into the peritoneal cavity is not common. The adhesion may be to the liver or pancreas, or, more rarely, to the spleen, diaphragm, colon, abdominal wall. By the extension of the ulcer these structures may be eaten into and their tissue exposed. The tissue when first exposed has its normal appearance, but it usually becomes condensed and cicatricial. Sometimes the irritation of the gastric juice produces suppuration and the formation of ABSCESS, especially in the case of penetration into the liver. But if adhesion does not occur then the ulcer is likely to cause rupture of the stomach. This will happen most readily where the wall of the stomach is most liable to shift about during the regular peristaltic movements, and also where there is no solid viscus to which it may readily adhere. Both these conditions are fulfilled in the case of ulcers of the anterior wall, and so it happens that rupture most frequently occurs in this situation. The ulcers which lead to perforation are frequently very small, and the aperture in the serous coat may be as large as the ulcer itself. The result of the perforation is acute and fatal peritonitis.

HEALING of the perforating ulcer is by no means an unusual occurrence. In the experiments to be referred to presently in which ulcers were produced artificially in animals, they healed very readily. In man also they are frequently recovered from, and we often meet with cicatrices in the stomach. They may indeed heal without leaving a very obvious cicatrix at all. The author met with a case in which three weeks after a very severe hæmorrhage, presumably from an ulcer of the stomach, only an obscure cicatrix could be found.

We have now to consider the MODE OF ORIGIN of these ulcers, and this is a matter of some difficulty. It is obvious from the shape and

appearance of the ulcer that it has arisen by the necrosis and subsequent digestion of a piece of the wall of the stomach. The question arises as to the cause of the necrosis. The funnel-shaped outline of the ulcer suggested to Virchow that the necrosis occurred by obstruction of or interference with an arterial branch, and he observed as confirmatory of this that the ulcers most frequently had their seat at the point of entrance of arterial branches into the wall of the stomach.

The experiments of Panum and Cohnheim confirm this view in so far as they show that ulcers may be produced by embolism of the arteries of the stomach. In Cohnheim's experiments, if the animals were killed a day or two after embolism had been produced there were found large ulcers with abrupt edges and perfectly clean floors. The difficulty of the case is, however, that the perforating ulcer is not met with specially in cases of embolism or thrombosis of the arteries of the stomach, but in the immense majority of instances in cases where no such disturbance of the circulation exists. It has been suggested again that a venous hyperæmia, by causing stagnation and even hæmorrhage (see afterwards) in defined areas of the mucous membrane, may produce such weakening of the tissue as to induce necrosis and digestion of it.

In most cases of gastric ulcer there is serious and usually prolonged DYSPEPSIA, and the persons are frequently anæmic. This seems to indicate that the condition of the gastric juice has an important relation to the gastric ulcer. It is also important in this connection that, while ordinary ulcers of the stomach such as are produced by wounds or the action of caustics, or by such experiments as those already referred to, heal readily, this form of ulcer is peculiarly chronic and shows a tendency rather to extend deeply than to heal. Some abnormal condition of the gastric juice by virtue of which it is peculiarly irritating to the mucous membrane seems to be the essential factor, while a weakened condition of the mucous membrane is also of consequence. In most cases the gastric juice is abnormally acid, and it has been thought that by neutralizing the natural alkalinity of the tissues it may lead to their necrosis.

On the whole it seems probable that an acrid gastric juice, taking advantage of any accidental stagnation in a defined area of the mucous membrane, may lead to its necrosis and the formation of the ulcer.

It has been already stated that while ordinary ulcers heal readily this form is peculiarly persistent. But if the condition of the gastric juice be improved, and especially if its excessive acidity be corrected while solid food is prevented acting on the surface of the ulcer, the

ulcer often heals readily, leaving a cicatrix which is sometimes very obscure, but may be more distinct and with some puckering.

The frequency of ulcer of the stomach may be judged from the fact that according to the results of post-mortem examinations it is said that there are ulcers or cicatrices in about one in twenty of the cases examined after death.

HÆMORRHAGE FROM THE STOMACH.

Besides the hæmorrhage which occasionally supervenes in the case of the perforating ulcer, and that which is occasionally a feature in cancer of the stomach, we have certain other forms which call for notice here.

The vessels are apt to rupture when the pressure of the blood in them is considerably raised above the normal. This will occur especially with disturbances of the vascular system involving hyperæmia of the portal system. In diseases of the heart leading to general venous engorgement, we have passive congestion of the liver reflected to the portal vein. In this case there are signs of general venous engorgement probably including dropsy of the limbs, etc. But disease of the liver itself, especially cirrhosis and cancer, may cause obstruction to the portal circulation. In these cases there is a general engorgement of the portal vessels, and hæmorrhage from the stomach frequently occurs.

The blood mostly escapes from the superficial vessels of the mucous membrane, which are least supported, and it passes into the cavity of the stomach. In some cases it is from a large number of small superficial vessels, and the exact source is not apparent. At other times the blood passes to some extent into the superficial layers of the mucous membrane, infiltrating it. The mucous membrane infiltrated with blood is acted on by the gastric juice and digested by it, so that small flat superficial ulcers are formed, the so-called HÆMORRHAGIC EROSIONS. These are generally present in considerable numbers, chiefly in the pyloric region. In the erosions there may be still some remains of blackened blood, and alongside them there are little areas of mucous membrane infiltrated with blood. In these cases also the mucous membrane is often generally red from the passive hyperæmia, and possibly thickened by catarrh.

The blood is generally mixed with the contents of the stomach, and blackened by the gastric juice. If the hæmorrhage be very severe, as from an ulcer perforating a considerable artery, the blood may be vomited nearly in the fresh state, but usually it is tarry or like coffee-grounds. The altered blood may also pass into the duodenum and onwards.

TUMOURS OF THE STOMACH.

CANCER.—This is the only form of tumour which is of much practical importance, and it is of exceedingly frequent occurrence. From the statistics of a considerable number of observers it appears that cancer occurs more frequently in the stomach than in any other situation in the body, the uterus being the next most frequent site.

The great frequency of cancer in the stomach is probably related to the fact that the epithelial structures of this organ are more exposed to various irritations than those of any other part of the body. Not only are there varieties of irritating foods, but the foods are liable, as we have seen, to decomposition, the products of which produce irritation. In cases of cancer there is very commonly a history of prolonged dyspepsia, perhaps from youth.

In this regard the simple ulcer may be again referred to. There have been cases observed in which cancer seemed to originate in the simple ulcer; but the simple ulcer is a disease mostly of youth, whereas cancer is a disease of middle life, the average age being fifty years. It is almost as if similar causes produced the simple ulcer in youth, and cancer in middle life.

In its structure cancer of the stomach is like cancer elsewhere. There are epithelial masses which tend to insinuate themselves among the neighbouring tissue elements, and there is a connective tissue stroma. The epithelial elements also originate in the existing epithelium, chiefly that of the glands. But in the mode of growth of the epithelium and its relation to the stroma there are considerable differences presented, and although not rigidly to be distinguished from each other it is possible to divide the cases into four forms.

In EPITHELIAL CANCER there is a tolerably definite gland-like new-formation, as we have in other cases of cylinder-celled epithelioma. There are ducts and acini lined with cylindrical epithelium, but very often this regular arrangement is lost in great part, and, except in the more recently formed part, we have more irregular masses. The glandular structures are limited by a distinct stroma, which is well formed. As in all cancers of the stomach, the new-formation of epithelium begins in the glands, and at first the tumour grows in the mucous membrane. But the growth extends into the submucous tissue, and insinuates itself among the other coats of the stomach, passing into the muscular coat, and even outside it into the

serous coat. From the glandular character of the tissue in this tumour it is sometimes called adenoma.

The tumour is a slowly growing one, and it generally involves a considerable portion of the stomach before the death of the patient. It usually begins in the pyloric region, frequently forming a ring around the stomach, but it extends inwards from this, it may be for some distance. The surface is nearly always ulcerated, and may be considerably excavated. There are sometimes papillæ on the surface of the tumour, especially at the marginal parts, which give the surface a warty appearance. The advancing tumour infiltrates and thickens the mucous membrane and the subjacent coats, and so while the greater part of the tumour may be rough and warty and somewhat excavated, the edges are usually prominent, and sometimes rather abrupt.

The epithelioma of the stomach is not a very frequent form of tumour, and it does not so readily extend beyond the neighbouring lymphatic glands to the liver as the next form.

Medullary or Soft Cancer of the stomach is probably the most frequent of all forms of tumour. In it the epithelial growth does not arrange itself in proper glandular structures, but there are large masses of comparatively loose epithelium in a sparse and delicate stroma. Hence the tissue is very soft. The epithelial masses tend to infiltrate the subjacent structures as well as to extend laterally.

The tumour is usually seated near the pylorus, forming, in some cases, a ring or a defined circular tumour. The tissue being soft it is specially liable to bleed and to ulcerate. The latter condition is so frequent and characteristic that the tumour often presents itself as a round, shaggy ulcer with prominent edges. Doubtless the gastric juice and the food acting on the surface of the tumour break down its tissue and lead to the ulceration. At the margins the cancer is infiltrating the mucous membrane, and so the edges are raised and somewhat abrupt.

This form of tumour is exceedingly malignant, the soft and loose cancerous elements readily finding their way into the lymphatic channels. Hence cancerous formations in the lymphatic glands around the stomach and in the other glands of the abdomen are very frequent. The liver also is very often the seat of numerous and large cancerous tumours, and a large proportion of the cases which clinically have the characters of cancer of the liver are primarily cases of this disease. The enormous secondary growths in the liver may contrast very markedly with the insignificant primary lesion, sometimes little more

than a comparatively small round ulcer with irregular surface and prominent margins.

The tendency to bleed which this tumour presents is to be borne in mind. The bleeding may be slight but frequent, and the blood carried off into the intestines. Or it may be more considerable, and even fatal.

SCIRRHUS is a somewhat frequent form of cancer of the stomach. Here, the new-formation of epithelial cells is not very rapid or vigorous, and it is accompanied by an excessive formation of connective tissue in the form of stroma. Originating in the glandular epithelium, long processes composed of rows of cells, often with few abreast, are produced, and they grow not only into the mucous membrane, but also into the muscular coat separating its trabeculæ, and even into the peritoneal coat. These processes seem to be peculiarly irritating, as they give rise to the production of dense connective tissue which is often much more manifest than the proper epithelial elements. These elements may, in fact, degenerate, and leave little besides condensed hard connective tissue.

The cancer mostly begins in the pyloric region, but extends inwards till, in some cases, it has involved the entire wall of the stomach, except the fundus. The wall of the stomach is converted into a stiff hard mass which may be, in some places, an inch in thickness. This dense structure has replaced the mucous membrane, and, to a certain extent, the other coats which, however, are usually separately distinguishable. The muscular coat is much hypertrophied by the new-formation both of muscle and of hard connective tissue, and a section of it presents the peculiar fan-like appearance already mentioned. The surface of the affected portion of the stomach is irregular, with rounded prominences, and there are sometimes ulcers present, but there is not a general ulceration as in the case of the epithelial and medullary forms. The stomach is often greatly contracted in this disease. The edges of the cancerous portion are not well defined, but shade off gradually into the normal mucous membrane.

Extension of the cancer to the liver does not readily occur, although neighbouring lymphatic glands may be involved.

COLLOID CANCER is not a frequent form as compared with the medullary, but it is met with in a considerable number of cases. The other forms and especially the epithelioma, occasionally undergo a partial colloid degeneration. In the colloid form as in the others the epithelial elements take origin in the glandular cells, and after infiltrating the mucous mem-

brane these epithelial masses insinuate themselves among the muscular trabeculæ (Fig. 102, p. 230), and even into the serous coat. The stroma consists of a somewhat abundant well-developed network of connective tissue. The peculiarity of this form is that the cells have a special tendency to undergo colloid metamorphosis. They seem from their first formation to present a regular intention in this direction, and even in the more recent parts there is often already a considerable advance in the degeneration. The outlines of the cells disappear as the protoplasm becomes transformed into colloid material, and as the nuclei resist the degeneration longer, we sometimes see the peculiar appearance of oval nuclei as if floating in a clear transparent material. Finally, the whole epithelial elements are converted into colloid material, and the structure presented is a beautiful reticulated network with spaces filled with a transparent colourless jelly (Fig. 101, p. 229).

As the colloid material occupies more space than the original cells, the spaces of the alveoli are, as it were, tightly packed with the jelly, and the fibres of the stroma rendered tense and rigid. Hence it happens that although the structure is composed mainly of a soft jelly, yet it is to the feeling hard and rigid, just as a tensely filled bladder may be.

The tumour, like other cancers, usually begins towards the pylorus, but it extends gradually till it comes to involve a large area, sometimes even as much as three-fourths of the entire extent of the viscus. The wall of the stomach is converted into a transparent glancing tissue, and in the more advanced parts it is impossible any longer to distinguish the different coats, all being homogeneously replaced by the cancerous tissue. The wall of the stomach is considerably thickened, and the internal surface may present an irregular aspect with prominences; but there is little tendency to ulceration. As the thickened wall is tense and hard, the stomach when cut into does not generally collapse but keeps its shape. There is no tendency to contraction of the stomach as in scirrhus, but, on the contrary, the organ may be considerably enlarged.

This form has a very marked tendency to extend continuously both along the stomach, and also through the stomach to the peritoneum. Hence it produces secondary tumours in the peritoneum itself much more readily than in the lymphatic glands and liver.

It will appear from what has been mentioned above that cancers of the stomach frequently lead to the formation of secondary tumours elsewhere. In this respect the cancers of the intestine resemble those of the stomach, and as the modes of extension present certain points of

interest and practical importance, a special section will afterwards be devoted to this subject in general.

The remaining tumours of the stomach are of trivial consequence. We have already seen that MUCOUS POLYPI and CYSTS occur in chronic catarrh. LIPOMAS and MYOMAS have been met with, as also FIBROMAS and SARCOMAS, but they are very rare.

E.—THE INTESTINES.

INTRODUCTORY.—The diseases of the intestines resemble in many respects those of the stomach, but there are important differences. In structure the intestine differs from the stomach in several respects. We no longer have the specific glands peculiar to the stomach, but, on the other hand, the intestine presents numerous closed lymphatic follicles in its mucous membrane, and these are only present to a very slight extent in the stomach. These lymphatic follicles are solitary or collected into groups, in the latter case forming the well known Peyer's patches.

Of considerable importance in regard to the diseases of the intestine are the time which the intestinal contents stay in the different parts of the canal, and the changes they undergo there. After leaving the stomach the food appears to pass rapidly through the upper part of the small intestine, occupying on an average $2\frac{1}{2}$ to 3 hours in doing so, and it is at the same time rendered alkaline and partially protected from further decomposition by the pancreatic fluid and the bile.

The movement of the intestinal contents is effected by the peristaltic contraction of the bowel, and the rapid passage of the contents through the small intestine indicates that here the peristalsis is peculiarly active, whereas, in the large intestine, it is slow. When the fæces reach the large intestine they are still fluid, and the chief function of the colon seems to be to complete the absorption of the fluid, and allow the fæces to become thicker. But if the peristaltic action of the large intestine be increased, then there will be no time for the fæces to become thick, and fluid evacuations will be the result. This will be still more the case should the movement of the small in-

testine be increased, and the contents carried even more quickly than usual through them.

It will be seen that diarrhœa results from increased peristaltic movement, and that the evacuations will be more fluid the higher up the increased movement begins. It is well known that certain medicinal agents produce fluid motions, and these seem all to act by increasing the peristalsis, their relative vigour depending greatly on the part of the intestine at which they begin to produce their effects. Irritating articles of food produce a like increase of the peristalsis and diarrhœa, and so may ulcers and inflammations of the intestine itself.

In the stools in diarrhœa we may expect to find chemical constituents which normally are present in higher parts of the intestine, but absorbed before reaching the rectum. If the diarrhœa arises from increased peristalsis of the colon, then we shall find material which is normal in the cæcum, such as undecomposed bile, leucin, chloride of sodium, peptones, and sugar, some of which are present in appreciable quantity in normal fæces. But if the diarrhœa has involved the small intestine, then we shall find these constituents much more abundantly, and also remains of undigested food.

We have already seen in the case of the stomach that many of its diseases are connected with the fact that the food stagnates and decomposes in that viscus. It will be seen from what has gone before that the intestinal contents stagnate chiefly in the large intestine, and next to that in the lower part of the small intestine. It is probably due to this that we find the jejunum peculiarly free from all forms of disease; in this respect it contrasts with the lower part of the small intestine, the ileum, but still more with the large intestine. Hence it is that the diseases of the large intestine resemble those of the stomach much more than those of the small intestine do. This is especially true in regard to simple inflammations, which very often concentrate themselves in those parts where the intestinal contents most readily stagnate, namely the cæcum and the rectum. It is true also of cancer, which is very rare in the small intestine but common in the large, especially in the cæcum and rectum.

It is to be remembered further that the intestine is a comparatively narrow tube, and is subject to obstruction in various ways.

Post-mortem Changes.—These are not so important as those of the stomach. After death the blood is apt to gravitate towards the more dependent parts of the wall of the intestine, and the colouring matter being dissolved out and staining the mucous membrane, it may give rise

to a deceptive appearance of inflammation. Similarly the intestine may be stained with the biliary colouring matter in the neighbourhood of the gall-bladder.

MALFORMATIONS OF THE INTESTINE.

Congenital malformations of the intestine are of considerable frequency. The most important are those in which, from a fault of development, a part of the intestine is wanting. The colon or the rectum may be entirely absent at birth, being represented by a solid cord; or the rectum may be partially occluded, in some cases in its middle part, in others at its lower extremity. All these cases present the characters of imperforate anus, but of course in view of possible surgical interference their gravity varies, the most hopeful being those in which only the extreme lower part of the rectum is defective, and the gut is separated from the anus only by a membrane.

There occurs also narrowness and defect of the small intestine, especially in the duodenum and lower end of the ileum. The whole intestine is sometimes deficient in length, having something like the form of the letter S instead of the usual convolutions. In such cases the absorption and digestion of food must be defective, but the persons may live on to old age.

The commonest malformation is MECKEL'S DIVERTICULUM. This consists in a finger-like projection from the intestine. It occurs in the ileum, about three or four feet above the ileo-cæcal valve in the adult, and about a foot above it in the new-born; it projects from the free convex border of the gut. It is from one to six inches long, possessing the same structure as the intestine, and communicates with the latter; it is narrower in its calibre, being of a diameter rather more than that of the finger. This diverticulum arises by the imperfect closure of the omphalo-mesenteric duct, and sometimes it is united to the umbilicus by a cord. Very rarely is the diverticulum continued to the umbilicus, and opens there by a fistula at the surface.

HERNIA OR RUPTURE.

True hernia consists in a protrusion of the intestine, omentum, or other abdominal organ into a sac formed by a prolongation of the peritoneum. The sac may project externally, or it may be contained

within the abdomen, and so we may distinguish EXTERNAL and INTERNAL hernias. The hernias, especially the external ones, are of so much importance in a surgical point of view that full descriptions are given in the surgical text-books, and need not be repeated here, except in outline.

For the most part the sac is an entirely abnormal projection of the peritoneum, and seems to be protruded before the contents. An exception to this occurs in the case of congenital inguinal hernia, in which the sac is formed by the persistence of a fœtal condition. There is a partial exception also in the case of most internal hernias, where the sac usually arises by the exaggeration of an existing normal pouch.

In the PRODUCTION OF HERNIAS, we have to account for the abnormal protrusion of the viscera. This is usually due to the abdominal contents being subjected to undue pressure. In severe muscular efforts, such as are involved in lifting heavy weights, the glottis is closed, and the muscles of expiration fix the chest and abdomen, the contents of the abdomen being subjected to severe pressure by the contraction of the muscles of the abdominal wall. If there is any part of the wall which is unduly weak a bulging outwards may occur here, and so give the starting point for the hernial protrusion. In this connection the greater frequency of hernia on the right side may be noted. In violent exertions the right arm is usually more used than the left, and as the chest is bent over to the left side to counterbalance the strain on the right, the lower surface of the diaphragm faces more to the right and presses the viscera towards that side. It is clear that straining at stool or otherwise will also increase the pressure on the abdominal contents, and any excess will predispose to hernia.

It has been said that the protrusion takes place where there is any weakness of the abdominal wall, and it is well known that the external hernias occur at specially unsupported parts of the wall, while the internal ones have usually a pouch ready made as a starting point. The abdominal wall from its anatomical conformation is weak at certain points in every person, but there may be congenitally a special weakness, which in some cases seems to be hereditary. Or the weakness may be induced by the stretching of the abdominal parietes by increase in their contents (ascites, tumours, pregnancy, etc.) or more directly by injury to a particular part.

In protruding, the viscera nearly always push the peritoneum before

them, and the proper sac is formed by the peritoneum, which shows a remarkable power of stretching. But there are cases of protrusion in which the aperture has been produced by actual rupture of the wall, and in these cases the hernia may be devoid of a proper sac. These cases, however, of what may be called FALSE HERNIA, are exceedingly rare, as an injury, although tearing the muscular wall and other tissues, will very often leave the elastic peritoneum uninjured and capable of protrusion.

The hernial sac acquires for the most part adhesion to the structures among which it is protruded, and it does so by a chronic inflammation. It very often happens also that the contents of the sac become adherent to its internal surface by inflammation, and in that case the hernia is irreducible.

It is not necessary to enter fully into the individual forms of hernia, and of the external ones little more than an enumeration will suffice.

THE EXTERNAL HERNIAS are, (1) Inguinal hernia in the congenital and acquired forms, or, as otherwise divided, direct and oblique. (2) Femoral hernia. These two are by far the commonest forms. Of comparatively rare occurrence are, (3) Hernia of the sciatic notch; (4) Perineal hernia, protruded between the fibres of the levator ani; (5) Vaginal hernia; (6) Hernia of the foramen ovale; (7) Umbilical hernia which is congenital or acquired, in the former case arising by protrusion into the dilated umbilical cord; (8) Abdominal hernia occurring in various parts of the abdomen, chiefly towards the edges of muscles, and arising by tearing of tendons or muscular fibres, hence, frequently, traumatic. Its commonest situation is near the linea alba.

INTERNAL HERNIA comes less frequently into sight, and the possibility of its existence is apt to be forgotten.

(1) DIAPHRAGMATIC HERNIA is perhaps the commonest. There is a congenital form in which a sac is protruded through one of the normal apertures, or through a part of the diaphragm which by reason of defective development has given way. The protrusion is into the chest, and the sac may contain intestine, spleen, liver, stomach. There is also an acquired form, due nearly always to some injury to the diaphragm, and the hernia is frequently devoid of a proper peritoneal sac. From a case recorded by Dr. Adams, it appears that a tumour growing against the diaphragm (in his case from the capsule of the spleen) may so weaken it as to lead to hernial protrusion. In dia-

phragmatic hernias from rupture, a large portion of the abdominal viscera may be protruded.

(2) RETROPERITONEAL HERNIA includes cases in which the intestine passes into a pre-existing pouch in the peritoneum, greatly enlarging and filling it. The hernial sac hence lies behind the peritoneum of which it is an offset. There are three pouches in the peritoneum which are capable of giving rise to such hernias.

The JEJUNO-DUODENAL pouch is the most important. It exists just where the jejunum arises from the duodenum, and lies between the last part of the duodenum, which bounds it on the right, and the aorta, which bounds it on the left. The pouch was present, according to Waldeyer, in about 70 per cent. of the bodies which he has examined, and is generally large enough to admit the terminal phalanx of the thumb. It is best seen when the jejunum and small intestine generally are raised and carried to the right, so that the origin of the mesentery may be exposed. The little pouch, if present, is then seen lying in the posterior wall of the abdomen with sharp sickle-like margins. Sometimes a fold of the jejunum passes into this pouch, constituting a hernia. The pouch may be greatly enlarged by the protrusion of further portions of the intestine into it, and cases have been recorded in which the entire intestine has passed into the greatly distended sac.

Another pouch of the peritoneum is the SUB-CÆCAL, which has its seat between the folds of the meso-colon ascendens. Into this pouch the intestine is very rarely protruded, and the pouch itself only occurred in about 30 per cent. of the bodies examined by Waldeyer.

The FOSSA INTERSIGMOIDEA is a pouch in the mesentery, lying between the two folds near the beginning of the sigmoid flexure. The aperture is in the under layer. This is the commonest of these pouches, occurring in about 80 per cent. of the bodies, but from its position it does not appear ever to become the seat of hernia.

The CONTENTS OF HERNIAS are usually the intestine, and, for the most part, the more movable small intestine. Sometimes also the great omentum is carried into the sac. The large intestine possesses for the most part no free mesentery, being only partially covered with peritoneum, so that it is hardly possible for it to pass into a sac unless it be dragged down with considerable force.

The method of descent of the large intestine merits a more special notice. The process may in some respects be compared to the descent of the testis in the fœtus. Before its descent the testis is only

partially covered with peritoneum, being free of it at its posterior aspect. As it descends it remains with only a partial peritoneal covering, and even in the tunica vaginalis, after the sac has separated from the general peritoneum, the testis lies behind with its posterior aspect free of peritoneum. And so in a hernial sac, the cæcum may be carried down, but in its new position it remains only partially covered with peritoneum, and really forms as it were a part of the wall of the sac. This will only occur in very large hernias as a rule, but when it does occur the piece of intestine will be irreducible.

A still more peculiar condition sometimes occurs. The intestine may be protruded mainly at the part where it is uncovered by peritoneum, and instead of pushing a peritoneal sac before it, it may as it were drag it after. As the gut is protruded it may even get more and more stripped of peritoneum, so that the hernia may be much more extensive than the sac. This, however, is an exceedingly exceptional occurrence, and it is more common to find that as an ordinary hernia advances it drags the colon into it, so that besides free loops of small intestine there may be, fixed in the wall and only partly covered by peritoneum, a piece of the cæcum, or the sigmoid flexure, or even the fundus of the bladder.

In a similar fashion to that just described, the ovary may be protruded. A large majority of cases of OVARIAN HERNIA are congenital, and they appear to arise by a fault of development by which the ovary descends as the testis does normally. The ovary passes through the inguinal ring and takes a sac with it, but just like the testis it is itself attached to the wall. The sac remains open like the tunica vaginalis in a congenital inguinal hernia. The ovary in that case will be irreducible, unless, as sometimes happens, the broad ligament is so long as to allow the ovary to pass back through the neck. In this case, however, the ovary will still have its fixed attachment in the sac. Apart from this congenital inguinal form, ovarian hernias may be acquired, and these may be either inguinal or femoral.

The STRANGULATION of hernias is of great importance. By this expression is meant the condition in which the neck of the sac is so tightly impacted that not only is the return of the contents prevented, but even the blood-vessels are obstructed by the pressure of the ring. This mostly occurs when, on account of some peculiarity in the situation of the intestine as it issues from the sac, there is, to begin with, a partial

obstruction. If the intestine at its entrance into the sac be free, while at its exit it makes a sudden bend so as to cause a partial obstruction, then the fæces will pass readily in, but will accumulate inside as they do not find free exit. The mere loading with fæces may cause irreducibility, and if the fæces decompose the development of gas may still further increase the bulk of the contents. In this way the sac will become too full, and as the neck is narrow there will be special constriction here. Again, the intestine already in the sac by its peristaltic movement may drag more and more of the gut after it, till stopped by the intestine becoming too tight for the neck.

In any case the neck of the sac constricts the portion of intestine concerned, and the most direct effect is obstruction of its veins. This itself, by producing hyperæmia, and, it may be, œdema of the mucous membrane, leads to swelling and further constriction. The whole protruded piece becomes of a dark colour from venous engorgement and hæmorrhage. Finally the pressure may be enough to close even the arteries.

The venous obstruction alone seems sufficient, if complete, to cause necrosis of the intestine, and so gangrene is an occasional result. If the arteries are also obstructed there is still greater probability of the occurrence of gangrene.

But sometimes the obstruction is relieved before gangrene has occurred, and yet in some of these cases a severe inflammation results after the intestine has been returned to the abdomen, leading on, it may be, ultimately to gangrene of the affected piece of gut. The probable explanation of this is that during the incarceration the arteries have been obstructed, and during this period the blood-vessels have been so damaged that on the restoration of the circulation they are no longer able to recover. It has been shown by experiment (in the ear of the rabbit) that if, by ligaturing the main arteries, the vessels of the part are deprived of blood for a time, and then the circulation restored by loosing the ligature, the result is, active hyperæmia, acute inflammation, or the hæmorragic infarction, according to the time during which the ligature has acted. So in the case before us, the release of the constriction, by allowing of the re-establishment of the circulation in vessels seriously compromised, may lead to inflammation or gangrene.

TWISTING OF THE INTESTINE.

This is a condition probably of frequent occurrence, but one which is perhaps too little borne in mind as a cause of obstruction. It occurs in the great majority of cases at the sigmoid flexure of the colon, and the reason of this will appear from the anatomical relations of that part of the gut. The ascending colon above the flexure, and the rectum below it, have virtually no mesentery, being fixed to the abdominal wall. The flexure therefore is fixed at its two extremities and these are near one another, while the loop forming the flexure is movable. It is as if the loop were attached by its two ends to a fixed point, and it is easy to understand how it should sometimes twist round this as an axis. The twist is, as it were, in two half turns (see Fig. 244), and it is usually the upper limb of the loop which turns round the lower at its neck.

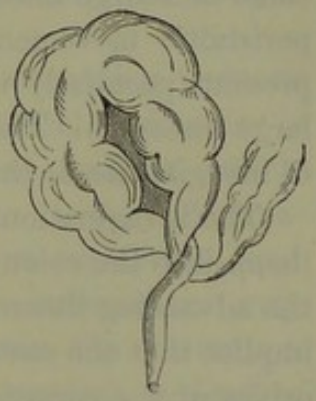


Fig. 244. — Twisting of the sigmoid flexure. The upper limb has a much sharper turn than the lower, so that a flexible tube could be passed up from the rectum.

It is clear that the twisting will cause some obstruction of the intestine, but this will not usually be complete. The lower limb is narrowed at its neck by being grasped by the upper limb twisted round it, while the upper limb is narrowed by the sudden curve which it makes. Fæces still pass into the flexure however, and they may accumulate in enormous quantity. This partial obstruction with accumulation of fæces may persist for months and lead to extreme dilatation of the flexure, so that it may fill the abdomen and reach up to the diaphragm. As the upper limb is twisted over the lower and the latter is straight, a tube may be passed from the anus up into the enormously dilated flexure. The walls of the intestine in these prolonged cases may be greatly thickened, especially the muscular coat. In some cases twisting may exist without any obstruction of consequence.

While twisting is most common in the sigmoid flexure, it is liable to occur also when other parts of the intestine assume similar relations, that is to say when a free loop of small intestine becomes fixed at its extremities, and these extremities are near each other. This will happen most frequently when one extremity is already fixed, as is the case at the upper and lower ends of the small intestine, where on the one hand the duodenum, and on the other the colon, is fixed to the abdominal wall and holds the intestine down. If, by inflammation or otherwise, an

abnormal adhesion is acquired so that the gut is fixed at a point near the situation of the natural fixation, then twisting is apt to occur, and probably more readily here than in the sigmoid flexure, as the small intestine is naturally more mobile.

INTUSSUSCEPTION OR INVAGINATION.

In this condition a portion of the intestine passes into a succeeding portion. In order that one piece may slip inside the other, the one must present active peristaltic contractions, while the other is relaxed. The portion narrowed by the violent peristalsis passes inside of the relaxed part.

These conditions are most frequently satisfied at the junction of the small and large intestines. The large intestine is naturally wide, and its peristaltic movements sluggish. If then the ileum at its last part presents peculiarly violent peristaltic contractions it may pass into the large intestine. This may explain the fact that the most frequent seat of invagination is this situation.

The invagination, however, is not usually a simple inversion of the ileum into the colon; in most cases the ileo-cæcal valve is carried before the advancing ileum and forms the apex of the intruded piece. This implies that the cæcum itself is carried inwards and inverted, and the orifice of the vermiform appendage is sometimes to be found near the apex of the invagination. The invagination is not infrequently very extreme, so that in children (in whom it most commonly occurs) the invaginated part may be carried right on to the rectum, so that the apex may be felt per anum.

Besides this form we also meet with invagination of the large intestine itself, one part into a succeeding. It occurs but rarely in the small intestine.

It has been stated above that invagination is peculiarly frequent in children, especially that form in which the large intestine is involved, and this is probably due to the much greater mobility of the colon in children than in adults. In the bodies of children also we frequently meet with a form of invagination which has produced no symptoms during life, and has really occurred just at the time of death. It is usually present in the small intestine, where a small inversion of one part into a succeeding one is found. The invagination is easily reduced by slight dragging, and there are none of the secondary changes visible such as are to be mentioned immediately as following

invagination. Just at death, or immediately after it (as may be frequently seen in animals), the intestine commonly shows violent peristaltic movements, but these are irregular, and it readily happens that a much contracted part passes inside a relaxed portion. This form of invagination is therefore either post-mortem or occurs just at the agony.

When a piece of intestine is invaginated, there are three tubes, the outside one in its natural position, forming the sheath, the internal one, which, although abnormal in position, runs in the usual direction, and the middle one joining the other two, and with its mucous surface directed outwards. It sometimes happens that a second invagination occurs, and then there are five tubes, or a third, in which case there are seven. The mesentery is carried in with the intestine, and by dragging on it at one side, it may give the gut a somewhat oblique direction.

The packing of intestine into the interior of succeeding portions causes considerable interference with the circulation, and this is increased by the mesentery being partly included and its vessels pressed on. In this way there usually occurs an acute inflammation, with swelling and hæmorrhage of the mucous membrane, and fibrinous exudation on the peritoneal surface. The inflammation may lead on to a general peritonitis with fatal issue. Again, the obstruction of the vessels may be such as, with the added inflammation, to lead to gangrene of the gut, and this by the slough separating and causing perforation may produce a fatal peritonitis. On the other hand, permanent adhesion may occur between the sheath and the upper end of the included part at the proximal extremity of the invagination, and, the inner and middle tubes becoming gangrenous, they may come away in whole or in part, as a slough, and the continuity of the intestine be restored with the loss of a piece.

It is not usual for complete gangrene of the included tubes to occur, but what remains becomes adherent to the sheath, and, by contraction, gradually accommodates itself, and so the calibre is fully restored.

PROLAPSE OF THE INTESTINE.

This condition connects itself naturally with invagination. It is the protrusion of the intestine outside the body through the anus or through an artificial anus. The commonest form is the ordinary PROLAPSUS ANI. This only occurs when the sphincter is greatly relaxed by catarrh or by

violent pressing at stool, but when it has frequently happened the sphincter atrophies and the prolapse occurs very readily.

There are, strictly speaking, two forms of prolapsus ani. In the one little more than the mucous membrane is protruded, and it is seen to be continuous with the skin at the anus. In the other form there is really an invagination as well as a protrusion. The lower part of the rectum is so fixed that the whole wall cannot be protruded, but only its mucous membrane as in the form just considered. But the upper more movable part may be invaginated into the lower part and then protruded. This mostly occurs as a consequence of violent peristaltic contraction of the rectum in cases of severe diarrhœa with tenesmus.

In both forms the exposed mucous membrane becomes inflamed and liable to bleeding. The inflammation sometimes causes through time adhesion and fixation of the bowel in its abnormal position.

SIMPLE INFLAMMATIONS OF THE INTESTINE.

We have already seen that the mucous membrane is frequently irritated by the contents being of an obnoxious nature by reason of decomposition or otherwise. In addition to that, inflammation may be produced by the action of specific morbid poisons, chiefly those of dysentery, typhoid fever, and cholera. We have therefore in the first place to consider the simple inflammations and afterwards these others. The term ENTERITIS is often used to designate inflammations of the intestine of all kinds.

PHLEGMONOUS INFLAMMATIONS of the intestine sometimes occur as the result of peculiarly irritating contents. We shall see that in dysentery we have an inflammation of this kind, but there are what may be called dysenteric inflammations without the special dysenteric poison, the anatomical changes being virtually the same, although as a rule much less intense.

CATARRH OF THE INTESTINE.—As already indicated, this occurs chiefly in connection with the presence of irritating contents, but exposure to cold may also lead to it. Perhaps this latter cause produces its effects by means of the former. That is to say, the exposure of the surface to cold may interfere with digestion and absorption, and so leave the contents to decompose and become irritating.

The influence of the intestinal contents in producing catarrhs is shown by the localities at which inflammations are most common. The large intestine is much more frequently affected than the small,

and in the large intestine the cæcum, with the vermiform appendage, is the most frequent seat, and next to that the rectum, apparently because the contents stagnate specially in these parts rather than in the much more movable transverse colon.

The catarrh is characterized by hyperæmia and swelling of the mucous membrane, with exudation of serous fluid and leucocytes. There is also increased secretion of mucus, which in the case of the colon may be very excessive. The exudation is usually mucous in character, but in the more acute inflammation it may assume more or less of a purulent character. If this be the case the mucous membrane is liable to be infiltrated with inflammatory cells, and after a time to undergo ULCERATION. This occurs with peculiar frequency in the cæcum, and next to it in the rectum. CATARRHAL ULCERS are usually of considerable area and comparatively superficial. Neighbouring ulcers may coalesce so as to produce extensive, variously shaped losses of substance, in the midst of which the remaining mucous membrane appears as raised patches with irregular outline. Sometimes the floor of the ulcer is so smooth, and the remaining mucous membrane so irregular from inflammatory infiltration, that it looks as if the ulcer were the normal mucous membrane and the patches of persisting mucous membrane adventitious.

In the course of catarrhs, ulcers also arise from the closed follicles. There are indeed some catarrhs in which the latter are mainly affected, appearing as rounded prominences and flat elevations, corresponding to the solitary follicles and Peyer's patches. This form is called FOLLICULAR CATARRH, or follicular enteritis. But without the inflammation preponderating in the follicles they are often enlarged, and may be so infiltrated with inflammatory products as to form virtually small abscesses resulting in crater-shaped ulcers which may afterwards enlarge. In this way arise the so-called FOLLICULAR ULCERS.

The ulcers of ordinary catarrh are superficial, and unless exposed to continued irritation, as by the prolonged presence of hard fæces, they do not tend to perforation, and readily heal when the cause of catarrh is removed.

If the catarrh be moderate—not so intense as to lead to ulceration—then, if long continued, it will give rise to hypertrophy of the mucous membrane such as we find so frequently in the case of the stomach. Here also there may be MUCOUS POLYPI and CYSTS as in the stomach. They are most frequent in the large intestine, and if seated in the rectum they may project through the anus.

LOCALIZED INFLAMMATIONS.—It has already been indicated that certain localities are more liable to inflammation than others, and as the inflammations of certain of these regions present special points of importance they have received special names, and require more particular attention.

DUODENITIS is usually an extension of a catarrh of the stomach, and it would not warrant any special reference except from the fact that the common bile duct often takes part in the catarrh, and we have obstruction and icterus sometimes resulting from this simple cause.

TYPHLITIS and PERITYPHLITIS designate conditions which require very special notice. These two terms mean respectively inflammation in and around the cæcum, but they are frequently used so as to include inflammations in connection with the vermiform appendage, and, in fact, Ziegler seems to limit the designations to these latter inflammations.

In some cases the cæcum is very seriously inflamed and ulcerated, especially when large masses of hard fæces lodge in it. Under these circumstances the ulcers may increase in depth, and extend, in the posterior part of the wall where the gut is not covered by peritoneum, through the entire thickness of the intestine so as to penetrate into the retroperitoneal connective tissue. The result is acute inflammation in this region, often going on to the formation of ABSCESS. It will be inferred that this condition is that designated PERITYPHLITIS.

The VERMIFORM APPENDAGE much more frequently gives rise to acute inflammations around the cæcum than the cæcum itself does, so that, although the term typhlitis is not applicable, yet perityphlitis is.

It may here be mentioned in the first place that the appendage sometimes undergoes peculiar transformations on account of the closure of its orifice, with or even without inflammation of its mucous membrane. If, as a result of inflammation or otherwise, the orifice be closed, the secretion, along with the catarrhal exudation, accumulates in the appendage and distends it, so as to convert it into a large RETENTION CYST (Fig. 245). The contents usually become serous, so as to constitute a dropsy of the vermiform appendage, but they may continue mucous in character and form a thickish jelly. The dilated appendage may acquire considerable dimensions, as in the case from which the accompanying figure is taken.

But of more importance are the inflammations due to the presence of

FOREIGN BODIES IN THE APPENDAGE. Any hard substance lying in the cæcum may, if small enough, pass into the vermiform appendage. In

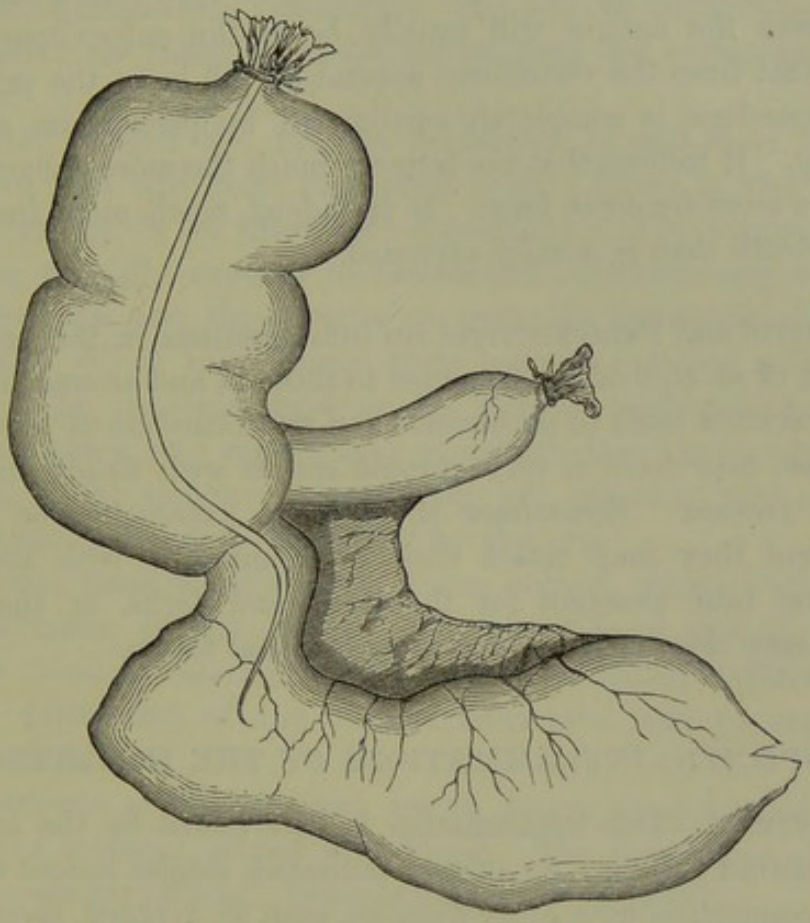


Fig. 245.—Cyst of vermiform appendage. The appendage is converted into a bulky cyst which was filled with gelatinous material.

this way apple, grape, cherry, or orange seeds are said to get into it. But much more frequently pieces of hardened fæces are met with, and as these dry and frequently assume the shape and appearance of cherry or orange stones, they are frequently mistaken for them. This occurs all the more because the inspissated fæces are often coated with phosphates which form a kind of rind.

The presence of the foreign body causes inflammation of the mucous membrane, and this, from the continued pressure and confined space, readily results in ulceration. The ulcers frequently penetrate through the appendage and lead to peritonitis. As a general rule the appendage has acquired adhesions before actual perforation occurs, and so the peritonitis is limited by the adhesions. But the inflammation is apt to recur, and not infrequently results in the formation of recurring abscesses. The bursting of one of these into the cavity of the peritoneum

often leads to fatal peritonitis. From the accounts in the newspapers, the death of M. Gambetta seems to have been due to this cause.

From the relation of the parts it will be seen that a perityphlitis arising from the cæcum will usually be in the subperitoneal tissue, whereas that from the vermiform appendage will be in the peritoneum, as the appendage is completely surrounded by peritoneum and has a mesentery. It follows that the latter is much the more dangerous as it is also the more frequent form. It is, indeed, much more frequently a cause of death than is usually supposed.

PROCTITIS and PERIPROCTITIS are inflammations in the rectum and around it, of an equivalent character to those in and around the cæcum. If the ulceration leads to perforation and the formation of abscess, then the disease may have a very chronic course with fistulæ discharging into the rectum. Sometimes these burst externally, or into the vagina, and they may retain their communication with the rectum, so forming false passages for the fæces and flatus, or the internal aperture may close, leaving merely an external fistula.

SPECIFIC INFLAMMATIONS OF THE INTESTINE.

DYSENTERY.—This inflammation is determined by the action of a specific morbid poison. As already indicated, similar lesions sometimes occur in connection with other diseases, such as typhoid fever, cholera, acute rheumatism, but in these also, although the virus is not the same, we may presume that a violent irritant is present. It is difficult to say whether the poison acts on the mucous membrane by being present in the intestinal contents, or because it is carried by the blood. At any rate, the locality of the disease is evidently determined by the stagnation of the intestinal contents. It is always most marked in the large intestine, and especially in the flexures, these being the parts where the fæces tarry longest. It usually decreases in intensity, from the rectum upwards, but not uniformly, there being more affected and less affected parts, the former corresponding usually with the flexures. In severe cases the whole colon is affected, and sometimes even the lower part of the ileum.

The disease manifests itself as an acute inflammation, which, in the milder cases, may present the characters of a severe catarrh, but is apt to go on to phlegmonous inflammation with sloughing of the mucous membrane. In the earlier stages the mucous membrane is swollen by

serous exudation, soft and juicy, and it is thrown into folds on the summits of which it is peculiarly hyperæmic. The surface is covered by a mucous or grumous material, consisting of shed epithelium with mucus and inflammatory exudation. The mucous membrane and submucous tissue are infiltrated with serous fluid and leucocytes in great abundance.

In higher degrees the mucous membrane is still more thickened and thrown into still more prominent folds. There is also considerable hæmorrhage in its substance occasionally. The summits of the folds being specially exposed to mechanical irritation very commonly undergo necrosis, and the sloughs are generally distinguishable by the brown colour which they assume from becoming stained with the bile pigment. The necrosis involves the mucous membrane to varying depths, sometimes very superficially, sometimes through its whole thickness, and, if the slough surrounds the gut, we may have a ring of necrosed tissue ultimately discharged by the anus.

Of course, these sloughs leave ulcers behind, whose walls present great infiltration of leucocytes. But ulcers form also by processes similar to those in catarrh, namely, by inflammatory infiltration and molecular destruction of the mucous membrane, and by suppuration of the closed follicles.

The contents of the intestine are in severe cases formed of dark decomposing material, mixed with blood. The mesenteric glands are always secondarily affected, being enlarged and hyperæmic.

If the patient survives the acute attack, the disease very commonly passes into CHRONIC DYSENTERY. The ulcers formed in the various ways described above show little tendency to heal, but remain as open discharging sores. Sometimes they penetrate more deeply, and lead to abscesses in the surrounding tissue, especially of the rectum (periproctitis). The remaining mucous membrane is swollen and in a state of catarrh. The whole intestinal wall is thickened except where the ulcers exist, and it is irregularly drawn in and adherent to the surrounding parts.

In some cases a tendency to healing manifests itself. If the attack has been slight and the ulceration only superficial, there may be a complete restoration of the mucous membrane, with insignificant cicatrices. But for the most part the ulceration has been considerable, and the cicatrices are of considerable superficial extent, perhaps surrounding the gut. When such cicatrices, in the usual fashion, contract, they cause narrowing of the intestine, which, in some cases, is very consider-

able. Alternating with the narrowing there is very commonly dilatation of the more healthy parts, so that a very remarkable pouching of the colon may result, the narrowed parts being probably adherent to the tissues around. The obstruction produced in this way is all the greater because the contraction often throws the remaining mucous membrane into folds which may act as valves to the constricted part.

CHOLERA.—This disease, which occurs in an epidemic form, depends on the action of a specific virus. In addition to the epidemic disease known as ASIATIC CHOLERA, there is a condition known as BRITISH CHOLERA, in which the poison does not appear to be a specific one, but in which the anatomical changes are identical with those in the epidemic form. From an individual case, therefore, it would be impossible to say which form is present; this must be judged by circumstances, bearing in mind especially that the Asiatic form is pre-eminently epidemic, and spreads by the extension of a specific virulent poison. The exact form of the virus is unknown, although there is room to believe that it is a micro-organism.

In both forms it is clear that a very violent irritation of the mucous membrane of the intestine is produced. During life the disease is characterized by the discharge of extremely fluid stools, which, from the intermixture of finely divided material, give the characteristic rice-water appearance. Sometimes a patient dies without the bowels having been moved, but in that case they are found distended with the rice-water discharge.

It is obvious that there is here an enormous transudation from the vessels of the intestine. The chemical character of the discharge, however, seems to indicate that it is not a mere inflammatory exudation from the vessels, but rather a secretion of the glands. Its specific gravity is low, 1006 to 1013. There is very little albumen present, and the discharge contains a ferment which has the power of converting starch into sugar.

It is commonly stated that the flakes which give their character to the rice-water evacuations are composed of desquamated epithelium. Investigations have shown, however, that this is not the case; they are little masses of mucus containing leucocytes. After death the epithelium may be found loose in the intestine, but this appears to be from post-mortem maceration, for, if examined sufficiently early, the epithelium is found present and apparently normal.

The most marked post-mortem appearance in the intestine is a

remarkable rosy injection of the vessels of all its coats, so that a red appearance is visible even in the serous coat whenever the body is opened. The mucous membrane is swollen and the closed follicles prominent. Occasionally there is a decidedly inflammatory condition present, which may be even of a dysenteric character.

The condition of other parts of the body is directly referrible to the enormous withdrawal of water from the blood. The blood itself is thick, dark, and imperfectly coagulated. The skin, serous membranes, and all the soft tissues are shrunk, and dry, and parchment-like. The membranes of the brain are frequently injected. The kidneys present the characters of a slight parenchymatous inflammation.

TYPHOID FEVER. This disease is also due to the action of a specific poison. In the affected parts of the intestine bacilli have been found, and exactly similar bacilli have been found in the mesenteric glands (see Fig. 246) and in the spleen. It may be inferred that the virus is present in the blood, and from this produces the general symptoms of the disease, while locally it produces the changes to be presently described. It is very probable that it finds entrance by the intestine, and produces irritation of the follicles and mesenteric glands in its passage.

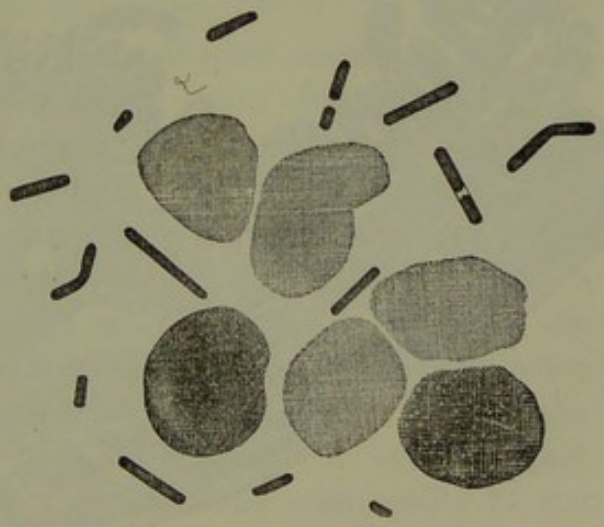


Fig. 246.—Bacillus from mesenteric gland in a case of typhoid fever. The rods are shown. The large bodies beside them are blood corpuscles, the paler ones the red, the darker ones the white. Preparation stained with methylviolet. × 1800.

The affection in the intestine consists of an inflammatory swelling of the closed follicles and of the mucous membrane in their neighbourhood, the inflammation often going on to necrosis and sloughing. The disease has usually its point of greatest intensity at the lower extremity of the ileum, and it is often possible to see various stages of the process in proceeding from above downwards through the small intestine till it culminates close to the ileo-cæcal valve.

In the normal state, especially in the adult, the Peyer's patches and the solitary follicles are very slightly prominent. The patch viewed from the surface shows a congeries of shallow depressions separated by slightly elevated ridges, which run in from the general mucous mem-

brane, and form a kind of network. It is in the depressions that the follicles are placed. In typhoid fever there is at first a general swelling of the patch; it is an inflammatory swelling accompanied by abundant infiltration of leucocytes which occupy both the closed follicles and the mucous membrane. The patch is obviously raised and its margins somewhat abrupt (Fig. 248, *a*). Viewed from the surface there is at this early stage simply an exaggeration of the normal appearance. The ridges of mucous membrane are swelled so that the depressions are more hidden, and an appearance is produced which has been compared to that of the convolutions of the brain in miniature. The swollen patch has a pinkish or whitish colour. At the same time the solitary follicles show themselves as elevations at intervals.

As time goes on the whole tissue gets more and more infiltrated with leucocytes (Fig. 247), and the raised patch gets more solid and its

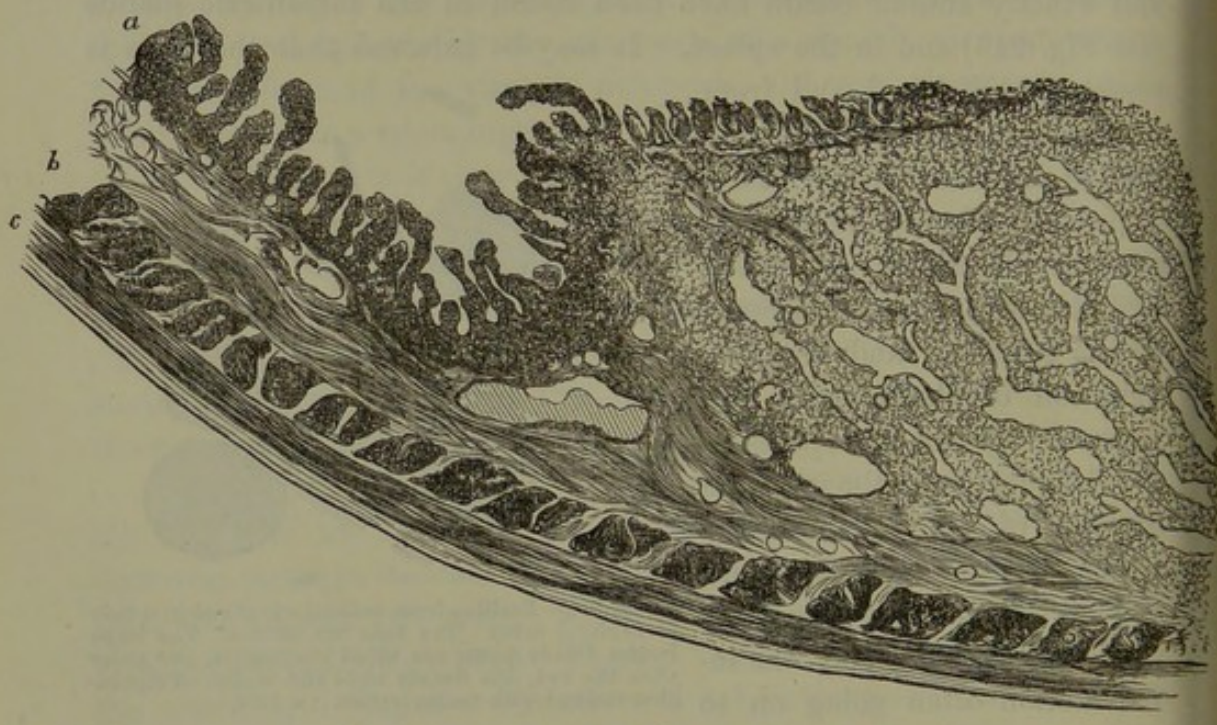


Fig. 247.—Portion of a Peyer's patch in an early period of typhoid fever; *a*, mucous membrane which becomes raised when the swollen patch is reached; *b*, internal layer, and *c*, external layer of muscular coat; *d*, swollen patch composed of round cells with dilated blood-vessels. At the right of the section the round cells are invading the submucous tissue and approaching the muscular coat. × 16.

surface more homogeneous. The invasion of round cells extends to the submucous and muscular coats, even to the serous, and passes to some extent beyond the patch. A similar condition occurs in the solitary follicles; they also present a marked increase in size, and are less defined, by reason of the infiltration around them.

On this condition follows necrosis (Fig. 248 *b*). The infiltrated and altered patch or solitary follicle forms a slough, of larger or smaller size. This slough remains adherent for a time, and like all sloughs in the intestine it becomes brown or yellow from the biliary colouring matter, which stains dead tissue, while the living structures are able to resist it. Generally there is a single slough on a Peyer's patch, not involving the whole patch, but of considerable superficial extent (see figure). Sometimes there are several sloughs corresponding to some of the closed follicles of which the patch is made up.

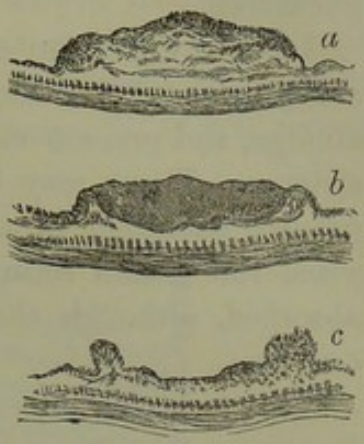


Fig. 248.—Diagrammatic representation of Peyer's patches in typhoid fever. *a*, early stage with swelling of the patch; *b*, later stage with sloughing; *c*, ulcer with infiltrated walls. (THIERFELDER.)

After a time the slough separates and an ulcer is left with infiltrated base and margins (Fig. 248 *c*). The ulcers are confined to the patches and solitary follicles, so that they repeat their shape and locality. The walls are succulent and vascular, and considerable hæmorrhage may occur from them. The ulceration may extend more deeply than the mucous membrane, involving a necrosis of the muscular and even of the serous coat, so that perforation may result. Perforation may occur in one of two ways. In the first place an ulcer may extend in depth till it penetrates through the muscular and serous coats. In this case the process is somewhat gradual, and there is generally a sufficient acute inflammation of the peritoneum to cause adhesion and prevent the intestinal contents passing into the abdominal cavity. In the second place, perforation sometimes occurs in a manner comparable to the perforation of the pleura in phthisis pulmonalis which leads to pneumothorax. The serous coat is undermined by the ulcer, and as its nutrition is cut off it undergoes necrosis. In such cases the brown slough may be visible on viewing the intestine externally. A partial separation of the slough may allow of perforation, and as this form is more acute and not so likely to be accompanied by considerable adhesions, the contents of the intestine are more apt to escape into the peritoneal cavity and produce fatal peritonitis.

When recovery takes place from the fever, the process in the intestine retrogrades. According to the stage reached will be the exact process of resolution. If, in any part, ulceration has not yet occurred, then there is a gradual diminution of the patch and a return to the normal. If

ulceration exists the ulcer fills up and cicatrizes. The cicatrix, however, remains long, often with a slaty colour, but not usually with much puckering.

In the LYMPHATIC GLANDS of the mesentery processes occur which are quite parallel to those in the follicles of the intestine. The glands enlarge, and present on section a red injected appearance and soft consistence. There may be necrosis here also, giving rise to an opaque greyish condition in the midst of the gland. When recovery takes place the glands return to the normal, and the sloughs are usually absorbed, although they may become caseous and subsequently calcareous.

It is to be remembered also that the SPLEEN is enlarged, and there is here more than in typhus fever a swelling of the Malpighian follicles, which are lymphatic in structure, and so the spleen is firmer and paler on section.

TUBERCULOSIS OF THE INTESTINE.

In the great majority of cases this condition is secondary to pulmonary phthisis, and it occurs in about three-fourths of the cases of that disease examined after death. It may be doubted whether it ever occurs as a primary disease. We have already seen that tubercular ulceration is very common in the mucous membrane of the bronchial tubes in connection with pulmonary cavities, and that it is also frequent in the tracheal and laryngeal mucous membranes. The tubercular lesions are doubtless due to the direct action of the virus carried from the lungs. The tubercular disease in the intestine is to be accounted for by the sputa being partly swallowed, and the virus applying itself to the intestine directly.

The virus here attacks the same structures as in typhoid fever, namely the closed follicles and Peyer's patches, and at first it produces a change of a somewhat similar kind. There is an enlargement of the closed follicles by reason of a great new-formation of cells which infiltrate the neighbouring mucous membrane as well as the follicles. This primary enlargement is, however, much less uniform than in typhoid fever. On the whole, it is greatest towards the lower part of the ileum, but it presents great irregularities. Even on the Peyer's patch it generally affects a few closed follicles, and not the whole, so that there are rounded prominences dotted over the patch. Moreover, it is not simply an inflammatory infiltration which occurs; there are tubercles present of characteristic structure.

The enlarged follicles undergo caseous necrosis, so that very soon they are seen to have an opaque yellow kernel, while the epithelium still covers them. In the next place softening occurs, and the caseous mass is discharged, leaving an ulcer. The ulcer is crater-shaped with over-hanging edges, which are infiltrated with leucocytes and contain miliary tubercles (see Figs. 249 and 250). There may be at first several

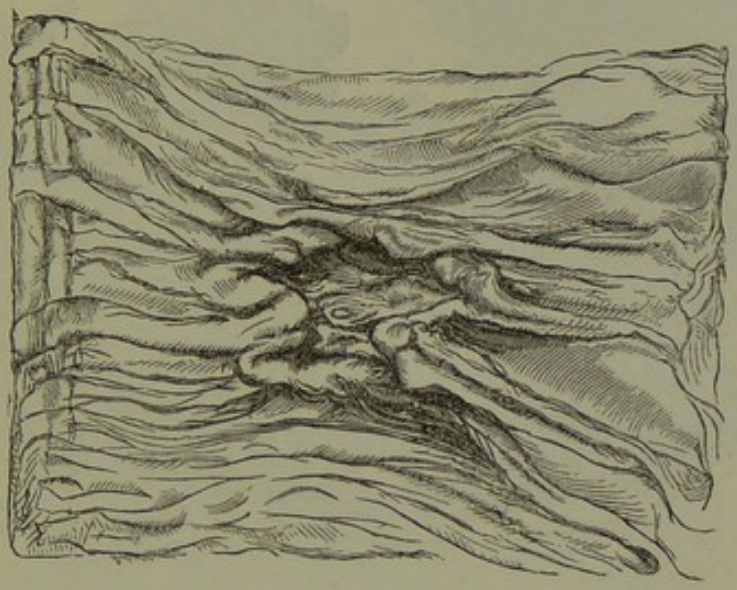


Fig. 249.—Tubercular ulcer of the intestine. Naked eye appearance. The swollen overhanging edges are indicated.

such ulcers on a Peyer's patch, and other solitary ones in other parts. They extend by fresh infiltration of the neighbourhood and fresh necrosis, while at the same time miliary tubercles are visible in the midst of the inflammatory infiltration. The infiltration very commonly involves the muscular coat, and even the serous (see Fig. 250), but the ulcer rarely extends in depth beyond the mucous and submucous coats. On the other hand tubercles are often to be seen almost free of inflammatory infiltration at a distance from the ulcers in the midst of the muscular coat, or even outside it and in the peritoneum.

The ulcer extends much more laterally than deeply, involving ever increasing portions of the mucous membrane. In its extension it does not in the least respect the boundaries of the Peyer's patches or solitary follicles, but extends beyond them, generally advancing more across the gut than longitudinally. In this way ulcers are, not infrequently, much elongated in a direction transverse to the intestine, and may even form a ring around it. As they begin largely in the Peyer's patches, the ulcers have usually their centres at the part of the gut opposite the

mesenteric attachment, the patches having their seats along this free portion.

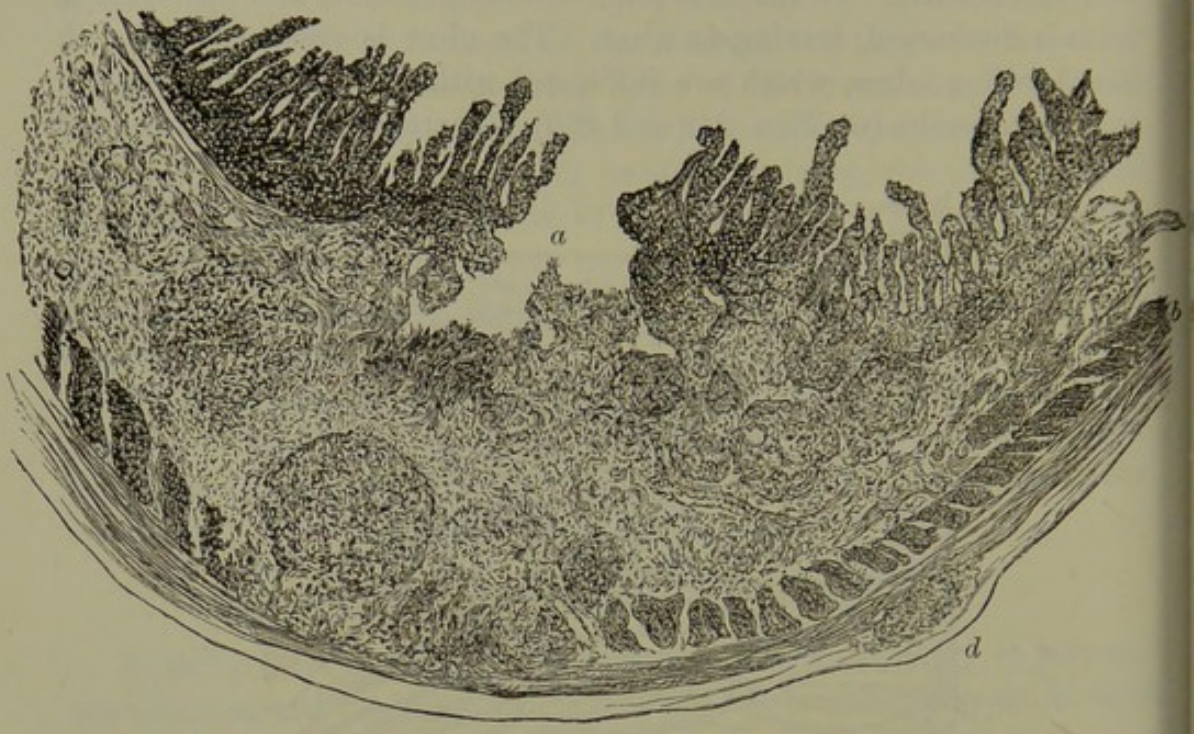


Fig. 250.—Section of a small tubercular ulcer. In the middle there is a crater-shaped ulcer (*a*) with overhanging edges. The mucous membrane around is infiltrated with round cells in the midst of which a few tubercles are indicated. Beneath the ulcer the muscular coat is infiltrated. At *d* there is a small sub-serous tubercle. × 16.

The position of the ulcers is often indicated before opening the intestine by the appearance of the peritoneal surface. If the ulcer be of any considerable size there is some inflammation of the peritoneum, evidenced by redness and, very often, elongated projections of vascular connective tissue. But above all we can generally see in the peritoneum groups of little white nodules, which are tubercles in or under the serous coat. The existence of these tubercles is sometimes even useful in determining whether an ulcer is a tubercular one or not. It is very rare indeed that the ulcer penetrates through the peritoneal coat, and if it does, it is usually protected by adhesion to neighbouring loops of intestine.

As a general rule the tubercular ulceration is most marked in the ileum, but not infrequently the colon is attacked, and there may be ulcers of very large size there.

The process is for the most part a chronic one, and the ulcers advance slowly. Sometimes, however, and usually in connection with acute phthisis, there is a rapid swelling of the follicles, and ulceration occurs

by softening, without preliminary caseous necrosis. In these cases perforation is much more liable to occur.

TUMOURS OF THE INTESTINE.

CANCER.—This is by far the most frequent and important form of tumour. Cancers are almost confined to the large intestine; we have already connected this with the fact that this portion is most exposed to the irritation of the stagnant fæces. This is the more evident as the most frequent localities are the rectum, the flexures, and the cæcum. At the same time cancers are not unknown in the small intestine.

The commonest form of cancer is a very CHRONIC EPITHELIOMA with gland-like masses of cylinder cells (Fig. 251). The tumour is very fre-

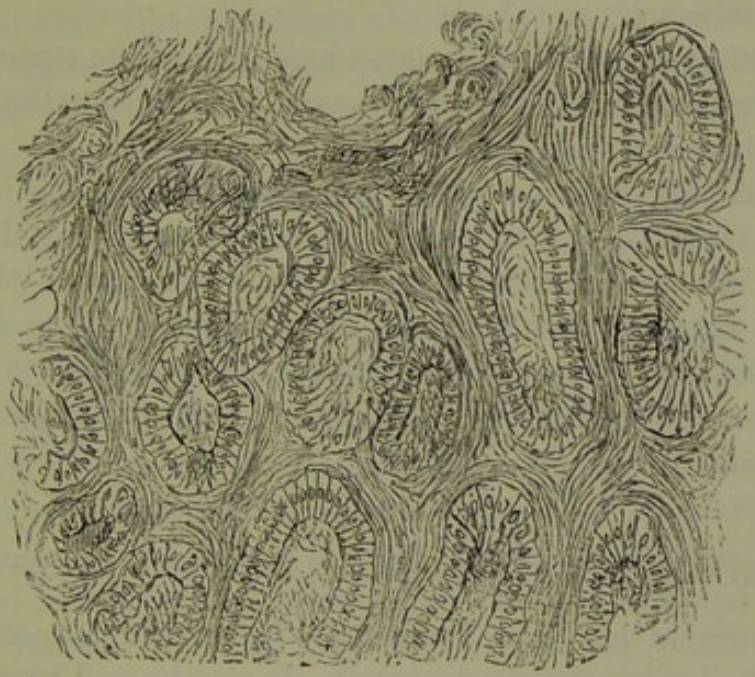


Fig. 251.—Cylinder-celled epithelioma of rectum. There are gland-like spaces containing epithelium, which at the periphery is characteristically cylindrical.

quently ring-shaped, and as ulceration readily occurs, there may be little more than an ulcer with infiltrated edges. Even the infiltration of the edges may be very slight, and it may be difficult to be sure that the disease is cancerous. The ulceration is accompanied by new-formation of connective tissue in all the coats of the intestine, and while adhesion occurs to parts around, there is great contraction of the intestine. In this way strictures arise, and the occlusion of the calibre may be increased by the mucous membrane at the edges of the ulcer being

thrown into folds. In fact, if we except hernias, this is probably the most frequent cause of intestinal obstruction.

It has been already noted that the proper cancerous structure is often to a large extent destroyed by ulceration, but at the edges we may distinguish masses of epithelial cells with a glandular arrangement. In the adhesions around the affected part of the intestine enlarged glands may be found with cancerous tissue.

Next to the epithelial the most common is COLLOID CANCER. This forms a much more prominent tumour which may involve a considerable length of the gut, and incorporate the entire coats. This form may produce obstruction by its mere bulk, although it also is liable to ulceration, and the consequent contraction of the gut added to the bulk of the tumour frequently effect obstruction. It does not so readily affect the lymphatic glands, but more usually extends through the wall into the peritoneum.

SOFT CANCER is much less common here than in the stomach, and it resembles the same form of tumour there. It extends to the lymphatic glands and frequently also to the liver.

The remaining tumours of the intestine are of little importance. FIBROMAS, LIPOMAS, MYOMAS and SARCOMAS occur, and they are all apt to pass into the interior of the intestine and assume the form of SUBMUCOUS POLYPI. It is said that these polypi by being dragged on in the peristaltic movements of the intestine may produce invagination. MUCOUS POLYPI are also to be mentioned as occurring, especially in the rectum in catarrh.

OBSTRUCTION TO THE CALIBRE OF THE INTESTINE.

This condition has been incidentally mentioned as occasioned by several of the lesions already described. It may be well here to sum up the various forms of intestinal obstruction and to describe the effects produced when the calibre of the intestine is interrupted.

Next to hernia, the most frequent cause of obstruction is the contraction of cicatrices resulting from ulceration, and in the great majority of cases the ulcers are malignant, that is to say, they arise by the breaking down of cancers. It is to be remembered that in contractions of the calibre such as these the direct cause of the final obstruction may be the folding of the mucous membrane above the stricture, this acting like a valve to the narrowed part. Tumours also obstruct sometimes by their bulk. Similarly gall stones, masses of fæces, collections of

round worms may occlude the calibre. Invagination is the commonest cause in children. There is also twisting or torsion. Lastly, we have obstruction by incarceration, the intestine passing into a position where a loop is caught at the neck and strangled. Hernias form the commonest examples of this kind, but there are a number of cases in which the intestine slips under a bridge or ligament and gets, as it were, pinioned and compressed.

This last cause of obstruction occurs so obviously to the mind that its frequency is apt to be thought much greater than it is. In reality it forms a small proportion of the entire cases. The abnormal band may be formed by the adhesion of structures to various parts of the abdomen so as to form bridges. Thus the vermiform appendage may adhere by its tip and form a bridge; or a Meckel's diverticulum may similarly adhere; or the omentum may be tied down in such a way as to form a narrow bridle. But sometimes the band is itself distinctly of new formation; there has been a local peritonitis, and two opposing surfaces have become adherent in the usual way of inflammatory adhesion, by vascular connective tissue; by the movements of the intestine the connective tissue has been dragged upon and elongated till it forms a band or ligament, which may afterwards tie down a loop of intestine.

A very unusual form of incarceration is that in which there is an APERTURE IN THE MESENTERY through which the intestine passes. This may be produced by a tear in the mesentery. But in a case observed by the author, there was a large round gap about 5 inches in diameter with rounded edges, and obviously of long standing, perhaps congenital. The greater part of the small intestine had become impacted in a complicated fashion into the aperture, and obstruction had finally resulted.

When obstruction occurs the intestinal contents accumulate in the parts of the intestine above. The bowel may be greatly distended and its muscular tissue paralysed by the internal pressure; the stagnating fæces decompose, and the contents of the small intestine may acquire the characters of those of the large. This decomposition of the intestinal contents leads to several important results. In the first place there may be great formation of gas which still further distends and may produce the condition of exaggerated inflation called METEORISM. Then a return of the fæces in the reverse direction may occur, and if the decomposition is sufficiently advanced there may be a vomiting of

matter having the characters of fæces. This alarming phenomenon of STERCORACEOUS VOMITING is sometimes referred to the reverse current extending from the colon. We can hardly suppose, however, that the fæces are able to pass the ileo-cæcal valve, and for the most part the vomited matters are really the stagnant contents of the small intestine which have undergone the fæcal decomposition. Of course there is a reverse current, else the intestinal contents would not reach the stomach. But this does not necessarily imply a vermicular movement in the reverse direction. If the intestine is distended, and is interrupted at a particular point, then the vermicular movement in the usual direction will carry the external layer of contents downwards to the point of obstruction. But in order to accommodate this fresh arrival there must be a return current upwards in the centre of the tube. There is a similar condition to what exists normally in the stomach where the contents are carried to the pylorus, and meeting the obstructing sphincter return for the most part down the centre of the cavity towards the fundus.

Again, the products of decomposition may be absorbed to an abnormal extent and appear in the urine. There are two substances resulting from the decomposition of albuminous substances which are normally present to a limited extent in the urine, namely, INDICAN and CARBOLIC ACID. In cases of obstruction these substances, or one of them, are increased in quantity sometimes to a very striking extent. This increase does not occur unless the stagnation extends to the small intestine where the albuminoids are present. It does not occur therefore in ordinary constipation which affects the large intestine alone, apparently because the albuminoids are absorbed before they reach the large intestine.

DISEASES OF THE LIVER, PANCREAS, AND PERITONEUM.

A.—THE LIVER.

INTRODUCTORY.—The liver is the largest gland in the body, its weight being on an average from 48 to 58 ounces in the adult male and 40 to 50 ounces in the female. From this alone it may be inferred that its diseases are of great importance.

When we come to consider the functions of the liver we are met with serious difficulties from the pathological point of view. Diseases may largely destroy or render inactive the proper parenchyma without seriously interfering with the general health of the patient unless, by interfering with the blood-vessels in the liver, they produce secondary effects in the portal circulation. Even the suspension of the biliary secretion may be without serious effect on the nutrition of the body. In considering the subject of diabetes mellitus (p. 64) the glycogenic function of the liver has been sufficiently referred to, and it only remains to be said here that, practically, nothing is known of the influence on this function of lesions which destroy the liver tissue. The influence may be very great and important, but no facts are known in regard to it. It is not to be inferred, however, that the liver is unimportant to the organism, but merely that the organism seems to have a remarkable power of compensation when its tissue is diseased.

In considering the diseases of the liver the arrangements of the circulation must be borne in mind. It is well known that most of the blood comes to the liver by the portal vein, and the proper hepatic tissue is arranged in relation to the ultimate ramifications of that vessel. The interlobular veins form these ultimate ramifications, and these are

in immediate connection with the hepatic lobules. The hepatic lobule is a group of hepatic cells with blood-vessels, having in man a polygonal or somewhat globular shape; it measures about the twentieth of an inch in diameter. The interlobular vein lying outside the lobule sends multitudinous capillaries into it, and these seeking the centre of the lobule open into the central or intralobular vein which is the radicle of the hepatic vein. Blood is also brought to the liver by the hepatic artery which supplies the connective tissue and walls of the blood-vessels chiefly. Its capillaries terminate in veins which open into the interlobular veins (according to Cohnheim and Litten), so that this blood also finds its way into the hepatic capillaries and on into the hepatic vein.

The connective tissue of the liver is often described as if it formed a special covering to the portal vein, being called Glisson's capsule. It really forms a supporting stroma which holds the portal vein, the hepatic artery, and the hepatic duct, which all lie side by side. The lymphatic channels are also contained in it. In some animals the connective tissue surrounds each lobule and defines it distinctly from its neighbour, but in man it stops short at the interlobular vein, and except where this vein is, the lobules at their margins merge into each other, and their capillaries are in common. Examination of Fig. 254, in which the lobules are demarcated by fatty infiltration, will show how they run into one another at their peripheries. Although no proper fibrillated connective tissue is present inside the lobules, yet a fine reticulum accompanies and supports the capillaries.

The lobules are large enough to be visible to the naked eye, yet unless there is some abnormal condition present, they are not individually distinguishable. On the other hand, it is they which give the liver when torn that granular appearance with which we are familiar.

It is important to remember that the circulation in the portal vein, and especially in the capillaries of the liver, must be unusually slow. The blood before it reaches the liver has passed through one set of capillaries, and here it passes through a second set; it has therefore lost very largely the force derived from the contraction of the heart. It is probably for this reason that the liver is so very frequently the seat of secondary diseases, such as tuberculosis, abscesses, cancers, etc. We may suppose that as the blood moves so slowly there will be time for any infective material to settle down and produce its special effects. We know that when vermillion is injected into the blood it is found

largely in the capillaries of the liver. Similarly the abnormal pigment present in the blood in melanæmia is found largely in these capillaries.

MALFORMATIONS AND DEFORMITIES OF THE LIVER.

Congenital malformations of the liver are not common. There are cases of absence of the liver, and of defect of one of the lobes, or irregularity in the lobes. What may be called supernumerary livers have also been found in the form of isolated pieces of liver tissue in the suspensory ligament. Of more importance is congenital absence of the gall bladder, along with which there is usually a dilatation of the bile ducts.

The liver is sometimes TRANSPOSED along with a general transposition of the viscera. In a case recorded by Fraser, there was not only a transposition but an occasional DISLOCATION of the liver, which came down into the left inguinal region.

An ACQUIRED DEFORMITY is very frequently met with IN FEMALES, and is to be associated with the method in which the clothes are worn. This deformity is usually stated to be due to tight lacing, but although doubtless greatly aggravated by this, it is also induced by the ordinary methods of suspending the garments used by females. These are held up by being drawn tight at the waist above the crest of the ilium, the projection of this bone preventing them slipping down. By this tight band, often of considerable breadth, the abdominal organs are compressed and the lower ribs are held down and pressed inwards. This is greatly aggravated by the wearing of stays, even although they be not tightly laced, as by them the lower ribs are kept compressed inwards. The effect on the liver is that it is greatly flattened, while a transverse shallow depression forms along the upper surface, affecting chiefly the right lobe. In this groove the capsule is thickened, and there is obviously considerable loss of liver tissue. Sometimes the atrophy along this groove is such that the liver is as it were divided by it, and the two portions can be folded together. With the flattening there is great displacement of the liver, whose lower edge may extend as far down as the umbilicus. More or less of this deformity is to be found in nearly all female bodies, and is even found in the bodies of men who have been in the habit of wearing tight belts round their waists.

Sometimes the upper surface of the right lobe of the liver presents elongated depressions passing from behind forwards, which are really

FOLDS OF THE LIVER, and are produced chiefly when there is some obstruction to expiration. In that case the diaphragm is depressed by the dilated lung, and at the same time the lower ribs are drawn down in violent expiratory movements by the abdominal muscles, and pressed against the liver, which is supported below by the contraction of the abdominal muscles.

The liver is very liable to CHANGES OF POSITION. Tumours or fluid in the abdomen carry it upwards. Depressions of the diaphragm press it downwards. The suspensory ligament may be elongated so that the organ is unduly movable, and may undergo displacement downwards.

PASSIVE HYPERÆMIA OF THE LIVER.

The names NUTMEG LIVER and RED ATROPHY are sometimes given in cases of prolonged passive hyperæmia, these names indicating certain appearances presented by the tissue, and to be referred to afterwards. Passive hyperæmia occurs when any obstruction exists in the circulation of such a nature as to interfere with the return of blood from the inferior vena cava to the right side of the heart. The commonest cause is valvular disease of the heart, especially mitral disease, but it also results from obstruction to the pulmonary circulation as in bronchitis and emphysema, etc. In these cases there is a general engorgement of the systemic venous circulation, with increase of blood pressure in the veins. We have already seen that in the capillaries of the liver, and consequently in the hepatic veins, the normal circulation is unusually slow, and the blood-pressure low. Any increase in the blood-pressure in the general venous circulation will, consequently, tell particularly on the vessels of the liver, and we may even suppose that the blood passing up the inferior cava may in such cases regurgitate into the hepatic vein.

The result of this is a very great distension of the hepatic vein and its radicles—the central or intralobular veins. The distension extends to the capillaries, which, as in Fig. 252, are sometimes found enormously dilated. The dilated capillaries by pressure cause ATROPHY OF THE HEPATIC CELLS, and it often happens that the central parts of the lobules are entirely occupied by enormously dilated capillaries, while the hepatic cells are hardly visible (see figure). The remains of the hepatic cells frequently contain brown pigment granules. The atrophy

of the hepatic cells in these regions may be complete, only a few pigment masses representing them.

Sometimes in addition to these changes there is a hypertrophy of the connective tissue surrounding the lobules, but this is usually incon-

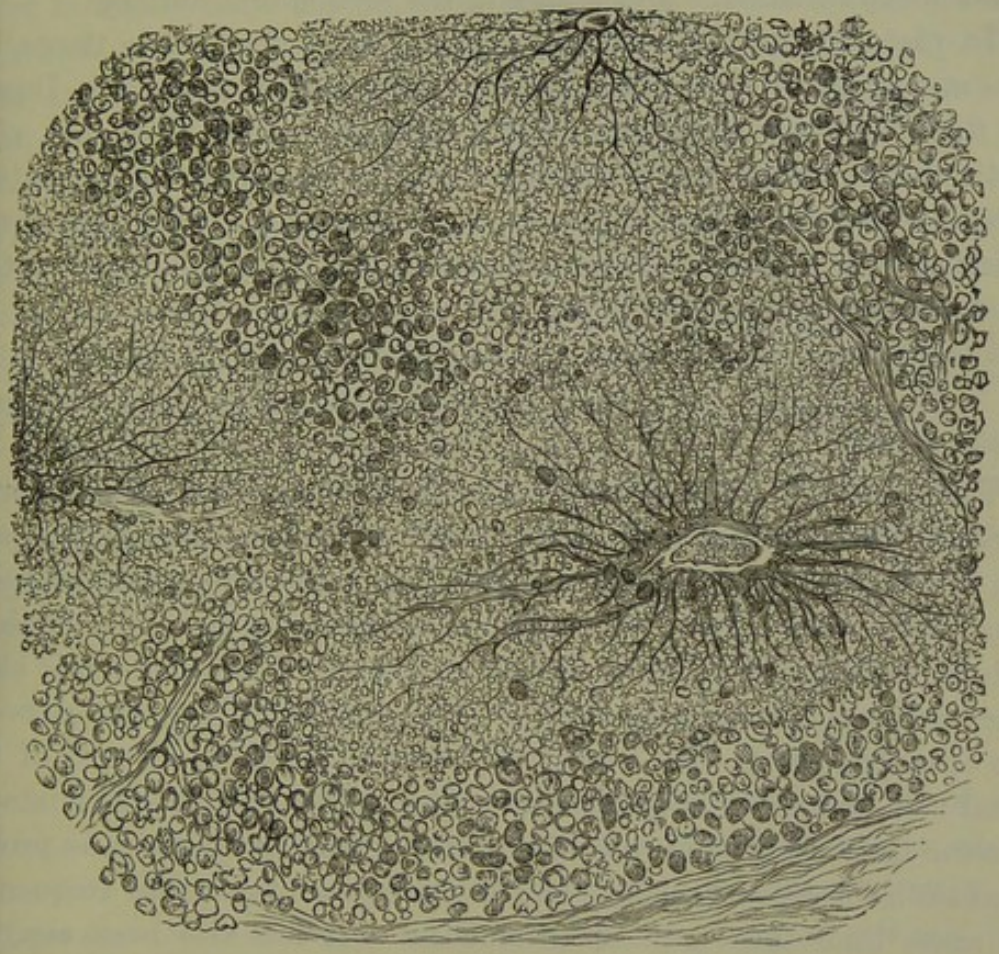


Fig. 252.—Passive hyperæmia of the liver. One lobule and parts of other two are shown. In the central parts of the lobules there is almost nothing but dilated capillaries containing blood-corpuscles only; a few atrophied and pigmented hepatic cells being visible. At the peripheral parts of the lobules the hepatic cells are seen, many of them pigmented. × 90.

siderable, and it is a mistaken view that a cirrhosis of the liver arises out of passive hyperæmia.

The naked-eye appearances may be directly connected with these minute changes. At first there is a general enlargement of the organ, which, on section, appears unduly red. On closer examination it is seen that there are minute areas of a deep red colour corresponding with the central parts of the lobules, and these are surrounded by zones of a grey or yellowish colour. The result is that the lobules are, as it were, mapped out by these contrasting colours, and are for the most part individually visible to the naked eye. Sometimes several adjacent

lobules are almost completely occupied by dilated vessels, and there is a narrower ring of normal tissue around each, so that the part of the liver as a whole has an almost cavernous structure and presents a deeper red colour on section. It is these variations in colour and figuring which give the cut surface the appearance of the section of a nutmeg.

In parts where there has been great loss of the proper tissue, the liver may appear to the naked eye after death partially atrophied. During life the dilated veins and capillaries are distended with blood, but after death, the blood-pressure being removed, these may, to some extent, collapse. In this way the surface has sometimes an irregular appearance, which may be mistaken for that of cirrhosis, but it will be noticed that the depressed or atrophied parts have a deep red colour.

THROMBOSIS AND EMBOLISM IN THE LIVER.

Thrombosis of the portal vein is of somewhat frequent occurrence, especially as a result of cirrhosis. It also occurs sometimes by propagation of a thrombosis from the radicles of the vein, or by embolism from them. The embolus may be a septic one, and there will be a phlebitis with the thrombosis. The coagulum in the vein if not of a septic character leads to a chronic inflammation with adhesion in its neighbourhood. The consequences to the liver itself, even of complete closure of the portal vein, are not so important as might be looked for. It is stated by some that it may lead to cirrhosis of the liver, but there is no proper foundation for this statement, and cirrhosis is much more frequently the cause than the result of thrombosis. It has also been asserted that diabetes mellitus may occur as a result of thrombosis of the portal vein. The consequences outside the liver are much more important. There is dilatation of the radicles of the portal vein in the abdominal viscera, with ascites, which is generally very extreme. The results in this regard are essentially similar to those which occur in cirrhosis, and are referred to more particularly below, under that heading.

Thrombosis and embolism of the hepatic artery are not of consequence unless the plug be of a septic nature. The hepatic artery is not an end-artery, and if some of its branches be obstructed the anastomosing communications restore the circulation. If the main branch of the artery be obstructed then we may have necrosis of the liver, but such an obstruction is scarcely liable to occur in man, and its effects have only been studied in experiments in animals.

HYPERTROPHY OF THE LIVER.

When considerable portions of the liver are destroyed, there is liable to be a COMPENSATORY HYPERTROPHY of remaining parts. The loss of liver substance may be congenital, as in a case observed by the author in which, probably from some injury early in fœtal life, the right kidney and the greater part of the right lobe of the liver were awanting. In that case the left lobe was greatly increased in size, and the liver as a whole was of the normal weight. There may be a similar compensatory hypertrophy from destruction of liver tissue in after-life. The destruction may be by pressure of hydatid cysts, syphilitic gummata, and cicatrices, or even by cirrhosis. The region of the atrophy will determine that of the hypertrophy, but sometimes the left lobe or the lobus Spigelii undergoes great enlargement.

Hypertrophy of the liver has been described as occurring in DIABETES. Undoubtedly the liver is frequently enlarged in this disease. Some of the enlargement is due to hyperæmia, and some to swelling of the hepatic cells. This latter is probably a true hypertrophy of the liver tissue.

RETROGRADE CHANGES IN THE LIVER.

ATROPHY OF THE LIVER.—We have already referred to the atrophy which occurs in passive hyperæmia. In the preceding section also we have seen that pressure, as by a hydatid cyst, produces atrophy. In old persons we meet with a senile atrophy, the organ as a whole being reduced in size, and more deeply coloured than normal.

PARENCHYMATOUS INFILTRATION of the liver occurs, as we have previously seen, in connection with many acute diseases. It is this which causes the enlargement of the liver in the acute fevers, pneumonia, erysipelas, etc. The hepatic cells are highly granular, and if the albuminous granules be destroyed by liquor potassæ it will be seen that there are numerous fine fat granules, the cloudy swelling passing into fatty degeneration.

FATTY DEGENERATION is not common except as a further stage of the condition just mentioned, and as occurring in acute yellow atrophy to be presently described.

Fatty Infiltration was referred to in a former part of this work, and its pathology considered (see p. 121). In this place we have to consider the locality of the fat and the changes it effects.

In the normal liver there is very little free fat in the hepatic cells. In fatty infiltration fat is brought in quantity by the portal vessels and deposited in the hepatic cells. It is first deposited in those nearest the terminals of the portal vein, that is to say, in the peripheral parts of the lobules (see Fig. 253), so that at first each lobule has a peripheral zone of



Fig. 253.—Fatty infiltration of the liver, osmic acid preparation as seen with a very low power. The peripheral parts of the lobules are demarcated by the fatty infiltration. ×16.

fatty infiltration. This is still more strikingly seen when a microscopic section is treated with osmic acid. The fatty peripheral parts become of a blackish colour, and the section assumes a very striking figured appearance as shown in the figure. As the condition advances, more and more of the lobule is affected, and the infiltration may overtake its whole extent. Even in extreme cases, however, it usually preponderates at the peripheral parts. The fat is present in larger and smaller drops inside the hepatic cells, but the tendency is for the drops to assume a considerable size (as in Fig. 254). The protoplasm of the cells is pushed aside by the fat, but probably its function is not greatly interfered with.

The fatty liver presents usually distinct appearances to the naked eye. According to the extent of the infiltration is the organ increased in weight, but in extreme cases it may be double the normal. The enlargement is general, the thickness especially being much increased. The consistence is unduly soft, and the colour a more or less opaque yellow. If the infiltration be not extreme, so that the whole lobule is not infiltrated, then with the naked eye we can see on the cut surface the indications of its presence. The lobules are, in fact, mapped out in the most characteristic figured manner, so that, on looking closely, we can distinguish each with perfect accuracy. The appearance presents a considerable resemblance to that of the nutmeg liver, where also the lobules are mapped out; but in the fatty liver it is by unduly pale tissue at the peripheral parts of the lobules, which contrasts with the normal central parts; while in the other case it is the normal which is at the periphery, and it contrasts with the red central parts, and the whole cut surface is unduly red.

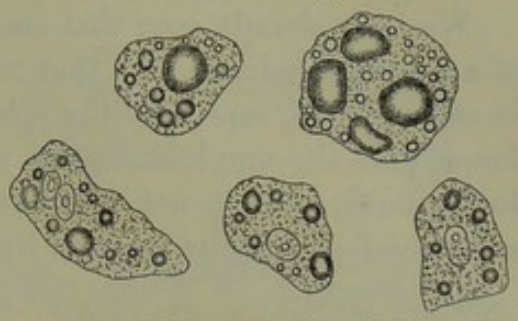


Fig. 254.—Fatty infiltration of liver. The cells are isolated, and they contain larger and smaller drops of oil. × 350.

Amyloid degeneration of the liver has already been considered in its general aspects (see p. 131). The degeneration appears first in the arteries and capillaries, the appearance in the latter being as if, at intervals, the wall were swelled up by a translucent material. In these earlier stages there is no difficulty in making out that inside the lobules it is the capillaries which are affected. The general arrangement of the capillaries is beautifully shown by the rose-pink colour of the amyloid ones in a section stained with methyl violet, the appearance being almost that of an injected specimen. Even in the earlier periods considerable atrophy of the hepatic cells can be observed as a result of pressure from the swollen capillaries, and the atrophic cells frequently contain fat. In advanced stages, however, the cells are very greatly destroyed, so that the liver tissue is replaced by amyloid substance.

It is remarkable that with this great loss of the secreting substance there is actual increase in size and weight of the liver. It is not uncommon to find the liver weighing two or three times the normal. The increase in size is not proportionate to that in weight, as the amyloid substance is of greater density than the liver tissue. The edges of the organ are rounded and its consistence elastic and resistant. The

surface, and especially the cut surface, present a peculiar translucent waxy appearance, which in advanced stages is highly characteristic.

We have already seen that amyloid degeneration of the liver is part of a general condition, and that it is associated with a similar condition in other organs, especially the spleen, kidneys, and intestine. We also know that the amyloid disease is very often the result of a chronic tuberculosis, and it not infrequently happens that miliary tubercles are to be found in the amyloid liver.

ACUTE YELLOW ATROPHY.

This is a disease whose exact pathology is somewhat obscure. It is characterized by a rapid destruction of the hepatic cells, but the exact cause of this destruction is doubtful. It is obviously due to the action of a morbid poison circulating in the blood, because changes of a somewhat similar nature are met with in the epithelium of the kidneys, and in the muscular fibre of the heart and elsewhere. This view also receives some confirmation from the fact that in acute poisoning with phosphorus changes occur in the liver and other organs very like those in the disease under consideration. In this regard also it is interesting to observe that two writers, Waldeyer and Zander, have described colonies of bacteria as existing in the liver in cases of this disease.

When the liver is examined after death it is generally found smaller than normal, and its tissue is soft and flabby. In some cases it is of the normal size, and it is stated that in the earlier stages it is even enlarged, although the disease is not fatal during these periods. The capsule is often wrinkled from the atrophy of the substance of the organ, and the organ flattens out by its own weight, its thickness being greatly diminished. The diminution in size sometimes affects the left lobe especially. On cutting into the organ the section shows usually different shades of colour. The predominating tint is yellow, varying from the colour of gamboge to a dark yellowish brown. Mixed with this, however, there is a red colour forming the red substance of Zenker. Where the colour is yellow the tissue is softest, but the red parts are the most atrophied, the red substance arising by the absorption of the degenerated hepatic cells.

On examining the yellow tissue under the microscope, it will hardly be recognizable as that of the liver (see Fig. 255). There are no proper hepatic cells, but instead, larger and smaller fat drops, with granular debris, and here and there rhombic crystals of a reddish-brown colour

(see figure). Sometimes leucine is found in opaque clumps, white in colour and generally stratified. Acicular crystals of tyrosine are also found. The crystals of pigment, which resemble those found in old blood clots in the brain, may be really formed from the biliary colouring matter.

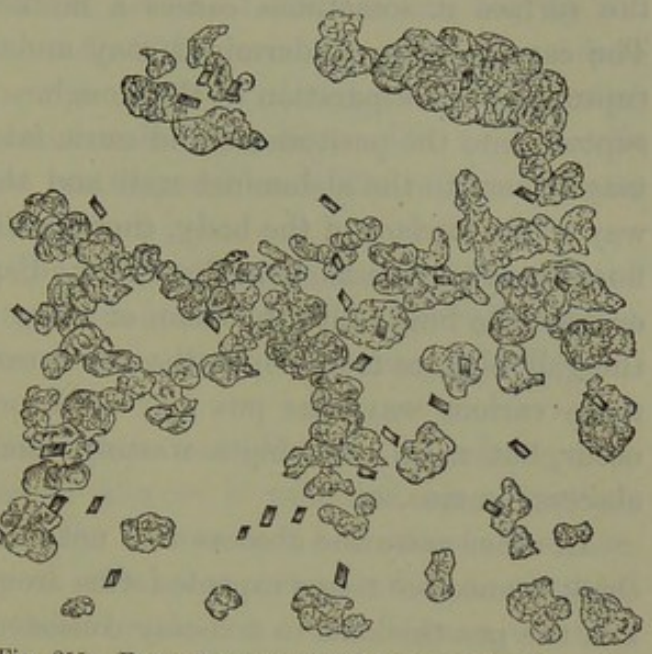


Fig. 255.—From liver in acute yellow atrophy. The hepatic cells form irregular clumps. There are numerous pigment crystals of similar shape to the crystals of hæmatoidin (Figs. 5 and 11), and of a similar deep red colour, but smaller. × 350.

The red substance does not present the abundant fatty debris; that has been cleared away, and there is now a fibrous material visible, merely sprinkled with fat granules. In some cases glandular-looking processes have been observed, and have been taken to indicate an attempt at regeneration of the lost hepatic substance, beginning in the capillary network of the hepatic ducts.

INFLAMMATIONS OF THE LIVER.

1. Purulent Hepatitis.—Abscess of the liver occurs in two forms, the tropical and the pyæmic or metastatic abscess.

(*a*) The tropical abscess is not met with in this country, except in persons who have been in hot climates, especially in India. Much doubt exists as to the cause of the inflammation which gives rise to the abscess. In a large proportion of cases it is associated with dysentery, and it is believed by many that the abscess in the liver arises by material being carried from the ulcerated intestine to the liver. This material presumably contains minute organisms, and the abscesses would be septic. This view, however, is not beyond question, and post-mortem examination shows that the tropical abscess is by no means uniformly associated with dysentery. While therefore we may admit that bacteria probably have to do with the causation of the tropical abscess, yet it is not unlikely that certain states of the liver predispose to their development, and that they may find entrance to the body by other paths than the intestine.

The abscess is mostly solitary, and it may grow to large dimensions causing great enlargement of the liver. Having approached the surface it sometimes causes a marked projection from the liver. The capsule being undermined may undergo necrosis, and the abscess rupture by the separation of the slough. In this case the abscess may rupture into the peritoneum and cause fatal peritonitis. Or the capsule may adhere to the abdominal wall and the abscess by and by find its way to the surface of the body, there to discharge. It also occasionally bursts in other directions, as through the diaphragm into the pleural cavity, or even the lung; into the colon or other part of the intestine; or into the gall bladder from which the pus is carried into the duodenum. In these various ways the pus may be disposed of and perhaps recovery occur, but more probably a wasting discharge from the cavity of the abscess remains.

In other cases the abscess does not enlarge, but rather dries in. A thick connective tissue capsule forms around it like the wall of a cyst, and the pus thickens to a cheesy consistence. Afterwards the contents may become calcareous and the disease virtually obsolete.

(*b*) PYÆMIC ABSCESSES are much more definitely understood in their causation and mode of formation. They are undoubtedly produced by bacteria being carried by the blood to the liver and propagating themselves there. Sometimes the abscesses in the liver are secondary to those in the lungs, the organisms being carried on by the blood after having developed there. But there are cases where abscesses occur in the liver alone, and these also arise in connection with putrid external wounds.

So long as it was supposed that, in order to the formation of such abscesses, an obstruction of an artery with an embolus was necessary, the occurrence of such abscesses in the liver was obscure. We know, however, that micro-organisms may be conveyed by the blood-vessels, and after passing the pulmonary capillaries be carried to the liver by the hepatic artery, or even, after traversing the intestinal capillaries, by the portal vein. We have already seen that the circulation in the capillaries of the liver is peculiarly slow, and it is probably for this reason that the bacteria so readily lodge there and propagate.

Abscesses may also be induced in cases where there is stagnation of bile, and where decomposition occurs in the bile, extending upwards from the intestine. Such abscesses will be referred to afterwards.

The bacteria multiply and form zoogloœa in the capillaries and interlobular veins, passing into the central veins. Wherever the colonies of

bacteria extend the liver tissue undergoes necrosis, the cells lose their nuclei and become individually indistinguishable. We have already seen that this arises, not from the direct action of the bacteria, but by the chemical products which are given off. These irritating stuffs also produce inflammation around, and there is here, as elsewhere under similar circumstances, an acute suppurative inflammation. The round cells accumulate around the necrosed portion, and gradually infiltrate it and break it down, so that an abscess forms.

The abscess may be primarily a small or a large one according as the capillaries over a smaller or larger area are invaded, but several abscesses may ultimately coalesce, and so we have them sometimes of very considerable dimensions.

The abscesses in this form are always multiple. In accordance with what has been stated the actual abscess is preceded by a grey or yellowish discoloration indicating the existence of necrosis of the tissue. There will be probably a group of such areas corresponding to necrosed hepatic lobules. Ultimately these break down and form a common abscess.

2. Chronic interstitial hepatitis or cirrhosis.—This is, for practical purposes, the most important affection of the liver, at least in this country. We have to do here with a chronic inflammation of the interstitial connective tissue of the organ.

As in the case of other inflammations, we have to consider here the nature of the irritant which induces the inflammation. Leaving aside in the meantime the case of syphilis, which will be taken up afterwards, it may be said that, as the disease occurs for the most part homogeneously throughout this organ, the irritant is contained in the blood circulating in the liver. The name "gin drinker's liver," frequently applied to this disease, involves the view that alcohol is commonly the irritant. Alcohol taken frequently in the form of undiluted spirits is believed to cause the disease, while beer and wine do not. This is probably in most cases the cause, but the disease may originate from other kinds of irritation whose nature is obscure. This is evident from the fact that it has been met with in young children, and the author has recorded a case in which a typical cirrhosis with the usual secondary phenomena occurred in a cat. The fact that it was a butcher's cat may indicate that it indulged in excess of eating rather than of drinking.

It has been asserted of recent years that obstruction of the bile ducts

is a cause of cirrhosis, and a special form of "biliary cirrhosis" has been distinguished. The frequent occurrence of obstruction by gall-stones and otherwise without any of the appearances of cirrhosis, however, rather contradicts this view. It is also stated that tuberculosis may induce cirrhosis, and there are some facts which seem to support this view.

In cirrhosis we have chronic inflammation of the connective tissue of the liver, resulting in new-formation of a similar tissue, which, like such inflammatory new-formation, has a special tendency to shrink. It will be proper to consider the distribution of this new-formation and its effects on the hepatic tissue on the one hand and the blood-vessels and ducts on the other.

The interstitial connective tissue of the liver follows, as we have seen, the portal vessels, forming a frame-work in which are supported the portal vein and its branches, the hepatic artery and hepatic duct. The new-formation occurs in the great majority of cases only in these regions, that is to say, outside the lobules. Cases have been described, however, in which the new-formation has extended into the interior of the lobules (so-called inter-cellular cirrhosis), but this is exceedingly rare ; it is stated to occur in cases of syphilis of the new-born. As a rule the new-formation occurs in such a way as to surround groups of lobules, so that as the disease progresses the liver is sub-divided into larger and smaller areas, each representing a set of lobules surrounded by new-formed connective tissue (so-called multilobular cirrhosis). In other cases the new-formation, although not extending into the interior of the lobules, is homogeneous in its distribution, occurring wherever there is fibrillated connective tissue, and so present at the peripheries of all the lobules (so-called unilobular cirrhosis).

In the earlier stages the affected connective tissue is abundantly cellular, like granulation tissue, and the process of new-formation is evidently similar in its details to that in other chronic inflammations (see Fig. 256). Along with these changes, however, there are appearances, which have received various interpretations. In many cases there are elongated gland-like processes in the midst of the tissue which look like new-formed ducts. Some suppose them to be ducts in process of formation from the existing bile-ducts. Certain French observers regard this condition as a special feature of " biliary cirrhosis," and take the changes in the ducts as well as the other changes to be the result of obstruction. Hamilton has stated that these duct-like processes are really composed

of hepatic cells which are in process of forming connective tissue. The most probable explanation is that they are really capillary ducts which

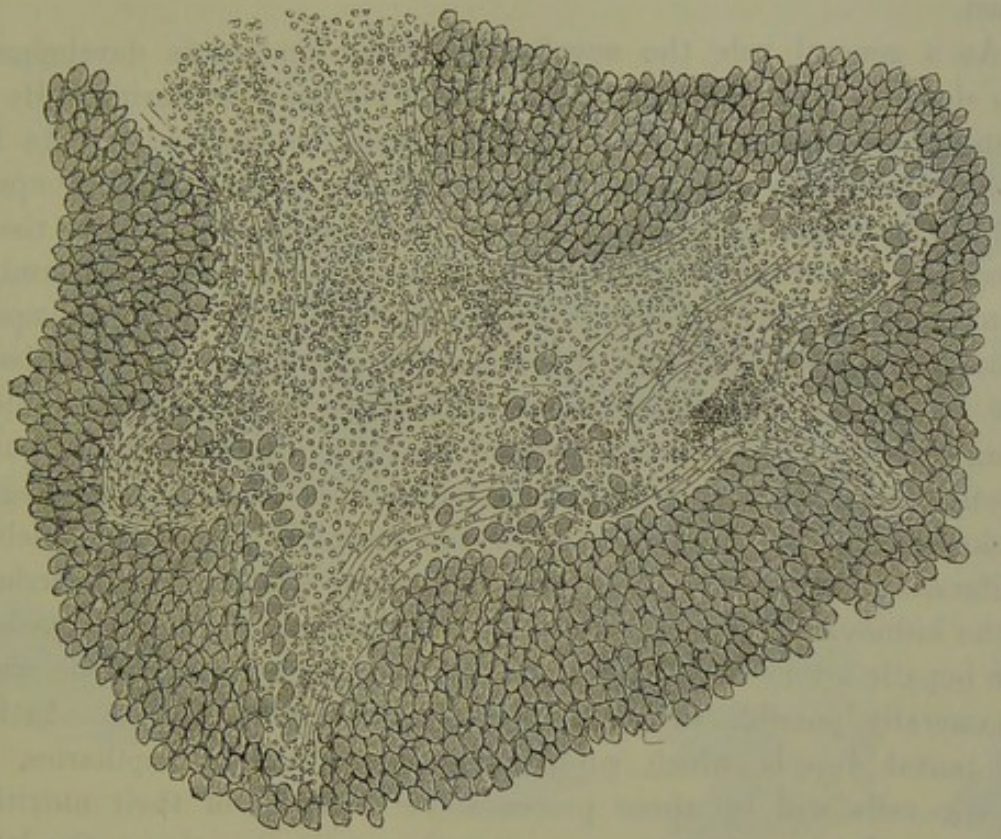


Fig. 256.—Cirrhosis of liver in earlier stage. The connective tissue is occupied by numerous round cells which are involving the peripheral parts of the lobules, the hepatic cells being here frequently isolated in the midst of the round cells. × 75.

have undergone enlargement, and so have become prominent. The normal capillary ducts are seated inside the lobules between the rows of hepatic cells. We shall see afterwards that the hepatic cells undergo great destruction in cirrhosis, but the capillary ducts may survive, and their epithelium may enlarge so as to give them the appearance of new-formed ducts. This appearance is only observed when the disease is in active progress, and the connective tissue shows a cellular character.

If there were nothing more than the new-formation of connective tissue hitherto mentioned, then the liver would be enlarged in this disease. In the earlier stages there is such enlargement, but the existence of the disease is not generally distinguished in these stages. On the other hand, Charcot and others have described a special form of HYPERTROPHIC CIRRHOSIS in which very great enlargement of the organ occurs. In this condition the distribution of the new-formation is unilobular, and the appearance of new-formation in the ducts referred to above, is manifest. It will be seen that the names biliary, uni-

lobular, and hypertrophic cirrhosis are used to designate a condition whose pathological bearings can hardly be said to be fully established.

As a general rule the new-formed tissue undergoes development into dense connective tissue which has a tendency to shrink. By its shrinking it causes atrophy of the proper hepatic tissue. As the cirrhosis is usually multilobular the contracting tissue isolates groups of lobules of larger or smaller size, and these, consisting of soft tissue, stand out somewhat when the liver is divided, or present themselves prominently at the surface. There are thus areas of remaining hepatic tissue which are being gradually encroached on by the connective tissue. The atrophy of the hepatic tissue takes place by the supply of blood being cut off. By the contraction of the new-formed tissue the portal vessels are narrowed, and there is in addition, according to Ziegler, thickening of the internal coat of the portal vein, an endophlebitis obliterans similar to the endarteritis obliterans which exists in cirrhosis of the kidney. This will increase the obstruction of the portal vessels. The hepatic artery is not much affected by the contracting tissue, and it is generally possible to inject it with considerable success. As it is the portal vessels which supply the proper hepatic capillaries, the hepatic cells will by these processes be deprived of their nutrition, while, as the hepatic artery supplies the connective tissue, the latter will be well nourished.

The consequence of this is great destruction of the hepatic cells. To a large extent this takes place by fatty degeneration, and one can often see, in the midst of connective tissue, islands of remaining hepatic tissue consisting of little more than collections of oil drops (see Fig. 257). The hepatic tissue is also commonly stained with bile pigment of a yellow or brown colour, and this we may associate with obstruction of the bile ducts by the contracting connective tissue. For the most part the pigment is biliary, but it is also to some extent blood pigment arising from the obstruction to the circulation. The connective tissue is also commonly stained, and to the naked eye the cut surface has a yellow colour, sometimes with here and there quite an orange tint. The name of the disease, cirrhosis, was originally applied from the colour of the altered organ.

The gall ducts are for the most part structurally unaltered. They are partially obstructed by the new-formed tissue, and on account of re-absorption of the bile there may be staining of the tissues and icterus. In some cases, as we have seen, and especially in hyper-

trophic cirrhosis, there is the appearance of new-formed bile ducts already referred to.

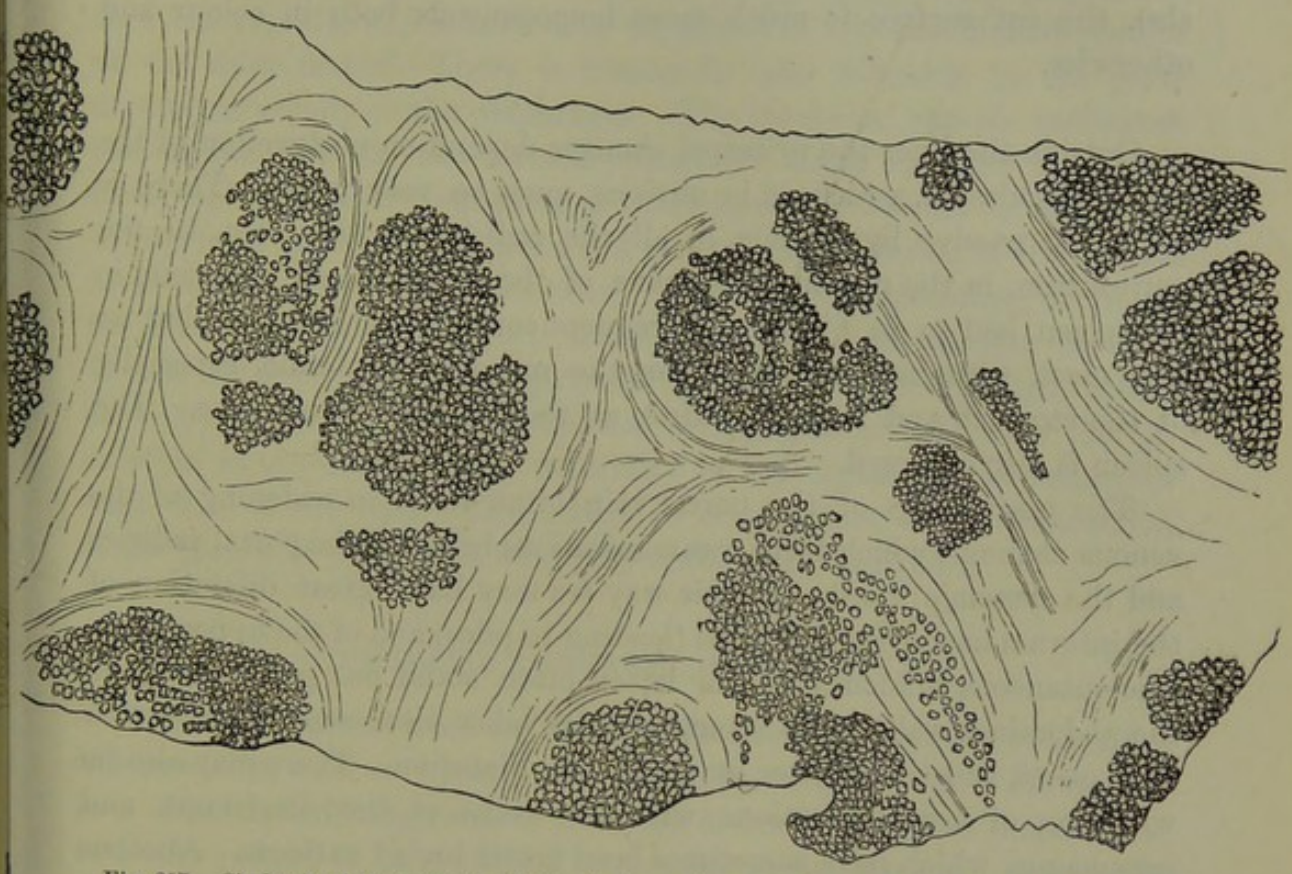


Fig. 257.—Cirrhosis of liver in an advanced stage, shown with a very low power. There are great areas of fibrous connective tissue, in the midst of which are islands of hepatic tissue having an opaque appearance from the presence of fat in the cells. ×20.

The result of all these changes is not only atrophy but distortion of the liver. The connective tissue contracts, and as it is irregularly distributed the contraction is irregular. The surface of the organ presents larger or smaller projections consisting of the less affected hepatic tissue between the cicatricial depressions. These projections may be comparatively large, forming the hob-nail appearance of the surface, or they may be smaller, giving a generally granular appearance. They are usually yellow or brown and opaque, being fatty and stained with pigment. Sometimes there is special shrinking of the left lobe, and generally there is dragging in of the edges, so that the liver assumes more of a compacted form, being perhaps even thicker than usual, but reduced in superficies. It is dense to the feeling, and more tough to cut than normal. On the cut surface it may be possible with the naked eye to make out the grey connective tissue, with islands of opaque or pigmented hepatic tissue in it.

In hypertrophic cirrhosis the liver is not only enlarged but smooth

on the surface. Sometimes it is adherent to surrounding parts, and there may even be a fibrinous exudation on the surface. On section, also, the cut surface is much more homogeneous both in colour and otherwise.

Outside the liver the principal changes depend on obstruction of the portal circulation, which, it is obvious, must be very great. There is a chronic passive hyperæmia in all the radicles of this vein, in the peritoneum, in the mucous membrane of the stomach and intestine, in the spleen, and so on. The most frequent consequence is ascites, but we also meet with hæmorrhages from the mucous membrane, especially of the stomach and large intestine, as well as catarrh of these. The spleen is also enlarged.

The obstruction of the portal vein often leads to widening of the venous channels which form communications between the portal radicles and the systemic veins. In this way we may have great dilatation of the internal hæmorrhoidal veins (leading to piles) and of the hypogastric. The cutaneous branches of the latter often stand out prominently on the abdominal wall. The hæmorrhoidal veins also communicate with the vesical, and these latter may undergo dilatation. There may also be widening of communications with the veins of the diaphragm and œsophagus, which have sometimes been found highly varicose. Another channel occasionally met with is a small vein which runs from the portal vein to the umbilicus. In some cases this is so much enlarged as to approach the size of the portal vein itself.

The patient generally dies from the disorders due to the continuous passive hyperæmia—the persistent catarrh of the alimentary canal, perhaps with hæmorrhages, the ascites, etc. There is great emaciation and sometimes icterus. It is not clear that the mere loss of the function of the liver bears an important part in the fatal result.

3. PERIHEPATITIS.—This condition is an inflammation of the capsule of the liver, and it is always secondary to some other lesion. A chronic pleurisy of the right side often extends through the diaphragm, and causes inflammation of the subjacent peritoneum, including the under surface of diaphragm and upper surface of liver, so that firm adhesion is the result. This is often the case in phthisis pulmonalis. A general chronic or acute peritonitis usually involves the capsule of the liver as well as other parts of the peritoneum. Sometimes cirrhosis or syphilitic disease of the liver extends to the capsule.

The inflammation is in most cases chronic, and results in a thickening of the capsule. Sometimes there are shaggy papilliform projections from the capsule, which have been compared to the pacchionian bodies of the dura mater. There is frequently also adhesion to the parts around, especially to the diaphragm. The thickened capsule undergoes contraction like the new-formed connective tissue in other inflammations, and the result frequently is considerable deformity of the liver. This is most marked when there is a general inflammation of the capsule as in cases of chronic peritonitis. The capsule contracting all round the liver doubles in its sharp anterior edge, and causes the organ to assume an approach to the globular shape. The contraction causes also atrophy of the liver tissue, and seriously interferes with the circulation in the organ. This deformity of the organ may be compared with that of the lung which occurs in consequence of the contraction of the pleura in chronic pleurisy, especially with empyema.

SYPHILITIC DISEASE OF THE LIVER.

Syphilis manifests itself for the most part as an indurative interstitial inflammation, with or without the formation of gummata. There may be a cirrhosis indistinguishable from the ordinary forms of this disease, and only judged to be syphilitic from other circumstances. Sometimes in the midst of the general new-formation of connective tissue there are numerous small gummata, distinguished especially by their caseous condition.

For the most part, however, the disease is localized. To the naked eye the liver is seen to present one or several cicatrices which often make deep indentations in its surface. These cicatrices are most frequent in the neighbourhood of the suspensory ligament. On cutting into the middle of the cicatrix a gummatous tumour is usually divided with its caseous central part. The periphery of the gumma is not distinctly demarcated from the surrounding connective tissue which extends outwards into the hepatic tissue. Other gummata may be found more deeply in the liver tissue, and these also are surrounded by cicatricial tissue.

The cicatrix is composed of fibrous tissue, and the gumma itself frequently presents irregular strands of connective tissue, but giving place to round cell tissue. The central caseous portion contains merely granular debris (see Fig. 258). Sometimes at the periphery of the gumma there is great dilatation of blood-vessels, giving almost a cavernous appearance.

When there are a considerable number of gummata, the cirrhosis may be nearly continuous, but with special cicatricial contractions at

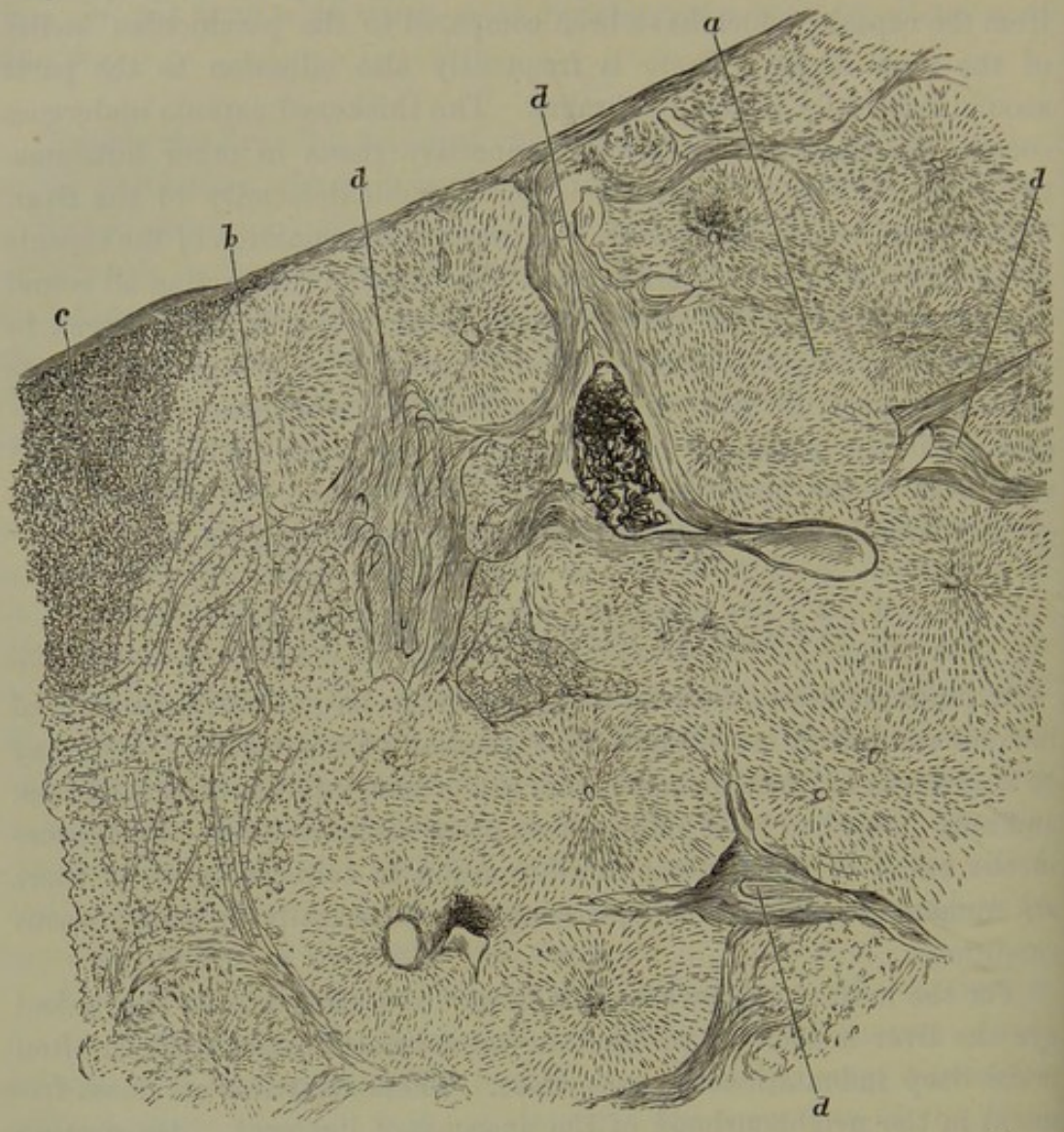


Fig. 258.—Gumma of liver. *a*, normal hepatic lobules; *b*, recent tissue of gumma with dilated blood-vessels; *c*, caseous part of gumma; *d*, *d*, *d*, connective tissue outside gumma extending into the hepatic tissue. × 16.

intervals corresponding to the gummata. The liver in this way may assume a very striking appearance, as if subdivided into manifold small lobes. Be the cicatrices large or small in number, the lobed and subdivided condition is characteristic of the syphilitic liver.

The liver is sometimes found affected in infants who are the subjects of CONGENITAL SYPHILIS. It may be a general induration forming a cirrhosis, usually of the hypertrophic form, with perhaps numerous small gummata; or the induration may be more localized, but never with

that cicatricial condition which we find in acquired syphilis. The connective tissue formation in this case does not confine itself to the neighbourhood of the portal vessels, but extends into the lobules, so that between the cells and around the capillaries there is connective tissue.

TUBERCULOSIS OF THE LIVER.

In ACUTE MILIARY TUBERCULOSIS the liver is almost without exception the seat of myriads of minute tubercles which are usually invisible to the naked eye. In PHTHISIS PULMONALIS examination very often shows the presence of tubercles in the liver, but much more sparsely distributed, and often associated with fatty infiltration.

The tubercles are situated in the connective tissue, and are therefore outside the lobules. They present (Fig. 259) the usual constituents; round cells with large giant cells in their more central parts. Very often the central parts are already caseous, or in more acute cases they may be affected by a more ordinary fatty degeneration with distinct refracting oil drops.

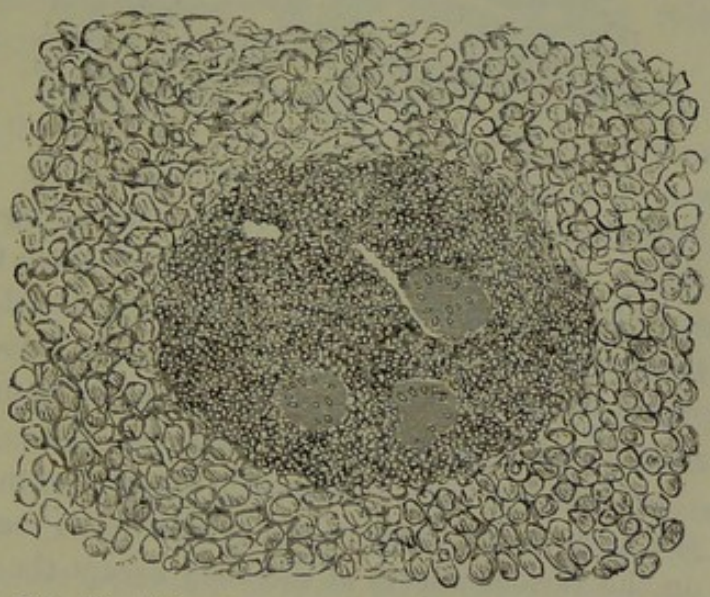


Fig. 259.—Tubercle of liver from a case of acute miliary tuberculosis. The tubercle is of a rounded form, and presents chiefly round cells with three giant-cells in the midst of these. × 75.

Along with the eruption of tubercles there is some interstitial inflammation affecting the connective tissue, and evidenced by the presence of round cells, but in acute miliary tuberculosis this is not usually considerable.

Besides this form of tuberculosis we sometimes meet with a condition in which numerous larger caseous tubercles are present, and are associated with a much greater indurative inflammation. The nodules are distinctly visible to the naked eye and sometimes are as large as peas. The larger ones may soften in the central parts and so small cavities may result. Cases have also been described in which

large solitary caseous tubercles have occurred, like the scrofulous tubercles of the brain, but all these forms are exceedingly rare.

TUMOURS OF THE LIVER.

Primary tumours of the liver are not very common, but secondary forms, especially cancers, are frequent.

CAVERNOUS ANGIOMA of the liver is the commonest form of primary tumour. Its structure has already been described (see p. 200). It develops apparently by dilatation of the existing capillaries and atrophy of the intervening hepatic cells. Subsequently the walls of the capillaries become thickened by new-formation of connective tissue and converted into the trabeculæ of the cavernous tumour (Fig. 260).



Fig. 260.—Angioma of liver. × 90.

Hence it is that the tumour replaces a certain portion of hepatic tissue. When seated immediately under the capsule the tumours are visible as red blotches, and on section they have a red colour and collapsed appearance, and usually it is only after the blood is washed out that the white trabeculæ become visible. The tumours present great varieties of size and may be as large as the fist.

A case has been described by Ziegler of multiple FIBRONEUROMA in the liver on the fibres of the sympathetic, there being similar tumours on the various nerves of the body except the olfactory and optic.

Concerning ADENOMA of the liver there is considerable variety in statement and opinion, mainly because on the one hand this form of tumour is rare, and on the other there are tumours concerning which it is difficult to say whether they should be called cancers or adenomas. There is one form of adenoma about which there is not much doubt; it is that already mentioned in the general section. It is sometimes designated NODULAR HYPERPLASIA, and occurs as solitary or multiple tumours which, while perfectly defined, have the same structure as the proper hepatic tissue, the cells being usually larger and some having double nuclei. If single they may reach the size of a cherry or larger;

if multiple they are smaller. The larger ones are sometimes surrounded by a connective tissue capsule. These tumours are of no practical consequence and are met with accidentally. They are not uncommon in the liver of the dog.

Another form sometimes called TUBULAR ADENOMA is described, in which, while the individual cells are like those of the liver, they are arranged not in groups like the acini of the liver, but rather in gland-like masses, which have been compared to the convoluted tubules of the kidney. It is clear from the epithelial character of these glandular masses that the structure approximates to that of cancer, and indeed some of these cases can hardly be distinguished from cases of cancer. The adenoma may grow to a considerable size, while secondary tumours develop in the hepatic tissue around. This latter fact again suggests cancer, and an observation by Professor Greenfield in which tumours formed by metastasis in the lungs is still more suggestive. According to some the glandular processes grow from the liver cells, while others hold that they sprout out from the bile ducts.

PRIMARY CANCER of the liver is of rare occurrence, and yet several varieties are described. The cancer may be in the form of several small tumours, or a large growth infiltrating a considerable portion, of the liver. The structure resembles that of tubular glands but less regularly formed than in the case of the adenoma, and more interpenetrating among the proper hepatic tissue. Another form has been described in which the cancer originates in the bile ducts, and the cancerous processes have at first their seat in the connective tissue accompanying the portal vessels, etc. There are in this form numerous tumours which follow the portal distribution. They may cause obstruction of the ducts and the formation of cysts with bile-stained contents.

SECONDARY CANCER is exceedingly frequent in connection with primary cancer of the stomach, pancreas and large intestine, but it occurs also in cancers of the uterus, the œsophagus and mamma. In the case of these last-mentioned localities the metastasis is produced by the way of the hepatic artery, while in the other case it is by the portal vein. We shall afterwards discuss in a separate section the subject of the secondary extension of cancers of the abdomen.

In the great majority of cases the primary seat of the cancer is the stomach, and next to that it is the large intestine, and the secondary

tumours arise by pieces of active cancerous tissue being carried to the liver by the portal vein. We shall see afterwards that there is reason to believe that, in some cases at least, the cancerous material does not come directly from the primary tumour. As the cancer is sown in every part of the liver, the consequence is the development of numerous tumours which may be found in all stages of growth.

It is usual to find a large number of isolated tumours of circular form and pale colour (see Fig. 261). They are seated in the liver tissue, but those near the surface produce rounded elevations of it which can often be felt through the abdominal parietes during life. Even to the naked eye the tumours show evidences of fatty degeneration in the appearance of opaque yellow coloration. The absorption of the degenerated cells is also indicated by the partial contraction of the larger tumours in their central parts, producing in the superficial ones a dimpling or UMBILICATION of the rounded projections. The liver, as a whole, is sometimes enormously enlarged, weighing not infrequently as much as ten or twelve pounds.

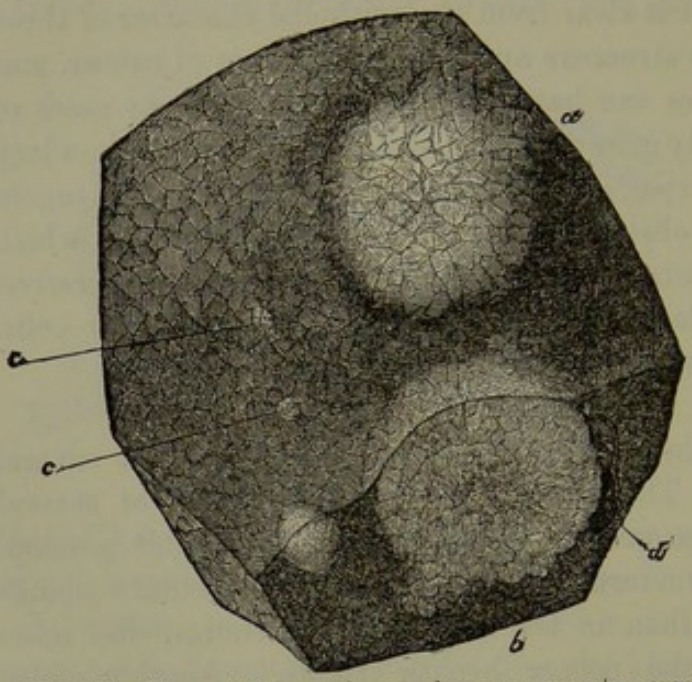


Fig. 261.—Piece of liver with secondary cancerous tumours in it. A larger one, *a*, is viewed from the surface. Another large one, *b*, in section. There are several smaller tumours, *c*, *c*. *d*, a vein in section. (VIRCHOW).

In some cases the new-formation is not so much in the form of individual tumours as a general CANCEROUS INFILTRATION, as if almost throughout the liver a simultaneous development had occurred, and the cancerous tissue had grown vigorously, displacing the proper hepatic tissue.

In structure the tumours follow the primary ones. For the most part it is soft cancers of the stomach that form the original tumours, and we have a well-formed stroma with irregular masses of epithelial cells. But sometimes the primary tumour is an epithelioma, and in that case the tumours in the liver are usually fewer in number, firmer and more distinctly defined. When the primary tumour is in such a

position that the cancer reaches the liver by the hepatic artery, the tumours are usually smaller in size and the liver not so much enlarged. This was at least very strikingly true in a case seen by the author where the primary tumour was in the mamma.

The cancerous material as it is brought by the blood-vessels develops inside them, and particularly in the portal vessels. It seems also that the tumour to a large extent develops by growing inside the capillaries, although also in the spaces in the connective tissue. The consequence of this great new-formation in the vessels is atrophy of the hepatic cells. These are often to be seen at the peripheral parts of the tumours arranged in concentric layers as the pressure is exercised, and they undergo atrophy. It is asserted by several authors that the cancerous tissue sometimes develops directly from the tissue of the liver, arising largely by a transformation of the latter. This is supposed to be effected by the influence of some infective material brought from the primary tumour, which induces the hepatic tissue to undergo this peculiar change. This view, however, stands in need of confirmation.

The hepatic cells are often deeply stained with bile, and it is clinically of importance that the whole white structures of the body are usually jaundiced. This implies that the ducts are obstructed, and the biliary colouring matter absorbed into the circulation. The numerous developing tumours press on the bile ducts and obstruct them, and this occurs all the more as the growths arise by embolism of the portal vessels, and are, in the first place, related to them. As the ducts are in the immediate neighbourhood of these vessels, they are liable to be pressed on very soon. The hepatic cells are frequently of a greenish colour, and the biliary pigment is sometimes extensively deposited in them as brown granules.

The portal vessels suffer obstruction, not only by the pressure of the tumours, but as being the seat of their primary growth, and hence we meet with ascites as a common result.

Sarcoma is of occasional occurrence in the liver in the spindle-celled and pigmented forms. Some cases of melano-sarcoma have been described as primary tumours, but secondary tumours following melanotic sarcomas of the eye are more common. The liver may be largely occupied by these black tumours, and greatly enlarged. Here also the growth appears to occur in the blood-vessels and results in destruction of the hepatic tissue proper.

PARASITES OF THE LIVER.

These have already been somewhat fully described. The most important constitutes the HYDATIDS of the liver arising from the tænia echinococcus. When the liver is examined after death there is found a sac or sacs of very various size, up to that of a man's head. The larger ones produce necessarily great enlargement of the liver as a whole, and atrophy of the hepatic tissue around them. They present first a connective tissue capsule, inside which the proper wall of the cyst appears. As the vesicles are sometimes much broken down, and it may even be difficult to find hooklets, it is important to remember that the proper cuticula of the cyst is lamellated (Fig. 146, p. 285). Sometimes the contents of the cyst, after the death of the parasite, form a fatty atheromatous or mortary material in the midst of which pieces of this chitinous membrane may be found with its characteristic lamellation. The multilocular and exogenous forms of hydatids are to be remembered, the former resembling colloid cancer in its general appearance. FLUKES do not frequently occur in the human liver, yet they have been observed (see p. 273).

B.—THE BILE DUCTS AND GALL BLADDER.

GALL-STONES.—As gall-stones not infrequently form the primary cause of further disease of the bile ducts, we may begin our description with them. They are of very frequent occurrence, especially in people past middle life, and they are often found in the gall-bladder after death without their existence having been suspected during life.

The cause of their formation is very obscure. They are formed in the gall-bladder by the deposition of the constituents of the bile, chiefly cholestearine and next to that bile pigments, but also lime and magnesia salts in varying proportions. Probably stagnation of the bile in the gall-bladder at least predisposes to their formation, and this is rendered the more probable from their more frequent occurrence in old people where the actions are sluggish. In the centre of gall-stones there is frequently a nucleus composed of remains of epithelium or mucus.

Gall-stones occur singly or in numbers. The SINGLE GALL-STONES are commonly composed almost purely of cholestearine, of which there may be over 98 per cent. They are oval in shape, somewhat nodulated on the surface, and have a glistening appearance, altogether not unlike that of a sugar plum. When divided or broken they present a characteristic radiating appearance from the centre, and also sometimes a concentric stratification. The broken surface has the same glistening appearance as the outer surface, and distinct scales can be separated. The stone is very light in weight, floats in water, and has a soft almost soapy feeling.

MULTIPLE GALL-STONES are more frequent, and although sometimes nearly pure, they are more frequently composed of cholestearine mixed with bile pigment and lime salts. There may be two or three, but they may be present in large numbers, fifty, a hundred, or several hundreds. If few they may be comparatively large, but if numerous they are small, the bladder sometimes having the appearance of a bag filled with peas. The multiple stones are always facetted, taking their shape according as there is room, and fitting into each other. In appearance they have been compared to the macerated carpal bones, having somewhat similar facets, and often presenting a similar greyish colour, although sometimes yellow, brown, or even black. They are very light in weight, and on section present little of the glistening appearance or radiating arrangements of the single ones, being rather stratified, more deeply pigmented strata alternating with less.

Gall-stones are sometimes met with which are composed almost entirely of bile-pigment. They are small and nearly black, and occur in considerable numbers at a time. They are very rare. Sometimes there are stones composed mainly of lime salts, especially the carbonate, but these also are very rare.

The calculi may remain long in the gall-bladder, which may be found full of them, and with no bile in it. Its mucous membrane may be inflamed, and the calculi surrounded by an abundant mucous secretion.

On the other hand a gall-stone often passes into the cystic duct, where it may remain for a time and obstruct it. After a time it often passes on into the ductus choledochus. The last part of this duct is narrow, and, if the stone is of any considerable size, it usually sticks here, at least for a time. By dilating the duct it may get into the duodenum, but very commonly it does not find its way through without ulceration, and sometimes it ulcerates into the peritoneum, producing

inflammation of this serous membrane. Lying at the mouth of the ductus communis it obstructs the outflow of bile and produces the results to be presently described. When it gets into the duodenum it usually passes off with the fæces, but if large, it may produce obstruction of the intestine at some point. This is of rare occurrence, and only in the case of large stones, chiefly of the solitary kind.

OBSTRUCTION OF THE BILE DUCTS AND ITS RESULTS. Obstruction occurs from various causes, of which the commonest is that just considered, namely, GALL-STONES. INFLAMMATION of the ducts sometimes produces obstruction, the inflammation being nearly always secondary. It occurs most frequently at the terminal portion of the ductus communis from prolongation of catarrh from the stomach and duodenum. As the duct here is narrow a trivial inflammatory swelling may produce an obstruction, which the bile, possessing a low pressure, is unable to overcome. Then gall-stones themselves may produce inflammation, leading to a more or less prolonged closure of the ducts. We shall see afterwards that inflammation is not infrequently a consequence of obstruction, and these two should not be confounded. TUMOURS and INFLAMMATIONS AROUND the duct may cause obstruction. This is not infrequently the case with cancers where the head of the pancreas or the lymphatic glands in the portal region of the liver are engaged. We have already seen that an obstruction of the hepatic ducts in the substance of the liver occurs in cancer of the liver, in cirrhosis, etc.

The RESULTS OF OBSTRUCTION vary according to the site of the obstruction.

If the CYSTIC DUCT ALONE be obstructed then the consequence is that no bile can get into the gall-bladder. In that case the bladder may shrink, and any mucus in it dry in and perhaps afterwards become chalky. In many cases, however, there is an abundant secretion of mucus, and the bladder gets filled with it. The mucus often after a time gives way to a more fluid secretion, and the bladder may be converted into a thin-walled cyst, which may be as large as the fist, with clear fluid contents. When the gall-bladder is thus cut off and no longer available as a store for the bile, there sometimes occurs a dilatation of the larger bile ducts, so that the bile may lie here instead of in the gall-bladder, and pass into the duodenum during digestion. This constitutes an imperfect compensation for the loss of the gall-bladder.

In the case of OBSTRUCTION OF THE DUCTUS CHOLEDOCHUS, there is

of course stagnation both in the gall-bladder and in the whole system of bile ducts. The stagnation tells first on the gall bladder, which dilates readily and stores up the bile. There may even be rupture of the gall-bladder from excessive dilatation. If the obstruction be prolonged great dilatation occurs throughout the whole system, and serious changes frequently result in the liver itself.

Next to the gall-bladder the ductus choledochus and the larger bile ducts, which are not supported by the firm liver tissue, are most liable to dilate. This dilatation may be very extreme, these ducts becoming sometimes as great in external size as the thumb, and sometimes even going on to rupture.

In the liver itself the dilatation is not generally so great, at least at first, but if prolonged it may lead to serious dilatation afterwards. The first result on the proper hepatic tissue is staining of it with the bile pigment. The hepatic cells assume a deep yellow colour, most marked at the peripheral parts of the lobules, being the parts nearest the bile ducts. In these the bile pigment is often deposited in the granular form, as green or brown masses. The pigment which is at first brown, may, after the tissue has been in alcohol or other fluid, become green. These conditions indicate the re-absorption of the bile, and this is also manifested in the staining of all the tissues of the body, forming a general jaundice. The absorbed biliary colouring matter is often deposited in the uriniferous tubules of the kidney, presumably in the process of excretion.

Sometimes considerable atrophy of the proper tissue of the liver occurs, and we have the smaller bile ducts dilated and forming numerous cavities or CYSTS throughout the liver. This probably does not occur without inflammation of the ducts, and may be accompanied by ulceration, so that the cysts are cavities like those occurring in the lung from dilatation of bronchi; they contain inflammatory products as well as bile.

There is sometimes even a more definite acute inflammation of the bile ducts apparently from decomposition of the bile, and this may lead to what may be called BILIARY ABSCESSES which contain a mixture of pus and bile. These abscesses may contain gall-stones deposited by the stagnant bile, and the irritation set up by these may have been concerned in causing the inflammation.

According to Charcot and others, as previously mentioned, the stagnation sometimes leads to inflammation of the connective tissue of the liver, producing cirrhosis of the hypertrophic kind.

TUMOURS OF THE BILE DUCTS AND GALL-BLADDER. Of these the most important are the cancers. We sometimes meet with primary cancer of the gall-bladder resembling in structure cancer of the stomach and intestine. By extension it may largely involve the liver tissue. We have already seen that some of the cancers of the liver probably take origin in the finer bile ducts in its substance.

C.—THE PANCREAS.

In some aspects the diseases of the pancreas are not of very great practical importance. Although the secretion of the gland is known to have important functions in the digestion of food, the starches, albuminates, and fats being all affected by it, yet lesions of the gland which destroy its functions seem to be compensated by the other secretions of the alimentary canal. On the other hand, the diseases of this organ, and especially cancers, may affect neighbouring structures, and cause serious disturbances around.

The pancreas has the structure of a salivary gland, consisting of glandular acini whose ducts communicate with a main duct lying in the centre of the gland (Wirsung's duct) and opening into the duodenum in common with the ductus choledochus.

The pancreas is occasionally the seat of HÆMORRHAGES into its substance. These may be the result of injuries to the abdominal wall or the consequence of passive hyperæmia in diseases of the heart, lungs or liver. Some cases of sudden death have been recorded by Zenker, Hooper and Klebs, in which the most obvious lesion was hæmorrhage into the substance of this gland. It is supposed that the lesion caused pressure on the neighbouring cœliac plexus and semilunar ganglion and a consequent reflex paralysis of the heart, just as paralysis of the heart is producible by blows on the abdomen (Goltz's experiment).

INFLAMMATIONS of the pancreas are of various kinds. We have suppurative pancreatitis like suppurative parotitis, resulting in abscesses; also indurative interstitial inflammation with loss of gland tissue, this condition being sometimes of syphilitic origin.

ATROPHY of the pancreas is observed often as a part of general emaciation, but it has been found in a good many cases of diabetes mellitus. It can hardly be held that the destruction of the function of the pancreas is the cause of the diabetes, and the probability is that, as Klebs suggests, the primary condition is disease of the cœliac plexus causing vaso-motor paralysis (see p. 69).

FATTY INFILTRATION of the pancreas is one of the commonest lesions of this gland. There is normally some adipose tissue in the midst of the gland, and this sometimes undergoes considerable increase, the proper glandular substance becoming atrophied, and adipose tissue taking its place, the shape and general appearance of the gland being preserved. The condition may be part of a general obesity, or it may occur in old age, and, in this latter case, it may be presumed that atrophy of the glandular tissue is the first condition, the adipose tissue developing afterwards, as in fatty infiltration of voluntary muscle.

The glandular structure sometimes undergoes CLOUDY SWELLING in common with that of the liver and other organs in the acute fevers. FATTY DEGENERATION is also met with.

TUBERCULOSIS is not common in the pancreas, but we meet with caseous masses having the characters of a local tuberculosis. More frequently the pancreas is involved secondarily in a tuberculosis arising in neighbouring lymphatic glands.

Of the tumours of the pancreas CANCER is by far the most important. It occurs most frequently in the head, rarely in the body or tail. It is mostly a dense tumour of fibrous appearance (scirrhus), but cases of soft and of colloid cancer have been seen. The cancer often produces obstruction of Wirsung's duct, or produces still more serious results by obstructing the ductus choledochus. It may even by its retraction cause a partial obstruction of the duodenum. There may arise in this way considerable disturbances from the continuous extension of the tumour. We may also have secondary tumours in lymphatic glands, liver or peritoneum. It is to be added that cancers of the stomach or duodenum may extend to the pancreas, and that the gland may be the seat of metastatic tumours when the disease becomes generalized.

The PANCREATIC DUCT (Wirsung's) is liable to certain changes. CONCRETIONS occur in it, comparable to those of the salivary glands. They are mostly round or oval and white or greyish white. In size

they have been met with as large as a hazel nut or larger, but they are usually small like grains of sand. They are composed chiefly of carbonate and phosphate of lime. They very often arise in dilated ducts, but if large may cause dilatation by obstructing the duct.

OBSTRUCTION and DILATATION of Wirsung's canal may arise, as we have seen, from calculi, cancers of the head of the pancreas, or from tumours in the neighbourhood. Dilatation also occurs secondarily to atrophy of the gland. The dilated duct forms a series of pouches, or else there is a more definitely localized dilatation so that actual cysts are formed. This latter will occur when the orifice is completely obstructed; the cysts may reach the size of the fist or that of a child's head, and these are sometimes designated RANULA PANCREATICA. The contents of the dilated duct may be simply the fluid secretion, but sometimes there is thickening of the contents and even hæmorrhage. In this way we may have coagula causing the cysts to look like aneurisms, all the more as the lining of the cyst may become the seat of calcareous plates like the internal coat of an artery in aneurism.

D.—THE PERITONEUM.

INTRODUCTORY.—The peritoneum which is stretched over so many different organs, and has so many recesses and pouches, is very liable to be affected by diseases having their source outside itself.

It is necessary here to make some reference to the general relations of the peritoneal sac. It is a large lymph sac and fluid is continuously circulating through it. The surface of the membrane is covered with endothelium, and there are innumerable apertures or stomata by which it communicates with lymphatic vessels beneath. It is proved by experiment that finely divided solid material introduced into the peritoneal cavity is very readily absorbed and carried into the lymphatics. The transudation fluid which normally passes out of the blood-vessels is doubtless absorbed by the stomata throughout the peritoneum, but there are two localities in which its absorption presents points of peculiar interest.

From certain facts to be afterwards referred to in connection with tuberculosis and cancer of the peritoneum, it may be inferred that the

GREAT OMENTUM is specially concerned in the process of absorption. This double layer of peritoneum lying free in the cavity may be regarded as A DRAIN by means of which the fluid is drawn off.

The relation of the DIAPHRAGM to the process of absorption is also important, and has already been referred to in considering the subject of acute pleurisy. The lymphatics of the diaphragm communicate on the one hand with the peritoneal sac and on the other with the pleura, so that fluid and finely divided solids may be carried through from one to the other. It is probable that the general course of the current is from peritoneum to pleura, although it may be reversed.

It is very important to bear in mind this great power of absorption possessed by the peritoneum, especially in relation to septic processes. The products of septic decomposition as well as the organisms which produce these changes may be absorbed, and that sometimes in such quantity as to produce fatal results before they have had time to induce any considerable local effects. Hence it is that septic processes in the peritoneum are so serious and lead so commonly to septicæmia.

The fluid in the peritoneal sac is not at rest, but circulates, and the movements of the intestines doubtless have to do with its transportation from place to place. This fact is also of great importance, because we shall find that when any pathogenic agent is introduced into the peritoneal cavity it is generally carried to every part of the sac and produces its effects in every region. Abundant examples of this are afforded by tuberculosis of the peritoneum, inflammations, and so on.

DISORDERS OF THE CIRCULATION IN THE PERITONEUM.

ACTIVE HYPERÆMIA of the peritoneum is not a condition of much practical importance. It is produced when from any cause a general relaxation of the arteries in the sac occurs. Leaving inflammation out of account, this will hardly occur except as a result of sudden removal of extra pressure from these vessels. If a large ovarian tumour be removed from the abdomen, or ascitic fluid drawn off, the arteries, which have previously accommodated themselves to the undue pressure on their walls, will relax, and a hyperæmia result. The hyperæmia may result in the occurrence of a peculiar form of CHRONIC HÆMORRHAGIC PERITONITIS, comparable with hæmorrhagic pachymeningitis (see p. 477), the effused blood being here also sometimes a prominent feature (HÆMATOMA OF THE PERITONEUM). As in the other case it may be a question whether there is an inflammation preliminary to the hæmorrhage, or

whether the hyperæmia induces bleeding, the succeeding organization of the clot leading to the formation of a membranous layer on its surface. Where ascitic fluid has been drawn off many times, there may be several layers of soft membrane on the surface of the peritoneum, the innermost being the most delicate and the newest.

PASSIVE HYPERÆMIA occurs as a result of obstruction to the portal circulation either alone or as part of a general venous hyperæmia. It is chiefly important in relation to ascites, of which it is the most frequent cause.

ASCITES.—This name is given to dropsy of the peritoneal cavity, and it occurs as the result either of excessive transudation of fluid from the blood-vessels, or diminished absorption by the lymphatics.

It is sometimes merely a part of a general œdema, occurring in diseases of the heart and lungs, in Bright's disease, and in anæmic states. But it is peculiarly prone to occur when the portal circulation is specially obstructed. This may happen by the portal vein being the seat of thrombosis, or pressed on from without, but more frequently it is by some lesion in the liver itself, such as cirrhosis or cancer, which obstructs the portal vessels, as it were, in detail.

In these cases the ascites is from increased transudation, and it is much less common to have it occurring from interference with absorption. This may have something to do with it, however, in cases of cancer of the peritoneum, where the numerous cancerous tumours originate from material carried into the lymphatic channels and growing there. These tumours will necessarily obstruct the lymphatics to a large extent in detail, although they may also produce by their irritation a hyperæmia of the peritoneal vessels. In a similar way the dropsy of tuberculosis of the peritoneum, although mainly inflammatory, may to some extent be referred to obstruction of the paths of absorption.

Ascites is of occasional occurrence in connection with OBSTRUCTION OF THE THORACIC DUCT by tumours, aneurisms, thrombosis, etc., interfering with the duct or with the vein into which the duct opens. If the obstruction be complete there is great distension of the duct and its radicles below the seat of obstruction. Occasionally an actual rupture occurs, and the chylous fluid passes into the pleural or the peritoneal cavity. The fluid is in this case a whitish milky material, and we have the conditions named respectively, chylous hydrothorax and CHYLOUS ASCITES. The fluid contains abundant leucocytes in which are fat granules.

The fluid in ascites is contained in the general sac of the peritoneum, but where adhesions have previously existed it may be confined to particular parts, and sacculated. Sometimes also, in children, there is a dropsy between the folds of the omentum.

The character of the fluid in ascites is that of ordinary transudations, a clear, slightly yellow, limpid fluid of low specific gravity. After it has stood for a time it often deposits a very gelatinous coagulum of fibrine. In some cases the fluid is slightly milky (chylous ascites).

In prolonged ascites the peritoneum is apt to get somewhat thickened, especially when puncture has been frequently performed. The great omentum is not infrequently gathered up so as to be thicker and shorter than usual, and in that case it will act less efficiently as a drain.

INFLAMMATIONS OF THE PERITONEUM.—PERITONITIS.

Inflammation of the peritoneum is very seldom spontaneous in its origin. It seems remarkable that, compared with the pleura or pericardium, this membrane is so seldom the seat of independent inflammation as a result, for instance, of the irritation of the blood in acute rheumatism, or of the more vague causes of irritation designated as cold.

The peritoneum is, however, peculiarly liable to inflammation of a secondary character, the irritant proceeding either from without as in wounds of the abdomen, or from one of the organs lying beneath the membrane.

Mere exposure to the air or the entrance of air into the abdominal cavity does not induce peritonitis, and even a somewhat prolonged cooling of the membrane, as during an operation, does not seem to lead to inflammation.

Most of the INFLAMMATIONS of the peritoneum are SEPTIC, that is to say, they are due to the presence and propagation of bacteria, usually in the form of micrococci, and the irritating chemical products which result. Those who are familiar with the manner in which bacteria propagate in suitable fluids will not be astonished that a limited inoculation of septic material produces a very rapid propagation in the peritoneum. The conditions are here peculiarly favourable to this. The movements of the intestine and the normal circulation of the peritoneal fluid carry the septic particles hither and thither, so that they are sown over an extensive surface, and supplied with nutritive material.

The warmth of the cavity also favours their propagation. So it happens that in comparatively few hours we may have an intense inflammation, or we may have, as already stated, such an absorption as to cause death by septicæmia before considerable inflammation can develop.

The septic inoculation may take place by a wound in the abdomen, made by accident or by an operation. More frequently the source is an underlying organ, as the stomach, or intestine, or the uterus after delivery. In regard to the last-mentioned source, acute peritonitis is often a special feature in puerperal fever, and as this disease occurs in epidemics and is highly contagious, we must infer that there is something specific in the organism which causes it.

The septic inflammations partake of the character of similar inflammations in the pericardium and pleura. They are pre-eminently acute, and tend rapidly towards suppuration. At first there is hyperæmia and a serous and fibrinous exudation. The exuded fibrine is visible on free surfaces as a soft yellow layer, and is often present in the fluid as yellow flakes. It glues together surfaces which are in contact, such as the loops of the intestine, but the adhesions are not firm ; they can be readily separated, and the gluing material is seen to have a soft gelatinous character. As the inflammation goes on, the fibrinous exudation, which from the first contains very numerous leucocytes and is correspondingly soft, becomes still more infiltrated with these, and assumes the characters of pus. Pus may be found in some parts, while in others there is still the soft fibrinous exudation. Thus pus may be found in the neighbourhood of the original source of the inflammation, as around the vermiform appendage, the inflammation being here more intense or of longer standing. The pus, and even any free fibrine that may exist, commonly gravitate to dependent parts, and we may find a collection of yellow pus in the pelvis, and especially in Douglas's pouch.

The peritoneum presents in its finer details changes similar to those in septic pleurisy and pericarditis. The endothelial cells are separated, and the connective tissue opened out by serous fluid and leucocytes. The underlying tissues are also altered, especially the wall of the intestine. The subserous, muscular, and mucous coats are often œdematous and thickened. There is not infrequently considerable tympanitic distension of the intestine from paralysis of its muscular coat. This METEORISM is sometimes a peculiarly distressing feature in puerperal fever.

It will be inferred that septic peritonitis, if general, is almost neces-

sarily fatal. Sometimes it is localized by adhesions, and even after the occurrence of suppuration may subside and give place to chronic inflammation.

CHRONIC PERITONITIS, whether developing out of the acute form or occurring in connection with disease in an underlying organ, is characterized by new-formation of connective tissue, frequently with adhesion of opposing surfaces. The details of this process are similar to those in chronic pleurisy, etc. ; it remains here to specify some of the more common occasions of the affection.

A diffuse chronic peritonitis sometimes develops in the course of Bright's disease. There is also commonly, in cases of secondary cancer of the peritoneum, a general chronic peritonitis.

Local thickenings of the capsule of the liver and spleen are of frequent occurrence in connection with diseases in these organs or their neighbourhood. Sometimes the connective tissue is hard, almost like cartilage. Very commonly there is adhesion to the parts around, especially to the diaphragm. On the other hand, the diaphragm may be adherent by reason of the extension of an inflammation from the pleura, the irritant having passed downwards in a direction contrary to that of the usual circulation.

The peritoneum around the female generative organs is liable to very frequent local chronic inflammations (PERIMETRITIS), resulting in complex adhesions and mattings of the pelvic organs. The contraction of the new-formed connective tissue may cause considerable distortion of these organs.

TUBERCULOSIS OF THE PERITONEUM.

TUBERCULAR PERITONITIS.—This disease is usually a primary and independent one, due to the existence of the tubercular virus in the peritoneal cavity. It may seem at first sight remarkable that tubercular ulcers of the intestine hardly ever give rise to a general tuberculosis of the peritoneum. We have seen that in connection with these ulcers tubercles are formed in the muscular coat and very commonly beneath or in the peritoneum, and it might seem probable that the virus would get readily into the peritoneal cavity. But it is to be remembered that the lymph circulation is from the surface of the peritoneal cavity into the substance of the membrane, and that the normal currents will not carry the virus into the sac. Whether this be the

true explanation or not, it is rare for tubercular ulcers to produce tuberculosis.

In tubercular peritonitis the virus gets into the sac, and is carried hither and thither throughout it by the regular circulation. The consequence is the formation of innumerable tubercular nodules and an inflammation of the peritoneum. It is not clear, however, in most cases, how the virus gets into the peritoneum. In a few cases the tuberculosis of the peritoneum has obviously had its origin in a local tuberculosis of the testis and vas deferens, and has begun in the inguinal region where the vas deferens approaches the peritoneum. But in the majority of cases no such source of infection can be found, and although commonly the person is in a state of ill health before the tuberculosis begins to manifest itself, and may have scrofulous tubercular manifestations elsewhere, yet the disease may supervene in persons apparently healthy and robust. We can only say that the formation of tubercles in every part of the peritoneum, and the fact that by reason of the communications through the diaphragm they also spring up in the pleura, are sufficient evidences of the existence of an infective material in the peritoneal cavity.

When a case of tubercular peritonitis is examined post mortem, we find evidences of chronic inflammation in the form of thickening of the peritoneum and multiplied vascular adhesions in every part. The loops of the intestine are adherent to each other, and the superficial ones to the anterior wall of the abdomen, the omentum is adherent to the intestine, the liver to the diaphragm, and so on. In the midst of these adhesions are numerous yellow masses of very various sizes, some as large as split-peas, and usually flat. These caseous masses are composed of groups of tubercles which have very much the character of those found in tubercular pericarditis. The caseous tubercles have developed in the usual way out of grey miliary tubercles, and examination will usually show examples in the various intermediate stages.

The condition of THE OMENTUM is worthy of special mention. It is drawn together and thickened, and closely adherent to the intestine and wall of the abdomen, while in its substance numerous tubercular masses are to be found.

All these conditions indicate a chronic inflammation, accompanied as usual by the new-formation of vascular connective tissue with consequent adhesion. The yellow caseous masses are collections of tubercles mostly obsolete, just as the caseous tubercles of the brain

are ; and here, as there, we may find recent tubercles at the margins of the caseous masses.

While this is the usual condition found after death there is reason to believe that the inflammation in the earlier stages is more acute. There is often at first considerable accumulation of serous exudation in the abdomen. This is by and by for the most part absorbed, giving place to adhesive inflammation, but often there is serous fluid among the adhesions, and during life the hand on the abdomen may sometimes enable one to detect the movement of fluid from space to space among the adhesions. The disease may be recovered from in these earlier stages, the virus being apparently overcome by the reinvigorated forces of the body. On the other hand the inflammation produced is sometimes more acute than usual, and in rare cases may be fibrinous and suppurative.

It has already been mentioned that tubercular pleurisy often develops in association with tubercular peritonitis. There is in the pleura for the most part a serous exudation, and as the eruption is usually recent the tubercles are in the form of small white or grey nodules. They are commonly grouped mainly in the lower part of the pleural cavity, in this way indicating the source of the infective material.

Tuberculosis of the peritoneum is sometimes met with in ACUTE MILIARY TUBERCULOSIS, but it is not frequent, and the appearances are altogether different to those of tubercular peritonitis. In the case of general tuberculosis the virus is in the blood, and the tubercles develop in connection with the blood-vessels and not specially on the surface. Besides, the disease proves fatal so soon that there is not time for the occurrence of adhesive inflammation or the development of groups of tubercles. The tubercles are very small grey nodules hardly visible to the naked eye and specially abundant in the upper part of the abdomen and omentum.

TUMOURS OF THE PERITONEUM.

These are rarely primary. Several cases of RETROPERITONEAL SARCOMA have been described in which a tumour of very large size has formed and distended the abdominal cavity.

Sometimes we meet with bulky gelatinous tumours in the abdomen, and the recognition of the exact nature of some of them is matter of considerable difficulty. Colloid cancer of the stomach and intestine

not infrequently, as we shall see afterwards, passes on till it reaches the peritoneum, and may result in the formation of bulky gelatinous masses there. But, besides that, there are primary tumours of the peritoneum which belong to the class of CYLINDROMA or PLEXIFORM ANGIOSARCOMA. In these cases there is a new-formation of blood-vessels in whose adventitia is produced a peculiar gelatinous tissue. These tumours may attain a large size, weighing as much as forty pounds.

SECONDARY CANCER of the peritoneum will be considered in the next section more fully and need not be taken up here.

LYMPHO-SARCOMA is not such a common tumour here as in the mediastinum, but it sometimes originates in the lymphatic glands of the mesentery and involves all the neighbouring structures. We may thus have bulky tumours occupying the place of a portion of the mesentery and intestine, and repeating roughly the anatomical relations of these.

THE SECONDARY EXTENSION OF CANCERS OF THE ABDOMINAL ORGANS.

We have seen in the study of the diseases of the stomach and intestine that the cancers of these organs very often lead to secondary tumours in the liver and peritoneum, and it may be well to consider here more systematically what paths the infective material follows in passing from the primary tumour to the seat of the secondary growths.

THE SECONDARY GROWTHS IN THE LIVER, in the case of cancers of the organs mentioned, form in connection with the portal vessels, and there is no doubt that the material is brought to the liver through the portal vein from its radicles. But the question remains, how does the cancerous material find its way into the radicles of the portal vein? We know that, as a rule, in external cancers the secondary tumours occur uniformly in the lymphatic glands, and it is only after these have been long involved that the cancerous material reaches the blood. We have to inquire whether the alimentary canal is in this regard placed in any different position to external organs or whether any other explanation may be practicable.

For one thing, we find in almost all cases of cancer of the stomach the lymphatic glands near it involved. They are the seat of cancerous growth, although perhaps not very large. This raises the question whether,

after all, the real course of events in the abdomen is not, first, metastasis to the lymphatic glands and then from the glands into the radicles of the portal vein. In that case the formation of tumours in the liver would be an occurrence comparable to the generalization of external cancers, where the blood becomes the vehicle of infection and tumours spring up all over the body, the material being carried by the systemic arteries. The tumours in the lymphatic glands would thus be the secondary and those in the liver really tertiary.

Supposing this view to be correct, then it follows that if a cancer of the stomach or intestine causes secondary growths in lymphatic glands whose veins are not radicles of the portal, the tumours of the tertiary order would not be in the liver but in the lungs, or beyond the lungs, in organs fed by the systemic arteries.

The author met with a case of cancer of the stomach in which, instead of the glands immediately outside its wall as is usually the case, the pre-vertebral glands were enlarged and cancerous. One of these was adherent to the wall of the inferior vena cava, and on opening this vein a little white thrombus was seen peeping out of a small branch which emerged from the enlarged gland into the vein. There were cancerous thrombi in other veins within these glands, and on microscopic examination it was found that the cancerous tissue in the glands had largely broken up the veins, and epithelial cells were found in them along with the blood. In this case there were innumerable cancerous embolisms in the lungs. Fig. 235, p. 562, shows a section of the lung with two arteries completely occluded with solid material, and with a high power cancer cells could be seen in these vessels. As shown in the figure, and the one following it, there were outside the arteries well-formed epithelial processes apparently inside the lymphatic spaces.

This case would seem to indicate that cancers in lymphatic glands may, by breaking up the gland, penetrate into the venous radicles in the gland, and so pass into the general circulation. It seems a legitimate inference from this exceptional case that when the liver becomes involved in cancer of the alimentary canal, it does so by the portal blood becoming infected through the lymphatic glands.

There remains one possible difficulty in the way of accepting this view. In external cancers it is exceptional for the general circulation to become infected. The disease generally ends by infecting the lymphatic glands, whereas in cancers of the abdominal organs the liver is affected in a large proportion of the cases. But this difficulty also is hardly insurmountable. A person with a cancer of the mamma, let us

say, very commonly dies from the ulceration of the primary or secondary growth, or of both. The lymphatic glands of the axilla being situated externally, are liable to ulceration, and the patient usually dies before the infection has reached the general circulation. In the case of abdominal cancers, however, the organs themselves, and especially the lymphatic glands, are protected by their position, and the cancers are not so apt to interfere with the general health as external cancers are. If the history of even an extensively ulcerating cancer of the stomach be compared with that of a cancer of the mamma, the difference will be very apparent. If the cancer of the stomach does not produce vomiting or stricture of the pylorus, there may be for a long period very little disturbance of the general health, and little more than symptoms of dyspepsia. It seems probable, from the history of some cases, that a cancer of the stomach may go on for many years without causing death. The abdominal lymphatic glands are still more protected. They practically never ulcerate, and in relation to direct injury to health cancer in them is of little account.

It seems probable, then, that in cases where the liver is affected the disease is of much longer duration in its primary seat than is often suspected. Cases of multiple cancer of the liver are often examined after death, in which no suspicion has existed during life of the existence of a primary tumour in the stomach, and this tumour may possibly have been going on for a period whose duration cannot in any way be gathered.

It is not to be inferred that the portal blood is infected only in the way indicated. It is possible that a cancer may make its way through the walls of the veins directly, just as an external cancer sometimes penetrates a vein.

We have now to consider the case of CANCEROUS INFECTION OF THE PERITONEUM by extension of cancer from the abdominal organs. The seat of the cancer may be any of the abdominal organs; the peritoneum becomes infected when the cancerous material finds its way into the cavity.

There are some cancers which have comparatively little tendency to extend along the lymphatics to the glands, but prefer to insinuate themselves among neighbouring structures, and advance by continuity of tissue. This applies especially to colloid cancer, which often grows through the wall of the stomach or intestine, while the glands are hardly at all affected. We can understand that a cancer with such

a rigid stroma as this form has, and with cells which so readily swell up and become transformed, will not readily allow of transportation of its elements. But this form of cancer very readily, after growing through the wall of the stomach or intestine, infects the peritoneum, and there is no form of cancer which, in such a large proportion of cases, produces secondary tumours there.

The cancers of the ovary being already very close to the peritoneum, readily produce cancerous infection, and do so in almost every form of cancer. Cancers of the pancreas also frequently have a similar course for the same reason. The ordinary cancers of the alimentary canal more rarely pass through the walls and infect the peritoneum, but they sometimes do. It is besides not uncommon to meet with secondary cancers of the liver which have produced an infection of the peritoneum, some of the tumours of the liver having reached the surface and extended through the capsule.

When the cancerous material gets into the peritoneum it is carried throughout it by the circulating fluid, aided by the movements of the intestine, and secondary cancerous tumours commonly spring up in the most diverse regions (Fig. 262). It is to be remembered that in the

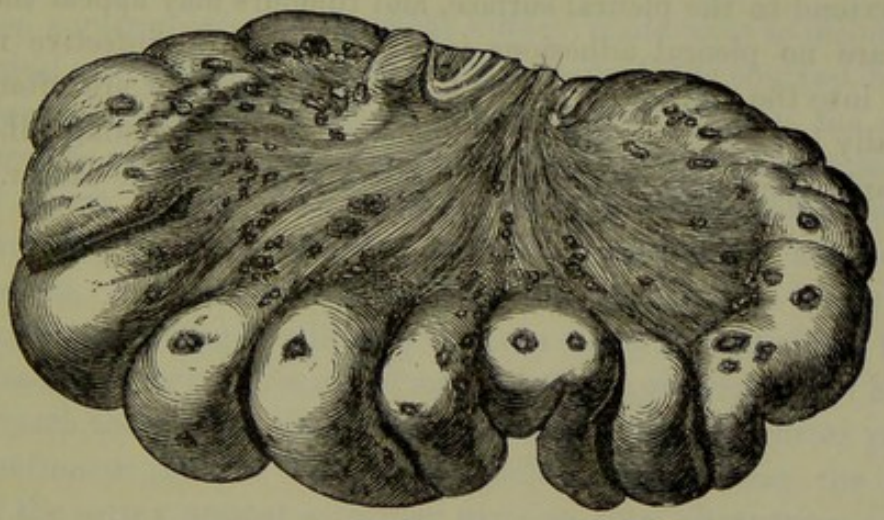


Fig. 262.—Disseminated cancer of the peritoneum, from cancer of the stomach. (VIRCHOW.)

peritoneum there are innumerable open stomata ready to absorb any finely divided solid matter that may be suspended in the peritoneal fluid. The infective material will therefore be carried from the surface into the substance of the peritoneum, or into the subperitoneal tissue, and the resulting tumours may even be subperitoneal. They form usually flat growths with smooth surface, the general surface of the peritoneum being perhaps unbroken. Not infrequently the tumours are continuous

with one another in some parts of the abdominal wall, a layer of cancerous tissue appearing like a subperitoneal thickening.

The GREAT OMENTUM is somewhat peculiarly situated in this regard. We have seen that it probably acts as a kind of drain in the peritoneal cavity, and if this be the case it will specially absorb any material which gets into the cavity. In accordance with this there is usually in cancer of the peritoneum great new-formation in the omentum. In colloid cancer it sometimes assumes the form of a bulky heavy mass, and in other forms we have it gathered up and converted into a solid tumour lying transversely in the abdomen. We may venture the statement that this fact is too little known among physicians, and that a great omentum thus altered is frequently taken during life for an enlargement of the liver, or a primary tumour of some obscure kind.

The relation of peritoneal cancers to THE DIAPHRAGM presents some points of interest. We have seen that the diaphragmatic lymphatics communicate with the peritoneal sac on the one hand, and the pleural sac on the other. In peritoneal cancers the diaphragm is usually permeated with cancerous growths, and these are often in the form of cords as if following the course of the lymphatics. Through time they extend to the pleural surface, and tumours may appear there. If there are no pleural adhesions in this region the infective material passes into the pleural cavity, and numerous tumours are often found, especially in the lower parts of the pleura. A pre-existing adhesion of the diaphragm to the lung prevents this extension of the cancer.

DISEASES OF THE URINARY ORGANS.

A.—THE KIDNEYS AND URETERS.

NORMAL STRUCTURE AND FUNCTION.—In studying the diseases of the kidneys, it is necessary to bear constantly in mind the general facts as to their structure, otherwise the examination of the organs will lead to confusion. The functions of the kidney must also be understood in their outlines in order to a comprehension of the changes wrought by disease.

When a microscopic section of the kidney, made so as to include both the cortical and pyramidal substance, is examined, the contrast between these two regions is sufficiently striking in respect that in the cortical substance the uriniferous tubules have a markedly irregular and convoluted course. If attention be now confined to the cortex alone, as in the figure 263, it will be seen that convoluted tubules are not the only kind present. There are straight tubules prolonged up from the pyramids in the form of tapering bundles (*a*) between which lie convoluted tubules (*b*). These tapering bundles, called medullary rays, or pyramids of Ferrein, do not reach the surface, the most superficial part of the cortex presenting a continuous layer of convoluted tubules. In this way the deeper parts of the cortex present a regular division into alternating areas of straight tubules or medullary rays, and convoluted tubules.

Among the convoluted tubules lie the Malpighian capsules (*e* in figure). These occur somewhat frequently, and at tolerably regular intervals.

In addition to these arrangements of the tubules, the blood-vessels must receive attention. The larger arteries, as shown (*d* in figure), run between pyramids and cortex, and send up stems given off at right angles into the cortex. These pass at intervals into the region of

convoluted tubules, and as they ascend they give off lateral branches to the Malpighian tufts. It will thus appear that the areas of convoluted

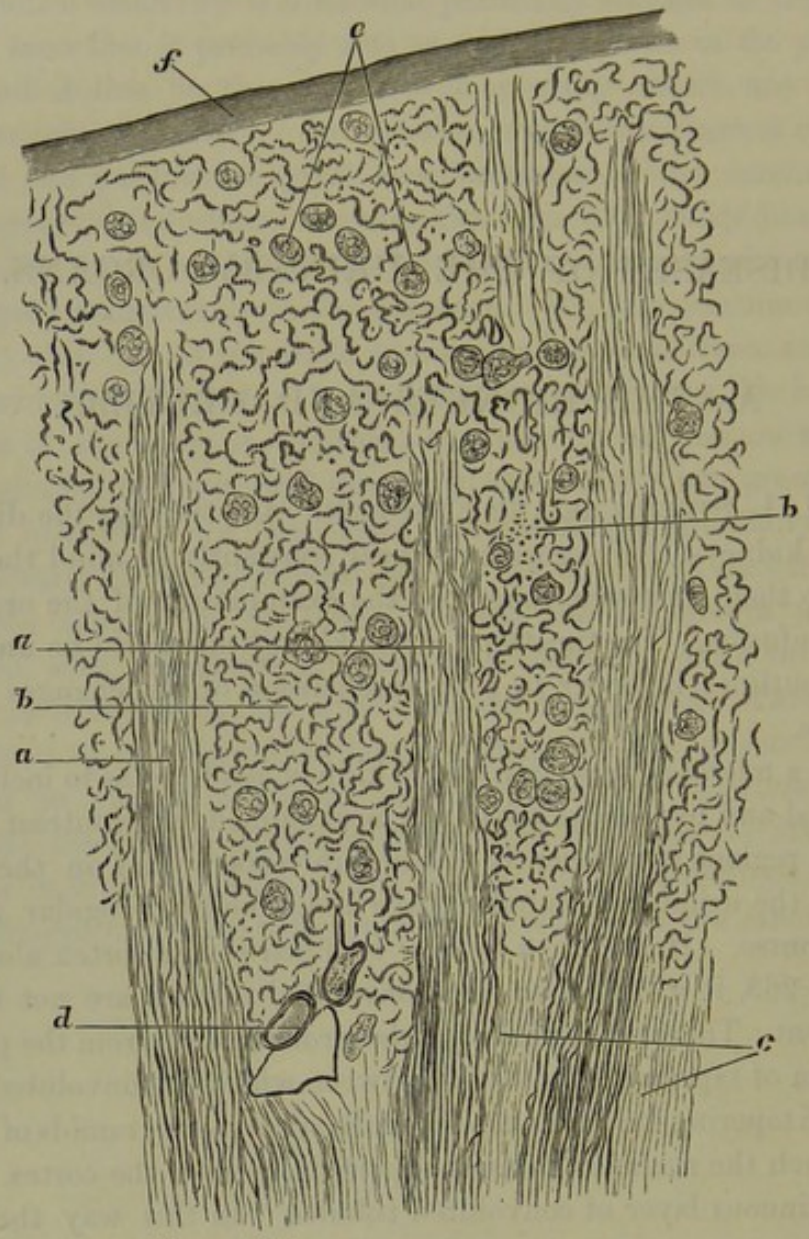


Fig. 263.—Section of normal kidney including cortex and base of pyramid with a very low magnifying power. *a*, medullary rays; *b*, convoluted tubules; *c*, region of arteriæ rectæ in pyramids; *d*, larger vessels running between pyramid and cortex; *e*, Malpighian tufts; *f*, capsule. × 12.

tubules are also the areas of the ascending arteries (which are also called interlobular arteries) and Malpighian tufts. In the Malpighian capsule the afferent vessel breaks up into a congeries of capillary vessels, called the tuft. These gather together to form the efferent vessel, which again breaks up into capillaries which surround the tubules with a rich network.

We have seen that the large arteries which run between the pyramids and the cortex give off the ascending or interlobular arteries to the cortex. They also give off arterial branches downwards to the pyramids. These arteries break up into bunches of straight arterioles (arteriæ rectæ, *c* in figure) which are increased by branches coming down from the afferent vessels in the deeper parts of the cortex. These bunches of arterioles taper as they pass down the pyramids so that they form small pyramids with their bases towards the cortex. They correspond in position with the areas of convoluted tubules, which areas they, as it were, prolong down into the pyramids.

In the normal kidney all these arrangements are very regular, and as in disease there is apt to be dislocation of the various structures in a high degree, it is important to become familiar with the normal appearances. Even with the naked eye the various regions indicated above may usually be made out to some extent in the normal kidney. There is first the distinction of pyramids and cortex, and, normally, the bases of the pyramids are strictly demarcated from the cortical substance. Then a more careful examination brings out in the cortex the medullary rays, as prolongations upwards of the pyramids. Alternating with these are the more irregular areas of convoluted tubules in which the Malpighian tufts may be visible as red dots. Then in the pyramids we may notice that as we follow the medullary rays downwards there are, alternating with them, red streaks which represent the bunches of arteriæ rectæ.

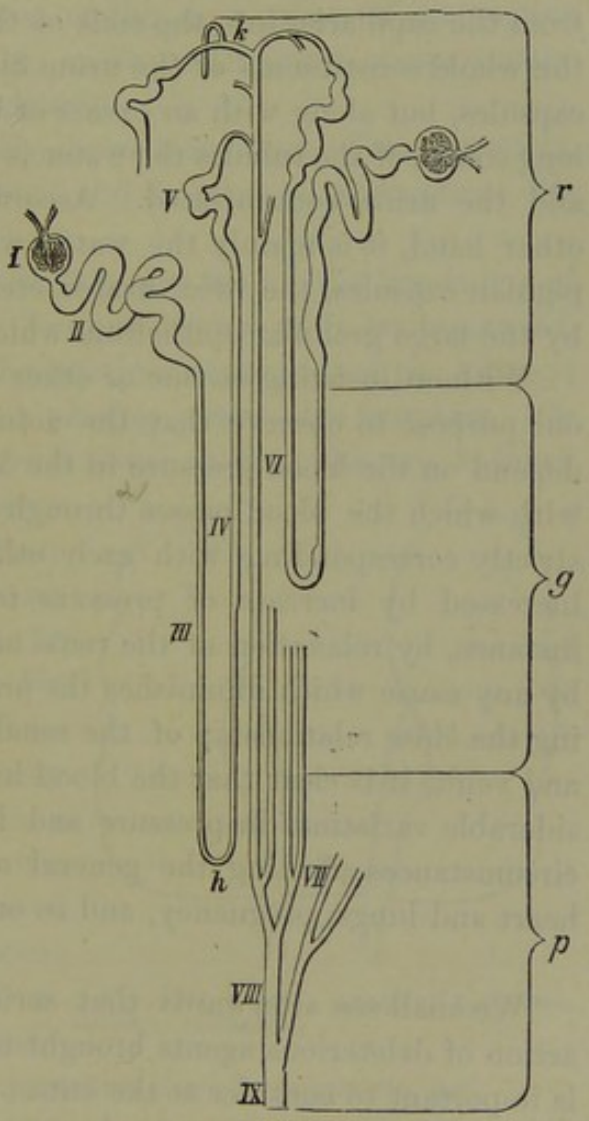


Fig. 264.—Diagram of course of uriniferous tubules from Malpighian capsule (I) to pyramid (IX). See text. (QUAIN.)

In studying the function of the kidney we have to remember in the first place the course of each uriniferous tubule, which may be followed

in the annexed diagram. It begins in the Malpighian capsule (I). Issuing thence the tubule becomes convoluted (II), and then it dips down in a long loop (Henle's loop) whose bend (*h*) is usually in the pyramidal portion. Turning upwards (IV) the loop comes back to the cortex, again becomes convoluted (V), and then opens, sometimes at an acute angle, into a straight tubule (VI) which passes directly downwards joined by other tubules (VII) till it opens at the apex of the pyramid (IX) into one of the calyces.

So far as the water of the urine is concerned, it is generally agreed that it passes from the blood at the Malpighian tufts ; it filters, in fact, from the capillaries into the ends of the tubules. According to Ludwig, the whole constituents of the urine filter through into the Malpighian capsules, but along with an excess of water. In travelling through the long course of the tubules the water is to a considerable extent absorbed, and the urine concentrated. According to Bowman's views, on the other hand, it is mainly the water which passes through at the Malpighian capsules, the urea, urates, etc., being secreted from the blood by the large granular epithelium which lines the convoluted tubules.

Without insisting on one or other of these views, it is important for our purpose to observe that the actual amount of urine secreted will depend on the blood-pressure in the Malpighian vessels, or on the speed with which the blood passes through the vessels, these two, as a rule, strictly corresponding with each other. The amount secreted will be increased by increase of pressure in the Malpighian vessels, as, for instance, by relaxation of the renal arteries, and it will be diminished by any cause which diminishes the pressure in these vessels. Considering the close relationship of the renal vessels to the systemic arteries and veins, it is clear that the blood in the former will be liable to considerable variations in pressure and in the speed of the current from circumstances affecting the general circulation, such as disease of the heart and lungs, pregnancy, and so on.

We shall see afterwards that serious results may follow from the action of deleterious agents brought to the kidneys by the blood, and it is important to consider at the outset how lesions brought about in this way will be distributed. In the first place, such diseases will probably affect both kidneys at the same time. But, further, considering that it is in the cortical portion of the kidney that the secretion of the urine takes place, it is not remarkable that these lesions occur mainly in connection with the Malpighian tufts and the convoluted tubules of the cortex.

MALFORMATIONS AND MISPLACEMENTS OF THE KIDNEY.

CONGENITAL MALFORMATIONS.—These are frequently such as to present comparatively little interference with the function of the organs. This does not apply to the extreme cases where both organs are absent or extremely small, but as this only occurs with serious malformations of the fœtus as a whole, the child does not survive.

DEFECT OF ONE KIDNEY is not infrequently met with in well-formed adults without any of the signs of disease of the kidneys. It is mostly the left kidney that is defective, and it may be entirely absent, its vessels and a diminutive ureter ending in a piece of connective tissue. The other kidney in these cases undergoes a compensatory hypertrophy, as we shall see immediately.

The kidney also not infrequently shows some trace of the ORIGINAL LOBULATION which exists in the fœtus and is retained throughout life in some animals.

COALESCENCE OF THE TWO KIDNEYS across the middle line is one of the most frequent malformations. Various degrees of it are presented. It may be a simple elongation of the inferior extremities of the kidneys which are united by a fibrous band passing across the vertebræ. Or there may be a proper isthmus of renal tissue uniting the two kidneys into one and forming the well-known HORSE-SHOE KIDNEY (Fig. 265). From this we have various grades on to complete coalescence of the kidneys into an elongated or square body across the vertebræ. In almost every case there are the regular two ureters or they may even be increased in number, and they pass down in front of the isthmus. This form of kidney is often depressed in position, even coming as low in some cases as the hollow of the sacrum. When depressed the arteries usually have abnormal origins, as from the common iliac, hypogastric, etc.

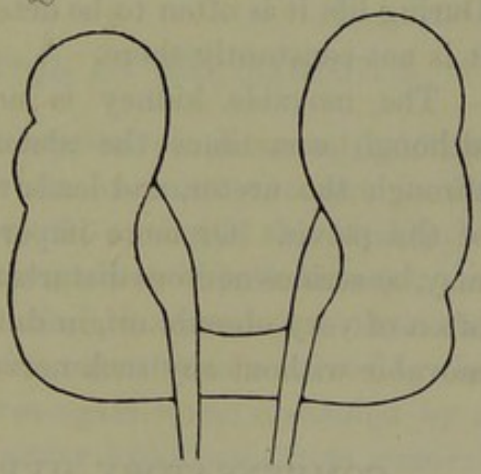


Fig. 265.—Outline sketch of horse-shoe kidney. (ROBERTS.)

VARIATIONS OF POSITION.—These may be congenital or acquired. In the former case and in some of the latter the kidney is fixed in its unusual situation. In congenital malposition it is generally the left kidney which is concerned. It may be depressed so as to lie as low as

the brim or even the cavity of the pelvis. It is not infrequently seated opposite the sacro-iliac synchondrosis. Such kidneys have usually the hilus presenting forward and are flattened, while their vessels are branches of the lower end of the aorta and the iliac veins or even entirely the iliac vessels. The kidney may also lie nearer the middle line than normal or in the middle line.

The malposition may be acquired by the pressure of tumours or of the liver, by the dragging of a hernial sac, and so on. In a case observed by the author the kidney was fixed near the middle line, apparently on account of the abnormal shortness of the renal vein.

Of great interest here is the MOVABLE or FLOATING KIDNEY. In connection with the etiology of this condition it is very important to remember that it occurs in the great majority of cases in females (according to Roberts in forty-six out of fifty-one cases) and mostly on the right side. This connects the lesion with the displacement and malformation of the liver caused by wearing stays, and perhaps also with the displacements of the organs generally, incident to the rise of the uterus in pregnancy. In the case of the movable kidney the organ is so loosely bound down by the peritoneum that it can pass forward out of its position, carrying the peritoneum before it till it lies at the edge of the liver. It is said in some cases to possess a kind of mesentery. During life it is often to be detected at the border of the liver, although it is not constantly there.

The movable kidney is not very liable to secondary changes, although sometimes the abnormal position interferes with the flow through the ureter, and leads to hydronephrosis, or even inflammation of the pelvis. Of more importance is the fact that by dragging there may be serious nervous disturbances, in the form of excruciating cramps, often of very obscure origin during life. The kidney may, however, be movable without any such nervous symptoms presenting themselves.

COMPENSATORY HYPERTROPHY OF THE KIDNEY.

This condition develops sometimes when one kidney is lost or congenitally defective. In the case of congenital absence of one kidney the other will be found homogeneously enlarged, and probably weighing nearly the same as the two normal kidneys together. The different regions of the kidney bear the same relations to each other, each being enlarged in its due proportion. The function of the kidneys is also completely carried out by the single one.

It has been determined by experiments in animals that compensatory hypertrophy develops after excision in full-grown animals, although it is more complete when the operation is done in the new-born. It is remarkable how soon after such excision complete restoration of the renal functions occurs, the secretion of urea reaching its normal in one case about two days after the operation, and the animals remaining from the first apparently unaffected in health. This would indicate that the kidney does not, like a gland, secrete the urinary constituents, but that these come to it preformed and are simply excreted by it.

Measurements have been made of the structures in the kidney to determine whether there is in compensatory hypertrophy an actual new-formation of glomeruli and tubules or merely an enlargement of these. The results are by no means conclusive, and some observers hold to one view and some to the other. Gudden, on the basis of observations in which he excised one kidney in new-born rabbits and examined the remaining hypertrophied one when the animals were full grown, concludes that there is no actual new-formation of glomeruli, but a simple enlargement of them. In relation to what follows it may here be noted that hypertrophy of the heart does not usually follow extirpation of one kidney.

DISORDERS OF THE CIRCULATION IN THE KIDNEYS.

Active Hyperæmia is caused by dilatation of the renal arteries. This may be from traumatic injury to the vaso-motor centre in the medulla oblongata. In a case observed by the author of this kind there was the most intense hyperæmia with enlargement of both kidneys, the injection affecting all the vessels. During the few hours that the patient survived large quantities of urine were twice removed by the catheter, and after death the bladder was again found distended by a watery urine. Again, we may have an active hyperæmia from removal of pressure, as after excision of large tumours from the abdomen or the removal of ascitic fluid, or even the removal of pleuritic fluid. Under these circumstances there is often for a day or two excessive secretion of urine lasting till the renal vessels resume their normal state of contraction.

The hyperæmia which follows on the administration of certain poisons, such as cantharides, arsenic, and carbolic acid, is to be regarded as really inflammatory.

Passive Hyperæmia results from obstruction to the venous circulation, and is most frequently met with in valvular disease of the heart and in diseases of the lungs in which the circulation is seriously interrupted, as in severe emphysema.

The naked-eye appearances of the kidney are usually very suggestive of overfilling of the vessels. There is a general redness, but this is generally most manifest in the pyramids where the arteriæ rectæ often show very special dilatation indicated by exaggeration of the red streaks which pass from the bases of the pyramids in the direction of the apices. The Malpighian tufts are also visible in the cortex as small red spots.

When hyperæmia has subsisted for a considerable time as in so many cases of heart disease, a more definite change occurs in the kidney. The connective tissue here, as in other organs (see passive congestion of the heart, p. 315), becomes hypertrophied, and the organ assumes a distinct increase in density. The organ, while harder to the feel, is sometimes slightly enlarged, and the capsule can be peeled from the surface even more easily than normal. Sometimes there is fatty degeneration of the epithelium, and this may result in collapse of some of the tubules, leading to slight depressions of the surface.

Under the microscope, the kidney shows overfilling of the vessels, the epithelium presenting little alteration, at most some fatty degeneration. The hypertrophy of the connective tissue is not accompanied by any considerable formation of round cells; it is simply seen that the interstitial tissue is more prominent and perhaps more definitely fibrous than normal.

Thrombosis of the renal veins is sometimes a result of passive hyperæmia, but it usually occurs just before death and when the patient is very much debilitated.

Embolism of the kidney has been already referred to with some degree of fulness (see p. 38). Remembering that the renal arteries are strictly end-arteries, it will be understood that when an artery is obstructed the infarction always occurs. The arteries of the kidney being distributed primarily to the cortex, the infarction is more or less wedge-shaped (Fig. 266), with the base of the wedge at the surface. If the wedge be of larger size it will extend also into the pyramids.

As a rule the infarction is of a pale colour and of dense consistence, the tissue having undergone coagulation necrosis. In some cases, and

especially in small infarctions, hæmorrhage occurs, and we may have the regular hæmorrhagic infarction, or a partial red colouration. Around the infarction, whether red or pale, there is commonly a zone of hyperæmia.

As already seen, the infarction gradually undergoes absorption, and is replaced by a cicatrix. In this way deep depressions of the kidney may occur, and if there are several of them the kidney may assume a lobed appearance. In cases of old mitral or aortic disease it is very common to find deep cicatrices, indicating that probably at the time of acute endocarditis, embolism of the kidney had occurred.

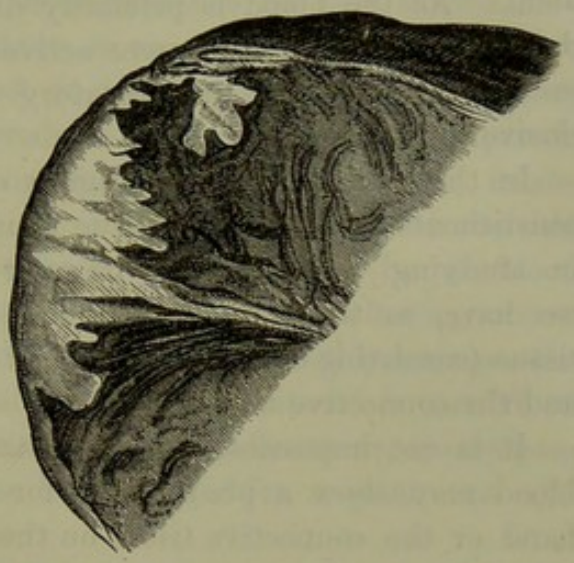


Fig. 266.—Embolic infarction of kidney. The white appearance and wedge shape of the infarction is represented. (After RAYER.)

The kidney is not infrequently the seat of SEPTIC EMBOLISM in pyæmia, ulcerative endocarditis, etc. The result is the formation of miliary abscesses, which will come up for consideration hereafter.

BRIGHT'S DISEASE, OR NEPHRITIS.

This is a subject of great complexity and difficulty, and one concerning many points in which differences of opinion exist.

GENERAL CONSIDERATIONS.—At the outset it may be said that we include here cases in which there are undoubted inflammatory manifestations in the kidneys, but we exclude those in which there are no such manifestations present. The domain of Bright's disease, therefore, is not coextensive with that of albuminuria, as the latter may include such conditions as amyloid degeneration and passive hyperæmia.

In studying the CAUSES of Bright's disease, we have to look for an irritant, and it is here important to observe in the first place that the inflammatory manifestations occur in both kidneys, and although, on examining the kidneys in detail, these manifestations will be found to present themselves in innumerable minute foci, and to confine themselves for the most part to the cortex, yet they do not affect a few definite areas, but are diffused over the length and breadth of the

organ. These facts indicate that the irritant is carried to the kidneys by the blood, and is distributed with the blood homogeneously over them. As the blood is primarily distributed to the cortex, and as the cortex contains the more active secreting tissue of the organ, it so happens that the inflammatory manifestations occur almost exclusively there.

In the various cases of Bright's disease we do not find the various constituents of the kidney tissue equally engaged, and it is necessary, in studying the causation, to refer to this matter. In the kidney we have, as the main constituents, the blood-vessels, the secreting tissue (consisting of the glomeruli and the tubules with their epithelium), and the connective tissue.

It is not impossible that an irritant brought to the kidneys by the blood may show a predilection for the renal epithelium on the one hand or the connective tissue on the other. But it seems more likely that in the majority of cases it will act on both at the same time. We have already had several opportunities of observing that chronic inflammations very commonly produce inflammatory new-formation in the connective tissue, and the kidney forms no exception in this respect. It may be said, therefore, that for the most part irritants which act through a long period and with little intensity produce a chronic inflammation mainly of the connective tissue. On the other hand, irritants which act intensely so as to produce acute inflammation, while they produce the usual changes in the blood-vessels which we have seen to occur in acute inflammations, affect mainly the epithelium of the uriniferous tubules. It may therefore be said that acute inflammations are mostly PARENCHYMATOUS, while chronic inflammations are mostly INTERSTITIAL.

This distinction, however, cannot be rigidly carried out. There are some acute inflammations which affect the interstitial connective tissue even more than the secreting epithelium, and in all acute inflammations which are somewhat prolonged the connective tissue is involved. On the other hand, inflammations which begin acutely frequently become chronic or sub-acute, and in them, while the epithelium continues to show marked changes, the interstitial tissue always shows distinct inflammatory proliferation.

After these observations, we are now in a position to consider what may be the nature of the irritants which produce Bright's disease. In the first place, as to ACUTE NEPHRITIS, a very common cause, and indeed in children the commonest, is the specific poison of SCARLET

FEVER. It may also be produced by the poison of measles and other specific febrile diseases. In adults the disease is mostly ascribed to COLD, and we have to consider how exposure to cold should give rise to an irritant of such a nature as to cause acute inflammation of the kidneys. It is of interest in this regard that, as Dickinson so well points out, cold mostly produces these effects when the person is exhausted or asleep, and when the exposure has occurred immediately after profuse perspiration. It is as if, the functions of the skin being suspended, some deleterious material accumulated in the blood and irritated the kidneys. It appears that nephritis hardly occurs in persons exposed to cold in the arctic regions, probably because, the respiration being more vigorous, the deleterious material is carried off by way of the lungs. In warm climates also nephritis is uncommon, probably because the body is less liable to sudden exposure to cold than in temperate regions.

Turning to the causes of CHRONIC NEPHRITIS, it sometimes remains after an acute attack. For the most part, however, when the disease begins as acute nephritis it remains subacute with repeated exacerbations, and the anatomical condition is a combination of that seen in acute Bright's disease and chronic, or, in other words, of parenchymatous and interstitial nephritis. Sometimes, however, the disease, even after scarlet fever, becomes definitely chronic, and the anatomical features are those of interstitial nephritis, although the changes in the tubules may still be such as to suggest an earlier, mainly parenchymatous, inflammation.

On the other hand, in a large proportion of cases, the disease is chronic from the outset, and is to be ascribed to a cause which has been acting with slight intensity for a long period. Of all these causes the most definitely determined is GOUT. The pathology of this disease is not very apparent, but there is an obvious alteration in the blood in consequence of which salts of uric acid are deposited in certain joints, generally with signs of acute inflammation. The same condition of the blood frequently induces chronic nephritis, and it is remarkable that when it attacks the kidneys it is less likely to affect the joints, and vice versa. Among the working classes gout largely arises from chronic LEAD-POISONING (see statistics in Dickinson's work on Albuminuria), and in these cases the disease is particularly liable to attack the kidney, so much so that a large proportion of painters and others who work with lead die of chronic nephritis. Where the gout is due to the constant use of alcohol the disease is more liable to attack the joints.

Chronic nephritis is also sometimes induced by the poison of SYPHILIS. In this case it is apt to be associated with amyloid disease, but may also occur as a simple inflammation.

PREGNANCY not infrequently leads to a chronic nephritis, in all probability by obstructing the vessels of the kidney by the pressure of the uterus. In recent cases there is extreme hyperæmia of the kidney, which, with repetition of the cause, may go on to assume the regular characters of chronic nephritis.

Lastly, there are cases in which there is no special cause apparent, and we can only say that the person has been exposed to some influence whose nature we do not know. In many cases the disease has been very prolonged, and all through, the actual active disease at any particular time has been very slight. With this very insidious march, there may be the most serious permanent changes in the kidneys before any prominent symptoms have called attention to these organs. Among the causes which are sometimes mentioned, it is proper to refer to prolonged mental disturbance. It is not impossible that the deterioration of the body, and the defective condition of the alimentary functions in such cases, may render the kidneys peculiarly liable to chronic inflammation.

THE ANATOMICAL AND HISTOLOGICAL CONDITIONS IN BRIGHT'S DISEASE.—We shall consider these changes under three heads, namely, inflammation mainly affecting the Malpighian bodies, or GLOMERULO-NEPHRITIS, that in which the tubules are chiefly concerned, PARENCHYMATOUS NEPHRITIS, and that which affects chiefly the connective tissue, INTERSTITIAL NEPHRITIS. We have already seen that no absolute line of distinction can be drawn between these, and especially that when parenchymatous nephritis becomes chronic, the interstitial tissue is more and more involved.

The term GLOMERULO-NEPHRITIS has been applied by Klebs to a condition in which the Malpighian tufts show the chief signs of inflammation. This he describes as being present in the kidneys of persons who have had scarlatina, and have died in consequence of the post-scarlatinal nephritis.

It seems strange that the actual pathological condition in the nephritis of scarlatina has been so little determined till of late years. It has been customary to state that the condition is a parenchymatous nephritis. Recent observations, however, have shown that in the

earliest stage of scarlatinal nephritis there is an accumulation of round cells in the glomeruli and connective tissue around. This observation, originally brought into prominence by Klebs, has been confirmed by the author, Klein, Charcot, and others, and may now be generally accepted.

Looking on scarlatinal nephritis as a typical acute inflammation of the kidney, we are not surprised to find that the occurrence of leucocytes in the Malpighian tufts is the most prominent appearance at the outset, and it is this condition apparently which is specially designated glomerulo-nephritis. The exudation is not usually confined to the glomeruli, but exists around them, and may extend to the general connective tissue. In the case of the author in which the patient died on the ninth day from the outset of the fever, there was an enormous infiltration of the interstitial tissue, as well as the glomeruli, with leucocytes (Fig. 267). It is stated by Rosenstein that in the nephritis caused artificially in animals by cantharides there is a similar appearance of leucocytes around the glomeruli and elsewhere.

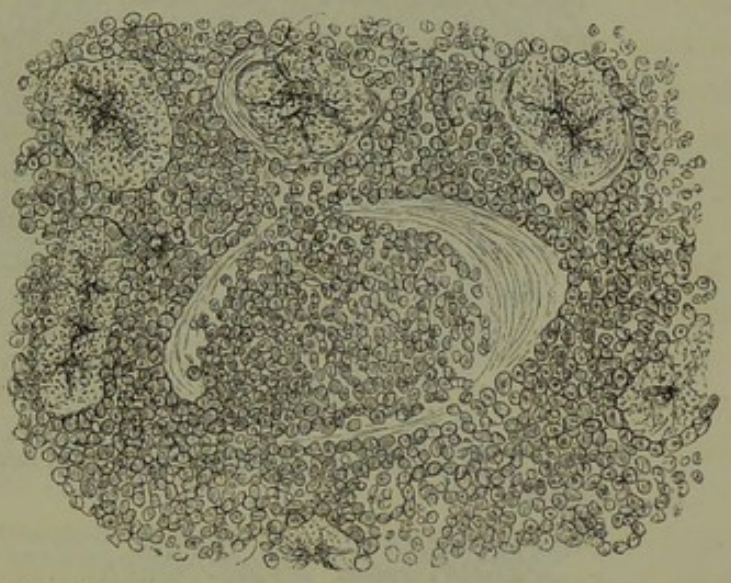


Fig. 267.—Glomerulo-nephritis from a case of scarlet fever. The Malpighian tuft in the middle of the figure is crowded with round cells, which are also present very abundantly in the interstitial substance between the tubules, whose epithelium is granular. × 300.

Besides these changes, there is very commonly in the acute stage of scarlatinal nephritis blood in the uriniferous tubules. The blood is in the convoluted tubules, and it is sometimes seen also inside the glomerulus. In a favourable section an appearance such as that shown in Fig. 268 may be found. There is seen to be blood (*b*) in the glomerulus, between the tuft of vessels (*a*) and the capsule, and there is also blood in a tubule (*c*) which is so related to the glomerulus as to be evidently its prolongation, although the section did not happen to be made so as to show the actual communication.

Sometimes the changes in the kidney do not consist so much of exudation of leucocytes or extravasation of the whole blood, but rather in alterations in the epithelium. In scarlatina the changes in the

epithelium also centre in the glomeruli. The epithelium lining the glomerulus is distinctly enlarged (Fig. 269), and whereas normally this



Fig. 268.—Hæmorrhage from a Malpighian tuft in a case of scarlet fever. *a*, tuft; *b*, blood between tuft and capsule; *c*, blood in uriniferous tubule extending from tuft. × 350.

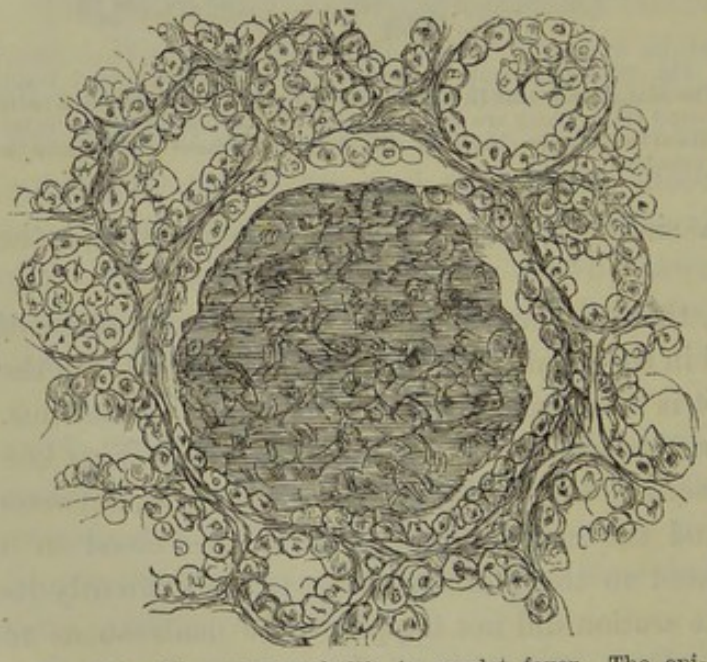


Fig. 269.—Glomerulo-nephritis in scarlet fever. The epithelium lining the capsule is unduly large and abundant. × 350.

epithelium is hardly visible, it may become remarkably prominent, as in the figure. It sometimes increases very greatly, as in Fig. 270, accumulating inside the glomerulus in such a way as to crush the tuft. In the case from which this figure was taken there were many tufts very seriously encroached on by the growing epithelium. Similar changes occur in the epithelium of the tubules, but there is a remarkable concentration of the lesion in that of the glomeruli.

In cases where there is little more than a glomerulo-nephritis, such as we have described above, there are sometimes severe uræmic symptoms leading, rapidly it may be, to death. It is to be remembered in this connection that the urine is secreted essentially by the glomeruli, and if in many of these the vessels are suddenly obstructed by the pressure of leucocytes as in Fig. 267, or of epithelium as in Fig. 270, or



Fig. 270.—Glomerulo-nephritis in scarlet fever. The epithelium lining the capsule is greatly increased so as to crush the tuft. × 350.

even by blood inside the capsule, then the secretion of urine may be much reduced. Under these circumstances suppression of urine and uræmia are not very extraordinary occurrences.

The kidneys in these cases may be very little changed to the naked eye; they are sometimes enlarged with considerable injection of the vessels. The glomeruli may be visible as red points, and there may be on the surface and on section red streaks and spots, indicating the intratubular hæmorrhage. Sometimes, on the other hand, the exudation of leucocytes may be sufficient to produce great enlargement, and the kidney (as in the author's case, from which Fig. 267 is taken) has all the appearance of the large white kidney.

PARENCHYMATOUS NEPHRITIS is characterized by the occurrence of changes in the renal epithelium. From what has been already stated it will be understood that these changes hardly ever occur without coincident signs of inflammation in the interstitial connective tissue.

The changes consist in the first place mainly in cloudy swelling of

the epithelium, with a tendency for the cells to become loosened and to discharge. The tubules are often found greatly distended, and as if choked with desquamated epithelium. Fatty degeneration occurs in the epithelium, and is often present in a high degree, not uniformly, but usually in a considerable stretch of tubule at a time. In the tubules, besides desquamated and frequently fatty epithelium, there may be blood, in the form of brown granular matter or fresh red blood. Tube casts are also to be found, often in great abundance. The tube casts lie in the calibre of the tubules as transparent hyaline cylinders, and they may be traced for a considerable distance. The changes in the epithelium are almost entirely confined to the convoluted tubules of the cortex, although the disintegrated epithelium may be carried downwards into the loops of Henle and the straight tubules. The tube casts are found in the straight tubules as well as in the convoluted.

The kidney as a whole is considerably enlarged, and it may reach twice its normal weight. The blood-vessels are intensely injected, so that the surface presents a red colour after removal of the capsule, which comes off easily. On section the cut surface is also seen to be red, and blood flows freely from it; the mucous membrane of the pelvis is injected. If the cut surface be washed so as to remove the blood, it may appear as if the tissue, apart from the blood-vessels, were unduly pale, and there may even be opaque streaks if fatty degeneration is considerable. The enlargement of the organ is seen to be mainly due to increase of the cortex, which may be very much thickened, and it is in the cortex that the paler colour mentioned above appears.

It is not common for death to occur in this exceedingly acute stage, and as the inflammation subsides into a subacute or chronic condition we have developed the LARGE WHITE KIDNEY. It is necessary here to mention that amyloid degeneration produces enlargement and paleness of the kidney, and confusion has no doubt frequently occurred between that condition and the one now under consideration.

In the large white kidney the tubules are still distended with epithelium, which is enlarged and desquamating (Fig. 271). There is here usually considerable fatty degeneration of the epithelium. The epithelium, and debris resulting from its disintegration, are often packed to a considerable extent into the straight tubules. Tube-casts are present usually in large numbers, and present the hyaline appearance already described, or else contain debris of epithelium and fat.

The changes in the tubules are so prominent that they are apt to

obscure the condition of the connective tissue. In every case probably there are round cells in the tissue, and sometimes they are present in

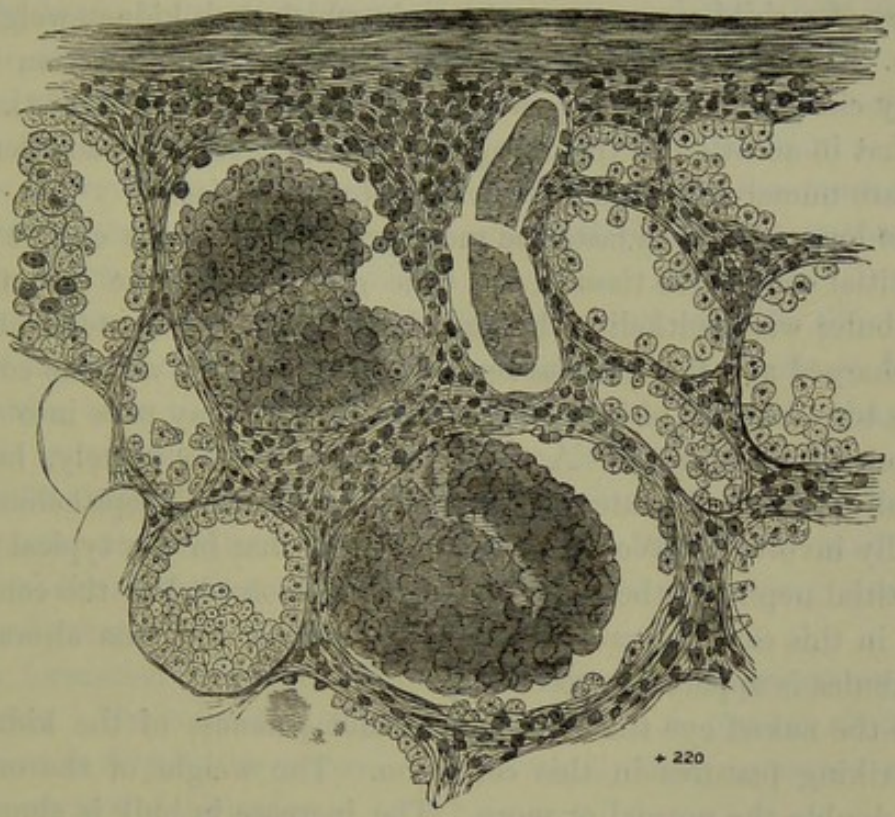


Fig. 271.—Section of large white kidney in a child of seven. The tubules contain irregular epithelium, and are distorted; in one a tube-cast is present. The interstitial tissue is greatly increased and contains abundant round cells. (DICKINSON.)

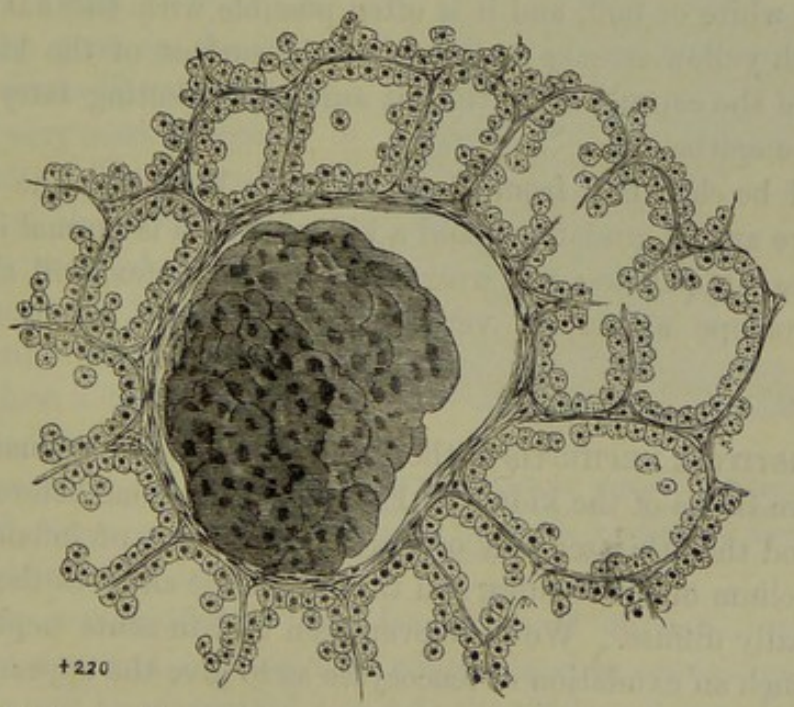


Fig. 272.—Section of normal kidney for comparison with preceding. (DICKINSON.)

great abundance. In the accompanying woodcut (Fig. 271), taken from Dr. Dickinson's work, the condition of the interstitial tissue is shown in the case of a child seven years of age, in which each kidney weighed 4¼ ounces. An illustration of the appearances of a similar section from a healthy child is given along with it for comparison (Fig. 272). It is seen that in addition to the changes in the epithelium already described there are numerous round cells in the interstitial tissue.

The longer the case lasts the more pronounced is the change in the interstitial connective tissue. As time goes on also the distension of the tubules with epithelium becomes less. The disintegrated epithelium is discharged and there is less reproduction. In this way the condition shades towards that of interstitial nephritis, and may pass into that of the contracted kidney. A case which has begun acutely, however, generally even in the later stages presents traces of the epithelium being specially involved. We shall see afterwards that in the typical chronic interstitial nephritis the epithelium is also involved, but the connective tissue in this case is increased to such an extent that the alteration of the tubules is apparently secondary.

To the naked eye the enlargement and paleness of the kidney are the striking features in this condition. The weight of the organs is often double the normal or more. The increase in bulk is almost altogether in the cortex, and its exceedingly pale colour contrasts with that of the pyramids, which are often unduly red. The colour of the cortex is opaque white or buff, and it is often possible with the naked eye to distinguish yellow streaks and spots on the surface of the kidney after removal of the capsule or on the cut surface, indicating fatty degeneration of the epithelium.

It will be clear that from the large white kidney to the contracted form there are all gradations, and a kidney which is normal in size, but which presents paleness and irregularity of the cortex, will show under the microscope already a very marked increase of the connective tissue.

Interstitial nephritis is the name applied to inflammation of the connective tissue of the kidney. From what has gone before it will be understood that this scarcely occurs independently of inflammation of the epithelium of the tubules, and that in almost all cases the inflammation is really diffuse. We have even seen that in acute nephritis there may be such an exudation of leucocytes as to give the appearance of an intense interstitial inflammation.

Even subacute nephritis is sometimes mainly interstitial, that is to say there is a persistence of the exudation of leucocytes which infiltrate the entire connective tissue of the cortex, and find their way also into the uriniferous tubules. In such cases leucocytes appear in the urine in considerable abundance, and they may even be so numerous as to give rise to the supposition that pus is present in the urine.

It is, however, in very chronic cases that we find the most typical interstitial changes, resulting in the so-called GRANULAR CONTRACTED KIDNEY, or CIRRHOSIS of the kidney.

The disease begins with a formation of round cells in the cortical part of the kidney, so that a kind of granulation tissue is formed. These cells, as in the other chronic inflammations, go on to the formation of connective tissue, so that there is a great increase in the interstitial tissue of the organ. This connective tissue tends more and more to assume a fibrous condition, and to contract, so that by its cicatricial shrinking it seriously interferes with the secreting tissue and the blood-vessels.

The formation of round cells does not take place homogeneously in the cortex. There are frequent areas in which it is present alternating with areas in which it is absent. It is usually most apparent at first near the surface of the cortex, and the cells often accumulate specially round the Malpighian glomeruli.

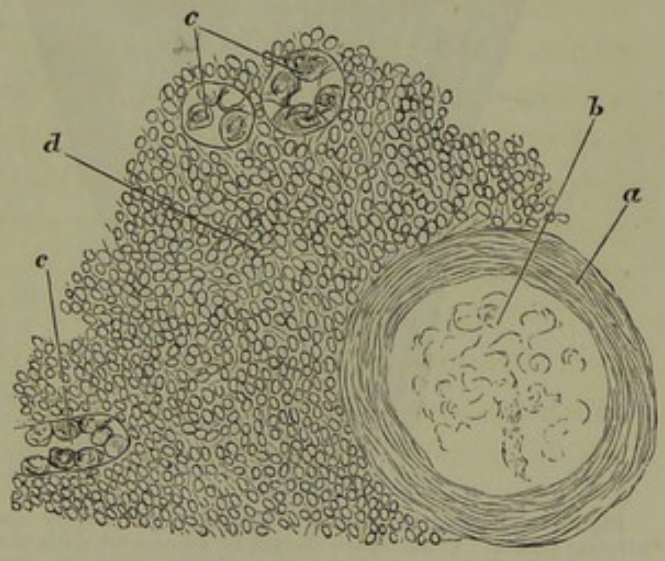


Fig. 273.—Interstitial nephritis. Sclerosis of glomerulus. *a*, thickened capsule; *b*, condensed vessels of tuft; *d*, abundant round cells in interstitial tissue; *c*, dwarfed tubules remaining. × 350.

As time goes on, the increase of dense fibrous tissue produces very marked secondary results. The capsules of many of the GLOMERULI undergo a marked thickening, as shown in Fig. 273 *a*, and the tuft of vessels (*b*) solidifies into a dense homogeneous nodule. In this way the glomerulus is greatly contracted (compare with normal glomerulus in Fig. 272, which is magnified a third less) reduced often to less than half its normal size, and composed of white glancing connective tissue, in which can still be recognized as a rule the thickened capsule presenting

a concentric fibrous arrangement (see figure), and the more homogeneous central part composed of the condensed and impervious vessels. This SCLEROSIS of the tufts is often very striking, as the small glancing bodies attract the eye.

The URINIFEROUS TUBULES undergo still more striking changes. In the midst of the new-formed tissue they are to a great extent destroyed, so that large districts of cellular connective tissue may be found with no tubules at all (*d* in Fig. 273). When they persist in the midst of the new-formed tissue they are greatly atrophied (*c* in figure), and their epithelium is rudimentary in appearance. This great destruction of tubules in conjunction with the contraction of the connective tissue causes the remaining structures to be drawn together, and the altered glomeruli are often crowded together in a very extraordinary way (see Fig. 274).

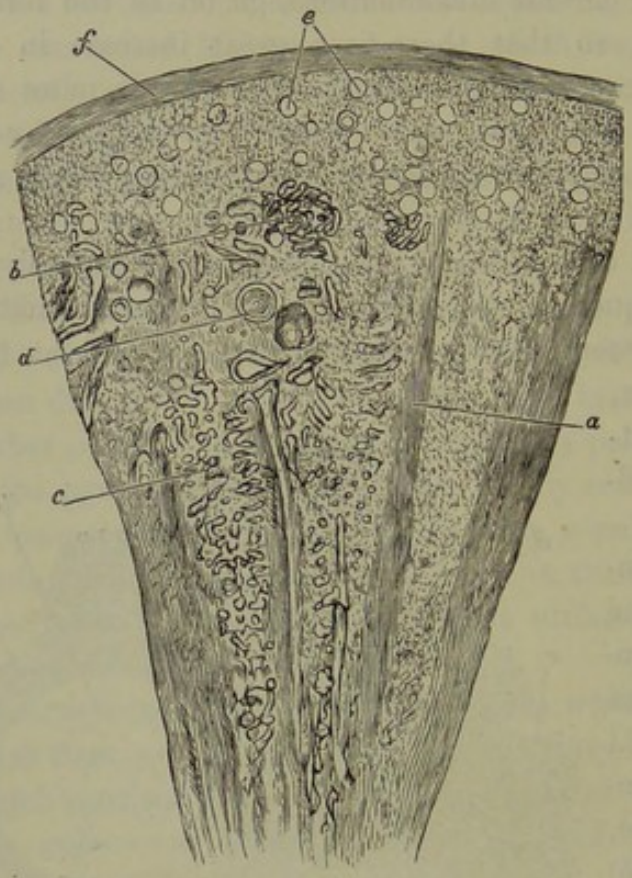


Fig. 274.—Section of contracted kidney with a very low magnifying power. (This figure should be compared with the next, which is similarly magnified.) *a*, medullary rays; *b*, convoluted tubules crushed together and dilated; *c*, region of arteriæ rectæ and loops of Henle, the latter dilated and forming cysts; *d*, large artery between pyramid and cortex, showing endarteritis obliterans; the space between this and surface represents the cortex, and may be compared with similar space in next figure; *e*, glomeruli, closely set and contracted, they also present a white homogeneous appearance; *f*, capsule. × 12.

Where the tubules are not directly destroyed by the contracting tissue, their epithelium presents alterations somewhat similar to those mentioned as characteristic of subacute parenchymatous nephritis. There is accumulation of epithelium and debris, often with great distension and distortion of the tubules (*b* in Fig. 274), and the epithelium frequently presents fatty degeneration. It will thus occur that parts where nothing but the merest traces of tubules are present will alternate with parts where they are greatly distended. As there is a general shrinking of the cortex the distended tubules are

gathered together into folds as if crowded towards the bases of the pyramids.

Cysts form not infrequently in the contracted kidney. There may be some visible to the naked eye, yet in most cases they are to be distinguished mainly by microscopic examination. They are round or oval in shape, and often lie in rows, especially in the pyramidal portion where they probably originate from the loops of Henle (see Fig. 274 *c*).

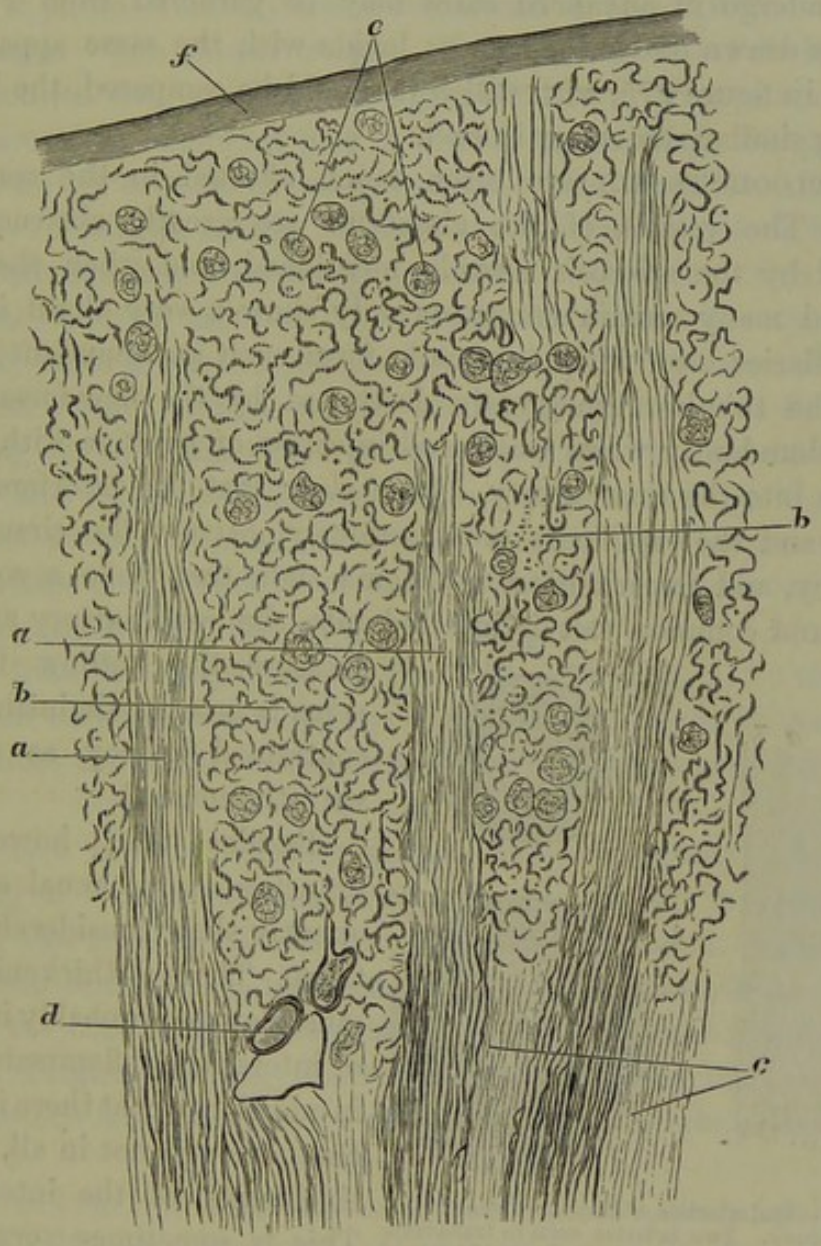


Fig. 275.—Section of normal kidney for comparison with preceding figure. The letters indicate similar regions, and the magnifying power is the same. × 12.

These small cysts are thin-walled and contain clear fluid. They arise by obstruction of the tubules from the contraction of the interstitial

tissue, which constricts them and causes the urine to accumulate and distend the tubules. The glomeruli may give origin to cysts of a similar nature, the fluid accumulating in the capsule and separating the tuft of vessels from the capsule. Cysts in the kidney sometimes contain a colloid material as if from degeneration of the epithelium in the tubules which have been cut off by the constriction of the connective tissue. The great alteration and dislocation which the structures of the kidney undergo in advanced cases may be gathered from Fig. 274, which was drawn under the camera lucida with the same apparatus as that used in figure 275, with which it should be compared, the lettering indicating similar structures in each.

THE BLOOD-VESSELS are often much affected in the contracting kidney. The vessels of the glomeruli are greatly obstructed and destroyed by the sclerosis already mentioned, and when the kidney is injected many remain empty or only show a very slight injection. The capillaries also, which normally form such an abundant network around the tubules, are greatly destroyed by the new-formation, as appears abundantly when a coloured injection of gelatine with carmine is thrown into the renal artery. It is clear that the interference with the tufts and the capillaries must seriously obstruct the circulation in the kidney, and experiments by Thoma show that when a solution of gelatine and common salt is injected into the renal artery at a fixed pressure the outflow from the veins is greatly diminished in the contracted kidney as compared with the normal.

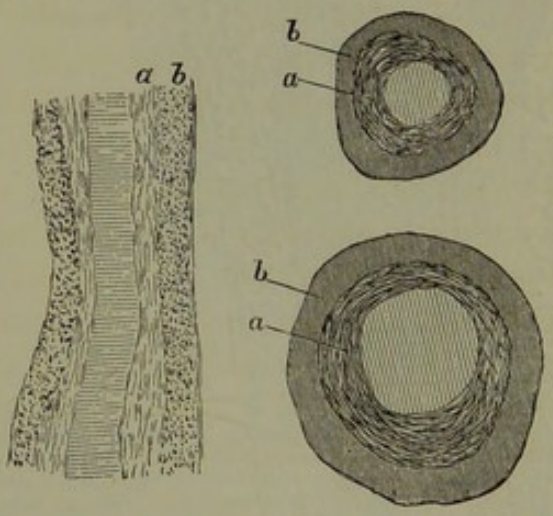


Fig. 276.—Endarteritis obliterans from a contracted kidney. Two arteries seen in transverse section, and one in longitudinal. *a*, thickened and fibrous internal coat; *b*, middle coat. × 350.

Besides this, however, the branches of the renal artery frequently show considerable alterations. There is thickening of the muscular coat probably in all cases of interstitial inflammation. But in addition to that there is, in many cases, though not in all, a marked thickening of the internal coat. This is sometimes very striking, as shown in Fig. 276, almost resulting in obliteration of the smaller arteries (endarteritis obliterans). It would even appear that this endarteritis may be an early lesion in some cases, occurring before the definite onset of the interstitial changes.

We have still to refer to the naked-eye appearances which are to be connected with the minute changes already described. The most definite change is loss of bulk. If the disease has begun with enlargement then the reduction in bulk may only bring the kidney back to the normal size. But in the ordinary chronic cases it is greatly reduced in size, so that it may weigh only 3 ounces or less. The capsule is adherent to the surface, strikingly so in the very chronic cases, so that in attempting to remove it pieces of kidney tissue come with it, and it may be thickened and opaque. The proper surface of the kidney is markedly uneven, being studded with small rounded granulations. The prominent granulations are often somewhat pale in colour, representing the parts where the tubules are to some extent preserved, while the intervening depressions have a reddish colour. Very often the general colour is red with only a pale mottling from the granulations. Cysts are often visible on the surface and on section. On section the cortex is very manifestly changed. It is much less regularly defined from the bases of the pyramids than normal, and the regular markings which we see in the cortex indicating the medullary rays are greatly obscured. Its colour is grey or buff, and its texture is much more dense and tough than normal. It is also greatly thinned, sometimes so that it forms merely a thin rind, perhaps only a twelfth of an inch in thickness between the bases of the pyramids and the surface. The great loss of cortex may be inferred from the comparison of Fig. 274 with Fig. 275; the arteries which run between cortex and pyramids (*c c*) are seen to be very little removed from the surface in the former figure as compared with the latter.

We have now to consider certain very important points in the pathology of Bright's disease, in regard to which it is necessary to bear in mind the anatomical conditions already described. These points are (1) the causation of albuminuria, (2) the formation of tube-casts, and (3) the condition of the heart and other arteries throughout the body in Bright's disease, chiefly in relation to the increased arterial tension which is so important a result of chronic Bright's disease.

ALBUMINURIA is well known to be the most important clinical sign of Bright's disease. By the term is meant escape of albumen from the blood serum along with the urine. It is probable that the albumen undergoes slight modifications in its chemical reactions (Kirk), but its source is undoubtedly the serum albumen. We have to consider under what circumstances albumen makes its escape.

It may perhaps be a necessary preliminary to inquire why it does not make its escape under ordinary circumstances, why the urine is not normally albuminous. We know that the other transudations from the blood contain albumen, and it seems at first sight strange that the urine does not. Some have even supposed that the urine as it is separated from the blood at the glomeruli is normally albuminous, and that in its subsequent passage through the tubules the albumen is absorbed by the epithelium just as the water is taken up and the urine concentrated. But this view is completely opposed to known facts. We have already seen that in chronic Bright's disease there is great destruction of the secreting epithelium, so that the glomeruli are, as it were, more near to the outlets of the tubules than normal; the urine secreted in these cases is very watery, and has, in fact, characters which are presumably those of the urine as it is separated at the glomeruli. But it is exactly in this class of cases that albumen is frequently absent from the urine. Again, in acute Bright's disease the renal epithelium is unduly active, and might be supposed to be peculiarly ready to absorb albumen as nourishment, but it is in these cases in which the quantity of urine is small that albumen is peculiarly apt to be present.

It might be supposed that increased blood-pressure in the vessels of the glomeruli might lead to albuminuria, but this also does not seem to be the case. We shall afterwards see that in chronic nephritis the blood is at an excessive pressure, the excess of urine being partly due to this, but here albumen is frequently absent. Then in active hyperæmia there is increased pressure in the vessels of the glomeruli, but the urine although excessive in quantity contains no albumen.

The occurrence of albumen seems, in fact, definitely related to the structural changes in the kidney. We have seen that the inflammation in its acute form affects the glomeruli primarily, and it is probably because the structure of the glomerulus is altered that the albumen escapes. In this view of it we infer that it is due to the structure of the glomerulus that the albumen does not get through in the normal kidney, and when this structure, especially the epithelium, is tampered with then albumen passes through as in ordinary transudations. It is to be presumed that other causes besides inflammation may interfere with the epithelium of the glomeruli. In acute febrile diseases it may partake in the general parenchymatous degeneration of the organs generally, and so allow of the passage of albumen. In passive hyperæmia also its nutrition will suffer and we may have albuminuria.

TUBE-CASTS.—In cases of Bright's disease these are usually visible in all parts of the tubules, in the convoluted tubules of the cortex, the loops of Henle, and the straight tubules, and they are sometimes present in very large numbers. Those in the convoluted tubules and in the straight tubules of the pyramids are of larger dimensions than in the loops of Henle. For the most part the casts are translucent and homogeneous in appearance, forming HYALINE casts. But there may be epithelium or fatty debris inclosed in them, and so we have EPITHELIAL and FATTY casts. Very frequently, as it lies in the tubule, a cast presents a transverse fracture, as if by shrinking it had parted in the middle.

In regard to the ORIGIN of these casts they are probably for the most part of the nature of fibrinous exudations. They are mostly present in the more acute forms of Bright's disease, and in these forms we have the conditions requisite for the formation of fibrine (see p. 87). The albumen in the urine indicates an exudation of blood-plasma containing fibrinogen, and there are also leucocytes exuded in these acute cases. The coagulation will occur the more readily if the tubules have already lost their epithelium. But, besides this origin, tube-casts may apparently be composed of altered epithelium. Epithelium may be broken down and discharged from the convoluted tubules and impacted into the loops of Henle, where it may form cylinders. The epithelium may also, as we have formerly seen, undergo coagulation necrosis, and even hyaline cylinders may have this origin. It will be observed, however, that such casts are hardly different to the proper fibrinous ones, the fibrinogen has the same source, while the epithelium furnishes the fibrinoplastic substance and ferment instead of the leucocytes.

It is well known that tube-casts are of common occurrence IN THE URINE, being washed out of the tubules. In this connection it is to be remembered that they are composed of a soft plastic substance and will be readily floated along, accommodating themselves to the various bends of the tubules. Looking to the large size of the convoluted tubules as compared with the loops of Henle which immediately succeed them, it has been supposed that tube-casts often become impacted in the latter and cause obstruction to the exit of the urine. It is very doubtful, however, whether this takes place to any considerable extent, the casts are so soft and compressible that they probably pass these smaller tubules very readily. It seems likely that tube-casts are often present in much larger numbers in the kidneys after death than they have usually been during life. Just before death the blood-pressure is generally

low, and the secretion of urine diminished, so that the casts are not washed out as they are during the more vigorous period of life.

We have next to consider the CHANGES IN THE HEART AND ARTERIES which are frequent concomitants of Bright's disease. Of the structural changes the most important are hypertrophy of the left ventricle of the heart and of the walls of the vessels, while the increased tension in the arteries is the most important functional alteration.

We have already referred to the hypertrophy of the left ventricle of the heart, and ascribed it to increase of the arterial tension. It has been held that the hypertrophy of the heart is itself the cause of the increased arterial tension, or at least that it is a concomitant, but it is now generally acknowledged that the increase of the muscular tissue of the heart is due to an effort to overcome an excessive resistance in the peripheral blood-vessels. There are several difficult questions which here come up for consideration. One of these is whether the lesions in the kidney are sufficient of themselves to produce increased blood-pressure in the general systemic arterial system. If this question be answered in the negative, then it has to be decided whether the changes in the arteries throughout the body are consequent on the kidney-disease, or coincident phenomena due to the irritant which produces the lesions in the kidney.

Here, at the outset, it is important to remark that in these discussions we have to do with chronic Bright's disease, that is to say, with cases in which interstitial changes have occurred. The changes occur most typically with the pronounced cirrhotic kidney, but they are also present with the large white kidney if the interstitial change be at all considerable. The hypertrophy of the heart does not occur unless the general health of the patient be sufficiently good to allow of the muscular substance of the heart being well nourished. Hence it is absent in cases where the presence of amyloid disease indicates that the blood is deteriorated. It is also absent in cases where a profuse albuminuria has rendered the blood highly watery.

Of late years there has been a tendency to regard the increased arterial tension as due to changes in the smaller arteries throughout the body, the changes in the kidney being merely a part of a general vascular lesion. This view has received its most systematic formulation in the descriptions by Gull and Sutton of the so-called ARTERIO-CAPILLARY FIBROSIS. Their view is that in the finer arteries and capillaries a development of fibrous tissue occurs, and that though

this may begin in the kidneys, it may also take origin in other organs. The contraction and atrophy of the kidneys, in this view, are but part and parcel of the general morbid change. We have here then represented a general disease of the vessels as the essential basis of chronic Bright's disease. Still more lately Mahomed has asserted the existence of increased arterial tension with hypertrophy of the left ventricle without any considerable disease of the kidney, and he even speaks of a stage of "chronic Bright's disease without nephritis."

As to the arterio-capillary fibrosis of Gull and Sutton, there are many very competent observers who, after careful investigation, have denied its existence altogether. The arteries usually chosen for investigation are those of the pia mater, and while hypertrophy of the muscular coat is generally acknowledged to be present, the thickening of the external coat is much more doubtful. It may be acknowledged that the walls of the arteries are thickened, however, and the degree of thickening may be inferred from the accompanying figures (Fig. 277) from Dr. Dickinson's work on Albuminuria. It may quite

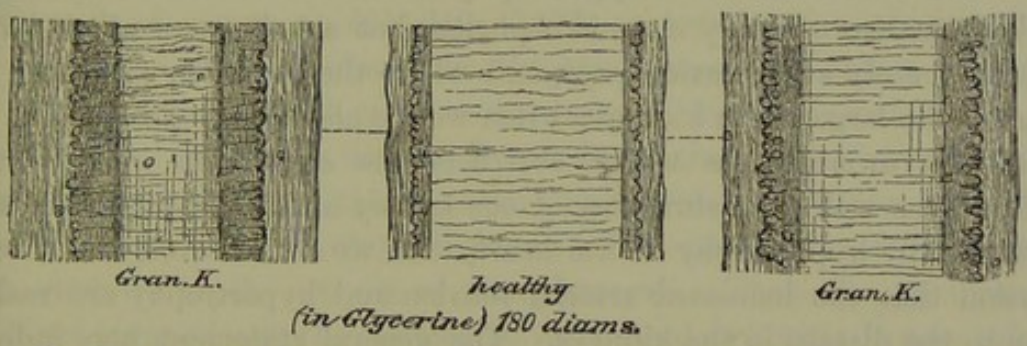


Fig. 277.—Arteries of the pia mater in case of granular kidney and in health. In the former the middle coat and, to some extent, the external are thickened. (DICKINSON.)

well be, however, that these conditions are really the result of increased tension. If the blood is present in the finer arteries at an increased pressure, then in order to prevent a permanent active hyperæmia the muscular coat must contract more vigorously, and this will produce a hypertrophy of it. The thickening of the external coat will fortify the middle coat and assist in keeping the circulation in proper condition.

This raises the important question whether there is any proof that lesions of undoubted renal origin ever produce increased arterial tension and hypertrophy of the heart. In order to answer this question it is necessary to leave out of account all cases in which the origin of the kidney disease is obscure, because it may be said that in these

cases arterial changes have occurred simultaneously elsewhere, and had a similar cause.

In answer to this question various facts may be adduced. Dickinson refers to cases in which distension of the pelvis of the kidney from stone has led to the contracted kidney with all the vascular and cardiac lesions. Then there are on record a considerable number of cases of double hydronephrosis in which extreme hypertrophy of the left ventricle has been present. Recently Gravitz and Israel have produced nephritis in animals by ligaturing the renal artery on one side for one and a half to two hours, and then letting the ligature loose. The consequence was similar to that already referred to in regard to ligature of the arteries in the ear of the rabbit, namely, an acute inflammation. If the animal survived long enough the inflammation resulted in contraction of the kidney, and in many cases there was hypertrophy of the left ventricle of the heart. Here is an undoubted case in which disease artificially induced in one kidney has resulted in hypertrophy of the left ventricle.

When we consider that hypertrophy of the left ventricle results not only from the ordinary chronic nephritis, but also in cases which have begun acutely after scarlet fever, and where the condition presented is that of the large white kidney ; when we see also that a disease such as double hydronephrosis which obstructs the circulation in the two kidneys, as well as a shrinking of the kidney artificially produced, are followed by hypertrophy of the heart, then we seem forced to the conclusion that the increased arterial tension and hypertrophy are really due to the disease in the kidneys. The general statement may indeed be made that, given a disease which seriously obstructs the capillaries and smaller arteries of both kidneys, you will have hypertrophy of the left ventricle, provided the person is in a tolerably vigorous state of health.

That there is a serious obstruction of the capillaries and small arteries of the kidney in interstitial nephritis does not admit of question. The mere anatomical details indicate this. We have seen that the uriniferous tubules, with their surrounding capillaries, are greatly destroyed, and the glomeruli to a large extent reduced to solid clumps. In addition to this the result of injection with coloured material shows that there is great impermeability of the capillaries and of the vessels of the glomeruli. This has been proved in a different way by some important observations of Thoma. He has injected at a constant pressure dilute solutions of common salt and gelatine into the renal artery

in normal and contracted kidneys, and observed the amount which flowed out by the veins in a given time. In the case of the contracted kidney the outflow per minute was considerably reduced, evidently pointing to an obstruction in the finer vessels.

We have now to point out that the effect of this obstruction in the capillaries and glomeruli will be to increase the blood-pressure in the remaining arteries of the kidney, provided there is no serious obstruction in them. The endarteritis which we saw to exist in interstitial nephritis narrows the calibre to some extent, but careful measurements by Thoma show that on the average the size of the arteries is but very slightly diminished, and that in comparison with the weight of the kidney the arteries are greatly larger than the normal. Under these circumstances, with a normal pressure in the aorta, there will be an excessive pressure in the general renal arteries and this pressure will tell on the vessels of the glomeruli which remain unobstructed.

There are several facts which indicate that the pressure, in the vessels of the glomeruli which remain pervious, is very excessive. The author, in a paper published in 1875, recorded some observations on injections of the kidneys in Bright's disease. When a solution of gelatine coloured with carmine was injected into the renal artery, in cases of chronic Bright's disease, it was found that while the capillaries were largely uninjected, the mass ran to a considerable extent from the glomeruli into the convoluted tubules. This would indicate an excessive pressure in the vessels of the glomeruli. Then the occurrence of blood-corpuscles in the tubules in interstitial nephritis is not infrequent, the blood being present in the first part of the tubules and obviously coming from the glomeruli.

The excessive pressure in the glomeruli is also indicated during life by the large amount of urine secreted by the contracted kidney. The increase in the general arterial tension, with the hypertrophy of the heart, doubtless has to do with this increased flow of urine, but when we consider that in cases of contracted kidney there are frequently only a few glomeruli still pervious, we may infer that a very excessive pressure must exist in their vessels in order to produce this exceedingly abundant flow.

One of Thoma's observations is of considerable importance here. In his various experiments, in which gelatine and salt solution were injected into the renal artery, he used a constant pressure. He desired to obtain the pressure in the renal artery, and in order to obtain this ap-

proximately, he connected the cannula inserted into that artery with a manometer. He found that while in the normal kidney the pressure was 14·5, in the contracted kidney it amounted to from 15 to 15·7 cm. of mercury. There was thus, even in the main renal artery, an abnormally high pressure in the contracted kidney, and in the finer arteries the excess of pressure must have been still greater.

We have now to consider what bearing these facts have on the question of increase of the general arterial tension. It is clear that, though the obstruction in the renal circulation is sufficient to raise the pressure in the renal arteries, it alone is not enough to raise it in the general systemic arteries, considering that there are such means of varying the tension in the arteries by relaxing or contracting the muscular coat. Ligature of the renal artery or extirpation of the kidney has not been found as a rule to raise the tension, and even ligature of the aorta at its bifurcation does not raise it for any considerable time. Even the view of Cohnheim cannot meet with general acceptance, at least in its original form. According to this view anæmia of an organ must be compensated either by hyperæmia in another organ or else by loss of a corresponding amount of blood, otherwise a rise in the blood-pressure occurs. When one kidney is excised or its artery ligatured a collateral hyperæmia occurs in the other kidney and it undergoes compensatory hypertrophy. But when both kidneys are simultaneously diseased, as in Bright's disease, there is no organ to compensate, and if the arteries of the kidney are to admit as much blood as normal there must be a rise of blood-pressure in them.

Looking now at the matter more closely, we have seen that, in the case of the contracted kidney, with a normal pressure in the general arterial system there is a greatly increased pressure in the finer renal arteries, and a considerable increase even in the main renal artery. This increase will be communicated to the general systemic circulation, as the renal arteries are in communication with the aorta. Let us suppose that it is at once compensated by a relaxation of many arteries throughout the body, and the pressure falls to normal. But even at the normal pressure there is a comparative increase of pressure in the renal arteries which is again communicated to the general circulation. So that as soon as there is a fall of pressure there will be a fresh renewal of the excessive pressure from the renal arteries, and it will be again raised. But if the rise of pressure is not immediately compensated by relaxation of the peripheral arteries throughout the body, then the blood passing into the renal arteries at an excessive pres-

sure will, in the arteries of the kidney, be raised to a pressure still farther above the normal for these vessels.

We have seen that the arteries proximal to the glomeruli are hardly at all reduced in calibre, and with the great obstruction ahead we may suppose these arteries distended and their walls reacting against the excessive pressure of the blood. It is as if at a part of the arterial system there were the continuous action of an apparatus engaged in raising the general pressure within this system.

On these principles we can even understand how, under certain circumstances, excision of one kidney may produce permanent increase of tension. After excision of one kidney the arteries of the other undergo a considerable relaxation and there is a collateral hyperæmia. An excessive amount of blood reaches the glomeruli, and it is conceivable that these and the capillaries may be unable to allow of the passage of this excessive blood quite freely. There will be thus a comparative obstruction in the glomeruli and capillaries with increased pressure in the arteries. As a rule, this is not sufficient to affect the general circulation, but according to the experiments of Gravitz and Israel extirpation of one kidney does lead to hypertrophy of the heart when the other does not fully compensate.

By some it may be supposed that, considering the small capacity of the renal arteries as compared with that of the entire arterial system, the effects of such a local increase of pressure must be very limited and insufficient to account for the general rise in pressure. If this argument be well founded then we have to look for some permanent obstruction in the systemic circulation, either in the arteries or in the capillaries, to explain the increased tension. From what has gone before it is manifest that such changes, if they exist, must be secondary to the lesions in the kidney, and are to be probably referred to changes in the constitution of the blood causing morbid effects in the arteries and capillaries. We may even suppose that the altered blood has greater difficulty in passing through the capillaries generally than normal, and this would produce increase of tension in the arteries.

SEPTIC INFLAMMATIONS OF THE KIDNEY.

These are such as are induced by the presence in the organ of septic organisms. There are two important classes of cases; in one the source of the organisms is outside the urinary organs, the septic material being brought by the blood; in the other the source of the organisms is de-

composition of the urine in the bladder, and they are propagated up from the latter.

We have already seen that in PYÆMIA and ULCERATIVE ENDOCARDITIS pieces of fibrine or other material may be carried to the kidneys and produce embolism there. In this way arise METASTATIC ABSCESSES. For the most part the emboli are small and are carried to the ascending arteries or the glomeruli before they stick. Hence the abscesses are mostly in the cortical substance, although they are not infrequently seen in the pyramids along the course of the arteriæ rectæ, and there may even be large ones taking in portions both of pyramids and cortex. The abscesses are usually elongated in the direction of the arteries, and they often project slightly from the surface when the capsule is removed. They are frequently present in considerable numbers in both kidneys.

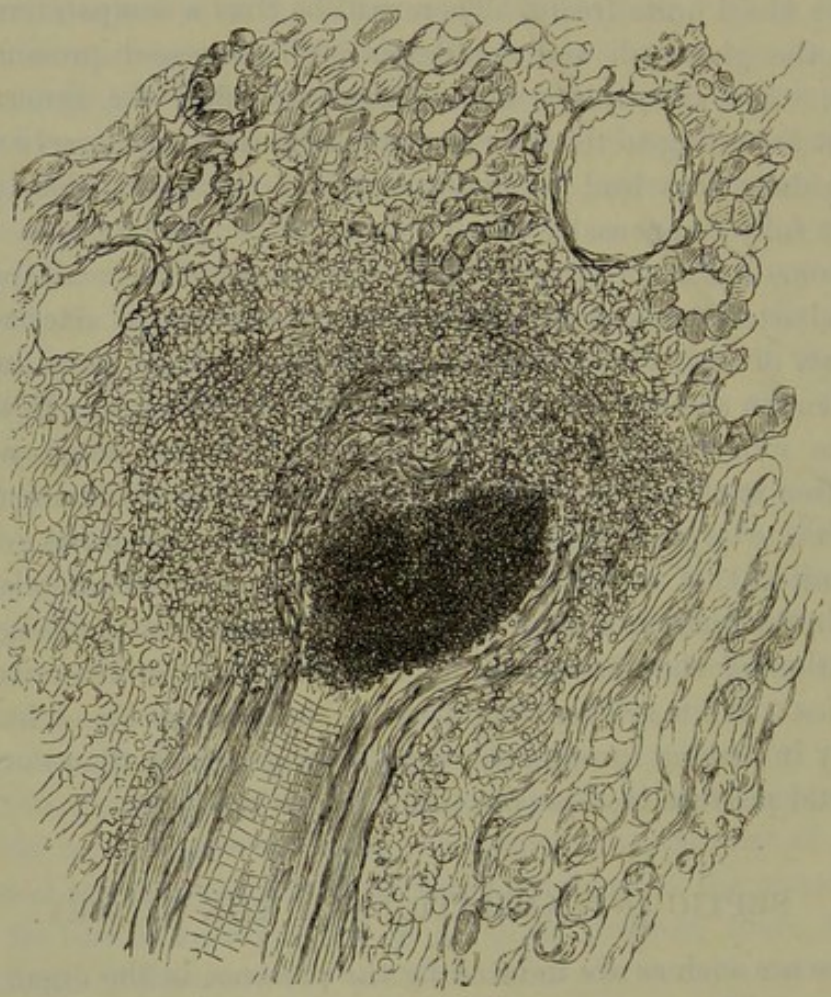


Fig. 278.—From a section of the kidney in ulcerative endocarditis. An artery is plugged with dark material which contains micrococci. In the neighbourhood of the plug the wall of the artery is necrosed. Leucocytes are infiltrating the tissue around, and extending through the vessel wall. × 90

Under the microscope it can be seen that the abscesses arise by obstruction of the arteries (see Fig. 278). Where the embolism has been recent the wall of the vessel and the tissue in the immediate neighbourhood of the embolus present evidences of necrosis, while around there are multitudes of leucocytes occupying the interstitial tissue. In the embolus there are colonies of bacteria in the midst of remains of the transported fibrine. When the abscess has fully formed, these characters may be lost in the great multiplication of leucocytes. Besides in the arteries colonies of bacteria are to be found in the vessels of the glomeruli, sometimes filling many of them out with a dark granular mass, and also in the capillaries. It is sometimes to be seen that these colonies are present in the glomeruli and capillaries without signs of inflammation around In such cases they are of recent growth and have not had time to produce inflammation by giving off irritating products. To some extent the bacteria may multiply in the glomeruli and capillaries after death.

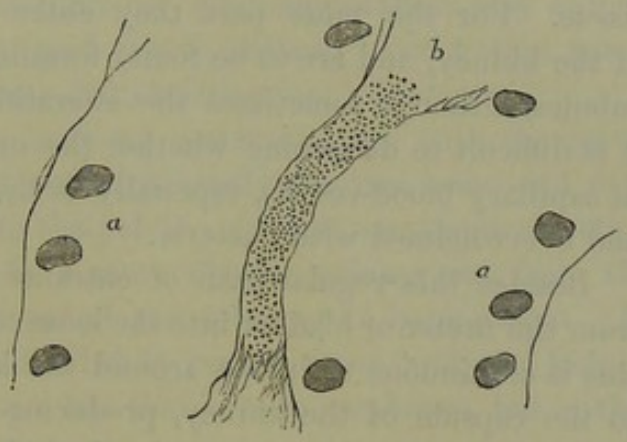


Fig. 279.—Micrococci in a capillary (*b*) of the kidney from a case of pyæmia. There is a tubule on either side, the nuclei of whose epithelium (*a*, *a*) are visible except in the neighbourhood of the micrococci, where they seem to be destroyed. × 650.

The bacteria found in these cases, as probably in all septic inflammations, are MICROCOCCI (see Fig. 279).

In cases of SCARLET FEVER colonies of bacteria are sometimes to be seen in the capillaries and uriniferous tubules of the kidney (Fig. 280). They are not evidently accompanied by local inflammation, and it is not improbable that we have here to do with the specific organisms of the fever, which have been sparsely present in the kidney at the time of death—perhaps in process of excretion—and have multipled into colonies after death.



Fig. 280.—Bacteria distending a capillary blood-vessel in a case of scarlet fever. × 350.

PYELONEPHRITIS.—The other kind of septic inflammation arises in connection with inflammation in the bladder, ureter and pelvis of the kidney. As the inflammation of pelvis and kidney is continuous the condition is often designated PYELONEPHRITIS, which means a combined inflammation of these two. The inflammation in all these parts is septic, due to the action of bacteria producing decomposition of the urine. We shall have to study afterwards the condition of the bladder, ureters, and pelvis in these cases, but meanwhile we have to note that the organisms may propagate themselves into the kidney tissue. For the most part they enter the tubules from the pelvis of the kidney, and are to be found forming the usual colonies inside the tubules, although sometimes the alterations in the tissue are such that it is difficult to determine whether the organisms are in the tubules or in capillary blood-vessels, especially as the epithelium is often necrosed and overwhelmed with bacteria.

Besides this regular path of entrance the organisms may penetrate from the ureter or bladder into the loose connective tissue around, and as this is continuous with that around the kidney they may propagate up to the capsule of the kidney, producing abscesses there (PERINEPHRIC ABSCESSES), as well as penetrating into the kidney from the surface and forming abscesses in it. This mode of travel has been followed out by Dr. Steven in a case which came under observation here.

The septic material in the tubules affects the renal epithelium most directly, causing necrosis and disintegration of it. But the dissolved products extend beyond the tubules and set up an acute inflammation of the kidney substance. The inflammation may be tolerably homogeneous, the leucocytes infiltrating the whole interstitial tissue, and appearing also in the uriniferous tubules. But as a rule there are special foci, in which it goes on to suppuration, resulting in the formation of small ABSCESSES. When the abscesses have formed it is usually difficult any longer to find the bacteria.

The appearance of the kidneys in such cases is usually sufficiently distinctive. It often happens that only one kidney is affected, the septic process having extended up one ureter and not the other. In this respect this disease differs from the preceding one, where the metastatic abscesses are always present in both kidneys. The kidney is greatly enlarged, and, generally with signs of inflammation of the pelvis, there are numerous small yellow points and abscesses in the kidney tissue. The abscesses are in the form of elongated streaks in the direction from pelvis to surface, and they are present as well in

the pyramids as the cortex. They are sometimes in groups, and we may have such groups visible, projecting from the surface, when the capsule is removed.

As a general rule the patient dies with these miliary abscesses in the kidney, but if only one kidney is involved he may survive and the process assume a further development. The abscesses, by fresh invasion of bacteria, may multiply and coalesce. In this way abscesses of large size may form, finally, perhaps, involving the entire kidney out to its capsule. The abscess may even increase in size after the whole kidney is destroyed, and form a bulky tumour. The suppuration may extend beyond the kidney and lead to perinephric abscess. Perforation some times occurs externally, or into a neighbouring loop of intestine.

Sometimes these abscesses have no communication with the pelvis throughout their course. But not infrequently they are associated with and originate in suppuration in the pelvis. In that case the destruction of the renal tissue proceeds in a more regular manner out from the pelvis, following the arrangement of the calyces to a large extent. In this way the abscess may be divided by partial septa, and the kidney may come to have an appearance like that in hydronephrosis, but in this case pus fills the cyst—PYONEPHROSIS.

With this great production of pus, or after it has attained its height, there may be production of cicatricial connective tissue, limiting the abscesses, and by its contraction producing sometimes considerable deformity. If the production of pus ceases the abscesses may dry in, and we may have the cavities filled with a pultaceous material from fatty and calcareous deposition. Sometimes the cavities of the abscesses contract greatly, and there may remain simply a shrunken kidney with some cavities in which are pieces of chalky substance or pultaceous material. It will be understood that these abscesses very often do not communicate with the pelvis, and that when they do the shape of the kidney is much better retained. In the shrunken kidneys there is often considerable obliteration of the pelvis from inflammatory adhesion.

PYELITIS.—This name is given to inflammation of the pelvis of the kidney, and it is very frequently associated with inflammation of the kidney itself. Even in acute Bright's disease there is often some inflammatory congestion of the pelvis of the kidney, and inflammations originating in the pelvis frequently spread to the kidney proper. Inflammation of the pelvis is very frequently septic, and in that case, as we have seen, it may associate itself with a septic inflammation of the

kidney, and go on to pyelonephritis. Sometimes the inflammation of the pelvis is particularly violent, so as to assume a necrotic character, going rapidly on to suppurative nephritis, and perinephritis.

Pyelitis is sometimes set up by the irritation of calculi in the pelvis. It is here for the most part a chronic inflammation. Chronic inflammation may also occur as the result of stagnation of urine from obstruction in the urinary passages. The mucous membrane is thickened, sometimes showing even irregular projections, and is not infrequently incrusted with phosphates from the stagnating urine. In this way calculi may form, and it may be difficult to say whether an existing calculus is the cause or the effect of the inflammation.

RETROGRADE CHANGES IN THE KIDNEYS.

Some of these occur, as we have seen, in the renal epithelium in Bright's disease, chiefly cloudy swelling and fatty degeneration, but we have here to do with such as are met with more independently.

SIMPLE ATROPHY occurs mostly as one of the phenomena of OLD AGE. The whole structures of the kidneys undergo diminution in size, but very often this affects especially the secreting epithelium of the convoluted tubules. If this be the case there may be a special shrinking of the cortex, and the kidneys may be like those of chronic Bright's disease. Sometimes also the surface is granular and the capsule adherent.

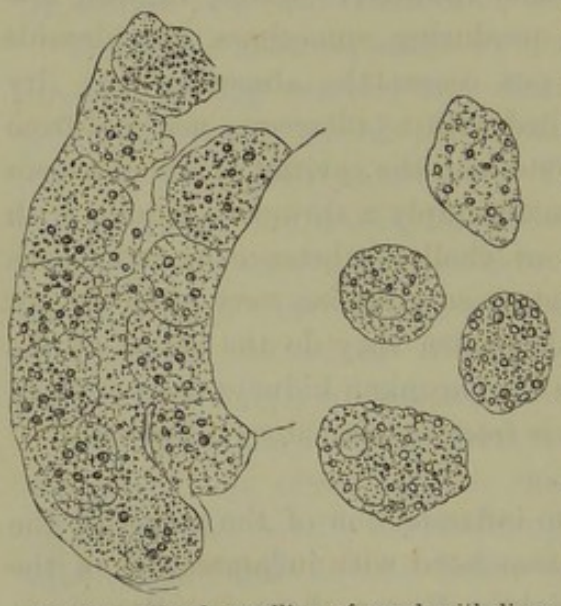


Fig. 281.—Cloudy swelling of renal epithelium. The cells are enlarged and filled with fine granules, in addition to which there are occasional minute oil drops. × 350.

PARENCHYMATOUS INFILTRATION, or cloudy swelling, must be remembered as liable to occur in acute febrile diseases. There is a general enlargement of the renal epithelium with infiltration of fine granules in the midst of which fine fat drops are scattered. (Fig. 281.) The pyramidal tubules as well as those of the cortex are involved, the affection being usually homogeneous. It is important to note that this condition may produce considerable enlargement of the kidney without obvious change in its structure to the naked eye.

FATTY DEGENERATION of the renal epithelium is not infrequently present in cachectic conditions such as advanced phthisis pulmonalis, in which, however, it is often associated with amyloid disease or interstitial nephritis. In severe anæmias it is also met with along with fatty degeneration of the muscular substance of the heart. It occurs, too, in acute yellow atrophy of the liver.

AMYLOID DEGENERATION OF THE KIDNEY develops, as we have already seen, along with amyloid disease in other organs in consequence of certain altered states of the blood. As in other situations so here it is chiefly the walls of the blood-vessels which are affected.

Even in very early cases, in which the amount of amyloid disease is slight we usually find it in two distinct and separate structures, namely, the Malpighian tufts and the arteriæ rectæ of the pyramids. The vessels of the tufts, generally along with the arteries leading to them, are swelled up and hyaline. The rose colour developed with methyl-violet is so striking that in sections stained with this dye it often looks as if the tufts were injected. They are also considerably enlarged, and even without the addition of iodine or methylviolet they form very prominent, transparent and glancing clumps in the cortex. The arteriæ rectæ run, as we have seen, in bunches, and their appearance with methyl-violet is that of a series of rose-coloured tubes. They are also sufficiently pronounced as a rule without any reagent, appearing as pearly glancing tubes.

While these structures are first and chiefly involved, others usually follow. There is amyloid disease extensively present in the arteries of the cortex, the ascending and afferent arteries. Very often there is here and there a capillary of the cortex affected, and sometimes these are extensively so even in comparatively slight cases. Lastly the basement membrane of the tubules may become amyloid, chiefly in the cortical substance. (See Fig. 282.)

Along with the amyloid disease of the vessels there is usually fatty degeneration of the epithelium of the tubules, apparently the result of anæmia from the obstruction of the vessels.

There is also very often interstitial inflammation present, and it is frequently so great as to present a combination of the amyloid and contracted kidney. Fig. 283 shows a microscopic section of such a kidney in which the amyloid glomeruli are brought close together by contraction and destruction of the tubules.

This combination of contracted and amyloid kidney is sometimes met

with in syphilis, the virus of which may be the cause of the interstitial inflammation. Again in phthisis pulmonalis, and in extensive suppurations from diseased bone, there may readily occur an absorption of

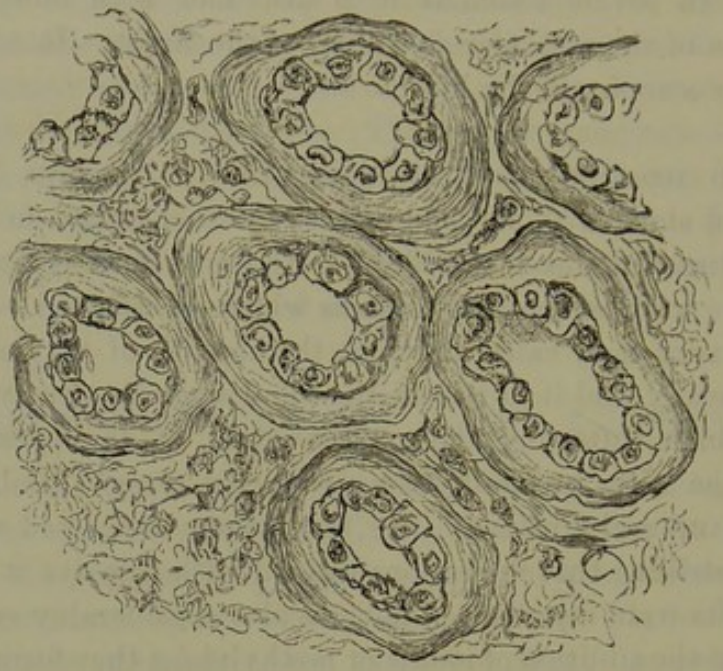


Fig. 282.—Amyloid degeneration of the basement membrane of uriniferous tubules. The thickened and translucent basement membrane is shown with the renal epithelium inside. × 350

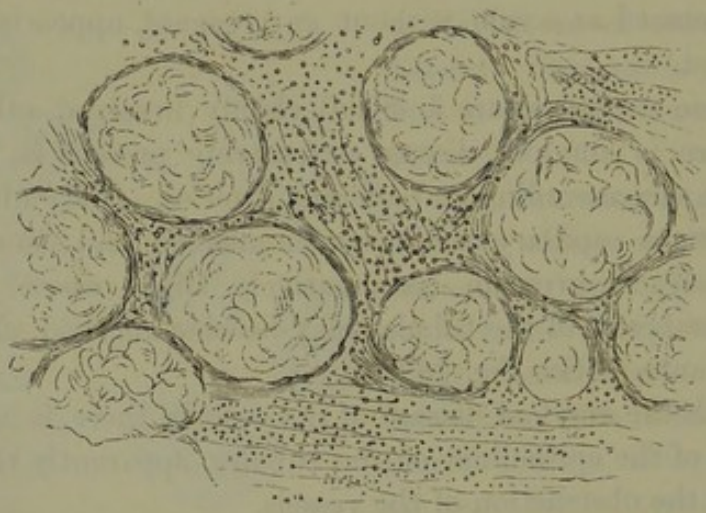


Fig. 283.—Amyloid and contracted kidney. The highly amyloid and therefore greatly enlarged Malpighian tufts are shown, their capsules being somewhat thickened. The tufts are very unduly close together, owing to contraction of the intervening tissue. Between them there is round-cell tissue with remains of tubules. ×85.

irritating materials which are capable of setting up inflammation. The contracted amyloid kidney is not accompanied by hypertrophy of the

heart, the reason apparently being that, as the blood is deteriorated, the compensatory growth of muscular tissue can scarcely occur.

In regard to the NAKED-EYE APPEARANCES, the simple amyloid kidney is enlarged, and sometimes greatly enlarged, so that the organ weighs nine or ten ounces. The surface is pale and the capsule comes off easily. On section the cortex is seen to be thickened and pale in colour. The general appearance therefore resembles that of the large white kidney, and doubtless many cases have been mistaken for that. But the organ in amyloid disease has a firm elastic feeling and a transparent bacony appearance on section, which is distinctive enough. The thick pale transparent cortex usually contrasts with the redder but still tolerably firm pyramidal substance, and the appearance has been somewhat aptly compared to the section of bacon ham. The name LARDACEOUS KIDNEY is often applied from the transparent appearance of the tissue. In the midst of the transparent basis opaque yellow streaks are often visible, from the fatty degeneration of the epithelium. The addition of a solution of iodine to the cut surface of such a kidney brings out the affected glomeruli as brown dots and the arteriæ rectæ as brown streaks. If the kidney be contracted, the granulations on the surface show the usual transparent waxy appearance of the amyloid kidney, and on section the cortex though greatly thinned shows a similar condition.

The amyloid substance apparently allows fluid to pass through it more readily than ordinary albuminous structures. Injection of the amyloid kidney shows that the vessels of the glomeruli and the arteries of the cortex are largely obstructed. It may well be that this leads to increased blood-pressure in the remaining arteries, but with the general narrowing of the smaller arteries this can hardly tell with much force on the glomeruli which remain pervious. The excessive secretion of urine, like the diarrhœa which is a prominent symptom in amyloid disease of the intestine, is probably to be accounted for by a greatly increased transudability of the vessels.

CONCRETIONS AND CALCULI IN THE KIDNEY.

Two very interesting forms of DEPOSITION IN THE TUBULES are met with IN NEW-BORN CHILDREN. In the common icterus of the new-born the BILIARY COLOURING MATTER (bilirubin) is excreted, as in the adult, by the kidneys, but in the new-born it very readily passes into the crystalline form, so that round or rhombic orange-coloured crystals are

found in the pyramidal tubules, sometimes in such numbers as to warrant the designation bilirubin-infarction. Similar crystals are found in the blood and tissues of the body. URIC ACID is found in the tubules of new-born children, in about half the cases of those which die within the first few weeks. It is mostly in children who have breathed that the crystals are met with, but they have been observed in still-born children, although very rarely. The concretions consist of salts of uric acid (mostly urate of ammonia), and they are deposited mainly in the tubules near the apices of the pyramids, giving the appearance of opaque yellow or reddish streaks, converging to the apex of the pyramid. Under the microscope amorphous urates are seen in the tubules, and when acetic acid is applied these dissolve and form crystals of uric acid.

URATES are also deposited in the substance of the kidney IN GOUT. In that disease salts of uric acid (urate of soda) are deposited as we have seen in the fibrous and cartilaginous structures in the joints, but they may also appear in crystalline masses in the kidney. These lie in the thickened connective tissue of the contracted kidney.

LIME SALTS are sometimes deposited in the straight tubules of the pyramids, especially in cases where from disease of bone there is excessive absorption of lime salts and excretion of them by the urine. The appearance presented is that of white streaks usually near the apices of the pyramids. It is to be observed, however, that a deposition of urates occurring after death in the straight tubules may produce a somewhat similar appearance.

CALCULI are of frequent occurrence IN THE PELVIS of the kidney. As we have seen, they may originate from chronic pyelitis, especially with stagnation of urine, but they may apparently originate in the uriniferous tubules, and having passed into the pelvis grow larger there. They sometimes attain to very large dimensions, moulding themselves into the shape of the pelvis and calices, so that we may have branches extending out into elongated recesses formed by dilated calices. By obstructing the flow of urine these calculi may lead to the occurrence of hydronephrosis, and as the cavity of the pelvis and calices enlarges so may the calculus. A small calculus will often pass into the ureter and obstruct it, in this way leading to hydronephrosis.

SYPHILIS AND TUBERCULOSIS OF THE KIDNEY.

SYPHILITIC DISEASE is rare in the kidney unless it be that some cases of contracted kidney from interstitial nephritis are due to this cause. Gummata have been found in a very few cases.

TUBERCULOSIS occurs as part of a general tuberculosis or as a local disease. In ACUTE MILIARY TUBERCULOSIS there are usually numerous tubercles scattered throughout the kidney. These mostly occur in groups visible to the naked eye, and they may even assume considerable dimensions. They are most abundant in the cortex, and they are prone to become caseous.

LOCAL TUBERCULOSIS gives rise to the condition frequently called RENAL PHTHISIS. The tuberculosis here is often propagated from the bladder and ureter, and may even originate in the passages of the organs of generation, as the vas deferens and vesiculæ seminales. On the other hand it very often originates in the kidney, and extends down the ureter. The disease is usually of one kidney, or at least involves one much more than the other.

It may begin in the pelvis of the kidney, in the calices, or at the apices of the papillæ, and there are the usual phenomena of tubercular ulceration. Tubercles are formed which become caseous and break down so as to form an ulcer. Fresh tubercles form outside the ulcer which undergo the same process and produce an extension of the ulcer. There is thus a continually extending ulceration, and a continually growing irregular cavity. But the extension of the ulcers occurs mainly into the kidney tissue, advancing here apparently by reason of the less resistance of the tissue. We have already seen that the papillæ are often attacked at the very first, and the ulceration extends into the pyramids, sometimes eating its way a considerable distance in. If several papillæ have been attacked, then we may have several ragged pouches extending out from the pelvis like prolongations of the calices, or even the whole kidney may be converted into an irregular cavity divided by partial septa. This condition is to be distinguished from pyelonephrosis, chiefly by the irregular ulcerated surface and the presence of broken-down caseous material.

Under the microscope the kidney tissue around the ulcer will be found infiltrated with round cells, in the midst of which tubercles in various stages of alteration will be discovered. The proper secreting tissue within this area will be pushed aside and greatly destroyed.

The tubercular ulceration affects the pelvis of the kidney, and usually the ureter. Their walls are thickened and infiltrated. In the case of the ureter the caseous material, instead of softening and discharging, may remain as a dense yellow layer lining the greatly thickened tube. The wall of the tube shows multitudes of inflammatory round cells in the midst of which tubercles appear, but their outlines are frequently obscured by the round cells. The existence of giant-cells at intervals may indicate their presence.

HYDRONEPHROSIS.

In this condition there is a dilatation of the pelvis and the calices of the kidney, as a result of obstruction of the ureter or urethra. The obstruction occurs in a considerable variety of ways. It may be congenital, and is then usually in the urethra, in which case there is dilatation of bladder, ureters, and pelves. Acquired stricture of the urethra is a less frequent cause, as it tends rather to produce dilatation and hypertrophy of the urinary bladder. A very frequent cause is obstruction of the ureter, and this itself is brought about very variously; as by a calculus descending from the pelvis, a tumour pressing on the ureter in some part of its course, a hydatid cyst bursting into the pelvis of the kidney, even a renal artery taking an abnormal course and crossing in front of the ureter below the pelvis. Sometimes the ureter does not, as in the normal condition, form a continuation of the pelvis, but starts from it at an acute angle, passing obliquely through its wall very much as the lower end of the ureter passes into the bladder. In that case, distension of the pelvis valves the upper orifice, and the valve may be only relieved when great dilatation is reached. This obstruction will be intermittent. Again, an abrupt bend in the ureter sometimes causes obstruction; this may be from a congenital convolution in its course, or the ureter may turn more abruptly than usual over the brim of the bony pelvis, if the edge here be unusually sharp. Such a sharp edge may be formed by the iliac arteries at the brim of the pelvis, when the tissues which naturally pad them are atrophied, as in cases of general emaciation. It appears from this last instance that a comparatively small external pressure may obstruct the ureter, and that the urine in the pelvis and ureter is at such a low pressure as to be incapable of overcoming a comparatively slight resistance.

As already seen, the result of the obstruction is dilatation of the pelvis and calices (Fig. 284), but in addition there is frequently a con-

siderable destruction of renal tissue. That is to say, the calices in dilating cause atrophy, first of the papillæ which project into them, and then of the pyramidal portion of the kidney, advancing into the deeper parts of the organ. We thus sometimes find the pyramids as if cut abruptly across transversely. But the condition frequently advances still further. The dilated calices increase in volume till, in the most extreme case, the kidney is replaced by a cyst which represents dilated pelvis and calices, partitions existing in it corresponding to the divisions between the calices. When this has occurred, the cyst may go on enlarging so as to form a tumour of great bulk. The ureter is also dilated, often very greatly, so as to look like a piece of small intestine. It sometimes becomes convoluted in its course as well.

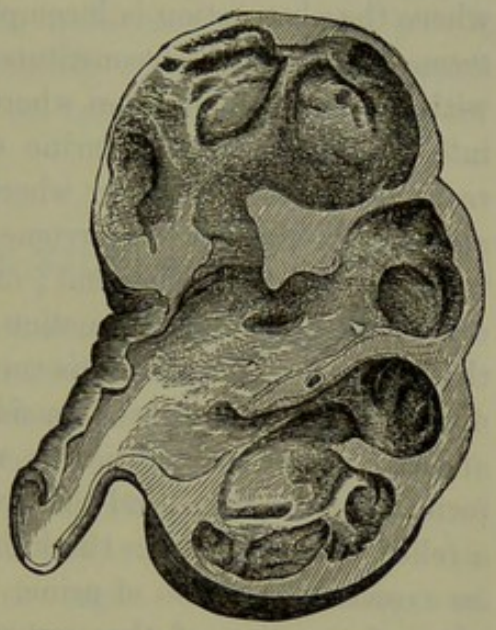


Fig. 284.—Kidney in hydronephrosis. The pelvis and calices are greatly dilated and the renal tissue reduced to a thin layer. (VIRCHOW.)

It is not in every case quite apparent what circumstances determine the degree of hydronephrosis. With complete obstruction we may have a moderate dilatation, and with an apparently trivial obstruction it may be much more considerable. In order to understand how this may be it will be necessary to refer to the course of events when the ureter is obstructed.

The ureter has been ligatured in animals and the processes observed. The first result is dilatation of the pelvis and of the ureter above the ligature. The tension of the urine in the ureter also rises up to a certain point, which, however, is far below the blood-pressure. When this point is reached the full extent of the distensile force derived from the secretion of the urine is attained. The secretion of urine, consisting in the transudation of a watery fluid through the vessels of the glomeruli, is due to the difference in pressure between the blood in the tufts and the fluid in the tubules, and when the pressure in the tubules is raised the secretion of urine ceases as soon as a state of equilibrium is brought about.

There are, however, two elements in the problem still to be considered. In cases where the ureter has been ligatured in animals the actual dilatation of the pelvis and calices has been comparatively slight,

the state of equilibrium of tension being easily reached. In cases met with in the human subject it appears also that where the obstruction is complete the hydronephrosis is generally much less considerable than where the obstruction is incomplete or is relieved at intervals. The extreme dilatation which constitutes a complete hydronephrosis may be met with, for instance, in cases where the ureter has an abnormal insertion into the pelvis, and the urine only gets out when the dilatation has reached a certain point, or where the ureter has a sudden bend in it, and the obstruction is overcome when the dilatation is sufficient, as it were, to round out the bend; or again, where the pressure of a tumour causes an occasional obstruction. The explanation of this seems to be that when the obstruction is complete the pressure of the fluid in the dilated pelvis soon causes considerable obstruction of the renal vessels, and the power of secretion is reduced. But if at times an outlet is formed for the urine and the pressure is suddenly reduced, there will be a relief of the vessels in the kidney and a violent hyperæmia leading to an excessive secretion of urine. As a matter of fact the sudden relief of an obstruction of the ureter has been found to be followed by an excessive secretion of urine which contained albumen. Where then there are such repeated sudden collapses and dilatations the advance of the hydronephrosis is much more complete.

At first the dilated pelvis and calices contain urine, but as the condition gets fully established the urinary constituents become absorbed and a watery albuminous fluid is found. Sometimes the dilatation is due to a calculus in the pelvis of the kidney, and in that case there may be inflammation, possibly with suppuration. If pus fills the cyst then the condition is designated PYONEPHROSIS.

It sometimes happens that where a prolonged obstruction has existed the external fatty capsule of the kidney is greatly thickened, while only a moderate hydronephrosis exists, the external outline of the organ being not at all increased. It is not unlikely that an œdema of the capsule following the obstruction of the ureter may be the cause of this great new-formation of fat by affording an extra supply of nourishing fluid, or perhaps by acting as a prolonged irritant.

We sometimes meet with cases resembling hydronephrosis, but in which some of the cysts, representing dilated calices, do not communicate with the pelvis, but form INDEPENDENT CYSTS. This occurs when from inflammation there has been partial or complete obliteration of the pelvis. The inflammation may be caused by the presence of calculi in the pelvis, and some of the cysts may contain calculi. Again, an

inflammation of the pelvis may extend to a dilated calyx, which, with others, is afterwards shut off by adhesion and obliteration of the pelvis. In that case we may have a cyst full of pus, or of the pultaceous material which we have seen to result from changes in the pus in pyonephrosis, and such cysts may be alongside others which have serous contents, these latter having been shut off before inflammation has extended to them.

TUMOURS OF THE KIDNEY.

Cysts are of peculiarly frequent occurrence and of several kinds. We have already seen that in the contracted kidney it is common to meet with small cysts which are the result of dilatation of the uriniferous tubules and Malpighian capsules from obstruction of the tubules.

Simple Cysts are frequently met with in kidneys which are otherwise perfectly normal, and the cysts themselves do not, as a rule, seriously interfere with the functions of the organ. They are larger or smaller well-formed cysts, which not infrequently project from the surface of the organ. They contain usually a clear fluid, but the fluid is sometimes colloid in character. The wall of the cyst is composed of connective tissue lined with a proper tesselated epithelium. These cysts sometimes grow to a large size and may push aside the renal tissue to a large extent. It is probable that they are of congenital origin, arising by fœtal obstruction of one or more uriniferous tubules. The obstruction and the beginning of the cyst are congenital, as those formed in after life do not apparently form such perfect cysts.

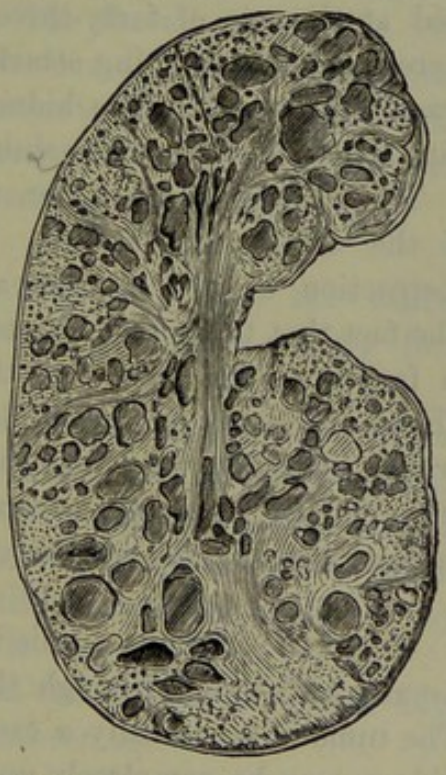


Fig. 285.—Cystic degeneration of kidney. The organ is shown in section, and is made up of a congeries of cysts of various sizes. (Virchow.)

Cystoid Degeneration of the kidneys is also a condition of congenital origin, at least in many cases and probably in all. The whole kidney is converted into a congeries of cysts of larger and smaller size. The cysts form rounded prominences from the surface, and on section (Fig. 285) they are seen to replace the renal tissue. The wall of the

cyst is composed of tunica propria with well-formed tesselated epithelium lining it. It contains usually a clear fluid, but the fluid may be brownish or even hæmorrhagic, and it is noteworthy that it contains the constituents of the urine, often with albumen, and sometimes throws down a granular precipitate of uric acid. Between the cysts there is very little space, but there are traces of remaining renal tissue, and the pelvis and ureter are present. The outline of the organ is greatly enlarged, measuring sometimes in the new-born child as much as eight inches by four.

Kidneys of this kind have been frequently met with in new-born children, and from their size they may seriously interfere with parturition, even requiring evisceration before delivery can be effected. It is of importance to note that this condition often co-exists with other congenital defects such as hydrocephalus, defective urinary bladder, and horse-shoe kidney. But cystoid degeneration is also met with in the adult, and it is remarkable that the functions of the organs may be preserved for a long time, although both kidneys are composed of a congeries of cysts. The author met with a case in which the patient died at the age of forty-three. For eighteen years before his death there had been recurring attacks of hæmaturia, and he at last died with uræmic symptoms. The kidneys were much enlarged and cystic, but with some renal tissue remaining between the cysts.

The cystoid degeneration in all probability arises by obstruction of the uriniferous tubules. Virchow has found in some cases an obstruction of the papillæ apparently from a fœtal inflammation. The fact that these cysts contain the urinary constituents is also much in favour of the view that they arise by obstruction of the tubules. Those met with in the adult are also most probably of congenital origin, although they may have grown on into adult life. In the author's case there was a congenital malformation of the aortic valve, indicating perhaps a proclivity to malformations.

Primary Cancer.—This is not of very frequent occurrence, and is usually unilateral, although there have been cases of bilateral cancer. The tumour is virtually a cancerous degeneration of the organ. The kidney may be completely converted into a tumour which sometimes attains a very large size, retaining the general shape of the organ and covered by its capsule. But in some cases only a part of the kidney is involved, and in that case, while the affected part retains the general shape of the organ, although enlarged, the remaining piece of kidney

has quite its normal appearance. To the naked eye it is as if a portion of kidney were transformed, and with the microscope it can be seen, at the margin of normal and pathological, that the tumour is advancing by a conversion of the proper kidney tissue. The epithelium of the tubules is multiplying so as to form the cancerous epithelium, and is becoming irregular in form (Fig. 286), while the cancerous stroma is being formed of the connective tissue of the organ.

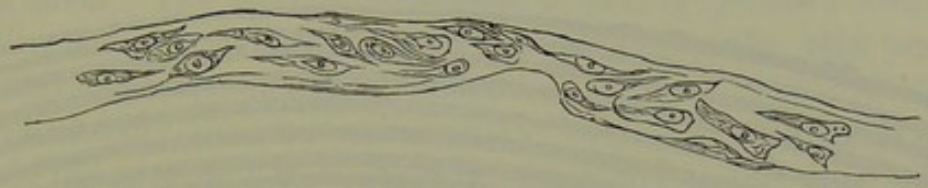


Fig. 286.—A uriniferous tubule at the border of an advancing cancer. The epithelium is undergoing transformation. × 300.

These tumours are usually very soft, but may be firmer. They present a remarkable tendency to break down the walls of the pelvis of the kidney and of the renal veins, so as to project in a fungating fashion into these. Hence arise hæmaturia on the one hand and thrombosis of the veins on the other. The thrombosis may be very extensive, the clot propagating itself in various directions. Pulmonary embolism may result, and cancerous elements may be present in the obstructing material. In a case observed by the author cancer cells were found in coagula in the pulmonary artery, and in the heart.

SECONDARY CANCERS occur not infrequently when the cancerous elements have got into the systemic circulation. They form multiple tumours.

SARCOMA, as a primary tumour, is rare in the kidney, but secondary tumours of this kind are tolerably common. Of the primary sarcomas reference has already been made to the MYOSARCOMA, which is usually a small tumour not larger than a pea, but may be of large dimensions. The LYMPHOSARCOMA sometimes forms bulky infiltrations of the kidney, and leukæmic lymphoid infiltrations may be very similar.

FIBROMAS of small size are common in the kidney, and some have occurred of large size. LIPOMAS have also been met with.

PARASITES.

The ECHINOCOCCUS is of occasional occurrence, sometimes along with a simultaneous hydatid cyst of the liver. There is here, as in the

liver, a large mother cyst surrounded by a distinct connective-tissue capsule, and containing the usual daughter cysts and brood-capsules. The cyst not infrequently bursts into the pelvis of the kidney, and the daughter cysts and heads may be evacuated by the urine; or rupture may occur into the pleura. Sometimes the parasite dies, and the cyst comes to be occupied by a pultaceous material in which the remains of the chitinous membrane are found (Fig. 287). The stratified character of

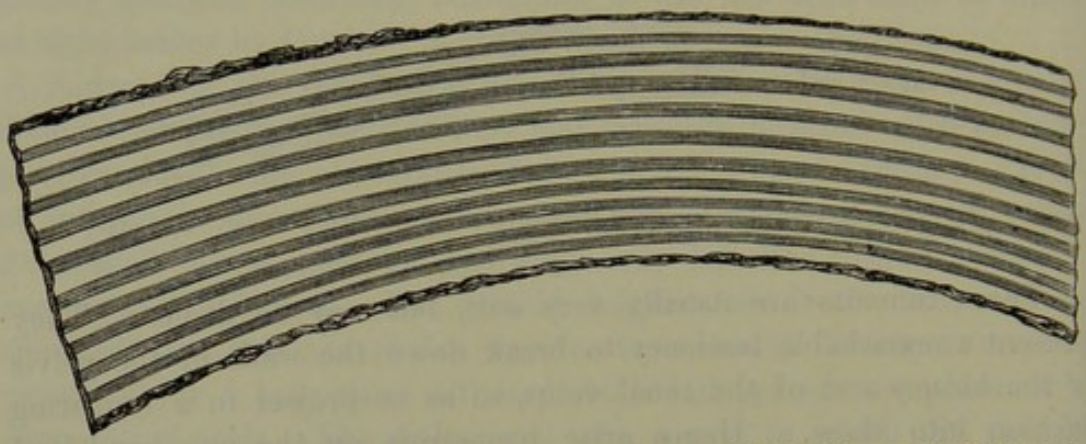


Fig. 287.—Section of a stratified chitinous membrane from an old hydatid cyst of kidney. ×90.

this membrane is here, as in the case of the liver, of assistance in distinguishing the nature of the cyst, especially as all other trace of the parasite, even the hooklets, may have disappeared. The kidney tissue may be considerably opened up and pushed aside by this parasite.

The FILARIA SANGUINIS occurs probably in the adult form in the lymphatic vessels of the kidney. The embryoes have been met with in the parenchyma of the kidney and in the CHYLOUS URINE which seems to be the result of the presence of the parasite.

B.—THE URINARY BLADDER AND URETHRA.

CONGENITAL MALFORMATIONS.—These are chiefly represented by EXTROVERSION OF THE BLADDER. In this the anterior wall of the bladder and the corresponding portion of the abdominal wall are wanting, so that the posterior wall of the bladder fills the gap, and is continuous at its margins with the skin. The symphisis pubis is also

usually incomplete, the rami ending in rounded lateral prominences; the urethra is also laid open on its superior aspect, the bladder being continued in the form of a gutter into the urethra. There are also generally other coincident defects in the organs of generation. The abdominal viscera bulge out the wall of the bladder which forms a red convex surface in the lower part of the abdomen. On this exposed surface the openings of the ureters may be seen with the urine trickling from them. The mucous membrane is usually inflamed and bleeds readily, and as the urine escapes involuntarily the skin around is irritated and frequently excoriated.

Occasionally the URACHUS REMAINS OPEN, generally from obstruction in the urethra. If the patency be complete the urine will come away from its aperture at the umbilicus.

PERFORATION AND RUPTURE OF THE BLADDER.—Rupture may be produced in various ways. It may be by a direct wound, by fracture of the pelvis, by injuries during parturition. Then ulceration not infrequently produces perforation, ulceration from stone on rare occasions, but most frequently the ulceration of a cancer. Lastly, the bladder may be ruptured by a blow, or by a catheter being pushed through its wall, but this will hardly occur unless its wall has already been greatly thinned by dilatation or ulceration.

These conditions are important chiefly in their consequences, leading as they commonly do either (1) to extravasation of urine in the surrounding tissue, or (2) to the formation of fistulous communications with the surface or neighbouring canals.

Simple extravasation of urine is not in itself serious. The normal urine is a bland fluid, and it may flow from a severed ureter or a ruptured bladder into the peritoneal cavity without producing any peritonitis, the urine being absorbed by the peritoneum and again excreted by the kidney. It is when the extravasated urine undergoes alkaline decomposition that it acquires excessively irritating characters. The urine being an exceedingly decomposable fluid, and being kept at the temperature of the body, it rapidly decomposes if the proper organisms find access to it. The products of decomposition lead to the usual violent septic inflammations associated with necrosis and suppuration.

Fistulous openings from rupture of the bladder may be into the uterus or vagina, into the rectum, or on to the surface of the skin. From these fistulæ the urine passes involuntarily as it reaches the bladder, there being no sphincter to retain it. They occur also as a

result of perforation of the bladder from without, especially from the uterus and vagina, the cause of perforation being sometimes cancer of these parts, sometimes sloughing from injury during parturition.

DILATATION AND HYPERTROPHY OF THE BLADDER.—A SIMPLE DILATATION may occur from a sudden obstruction to the urethra, or from paralysis of the muscles concerned in emptying the bladder. In this way a very extreme general dilatation may result.

HYPERTROPHY OF THE MUSCULAR COAT is of very frequent occurrence as a result of some obstruction either at the neck of the bladder or in the urethra. The commonest cause is enlargement of the prostate leading to the prominence of the so-called middle lobe at the internal orifice of the urethra. The muscular coat of the bladder is in the form of bundles of muscular fibre-cells which run in special directions. The muscular coat is therefore not a homogeneous layer, but more like a network of interlacing bands. It is so at least when the bladder is distended, the bands coming closer together as the bladder contracts. When hypertrophy occurs these bundles increase greatly in size, and the internal ones raise the mucous membrane into elongated prominences. As the bundles interlace, the result is that the internal surface of the bladder presents a network of prominent trabeculæ which suggest the appearance of the internal surface of a ventricle of the heart.

As these trabeculæ interlace, little spaces are left between them in the form of small pouches. Sometimes these pouches undergo considerable enlargement, and we may have DIVERTICULA formed in this way, which sometimes attain to a considerable size. The diverticulum is originally formed of the mucous membrane pushed out between the thickened muscular trabeculæ. When small it will be contained in the thickened wall of the bladder and emptied during micturition. But as it deepens and projects outside the wall of the bladder it becomes free of the muscular coat, and as it possesses no muscular coat of its own the effect of contraction of the bladder during micturition will be to force the urine into it, just as it is forced into the urethra. The diverticulum is liable in this case to periodical dilatation. The urine also will stagnate in it, and if decomposition occurs, then there will be inflammatory disturbances in the wall of the diverticulum. New-formation of connective tissue occurs, and as this tissue is at first soft the recurring dilatation during micturition causes it to yield so that a continuous enlargement goes on. In this way we sometimes meet with a large sac, usually behind the bladder and communicating with it by a narrow

neck (Fig. 288). The sac may be larger than the bladder itself, and it presents a somewhat thick fibrous wall with signs of recent inflammation internally.

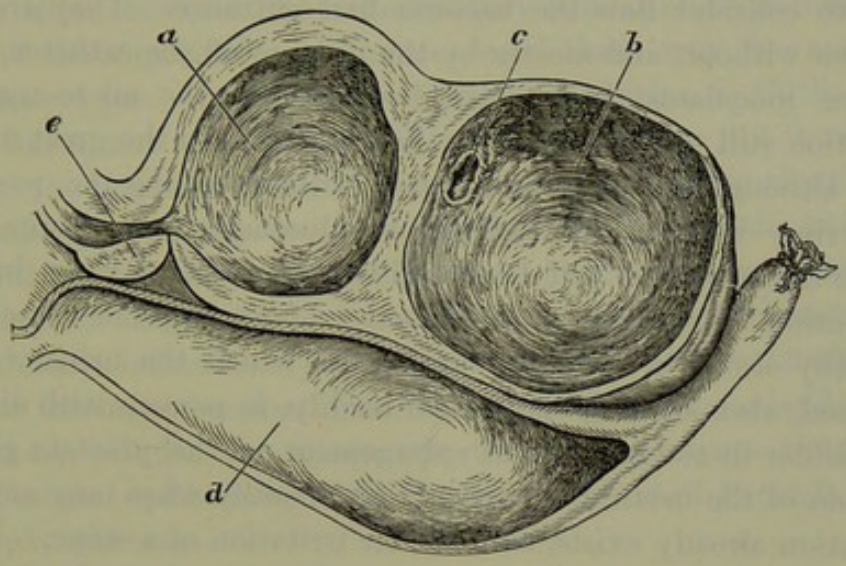


Fig. 288.—Large diverticulum of urinary bladder; *a*, bladder with greatly thickened wall; *e*, prostate and prostatic urethra; *b*, diverticulum with fibrous wall; *c*, aperture between bladder and diverticulum; *d*, rectum.

In diverticula of moderate or large size calculi are liable to form from the stagnation of the urine. Or a calculus may slip into such a pouch and escape detection with the sound.

Disturbances of the circulation in the bladder.—Passive Hyperæmia occurs in consequence of obstruction in the veins by tumours or otherwise. Sometimes in such cases the veins of the mucous membrane undergo great dilatation and become varicose, especially in the floor of the bladder, giving rise to vesical hæmorrhoids. The dilated veins may even obstruct the orifice of the urethra, and there is sometimes hæmorrhage from them.

Hæmorrhage from the bladder may occur also in consequence of the irritation of calculi, from tubercular ulcers, from papillary and cancerous tumours. There may be hæmorrhages from the mucous membrane in scurvy, hæmorrhagic small-pox, etc. If the bleeding into the bladder be considerable the blood may coagulate, and may be discharged with some difficulty. Or it may mix itself with the urine, and no consistent coagulum be formed.

Inflammation of the bladder.—This occurs as a consequence of various kinds of irritation. Stone may produce it, and the extension

of gonorrhœa, but by far the most frequent cause of it is alkaline decomposition of the urine.

This decomposition of the urine is due to the growth of bacteria, and we have to consider how the bacteria find entrance. They are introduced from without, and mostly by the passage of the catheter, which, as it were, inoculates the contained urine with the micro-organisms. The question still remains, however, how it is that in the great majority of cases, although the catheter be used without taking the precaution of rendering it free of bacteria, no decomposition results. The answer to this question will be found in the kind of cases in which decomposition does occur in consequence of passing the catheter. It very readily occurs in cases of paraplegia in which the urinary bladder is paralysed, also, although much less readily, in persons with dilatation of the bladder in consequence of enlargement of the prostate gland, or obstruction of the urethra. It occurs also readily when any amount of inflammation already exists, as from the irritation of a stone. In these cases the mucous membrane of the bladder is abnormal. In the case of spinal paralysis its muscle is paralysed, and probably the mucous membrane is affected in its nutrition. In cases of dilatation the mucous membrane is stretched, and in inflammation it is directly altered. We may infer, therefore, that while the normal mucous membrane is able to prevent the multiplication of bacteria, like other living tissues, the altered mucous membrane is less able to do so. In addition to this, in most of the cases there is stagnation of the urine, and the organisms get leave to multiply, whereas normally they are carried out at the first micturition. Besides being carried in by the catheter, the bacteria may find other means of entrance, as by fistulous openings. It is not impossible that in the case of the short female urethra they may propagate along that passage from the vagina.

The products of decomposition produce the usual inflammatory manifestations with various degrees of violence. In very acute cases there is great swelling of the mucous membrane, it may be with superficial or deep sloughing. In more chronic cases the mucous membrane gets thickened and very frequently becomes the seat of ulceration, so that with thickening and ulceration there is very great irregularity of the surface, sometimes with polypoid projections. The surface is occasionally incrusted with phosphates deposited by the alkaline urine. The muscular coat is often thickened, especially when there is at the same time obstruction to the passage of the urine, and there is the usual trabecular appearance, but obscured by the thickening of the

mucous membrane. The bladder may undergo great contraction in consequence of this chronic inflammation, the new-formed tissue in the mucous membrane shrinking.

The urine contains the inflammatory exudation as well as the products of decomposition. In acute cases there may be considerable quantities of pus. In more chronic cases the urine is thick and gelatinous like a mucous secretion. The toughness does not, however, depend on the presence of mucin, but is occasioned by the albumen of the inflammatory exudation being acted on by the alkaline salts in the urine. It is well known that the presence of pus in the urine may be detected by adding an alkali; the urine assumes a gelatinous character. The pus and other inflammatory products in the bladder are similarly acted on when the urine becomes alkaline, and we have the viscid character referred to. Under the microscope the urine presents abundant pus corpuscles and epithelium, with immense numbers of bacteria and crystals of phosphates.

TUBERCULOSIS OF THE BLADDER.—This condition is usually only a

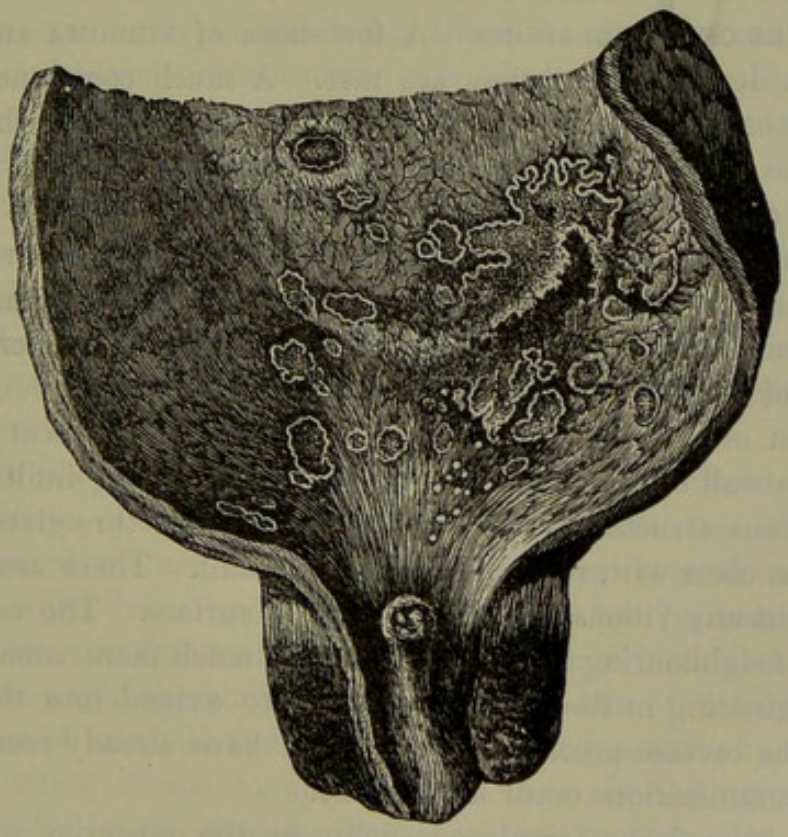


Fig. 289.—Tuberculosis of the bladder. Many round or serpiginous ulcers are shown. These are superficial, but are defined by their white edges which represent recent tubercles. There are several white spots, indicating tubercles which have not yet ulcerated. (VIRCHOW.)

part of much more extensive tuberculosis. There is often a coincident tuberculosis of the kidney and ureter, the disease having originated there and extended downwards to the bladder, or more rarely it has begun in the bladder and passed upwards. Then the vesiculæ seminales, vas deferens and testicle are not infrequently affected, and the bladder affection may be due to propagation from an organ as far off as the testicle.

The tuberculosis is in the form of ulcers of the mucous membrane which at first are circular, but acquire various shapes by coalescence (Fig. 289). The ulcers are mostly superficial and their edges very slightly raised, the latter having a pale colour so that the ulcer is surrounded by a whitish zone. The disease begins by the formation of tubercles in the mucous membrane. These break down and form ulcers, which continuously extend by the infiltration of their walls and the breaking down of the infiltration. The general appearances of these ulcers are very well shown in the annexed figure from Virchow's work on tumours. Their superficial character renders them liable to be overlooked.

TUMOURS OF THE BLADDER.—A few cases of FIBROMA and MYOMA have been described, but they are rare. A much commoner form is the PAPILLOMA. This is met with for the most part in the inferior parts of the bladder, and forms either a prominent mass with projecting papillæ or else a surface covered by villi. The tendency of these villi to bleed is an important fact. Sometimes the villi break down and an ulcer forms. In any case they discharge abundant epithelium, which is to be found in the urine, and is not to be taken as evidence of the existence of cancer.

CANCER of the bladder is mostly met with in the form of villous cancer, the wall of the bladder beneath the villi being infiltrated with the cancerous structures. In some cases the structure gives way and a cancerous ulcer with raised edges is the result. There are also cancers without any villous projections of the surface. The cancer may extend to neighbouring structures, but it is much more common for a cancer originating in the uterus or rectum to extend into the bladder than for the reverse process to occur. We have already seen that fistulous communications occur in this way.

CYSTS have been found, especially in the posterior wall of the bladder.

PARASITES.—If we except the bacteria already referred to, parasites in the bladder are of secondary importance. We have already seen that the echinococcus may burst into the pelvis of the kidney, and portions of the parasite will pass into the bladder. Ascarides and oxyurides have been found to wander into the bladder. The distoma hæmatobium, as we have seen, by the penetration of its ova may produce considerable irritation and hæmorrhage. The filaria sanguinis is also found in the bladder as in the kidney and its pelvis.

Sarcinæ have been found in the urine by no means infrequently. From what has already been stated as to their development from the blood, their occurrence here will be understood. They are met with in cases of inflammation of the bladder.

CONCRETIONS AND CALCULI IN THE BLADDER.

These consist of the urinary constituents, normal or abnormal, deposited in bulk so as to form distinct smaller or larger stones. We have to consider what determines this abnormal precipitation of the urinary constituents, and we may begin by considering how these same constituents come to be precipitated in the urine after evacuation.

The most frequent constituents of urinary calculi are phosphates, uric acid and oxalate of lime. Phosphates are precipitated from alkaline urine, uric acid and oxalate of lime from acid urine. The phosphates are deposited abundantly when the urine undergoes its usual alkaline decomposition, uric acid and oxalates are thrown down in crystals when the urine, at the time of evacuation or afterwards, becomes unduly acid, the deposition of oxalates occurring usually some time after the urine has been passed, so that this precipitate often, as it were, powders the surface of other deposits.

Inside the bladder or the pelvis of the kidney, phosphates may be deposited because of undue alkalinity, especially in the case of alkaline decomposition of the urine. These often form an external coating on other stones when, from decomposition, the urine has become alkaline. Phosphates are also frequently deposited on foreign bodies which have found their way into the bladder, such as broken bits of catheters.

In the case of uric acid and oxalate of lime it seems that sometimes their precipitation is due to an excess of them in the urine. This applies especially to the oxalates, and there are undoubtedly cases in which there is almost continually an excess of oxalate of lime in the urine (oxalic acid diathesis). But in both cases the substances are de-

posited from an acid urine, and in the case of uric acid it must be strongly acid. The cause of this abnormal acidity is not always clear. In some cases it may be due to excessive development of acid in the stomach.

The formation of calculi of uric acid and oxalate seems always to begin in the kidney, and even in some cases in the uriniferous tubules. In these and in the pelvis it is very common to find small concretions of uric acid, forming the so-called SAND and GRAVEL, composed of aggregates of uric acid crystals usually rounded in shape and of a brownish red colour. There may even be large concretions of uric acid in the pelvis of the kidney. In connection with the formation of the uric acid and oxalate calculi it is interesting to observe that the two bodies are often combined in one calculus, the mulberry stone especially having frequently a nucleus of uric acid, and perhaps layers of it alternating with the oxalate.

It may now be convenient to give a brief description of the different forms of calculi, with an indication of the chemical methods for determining their constitution. As a rule it is convenient to have the calculus sawn through the middle with a lapidary's saw, so that the arrangement of its layers may be seen and the character of its nucleus.

THE URIC ACID CALCULUS is the most frequent. It is usually a small oval stone with small rounded prominences regularly distributed over the surface. The colour varies from a light fawn to a deep brick red. It is heavy for its size, and of hard consistence. Uric acid is insoluble in water and dilute acids, but very soluble in caustic alkalies and weak solutions of alkaline carbonates. A convenient test is the *murexid* reaction. A fragment of the calculus is treated with a drop of strong nitric acid and heated. Effervescence occurs, and the heat is continued till a dry yellowish red residue remains. When caustic ammonia is added a bright violet red hue is developed.

Calculi formed of URATES are rare, the salts being urates of ammonia and magnesia. They are small soft concretions formed in the kidney, and are distinguished by their solubility in boiling water. They hardly deserve to be reckoned among the vesical calculi.

The OXALATE OF LIME OR MULBERRY CALCULUS is a very important form. Sometimes small stones are discharged as gravel, forming smooth, round, grayish balls like hemp seeds. The calculus proper is mostly of an irregularly spherical shape, tuberculated on the surface like a mulberry, and of a grayish or nearly black colour. On section it

is seen to be in layers, some of them generally composed of uric acid, which usually forms the nucleus. The calculus contains abundant organic material which holds the colouring matter, so that when the oxalate is dissolved out the organic basis often retains the shape of the calculus. Oxalate of lime is insoluble in the alkaline carbonates and organic acids, but soluble in nitric and hydrochloric acids. If a fragment be heated on a piece of platinum before the blow-pipe it becomes black, swells up and leaves a bulky white ash of caustic lime which renders litmus blue.

Calculi of BASIC PHOSPHATE OF LIME alone are very rare. They form comparatively small yellowish or grayish white stones, rather hard and smooth on the surface.

The MIXED OR TRIBASIC PHOSPHATIC CALCULUS is very common, at least many calculi are partly formed of these salts, although few are so entirely. The phosphates are deposited from alkaline urine as a light, bulky, white substance, which is commonly very brittle. The salts are insoluble in water and alkalies, but are very soluble in acids. When a fragment is heated in the blow-pipe flame, the salts melt and form a hard enamel; hence this form is often called the FUSIBLE CALCULUS.

The CARBONATE OF LIME CALCULUS is rare. It forms small, round, soft stones. The salt dissolves with effervescence on adding an acid, leaving an organic matrix of the shape of the stone.

CYSTINE forms calculi in persons who are subjects of CYSTINURIA. It appears as if by a congenital derangement of the nutritive processes such persons form cystine, to a certain extent probably in place of uric acid; and this peculiarity occurs frequently in several members of the same family. The urine, continuously or frequently, contains flat hexagonal crystals of cystine, and these may be already present in the urine at the time of evacuation, or may be deposited after the urine has stood for a time. The cystine may begin to be deposited in the uriniferous tubules so that calculi are formed in the pelvis of the kidney, or it may be deposited in the bladder. The stones are oval in shape and have a waxy consistence. The surface is brownish or greenish yellow in colour, and crystals can often be separated from it. The stone may be buried in a shell of phosphates. Cystine is soluble in alkalies, mineral acids, and oxalic acid.

XANTHINE CALCULI are exceedingly rare. The substance is allied to uric acid, and the stones are like those of uric acid but of a redder colour. On applying the murexid test to a fragment of such a stone, it is found to dissolve in nitric acid but without effervescence; the addition of ammonia gives an orange colour.

DISEASES OF THE URETHRA.

Of these the most important are the inflammations.

GONORRHŒA is a specific inflammation accompanied by redness and swelling of the mucous membrane with purulent exudation, sometimes mixed with blood. The inflammation is thus at first acute, and it may result in suppuration around the urethra, in the prostate or in the testicle, the virus in the last-mentioned case probably propagating itself along the vas deferens. There may be an ulceration of the mucous membrane as a consequence of the inflammation.

If the acute stage subside there often remains a chronic inflammation, characterized mainly by a persistent mucous or muco-purulent discharge. As in other chronic catarrhs there is new-formation of connective tissue, and in the male urethra this frequently leads to STRICTURE. The new-formed connective tissue contracting narrows the tube, and sometimes quite a hard cicatricial tissue occupies the mucous membrane and sub-mucous tissue. Or the thickening may be mainly in the mucous membrane which bulges inwards and forms folds which obstruct the calibre in the male urethra, or form projecting or prolapsed folds in the female.

Besides gonorrhœa we may have inflammations produced by other causes. A simple catarrh may arise, especially in the female urethra, sometimes from propagation of an inflammation from neighbouring parts.

DISEASES OF THE FEMALE GENERATIVE ORGANS.

INTRODUCTORY.—It is hardly necessary to state that these organs are specially liable to disease from their functional relations. At the times of menstruation and pregnancy very extraordinary changes occur, some of which although strictly physiological border on the pathological. The anatomical relations of the internal organs of generation in the female have also to be taken carefully into account in connection with the changes in position to which the uterus is especially liable. It will be necessary to take up the individual portions of the organs of generation separately, but for purposes of convenience the malformations of the whole set of organs will be taken together.

MALFORMATIONS OF THE FEMALE ORGANS.

In treating of this subject it is necessary to bear in mind that the internal and external organs have no connection with each other in their origins, and so the malformations of the one are not necessarily connected with the malformations of the other.

HERMAPHRODITISM.—This name implies the union of the two sexes in the same individual. So far as the internal organs are concerned such a condition is rendered possible by the fact that in every fœtus the embryonic structures for both sexes are present at a certain period of development; the Wolffian ducts go to form the male organs, and the Müllerian ducts go to form the female organs. It is by the subsequent retrogression of one of these and the preponderance of the other that the sex of the child is determined. It is well known that in the adult the testicle is represented in the female by the parovarium, and the ovary is represented in the male by the hydatid of Morgagni which lies

beside the epidydimis, while the vesicula prostatica represents the uterus.

These facts indicate that we may have a TRUE HERMAPHRODITISM, in which ovary and testicle are both represented. Cases have been recorded in which on both sides both of these glands have been present, one of them however generally ill-developed. This would form a true BILATERAL HERMAPHRODITISM. On the other hand there may be a testicle on one side and an ovary on the other, forming a true LATERAL HERMAPHRODITISM. It is necessary, however, in such cases to be careful, and not to conclude that an organ is testis or ovary from its mere position, but to subject it to microscopic examination.

It is clear that the sex of an individual is determined by the existence of the testicle on the one hand or the ovary on the other, and no case is truly bisexual unless both these glands are present. But there are cases in which, with the sex determined by the presence of ovaries or testicles, the other parts present the structures belonging to different sexes. In such cases the designation PSEUDO-HERMAPHRODITISM is used, and according as the ovaries or the testicles are the glands present, they are male or female.

In cases of MALE PSEUDO-HERMAPHRODITISM, three different combinations may be recognized, but in all there are testicles present. (1) *Internal.* In this case the external organs are those of the male and the testes are present, but from the prostatic urethra a canal arises which represents an elementary vagina with a uterus at its extremity, sometimes with Fallopian tubes. The uterus may be of the regular form but small, or it may be two-horned, or with one horn and a Fallopian tube. We have already seen that the vesicula prostatica is the representative in the male of the vagina and uterus, and the condition we are now considering is an exaggeration of that pouch due to an unusual persistence of the lower part of Müller's ducts. There may be all degrees of this persistence, but the case is not one of pseudo-hermaphroditism unless there is something that can be called a vagina and uterus, even if very rudimentary. (2) *Complete male pseudo-hermaphroditism* is the condition in which, while the glands are the testes, all the remaining organs both internal and external approach to those of the female. This arises by a persistence of Müller's ducts and an imperfect closure of the urethra. It may here be remarked that as the external generative organs arise from the same fœtal structures in both sexes, they cannot really represent both the female and the male sexes in the same person. But as

the male organs present as it were a further development, chiefly consisting in enlargement of the clitoris and closing in of the urinary passage to form a urethra, we may have, by arrest of development, more or less approach to the condition of the female organs. (3) *External male pseudo-hermaphroditism* is characterized by the external organs presenting the characters of those of the female while the entire internal organs are those of the male. The cases are to be excluded in which there is simply an opening up of the urethra (hypospadias) from arrest of development. There must, in addition, be an approach in the form of the organs to those of the female. At the same time the general form of the body is that of the female. Several such cases have been married as females, and the true sex only discovered on post-mortem examination.

FEMALE PSEUDO-HERMAPHRODITISM is of much more rare occurrence than male and is susceptible of similar division. In all these forms there are ovaries, and the variations are in the other organs. There is (1) the *internal* in which with well-developed female organs, both external and internal, there are male organs present in the persistence of the Wolffian ducts, tubes passing from the parovarium to the uterus or vagina. This condition is excessively rare, although in ruminating animals it is a normal condition. (2) *Complete female pseudo-hermaphroditism* presents the male form of the external organs as well as a portion of the male internal organs, while the ovaries are the glands present. In one case the male organs were complete as far as the prostate, but from this sprang vagina, uterus and Fallopian tubes. (3) In *external female pseudo-hermaphroditism* the external parts have the characters of the male while the internal have those of the female. It will be understood that an elongation of the clitoris will cause the parts to approach to those of the male, and some cases present nothing more than this. The name hermaphrodite can hardly be applied unless there is as well a type of body approaching that of the male. A case is recorded in which the real sex was only suspected when the person became pregnant.

OTHER MALFORMATIONS OF THE FEMALE ORGANS.—We have DEFECT of various parts and in various forms. The ovaries may be wanting or may remain rudimentary. The uterus may be awanting, and with it the Fallopian tubes; or it may be quite rudimentary (Fig. 290), presenting perhaps a solid rudiment, or merely two diverging horns. With this the vagina is often defective. Then the uterus may remain in the adult of the fœtal or infantile form. Again, the uterus or

vagina may be imperforate, or the hymen imperforate. There are also various defects of the external organs, as absence of the vulva,

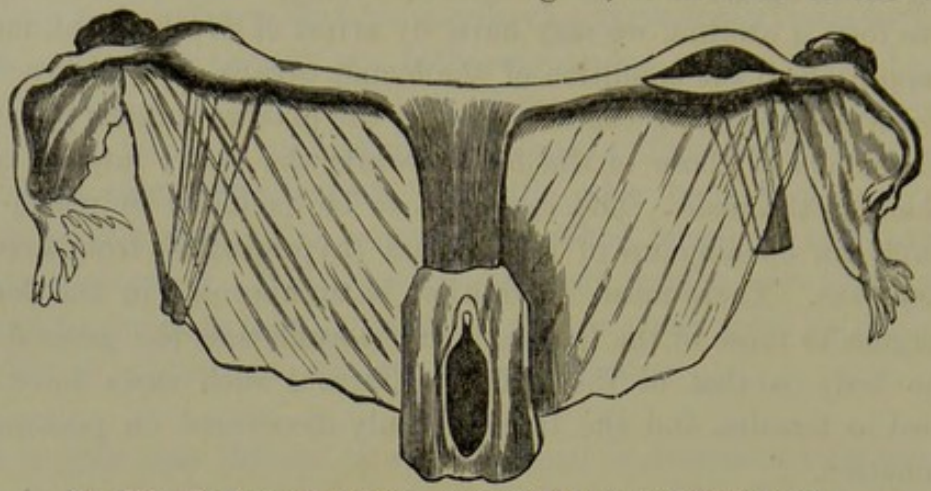


Fig. 290.—Rudimentary uterus. (Graily Hewitt from Kussmaul.)

the vagina and urethra opening by a small aperture in the region which the vulva should occupy. The hymen may be absent, or it may present fimbriated processes sometimes so large as to project externally.

A very interesting and important malformation is the DOUBLE UTERUS. This arises by reason of the two Müller's ducts uniting imperfectly, and there may be several varieties. We may have the uterus forming two distinct diverging horns, and each with a separate vagina. Or the two horns may unite below to a greater or lesser extent (Fig. 291), the cavities remaining separate, and with the vagina

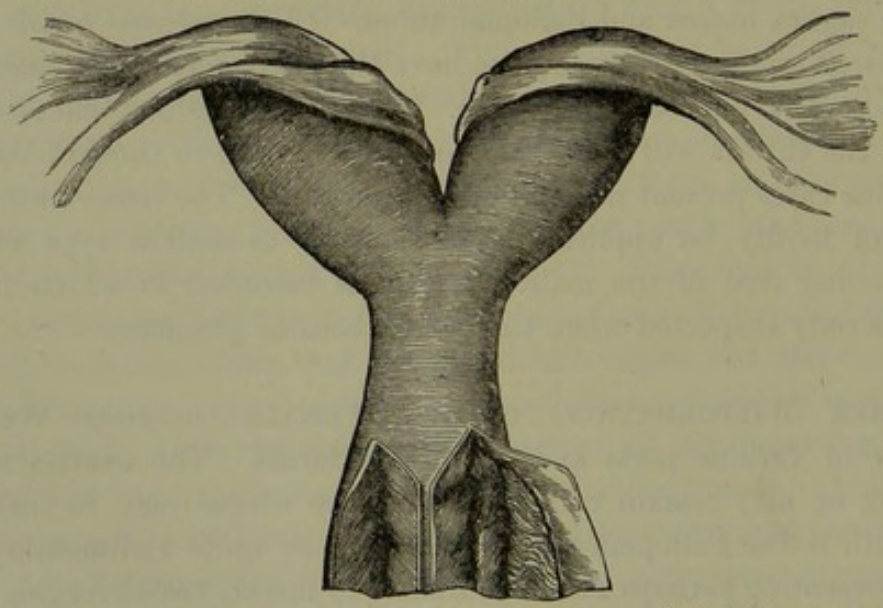


Fig. 291.—Uterus bicornis. The two horns, which are distinct above, are coalesced in the lower part. The cavities, however, are separate, and there are two vaginas, as shown in figure. (Graily Hewitt from Kussmaul.)

single or double. Or the two horns may be so united that the cavity of the neck or even a portion of the body is single.

There are again cases in which, without any indication of separate cornua, the uterus is divided up the middle by a septum, each half with a separate cervix and sometimes a separate vagina. Or the division may be only partial, the body of the uterus having usually a septum, while the cervix has none.

The UTERUS UNICORNIS occurs when one Müller's duct is undeveloped. This uterus is a long thin structure which curves to one side, while the other horn is absent or rudimentary (Fig. 292).

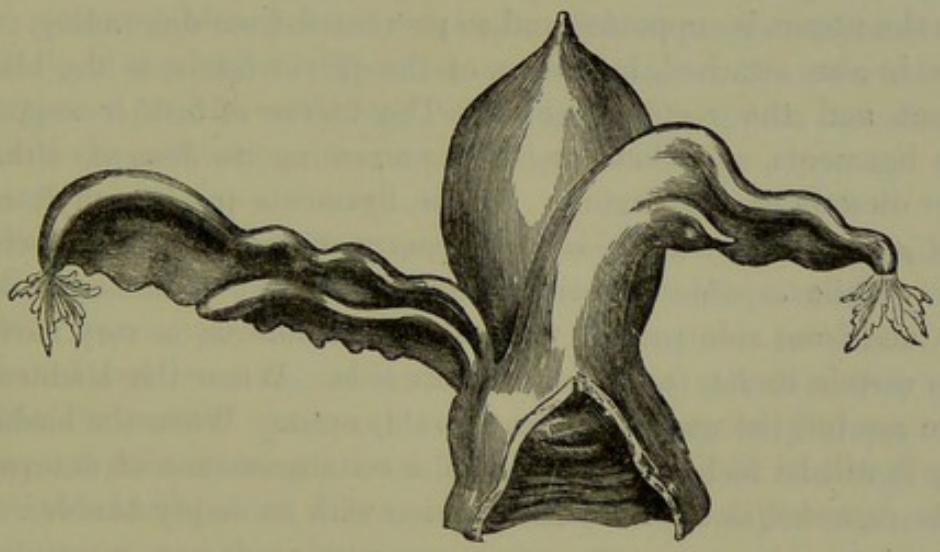


Fig. 292.—Uterus unicornis. The parts are viewed from behind, and the distended bladder occupies the background. The right horn is large, and runs into the Fallopian tube whose fimbriated extremity is shown. There is no proper left horn, the Fallopian tube and round ligament springing from the base of the right horn. (GRAILY HEWITT from KUSSMAUL.)

Pregnancy may occur in all these forms of malformation, the fœtus developing in one half of the uterus. Even the single horn in the case of uterus unicornis, although usually imperfectly formed, may be the seat of a developing fœtus, which, however, usually causes rupture of the ill-developed organ in the third to the sixth month.

A.—THE UTERUS AND VAGINA.

MISPLACEMENTS OF THE UTERUS.

The arrangements by which the uterus is supported are of importance to the understanding of the misplacements of the organ. In the virgin the vagina forms a tolerably solid column, on the summit of which the uterus is supported and so prevented from descending. The vagina is also attached, by means of the pelvic fascia, to the bladder in front and the rectum behind. The uterus is further supported by its ligaments, and these assist in preventing its descent, although not so directly as the vagina. By the ligaments passing off from its lateral aspects, the uterus is kept from inclining to one side or the other. While capable of very limited movement from above downwards and from side to side, the body of the uterus is very movable, within certain limits, from before backwards. When the bladder and rectum are full the uterus will be tolerably erect. When the bladder is empty it will be inclined forward, and a certain amount of anteversion may be regarded as the normal condition with an empty bladder.

Prolapse or Descent of the Uterus.—This occurs for the most part as a result of the loosening of the attachments of the organ, combined frequently with increased weight from chronic inflammation. It may also be produced suddenly by a severe exertion, as in raising a heavy weight. In this case the abdomen is fixed in the expiratory position, and by the pressure of the abdominal muscles and diaphragm the viscera are forced downwards and so may carry the uterus down, although here also there may have been some preliminary looseness of vagina and ligaments. Besides increased weight of the organ itself, a tumour by its weight may assist in dragging it downwards. It will be apparent that pregnancy, with its various circumstances, will have great effect in loosening the attachments of the uterus, and prolapse is consequently much more frequent in married women than in virgins.

The degree of descent is very various; it may simply amount to a lowering of the position of the uterus an inch or so, or it may be to any extent up to the presentation of it in the vulva or outside, this

latter condition being designated PROCIDENTIA. The vagina must be inverted in proportion to the descent of the uterus, and in cases where it is completely procident the vagina will form an external covering continuous with the skin around.

As the uterus descends it is held more by the posterior attachments to the rectum than by the anterior ones to the bladder, and there is accordingly a certain amount of retroversion along with the prolapse.

The mucous membrane of the uterus is mostly in a state of catarrh in prolapse, with a profuse mucous discharge, and the organ itself is enlarged. There is often a special enlargement of the cervix which may be so elongated as to present externally without much misplacement of the body of the uterus. The mucous membrane of the inverted vagina is thickened, and its epithelium, where exposed, acquires characters like those of the epidermis.

PROLAPSE OF THE VAGINA.—This occurs mostly in connection with pregnancy, and seems to be caused by the walls remaining hypertrophied when they ought to undergo the regular involution. The thickened and loose vagina is thrown into folds, and these may project outside the vulva. As a consequence there may be prolapse of the uterus. Again, looking to the close connections of the vagina with the rectum and bladder, it is not surprising that prolapse of the former causes dragging on these latter structures. The connection of the vagina with the neck of the bladder and trigonum is much more intimate than with the rectum, and so we have more frequently descent of the former than of the latter. In this way CYSTOCELE and RECTOCELE occur, pouches or diverticula, from these organs respectively, passing downwards with the prolapsed vagina.

INVERSION OF THE UTERUS.—This is of very rare occurrence. It can only happen when the uterus is somewhat enlarged, or when, either by its own contraction or by the exercise of traction on its fundus, the organ is turned outside in. These conditions are best fulfilled during or after parturition, especially when the umbilical cord is pulled on while the placenta is adherent. It may also occur in connection with a tumour growing inside the uterus and attached to its internal wall. The inverted uterus projects from the vulva as a bleeding mass, the hæmorrhage being frequently so severe as rapidly to cause death. If the patient survives and the organ is not restored, inflammation results,

and the uterus acquires attachments in its new situation, so that resort has sometimes to be had to amputation.

ANTEFLEXION and RETROFLEXION.—By these names are designated the bending of the uterus on itself, the lower part forming an open angle with the upper. The flexion takes place at a point corresponding with the internal os, and the explanation of this seems to be that the portion of the uterus corresponding with the cervix is, in front at least, closely attached to the wall of the bladder, the pouch of peritoneum between bladder and uterus not reaching below the level of the internal os. The cervix therefore being comparatively fixed, the rest of the uterus may be bent either forwards or backwards. Abnormal looseness of the texture of the uterus, occurring especially after delivery, renders it more liable to bend, and the flexion is always at this place. But again, if the fundus or body of the uterus acquires adhesions to the parts in front or behind, then these adhesions will tend to give it a permanent bend in their direction. There is another circumstance which tends to make the flexions permanent; the uterine tissue is apt to waste in the concavity of the bend, and so there is all the more tendency to doubling up.

All that has been stated applies equally to anteflexion and retroflexion, and they are both of frequent occurrence, the former being usually regarded as the commoner form.

ANTEVERSION and RETROVERSION.—In these conditions there is displacement of the entire organ forwards or backwards. The organ comes to lie more horizontally than usual, and the cervix and os will be displaced backwards or forwards in the opposite direction to the fundus. These changes in position occur for the most part as a result of pregnancy, the uterus remaining loose and unable to support itself properly in some cases. Anteversion and retroversion rarely occur without a certain amount of the corresponding flexions.

These flexions and versions sometimes produce serious results in the uterus itself. We have already seen that, in the concavity of the bend, the uterine tissue frequently wastes and becomes less able to retain the uterus in the upright position. Then the bend, if at all sudden, compresses the vessel, and may lead to a chronic congestion, by and by resulting in hypertrophy. Again, the curve may obstruct the canal of the cervix, thus leading to dysmenorrhœa. The flexions and versions not infre-

quently predispose to prolapse. The fundus of the uterus projected backwards or forwards is apt to irritate the bladder or rectum and so induce repeated straining efforts which tend to force the uterus down.

ATROPHY, HYPERTROPHY, AND DILATATION OF THE UTERUS.

ATROPHY.—We have already seen that the uterus may retain in adult life the undeveloped condition of that of the child. On the other hand the organ becomes smaller at the close of the period of sexual activity, a kind of physiological atrophy. There may be, however, a premature atrophy, in some cases ascribed to long-continued catarrh, frequent pregnancies, pressure of tumours, etc.

HYPERTROPHY.—This sometimes occurs as a result of imperfect involution after the physiological enlargement of pregnancy, and in this case the increase in size is from excess in the muscular substance mainly. Hypertrophy of a similar kind occurs, though very rarely, without apparent cause. There may be hypertrophy from congestion and chronic inflammation however caused.

A special HYPERTROPHY OF THE CERVIX has been observed in many cases. It occurs as a result of imperfect involution after pregnancy, but also as a consequence of prolapse of the vagina, the cervix being dragged down and greatly elongated. With very little descent of the uterus the cervix may be so elongated as to present externally.

DILATATION.—This occurs in consequence of the retention and accumulation of material in the cavity of the uterus. It results, therefore, from obstruction of the vagina or of one of the orifices of the uterus. There may be congenital closure of the external or internal os (generally the external) or imperforate hymen. When the period of puberty is reached and menstruation begins the blood accumulates in the uterus, and there may be enormous distension, the contents having a tarry or pulpy character. This condition is designated HÆMATOMETRA. The uterus may assume the size of the pregnant organ, and there is thickening of its walls, which, however, are loose. If escape is not provided artificially the uterus may actually rupture, not usually into the peritoneum, but, after the formation of adhesions, into some neighbouring organ. The rupture is by a process of ulceration from within, unless external violence bursts the distended organ.

There may be an acquired obstruction of the os uteri as from chronic catarrh, or even from inflammation occurring after delivery.

In such cases also we may have dilatation with the menstrual blood. It is more common, however, to have such closure after menstruation has permanently ceased, and as a result of chronic catarrh. In that case the catarrhal secretion may accumulate and distend the uterus. After a time the contents, which are at first mucous in character, become serous. This condition is sometimes called HYDROMETRA.

Lastly, the organ is sometimes distended with GAS. This may be the result of decomposition of the accumulated fluid in hydrometra, or from decomposition of retained clots, etc.; but cases have occurred in which the cavity has been dilated with gas and assumed considerable proportions without apparent cause.

INFLAMMATIONS OF THE UTERUS AND ITS APPENDAGES.

These are somewhat various, and they are differently named according to the locality specially affected. In this way we have to consider ENDOMETRITIS, METRITIS, PARAMETRITIS and PERIMETRITIS. The condition of the uterus and vagina after delivery lays them open to the occurrence of septic inflammations, and many of the conditions here have often this origin.

(1) ENDOMETRITIS.—This is an inflammation of the mucous lining of the uterus. We may have an acute inflammation set up by catching cold at a menstrual period, or by the extension of a gonorrhœal inflammation from the vagina, or in the course of an acute fever. The inflammation may go on to suppuration or even to sloughing of the mucous membrane and the formation of ulcers.

CHRONIC ENDOMETRITIS or chronic catarrh is a very frequent disease, and as a whitish discharge is a characteristic feature the condition is often called leucorrhœa. Apart from the excessive secretion the mucous membrane is apt to become thickened, and it may be thrown into folds or give origin to mucous polypi. The cervix especially is often thickened, and the os may present ulcerations. These ulcerations are for the most part little more than superficial excoriations, and are important chiefly as indicating the existence of catarrh of the cervix and interior of the uterus. Chronic catarrh sometimes arises without any apparent exciting cause except a general anæmia, which may be related to scrofula or chlorosis. During pregnancy inflammations sometimes arise giving occasion to abortions, adhesions of the placenta, and other lesions. The catarrh may also have its origin in a tumour, a flexion, or a version of the uterus.

(2) METRITIS.—This name is given to inflammation of the wall of the uterus, but it hardly occurs as an independent affection, being commonly the result of extension of inflammation from the mucous membrane. Acute inflammation, even with infiltration of the muscular substance with blood, may follow gonorrhœa. We may have also, from various causes, a chronic inflammation leading to induration, it may be with enlargement of the uterus. This is sometimes related to imperfect involution of the uterus after parturition, or to the various causes which bring about endometritis.

The terms *Perimetritis* and *Parametritis* are used to designate inflammations occurring in the peritoneum around the uterus (perimetritis), and in the connective tissue around the organ between it and the peritoneum (parametritis). As, however, the whole of the peritoneum of the pelvis is apt to be involved in the one and the whole of the connective tissue of the pelvis in the other, the names *pelvic peritonitis* and *pelvic cellulitis* are at least equally appropriate terms. It will be understood also that with inflammation of the pelvic peritoneum, there will frequently be an inflammation of the sub-peritoneal connective tissue, so that these two conditions frequently go together.

(3) PELVIC PERITONITIS or PERIMETRITIS includes inflammations produced by all sorts of causes. Most frequently it is an inflammation of the uterus occurring after delivery or from gonorrhœa, which extends through the substance of the organ to its serous coat. Or it may be inflammation in the neighbouring intestine or bladder that has led to it. Or a tumour in the uterus or outside it may so far irritate as to cause a chronic inflammation.

In some of these cases the inflammation is acute and there is danger of a general peritonitis, but even when acute or subacute it may be circumscribed by adhesions, and an abscess may form which remains confined to the pelvis. Such an abscess may afterwards burst into the rectum, or vagina, or externally. When the inflammation is more chronic the result is adhesion of the pelvic organs, the adhesion being effected here as in the pleura, pericardium, etc., by new-formed vascular connective tissue. The adhesion and contraction sometimes lead to great matting together of the pelvic tissues and considerable fixity of the uterus, frequently with misplacement and deformity.

(4) PELVIC CELLULITIS or PARAMETRITIS.—This consists in a subacute inflammation of the pelvic connective tissue, generally occurring

after delivery, but also sometimes as a result of operations on the uterus, the introduction of pessaries, the uterine sound, etc. The inflammation is no doubt septic, being propagated through the uterine wall, being in this respect comparable with erysipelas and phlegmonous inflammations generally. The inflammation extends from the uterus, finding its way apparently by the lymphatic spaces. There are the usual results of inflammation, but the exudation is here the most important. The spaces of the connective tissue get filled up with a serous exudation which may be partly fibrinous. There is in this way a great tumefaction of the subperitoneal tissue, especially of the broad ligament, but also that in front of and behind the uterus and in the pelvis as a whole. The uterus is thus, as it were, fixed in the midst of tumefied connective tissue, which may be felt as a firm swelling on examination per vaginam.

Suppuration generally ensues, but it may do so very gradually, so that it may be long after parturition before it occurs. The pus sometimes extends a considerable distance from the neighbourhood of the uterus. In this way the inflammation may extend and the suppuration follow into the iliac or even into the lumbar region. The abscesses which result open in very various localities, into the vagina, the rectum or the bladder, or at the surface in the iliac or inguinal region. In these latter cases the condition may simulate that of lumbar abscess, and mistake is the more likely as the suppuration has perhaps occurred long after the originating cause. The pus discharged has usually the characters as of having been long retained, the corpuscles are largely fatty, and there is usually a fæculent odour due to the proximity of the abscess to the rectum.

PUERPERAL FEVER.

We have in this case not merely a local inflammation but a general affection of the system. The disease is really a septic infection with or without pyæmic abscesses.

We have here to deal with the entrance into the body of pathogenic bacteria. From what has gone before, especially in studying pyæmia, it will be apparent that it is probably a special kind of bacterium which is concerned. It is not necessary to suppose that the organism is so special as that which causes splenic fever, or in fact that it is always the same organism. But it must be a pathogenic form capable of living and multiplying inside the body. There are probably organisms of this

kind in many putrid fluids, but they are greatly multiplied in the body of a person infected with them, and are much more likely to be carried to another person from such an one. The infective material of other diseases, especially erysipelas, may be the cause of puerperal fever. Hence, although puerperal fever is not to be ranked as one of the specific fevers, we can understand how it is highly communicable, and how it occurs in groups of cases so as to simulate the epidemic form. In regard to the form of the organism, it is here as in other septic diseases a micrococcus, and in the peritonitis which is a frequent feature of puerperal fever, there may be myriads of these organisms in the peritoneal cavity.

The disease occurs in connection with the puerperal state, and in most cases there has been some wounding of the soft parts by the passage of the child. The protecting epithelium being removed, the bacteria may penetrate into the submucous tissue. The result is usually a very violent local inflammation, generally with a distinctly gangrenous tendency. The inflammation, with sloughing and suppuration, extends over the internal surface of the uterus, and extensive ulceration may occur. The fibrinous exudation covering and involving the mucous membrane, may have the appearance of the diphtheritic exudation in the fauces. Sometimes, however, the local inflammation is not very considerable.

From its local seat the process extends, and results in a more general infection. The path of extension and the resulting conditions are various. The septic inflammation may extend along the Fallopian tubes and septic pus find its way into the peritoneum. The resulting peritonitis is rarely localized, but we have rather a general septic peritonitis with resulting absorption of the products, and septic poisoning. In other cases the organisms get into the uterine veins, and by the ordinary process of thrombosis, etc., we may have a pyæmia having the usual characters, with suppuration in the joints and miliary abscesses in the lungs and elsewhere. The thrombosis here nearly always starts from the veins of the placental part of the uterus. In some cases there appears to be a septic infection of the blood without any local abscesses from embolism. In other cases the inflammation extends to the connective tissue of the pelvis. We have a violent parametritis with acute suppuration. The inflammation extends by and by to the peritoneum, and there is a violent septic peritonitis, just as when the extension is by the Fallopian tubes. The inflammation may extend through the diaphragm, and lead to a pleurisy.

It will be seen that in all these cases there is a vigorous multiplica-

tion of the micrococci, and that there must consequently be a great formation of chemical products. An acute septic poisoning is the result, and it is probably this which leads to the more pronounced symptoms of puerperal fever.

PHLEGMASIA DOLENS.

This is an affection in which great œdema occurs in one or both legs, usually as a sequel to the puerperal state. There is thrombosis of the uterine veins, the thrombi growing, as we have seen thrombi readily do, into the iliac veins, and onwards into the femoral and its branches. The starting point of the thrombosis is the placental surface of the uterus, and it is most apt to occur when, through imperfect contraction of the uterus, the veins are left with gaping mouths. It may be a question whether the introduction of septic material induces the coagulation, but in the usual absence of the general symptoms of septic poisoning, it may be doubted whether this has to do at least with the extension of the coagulation. The thrombosis may also have its starting point apart from the puerperal state, as in tumours of the uterus, dysentery, disease of the rectum, typhoid fever, etc., but as causes these are exceedingly rare.

We have already seen that there may be extensive thrombosis in the veins of the leg without œdema, and so in this case œdema is by no means coincident in its occurrence with the thrombosis. As, however, the femoral vein takes by far the greater part of the blood from the leg, and as the other veins of the leg also join the iliac, and are consequently liable to thrombosis as well, there is often ultimately a very complete plugging of the veins of the leg. This results in a very marked œdema. It is not improbable that the lymphatics may be also to some extent obstructed. We have formerly seen that thrombosis of a vein induces a chronic inflammation in its wall and around it (phlebitis and periphlebitis), so that there is often considerable adhesion of the vein to its sheath and of the sheath to the parts around. The lymphatic vessels may be affected by this adhesion and partially obstructed. The disease occurs most frequently in the left leg, and this is ascribed by some to the fact that the parts on the left side of the pelvis are more liable to bruising during delivery than those on the right.

PERIUTERINE HÆMATOCELE.

This name is given to the condition in which blood accumulates around the uterus, usually in Douglas's space. The bleeding occurs nearly always at a menstrual period, and it is natural to look for the source of the blood in the processes occurring then, namely the bursting of the Graafian vesicle and bleeding from the uterine mucous membrane. If there is an obstruction to the exit of blood from the uterus it may pass backwards by the Fallopian tubes into the peritoneum. This is probably the commoner source of the hæmorrhage, which also occurs from rupture of one of the veins of the uterine plexus, especially if these be varicose. At the menstrual period there is hyperæmia of these veins, as of the whole vascular system of the uterus, and they may rupture. There may also be hæmorrhage by rupture in extra-uterine pregnancy, but this falls to be considered afterwards. It is also stated that rupture of the vessels forming adhesions in perimetritis may cause the hæmorrhage.

For the most part the blood falls by gravitation into Douglas's space behind the uterus, where, as the serum is pressed out by the contracting clot and absorbed, the coagulum becomes condensed and assumes a kind of permanent position, from which the designations HÆMATOMA and HÆMATOCELE have been given. The uterus is pushed forward by the tumour which can be felt filling Douglas's space on vaginal examination.

But the blood is probably not in every case within the peritoneum, although in most cases it is so. When the blood escapes from a ruptured vein it may accumulate either in the peritoneum, or else in the subperitoneal connective tissue, thus forming a PARAMETRIC or extra-peritoneal HÆMATOCELE. It must be said, however, that as the blood when in the peritoneum sets up inflammation with multiform adhesions, it may be difficult in some cases to say whether it has been originally intra- or extra-peritoneal.

The blood acting as a foreign body sets up a chronic inflammation. Connective tissue is produced around it forming adhesions of the neighbouring loops of intestines and the ligaments of the uterus. The blood thus becomes enclosed in a capsule, and it may be slowly encroached on by the connective tissue and undergo a gradual absorption. After absorption there will usually remain more or less serious adhesions causing misplacement and deformity of the uterus, tubes, or ovaries. In some cases the inflammation is more acute, and suppuration occurs in and around the blood. Thus an abscess may

form which bursts into the vagina, rectum, or bladder, or even into the peritoneal cavity with probably a fatal issue.

EXTRA-UTERINE PREGNANCY.

In this condition the fœtus does not develop in the uterus, as usual. It is not necessary to describe particularly the various forms here, as these are taken up in works on midwifery. The ovum may be impregnated in the ovary itself, and, probably after the rupture of the Graafian vesicle, may remain in the ovary and develop further. In this case we have an OVARIAN PREGNANCY, which is exceedingly rare. Or the ovum may drop into the peritoneal cavity, and having been impregnated either before or after its escape from the ovary, it may develop in the abdomen, forming an ABDOMINAL PREGNANCY. Or it may fail to reach the uterus, only travelling a certain distance along the tube—lodging at any part of the tube—TUBAL PREGNANCY—which is the commonest form. Sometimes it is in the last part of the tube so close to the uterus as to be imbedded in the substance of the organ—INTERSTITIAL PREGNANCY.

In all these situations the fœtus develops and is surrounded by its regular membranes, the whole being usually enclosed in a capsule formed of connective tissue from the parts around. The placenta forms and attaches itself to some of the parts around, although cases occur in which the placenta is in the uterus, while the fœtus is in the tube or even in the abdomen. After developing for a time the cyst usually ruptures, this occurring earliest, as a rule, in the tubal cases. The result is profuse and generally fatal hæmorrhage. If the hæmorrhage does not cause death, peritonitis usually develops and proves fatal. But the person may even survive this, and in that case, as a general rule, the fœtus softens and an abscess forms, which by and by bursts externally, discharging the more solid parts which have escaped the process of softening. In some cases, however, after rupture of the cyst the fœtus may produce little inflammation and become quietly encapsuled, or even without rupture it may die and lie quiescent as a foreign body. In these cases the fœtus shrivels and becomes mummified, being surrounded by a capsule formed of connective tissue and adherent to surrounding organs. In the mummified fœtus the various tissues may be recognized years after. The capsule usually becomes infiltrated with lime salts, so that a kind of shell forms around the fœtus.

In cases of extra-uterine pregnancy the uterus enlarges, usually

becoming two or three times as large as in the unimpregnated condition.

SYPHILIS AND TUBERCULOSIS OF THE UTERUS.

SYPHILIS manifests itself in the vagina and vulva in the form of the hard chancre, which may even occur at the os uteri. It does not present in these situations any peculiarities distinguishing it from chancre of the skin elsewhere. Condylomata of considerable size also occur in the vulva and vagina, often forming warty projections.

TUBERCULOSIS hardly occurs in the vagina; it is met with in the uterus, but is probably always secondary, being propagated from the Fallopian tubes (see p. 762). It may produce extensive destruction of the uterus, ulcers forming, on the surface of which there may be considerable caseous masses. Tubercular nodules form outside the ulcers in the mucous membrane and muscular substance, and the ulcers enlarge by caseous necrosis and breaking down of these tubercles. The ulcers thus enlarge in depth and superficies, and may involve the whole interior of the uterus, whose surface is exceedingly irregular. There is nearly always associated tuberculosis of the tubes and sometimes of the ovaries and peritoneum.

TUMOURS OF THE UTERUS AND VAGINA.

POLYPOID HÆMATOMA OF THE UTERUS.—This form of tumour consists of coagulated and condensed blood, and strictly speaking is not a proper tumour. It is of importance, however, as it considerably resembles the much commoner myoma of the uterus. It is sometimes designated the FIBRINOUS UTERINE POLYPUS. It consists of a mass of blood clot which by shrinking has become dense and hard. It may attain considerable dimensions, hanging it may be into the vagina. Consisting of blood-clot it has originated in hæmorrhage, but there must be some reason for the adhesion of the clot to the uterine wall. This is mostly afforded by the placenta which has been retained after delivery or abortion. The whole placenta may be retained as in Fig. 293, or it may be only a portion. On the other hand, the rough surface, after removal of the placenta, may induce the coagulation of blood, which if retained may grow by fresh coagulation. As the hæmatoma originates in hæmorrhage it is usually associated with it throughout its course. The blood mostly escapes into the vagina, but some of it may coagulate and increase the size of the polypus.

MYOMA OF THE UTERUS.—This is an exceedingly frequent form of tumour; it is said to occur in about every tenth woman. Nothing can

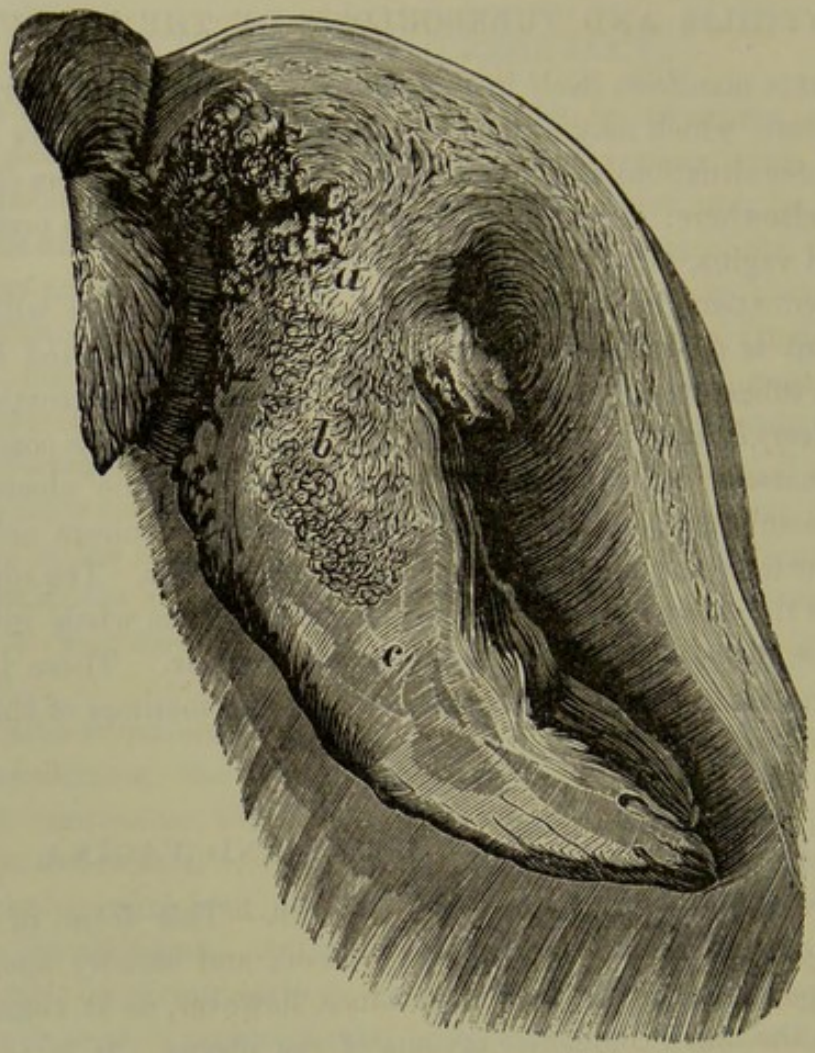


Fig. 293.—Polypoid hæmatoma of uterus after an abortion in the second month; *a*, projecting part of maternal placenta and wall of uterus; *b*, remains of fœtal placenta; *c*, stratified coagula around the fœtal placenta. Natural size. (VIRCHOW.)

be said definitely as to the cause of the formation of these tumours, but as they grow for the most part in the form of isolated pieces of muscular tissue, it may be supposed that in the fœtus there have been bits of the embryonic muscular tissue left over in the formation of the organ.

The structure of the myoma has already been sufficiently described in the part devoted to this form of tumour in general (see p. 194, and Figs. 70 and 71), and we have here mainly to do with certain local peculiarities. The tumour is very often multiple, and there may be as many as fifty attached to the same uterus. We may have a single small tumour no larger than a pea, or a large growth weighing as much

as fifty pounds, or a group of tumours surrounding the uterus and burying it.

The SUBSEROUS MYOMA, originating in the external layers of the uterus, passes outwards as it grows, and pushes the peritoneal coat before it. In this way it frequently becomes pedunculated. The subserous form is often multiple, and as from its situation it is protected, the tumour may grow for many years undisturbed, and reach very large dimensions. Such large myomas may be mistaken for ovarian tumours and excised as such, and this is the more likely to occur as the formation of cysts, to be referred to presently, not infrequently occurs in them. A subserous myoma has been known to part company with the uterus and become attached to a neighbouring part of the peritoneum where it has grown. Of course the separation and the acquirement of new attachments would be gradual.

The INTERSTITIAL or INTRAPARIETAL MYOMA arises in the middle layers of the uterus. In its growth it involves the wall of the uterus, and may cause enormous enlargement of the organ. This form develops mostly at the fundus. The tumour and greatly enlarged uterus may form together a very bulky mass, which as a whole is liable to be mistaken for an ovarian or other tumour. The author has met with several cases in which the tumour and uterus were excised under this belief. In one of these the tumours seemed to be multiple and the uterine wall could not be distinguished from tumours, the greatly enlarged cavity of the uterus being surrounded by irregularly lobulated masses of muscular tissue. In this case it looked as if the uterus as a whole had undergone an irregular hypertrophy, or had grown into a massive tumour.

The SUBMUCOUS MYOMA is the form which most frequently comes under the notice of the practitioner. Arising in the internal layers of the uterus, it readily passes inwards, pushing the mucous membrane before it, and from the action of gravity it tends to become pendulous. The submucous myoma, therefore, very often presents itself as a polypus (the so-called fibroid polypus), and it may have a very narrow neck. It very often arises at the fundus, and may grow to such dimensions as to fill the uterus, and hang down through the cervix into the vagina. The mucous membrane covering the tumour is subject to irritation, and there is frequently hæmorrhage and ulceration, even with sloughing in some cases.

The myomas present considerable varieties in the details of their

structure. They vary in the proportion of muscular to fibrous tissue, as we have already seen, but the muscular bundles always occupy such a preponderating relation that when attention is paid to the arrangement of the nuclei (Fig. 294) there can never be any doubt as to the



Fig. 294.—Section of a myoma of uterus stained with carmine so as to show the multiple nuclei. ×350.

nature of the tumour. It is true that the hardness of many myomas, and the glistening character of the cut surface, as well as the concentric arrangement of the trabeculæ as seen with the naked eye, suggest the characters of a fibrous tumour. But even in the hardest of them the muscular elements are perfectly pronounced, and the name uterine fibroid is misapplied. There is always a certain amount of connective tissue in myomas, as in all tumours, this tissue accompanying and supporting the blood-vessels just as in other tumours. It sometimes undergoes increase and causes INDURATION of the tumour, but the hardness of myomas is by no means always in proportion to the amount of connective tissue which they contain.

ŒDEMA occurs in myomas, especially when they are polypoid, and have a narrow neck. The œdema consists in a distension of the

lymphatic spaces with fluid, and it causes the tumour to be remarkably soft, so as even in some cases to resemble a mucous polypus. The formation of CYSTS may be a further development of the œdema, but it also occurs by breaking down of the tumour tissue. This occurs for the most part in large subserous myomas. The cysts are very irregular in form, and have no proper layer of epithelium lining them. Their origin in connection with the lymphatics is often indicated by the fact that the fluid, when withdrawn, frequently coagulates spontaneously.

DILATATION OF THE BLOOD-VESSELS occurs not infrequently, and especially in the uterine polypi. This dilatation, occurring at the expense of the muscular tissue, may lead to a cavernous condition of the tumour, there being large irregular spaces filled with blood. In that case there may be considerable hæmorrhage in the substance of the tumour, as well as externally.

As we have already seen, the connective tissue of the tumour may undergo CALCAREOUS INFILTRATION, so that the tumour has

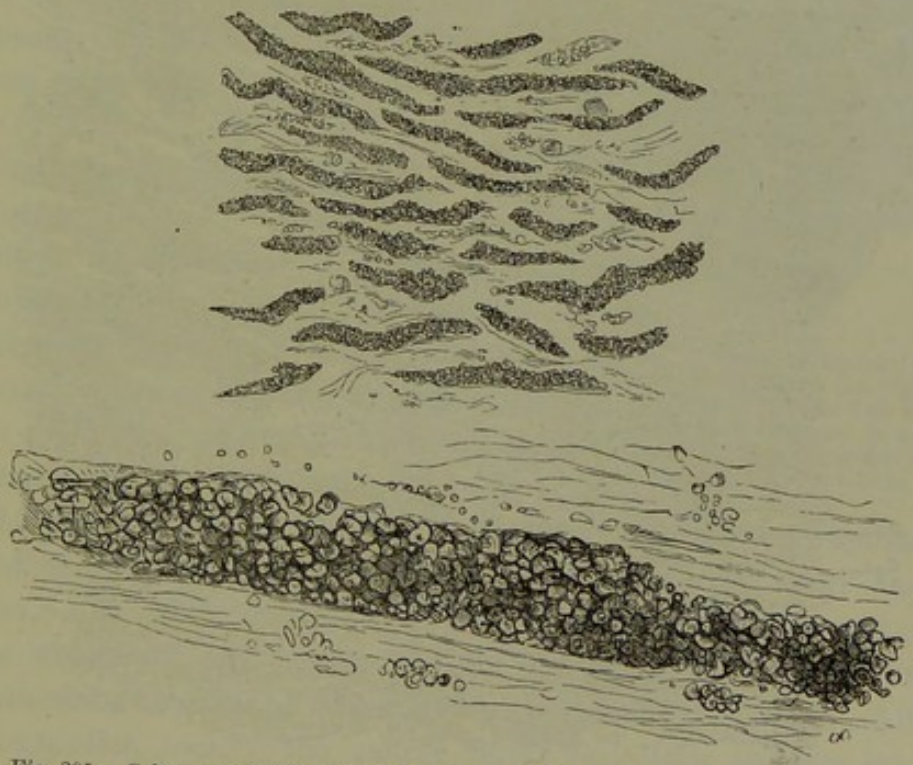


Fig. 295.—Calcareous infiltration of a myoma of the uterus. The muscular fibre-cells and a blood-vessel are infiltrated. ×350.

externally a hard shell, and is divided internally by septa, between which there lies the muscular tissue. The muscular tissue itself also sometimes undergoes calcification, as we have seen, and as Fig. 295 shows.

CANCERS OF THE UTERUS AND VAGINA.—In the great majority of cases the cancer begins just about the junction of the uterus and vagina, and involves both as it extends. The disease scarcely occurs before the age of thirty, and is most prevalent between forty and fifty. It appears also from the statistics of West that, contrary to what is sometimes stated, it occurs much more frequently in women who have borne children than in those who have not, and most frequently in those who have had more than the usual number of pregnancies; as if the disease developed most readily when the uterus is deteriorated by repeated conceptions.

There are various appearances presented by cancer of the uterus, but the commonest form is that usually described as SOFT or MEDULLARY CANCER. The individual elements are not essentially different to those in what is called epithelial cancer, but this form tends much more to infil-

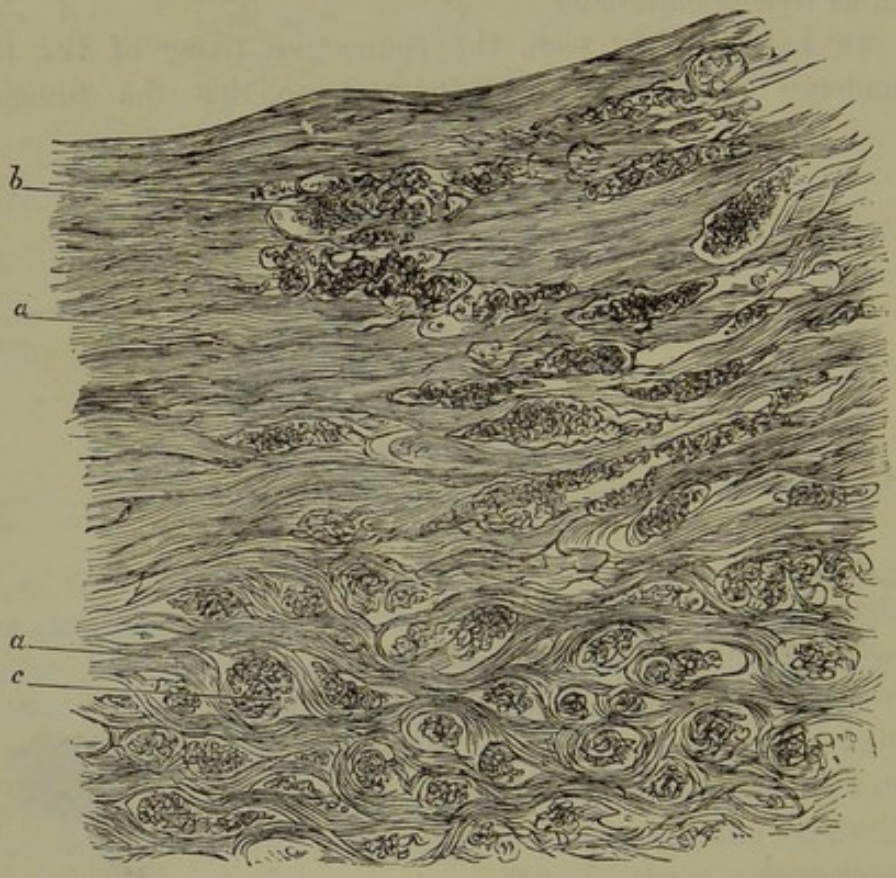


Fig. 296.—Section of cancer of uterus under a very low power, showing mode of advance into wall of uterus; *a*, muscular substance of uterus, interrupted frequently (as at *b*) by masses of cancerous structure. At lower part of figure (at *c*) the muscular substance is still more frequently interrupted and the tissue has quite an alveolar appearance, the muscle partly forming the stroma. ×22.

trate deeply, while the epithelioma is more superficial in its mode of growth. The medullary cancer begins as an infiltration of a limited part of the

portio vaginalis of the cervix, and thus extends more or less round the external os. By and by the whole portio vaginalis is converted into a hard, irregularly prominent tumour. At first the infiltration is confined to the mucous membrane and submucous tissue, but by degrees it spreads both deeply and laterally. It insinuates itself into the muscular substance of the uterus, separating and breaking up the muscular trabeculæ, which come to form a kind of rough stroma for it (see Fig. 296). It also passes into the vagina, infiltrating its wall. Very soon ulceration of the surface sets in, and in the subsequent progress there is a progressive ulceration and infiltration, the former following the latter. The infiltration passes into the body of the uterus, but does not usually reach the fundus before the death of the patient. If the parts be now examined post-mortem (Fig. 297), it will be seen that an irregularly excavated ulcer occupies the adjacent parts of the uterus and vagina, rendering their respective limits inappreciable. Then outside this there is the whitish cancerous tissue, which extends into the uterine substance some lines beyond the ulcer.

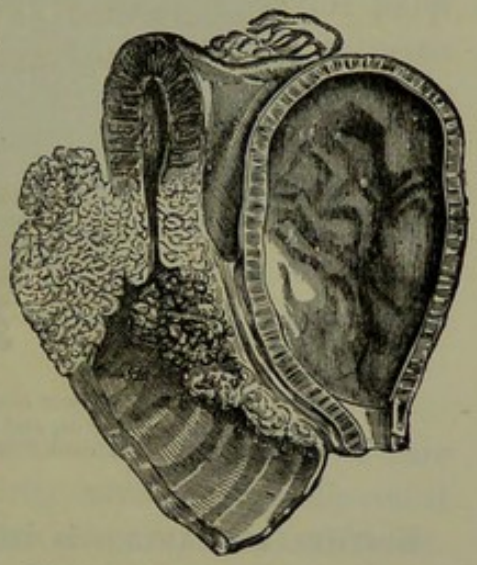


Fig. 297.—Cancer of uterus, the parts shown in section. To the right is the urinary bladder. To the left are vagina and uterus, both of them to a large extent converted into irregular cancerous masses. (Graily Hewitt from Martin.)

This disease affects neighbouring structures. There are cancerous masses usually in the ligaments and under the peritoneum. The bladder is frequently adherent to the uterine cancer and its mucous membrane red and irregular, or else it presents cancerous nodules. The ulceration even extends sometimes into the bladder, which forms thus a communication with the vagina. The rectum is much less closely related to the cervix uteri than the bladder, and it is less frequently involved. Those parts of the uterus which are not engaged in the cancerous disease are inflamed, and adhesions are formed to the rectum and urinary bladder. Although thus extending locally, the cancer tends very little to form secondary tumours in the lymphatic glands, and still more seldom does it become generalized.

It sometimes happens that the new-formation of cancerous tissue is more vigorous than the ulceration, and in that case we may have prominent ragged masses hanging into the vagina.

The microscopic examination of this form of cancer shows masses of epithelial cells, usually of considerable size, arranged irregularly in alveoli, the stroma being largely formed by the remains of the structures into which it has infiltrated.

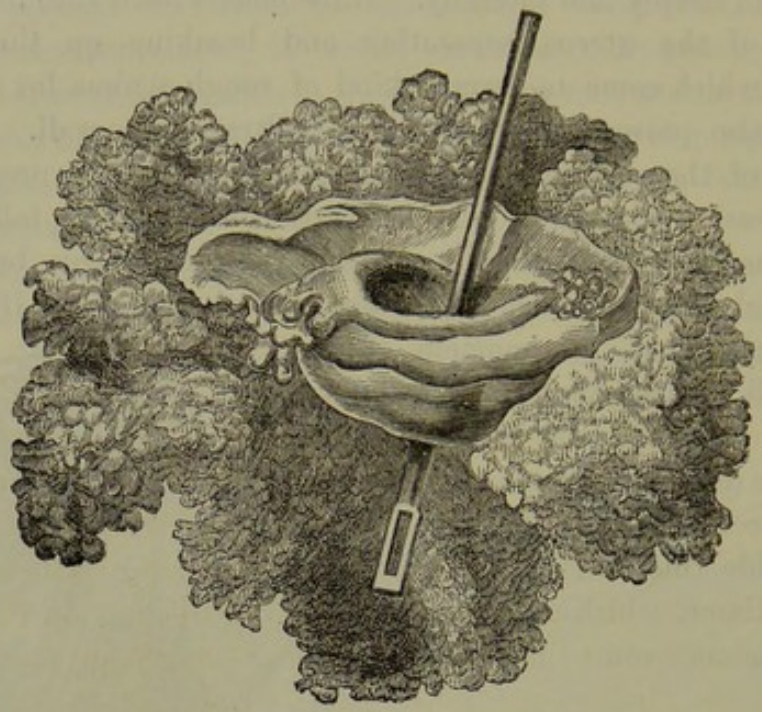


Fig. 298.—Cauliflower cancer of posterior lip of os uteri. A probe is passed through the os, and the anterior lip in front of it is seen to be normal, while a cauliflower growth projects from the posterior. (Simpson.)

Epithelial Cancer is hardly to be distinctly delimited from the former, but is characterized by a more superficial outgrowth of prominent warty projections, while the deeper infiltration is slower and less in degree. The disease begins, as in the other case, in the portio vaginalis, and at first there is little more than a prominent warty outgrowth. But the warty growth increases while the base becomes infiltrated till a bulky prominence results, whose surface, consisting of masses of papilliform projections, gives the character of the cauliflower excrescence (Fig. 298).

This form of tumour is also liable to ulceration, and there may be a combination of ulceration with papilliform projections, although, after a time, the papillæ may be destroyed and the appearances approximate to those of the other form of cancer.

Under the microscope the structure here is more that of flat-celled epithelioma. The prominent papillæ are covered with pavement epithelium, and the deeper infiltration consists of masses of flat cells.

A few cases have been observed in which COLLOID CANCER has been the form occurring in the uterus, the situation being the same as in the other more common forms. In rare cases also a cancer may arise from the fundus uteri.

MUCOUS POLYPI OF THE UTERUS.—These are met with mainly as the result of chronic inflammation of the mucous membrane, and may spring from the body of the uterus or the cervix. Sometimes there is a general irregular prominence of the mucous membrane, but usually there are definite polypoid outgrowths. The mucous polypus may consist of a limited hypertrophy of the mucous membrane, the tumour being a tolerably firm one unless, as sometimes happens, it becomes soft by œdema or by the excessive development of its vessels. In this latter case we may have a tumour approaching to the cavernous character. Or polypi may consist largely of glandular structures, mucous glands being apparently new-formed so as to provide the tissue of the tumour. These polypi are comparatively soft, and may grow to a considerable size, especially when they become cystic. We have already seen that tumours consisting of glandular tissue are peculiarly apt to become cystic, and these form no exceptions. These larger polypi may somewhat distend the uterus.

OTHER TUMOURS are seldom met with. SARCOMAS are of rare occurrence, and of those recorded the majority have been spindle-celled sarcomas, although the round-celled form has also been seen. The sarcoma may develop in a myoma, or a muscular tumour in its rapid growth soft consistence and looser structure may assume the characters of a MYOSARCOMA. PAPILLOMAS are also met with at the portio vaginalis, and may resemble cauliflower cancers.

PARASITES are rare in the uterus and vagina. Thread worms may pass over from the rectum. Bacteria are frequently met with in the vaginal secretion, and the fibres of leptothrix also occur frequently. The oidium albicans is found in connection with thrush. The cysticercus cellulosæ has been doubtfully seen in the uterus, and the echinococcus with exceeding rarity.

B.—OVARIES, FALLOPIAN TUBES AND LIGAMENTS.

OVARIAN HERNIA.

In this condition one or both ovaries descend into a regular sac. The ovary sometimes forms part of the contents of an ordinary hernial sac, but there are cases in which the ovary alone is present, and its descent constitutes the primary condition. These cases are mostly inguinal and have a congenital origin, and there seems reason to infer with Englisch that they are produced by a descent of the ovary comparable with the normal descent of the testicle. When the testicle has descended, the sac forms the tunica vaginalis, and is shut off from the peritoneum except in the case of congenital inguinal hernia when the sac remains open. In ovarian hernia the sac remains open also, so that it is like congenital inguinal hernia in the male, but generally without the presence of intestine in the sac. The sac usually appears in the upper inguinal region, but may pass into the labium majus. Like the testicle, the ovary is fixed in the wall of the sac except in so far as its ligaments allow of a certain mobility. Hence it is usually irreducible, although, if the ligaments are long, they may allow of the ovary passing into the abdomen while still attached to the bottom of the sac.

The ovary in its abnormal position undergoes the usual changes at the menstrual periods, and being in a confined position its enlargement may cause pain. Sometimes the condition is discovered by attention being directed to it by pain and inconvenience during menstruation. The ovary may also become the seat of tumours while in the sac or may be inflamed. Sometimes it has given rise to such inconvenience in its abnormal situation that excision has been resorted to.

Besides these cases of inguinal hernia the ovary may enter a crural or an abdominal hernia, but these are not congenital and are not in the same relation to the descent of the testicle as the case just considered.

INFLAMMATIONS OF THE OVARIES AND TUBES.

The Fallopian Tubes sometimes inflame when the uterus is the seat of acute inflammation, but they and the ovaries are most frequently affected with acute inflammation in connection with the puerperal con-

ditions already considered. An acute perimetritis or a puerperal fever is very often accompanied by suppurative inflammation of the tubes, which may be distended with pus so as to form abscesses, their apertures having become obstructed. In addition to that the tubes are often adherent and distorted by chronic inflammations of the uterine peritoneum and of the ovaries. Those chronic inflammations, by contorting and obstructing the tubes, often lead to dilatation by the secretion being retained.

Acute Oophoritis, or acute inflammation of the ovaries, occurs also as a sequel of the puerperal state. It may be a part of a perimetritis, or a pelvic abscess may be associated with abscesses in the ovaries, and as these conditions rarely occur apart from pregnancy so is it with the ovarian inflammation. The ovary becomes swollen and hyperæmic and suppuration usually ensues. The pus at first forms in elongated streaks from the hilus to the periphery, but after a time there are more distinct abscesses. The Graafian vesicles also frequently become filled with pus. The peritoneal surface will also be inflamed and probably coated with a fibrinous or semi-purulent exudation.

Chronic Oophoritis is a condition concerning which considerable variety of opinion is held. We know that at each menstrual period the ovaries undergo changes which present many analogies with inflammation. They become hyperæmic and enlarged, and a Graafian vesicle bursts, leaving a wound which has to heal by granulation. At these periods then it seems likely that a chronic inflammation may be readily set up by exposure to cold, cold baths, or sexual excitement. But it is not to be inferred in all cases where ovarian disturbances are thus produced that there are present the actual anatomical phenomena of inflammation.

Chronic inflammation is manifested by an interstitial new-formation of connective tissue, and is comparable to cirrhosis of the liver or kidney, and like these accompanied by shrinking of the organ. The capsule is thickened, and the contracting tissue in the organ produces irregular depressions of the surface. The thickening is often peculiarly manifest around the Graafian vesicles, and this with the thickening of the capsule may prevent the vesicles bursting. Sometimes a ripe vesicle instead of bursting externally ruptures into the substance of the ovary, and so produces further inflammatory disturbance. With these changes in the ovary itself there is usually adhesion of the capsule to the parts around, the chronic inflammation causing the formation of vascular con-

nective tissue which unites opposed surfaces. In this way there may be displacements of the ovaries.

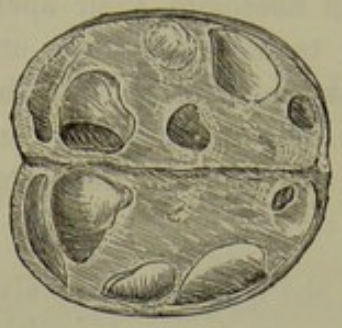


Fig. 299.—Cystic formation in ovary from dilatation of Graafian vesicles. (VIRCHOW.)

If the Graafian vesicles are prevented from bursting, the fluid which naturally exists in them may become augmented, and the vesicles thus be converted into CYSTS (Fig. 299). A limited number of small cysts may thus be formed, and it is not impossible that cysts having this origin may grow to some size, having always the character of simple cysts with serous contents.

It is to be remembered that in old age the ovaries are often shrunk and the capsules thickened, but this is not to be set down as the result of chronic inflammation.

TUBERCULOSIS OF THE OVARY AND TUBES.

This affection occurs with exceeding rarity in the ovaries, in the form of caseous masses. It is more common in the tubes, and here the appearances are very like those in tuberculosis of the ureters. The tube is

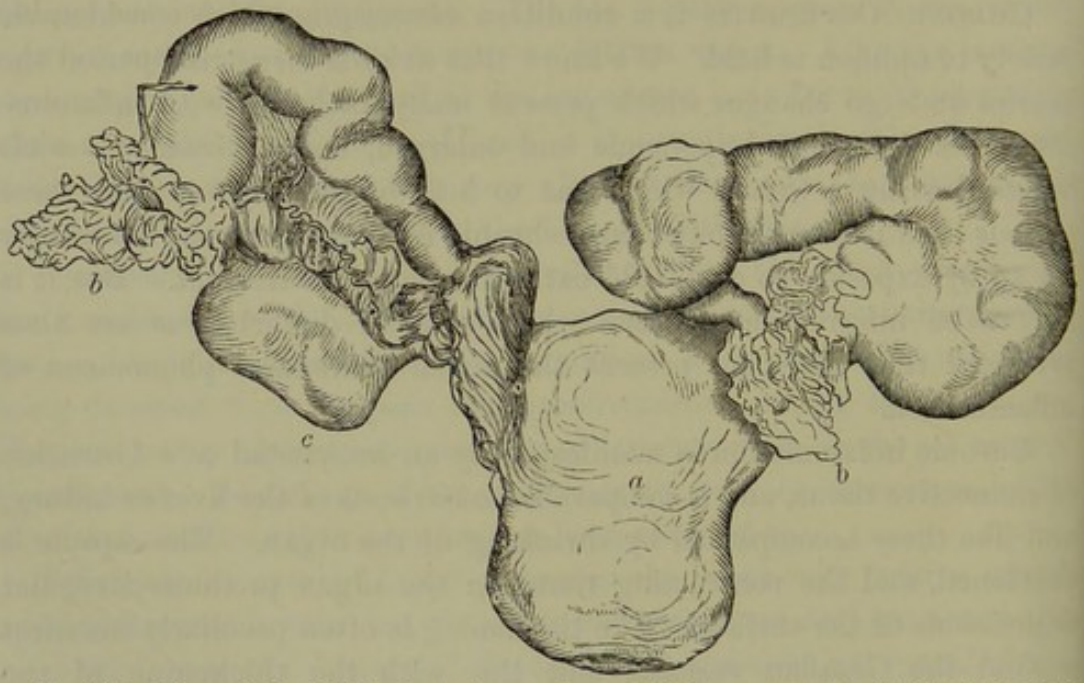


Fig. 300.—Tuberculosis of Fallopian tubes seen from behind. *a*, uterus; *b*, *b*, fimbriated extremities of the tubes; *c*, right ovary. The right tube is seen to be very greatly dilated and convoluted. The dilatation disappears just before the uterine termination of the tube. The left tube is much less affected, being most dilated at its distal part. There was also tuberculosis of the lungs and mesenteric glands.

enlarged, sometimes very greatly so, and it forms varicose sausage-like convolutions (Fig. 300). Internally there is a caseous layer with, it

may be, some accumulation of pus, mucus, and debris. The caseous layer is somewhat consistent, forming a continuous lining to the tube. Outside this the wall is greatly thickened, mainly by inflammatory new-formation in which tubercles are to be found.

Along with the tuberculosis of the tubes and the very rare tuberculosis of the ovaries there is usually similar disease elsewhere, such as phthisis pulmonalis, tuberculosis of the urinary organs, or tuberculosis of the peritoneum. The disease commonly affects both tubes, generally beginning near the abdominal extremity, and often extending the whole length of the tube even into the uterus.

TUMOURS OF THE OVARY.

Tumours of the ovary have the peculiarity that they commonly grow to large dimensions. We may perhaps associate this with the functions of the organ, which imply, at least in the Graafian vesicles, a remarkable formative power. The cysts are the most frequent and important forms, and they are here taken first.

Simple Cysts occur which are in many respects comparable with the simple cysts which are so frequent in the kidney, and like them have no very special significance. They are produced, as already indicated, by dropsy of the Graafian vesicles, as was proved by the discovery by Rokitansky of an ovum in such a cyst. Simple cysts may be of congenital origin, having been observed in new-born children. As a general rule there are several cysts simultaneously developed, usually from ten to twenty, but one or a few may attain a preponderating size. The cysts have a distinct smooth lining membrane, with a single layer of epithelium. The contents are mostly clear serum, but from hæmorrhage they may be dark, or from inflammation turbid. The enlargement of the ovary is not generally great in this form of cystic disease; it rarely reaches the size of the fist, and still more rarely that of the head. If there are several cysts, they take shape by mutual pressure.

Colloid Ovarian Cysts.—These are of much more frequent occurrence and vastly more important. To this class of cysts the name cystoma is properly applied, because they arise by a distinct new-formation, there being first produced a preparatory tissue, which goes right on to the formation of the cysts.

These cysts form very bulky tumours, and while the tumour itself is formed of a number of larger and smaller cysts, there is always in the walls of these more or less solid material which shows various stages in the process of cystic formation. It is to be noted also that the tumour, sometimes of enormous size, represents the ovary as a whole, and is not merely something added to it, the external covering of the cyst being strictly analogous to the surface of the ovary.

It has been said that in the wall of the cysts there is solid tissue which shows the various stages in the process. If this be examined microscopically, there will be found a glandular structure (see Fig. 301)

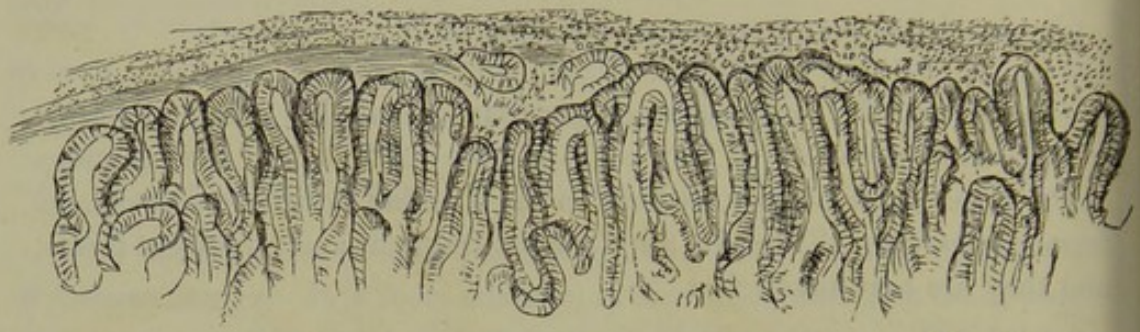


Fig. 301.—Section of tissue in wall of an ovarian cyst. There is a congeries of glandular structures lined with cylindrical epithelium. × 150.

in the form of tubular canals lined with cylindrical epithelium. These gland-like structures often project into cysts in a somewhat papilliform

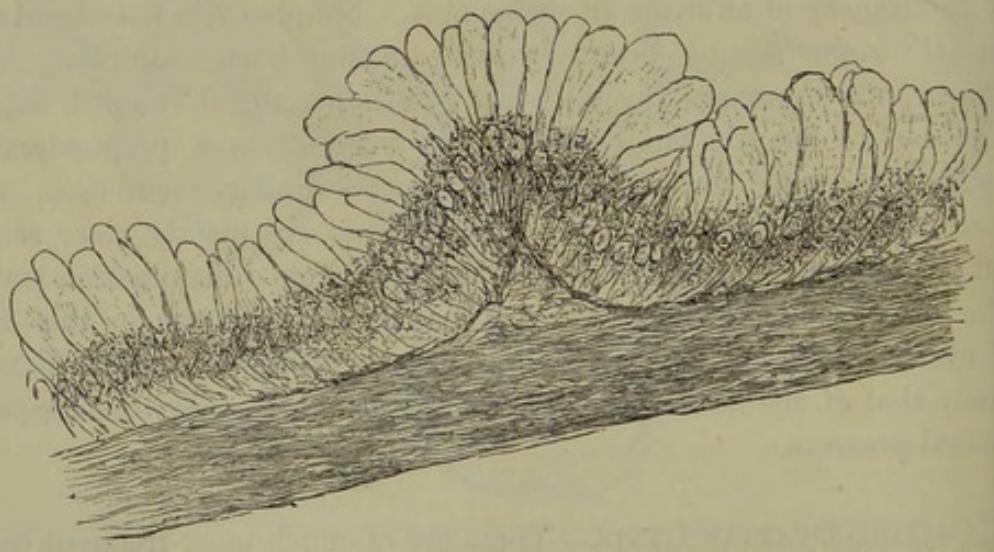


Fig. 302.—Portion of wall of colloid ovarian cyst. The lining epithelium is mostly in the form of goblet cells. × 350.

manner, and altogether they show a very striking power of new-formation. We have in this way glandular tubes on the one hand, and

villous or papillary outgrowths on the other. The transformation into cysts is readily seen in many cases. The glandular tubes become constricted at their necks, or, the villi being pressed together, unite at their apices. The cylindrical epithelium presents very markedly the goblet form seen in mucous glands (Fig. 302), and it secretes a colloid material, which accumulates in the cavity and distends it more and more into a globular cyst. We have therefore in the walls of the cysts, very commonly large numbers of smaller cysts which take their shape by mutual pressure as in Fig. 303. Cysts formed in this way project into the

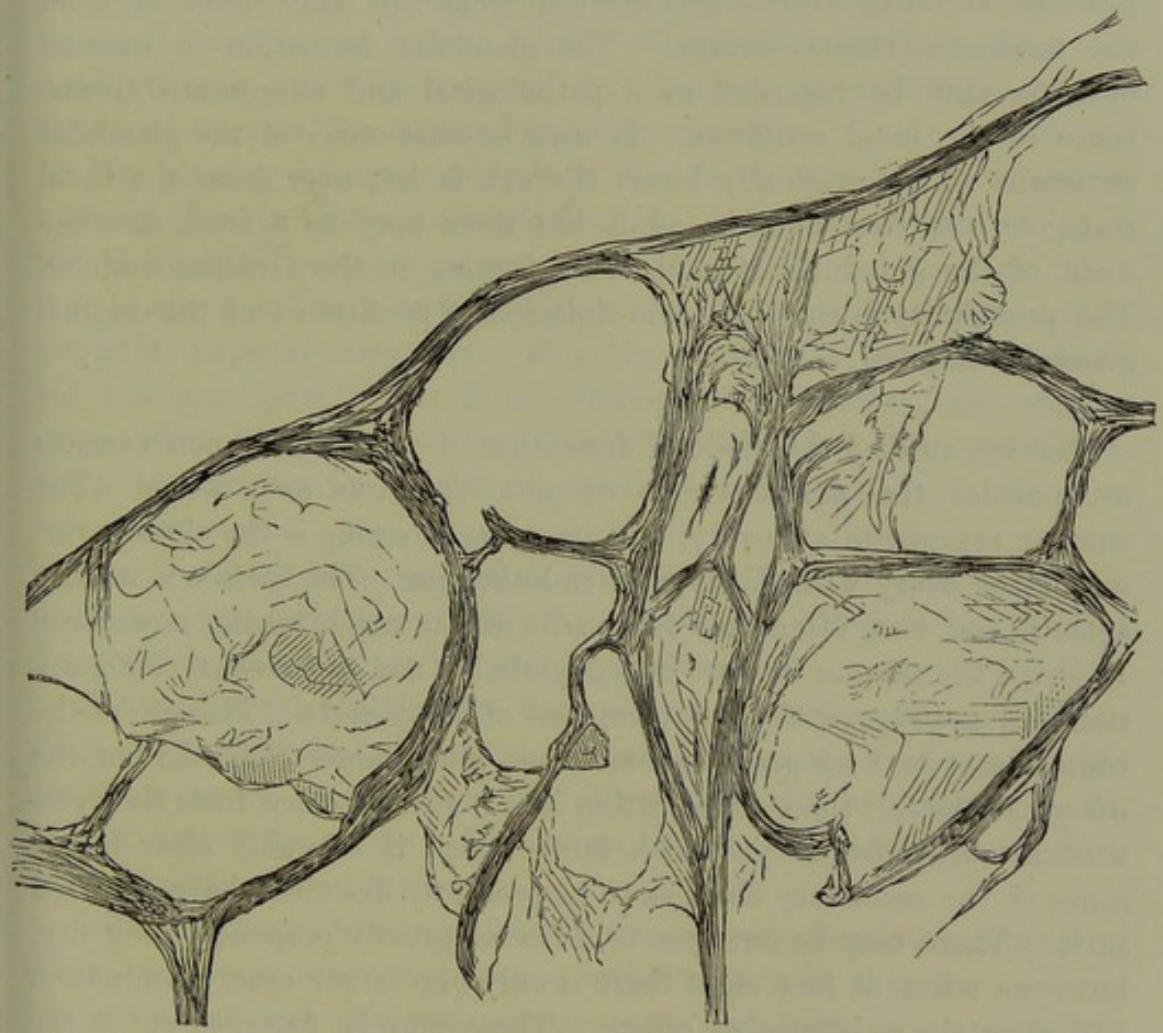


Fig. 303.—Section of portion of a projection on internal surface of ovarian cyst. It consists of a congeries of variously sized smaller cysts. × 20.

already existing cysts as they grow, and may afterwards burst and become flattened out on the wall of the older cyst. As all the cysts have had a similar origin, they are lined with epithelium, whose function it is to secrete a colloid or mucoid fluid, and so the cysts, once formed, have an almost continuous tendency to increase.

There arises here the question as to the ORIGIN AND SIGNIFICANCE OF THIS GLANDULAR TISSUE, and in order to understand this we must go back to the original development of the ovary. The primordial ovary consists of a layer of epithelium on the surface of a connective tissue projection. The ova form by the penetration or reduplication inwards of this superficial epithelium, which at first forms a series of communicating channels, which Waldeyer compares to a cavernous tissue. By the constriction of these canals the ova are formed, it being doubtful whether the cells of the membrana granulosa which line the Graafian vesicle are derived from this epithelium or from the connective-tissue stroma. The glandular formation in ovarian cystoma may be regarded as a pathological and exaggerated recurrence of the fœtal condition. It may be that some of the glandular structure which originally forms the ova is left over from the fœtal state, or else that even in adult life there may be a fresh development of the glandular structures, originating in the Graafian vesicles. The probability is that the real origin is in a persistence of the original glandular tubules.

Having studied the mode of formation of the cysts, it now remains to consider the APPEARANCES OF THE TUMOURS as a whole. The tumour represents an ovary, and its outer covering is the outer covering of the ovary with its layer of endothelium. The surface is usually smooth and very often free from adhesion to neighbouring structures. In shape the tumour is more or less globular, and its external configuration may not suggest that it is composed of many cysts. The size of the tumour may be very great in some cases, much larger than that of the uterus at the full time. On cutting into it there escapes from the cysts a sticky brownish or yellowish fluid, which is tolerably clear unless some of the secondary changes to be presently described have occurred in it. There may be one cyst or a few of greatly preponderating size, but even when at first sight there is only one larger cyst, examination will show the existence of others. These may be flattened out in the wall, or they may be collected here and there in clusters. Generally towards the base of the tumour, but in many cases at various places, there are solid or semi-solid masses in which cysts are in process of development in the way already described. Sometimes the glandular tissue presents a tendency to form papilliform projections into the cysts, and we may have in this way dentritic or shaggy projections in the internal wall. If, as is usually the case, there are many cysts,

they take shape by mutual pressure against each other, while the general globular outline of the tumour as a whole is preserved.

The cysts are liable to undergo certain CHANGES which concern chiefly their contents. It seems almost a normal condition in large cysts that the internal wall should present collections of cells in a state of fatty degeneration, these cells being often in many layers. The cells also pass into the fluid, so that in all ovarian fluids cells are to be found of round shape and with oil drops in them. So universally are these present in the fluid from ovarian cysts that Dr. Drysdale has insisted on their discovery as an important diagnostic indication. In addition to small cells having a few minute oil granules in them there are usually larger ones with more oil drops, up to large cells having the regular characters of compound granular corpuscles.

The number of these fatty cells may be greatly increased, and as many of them in that case break down we may have a fluid which is turbid from the presence of numerous fatty cells and free oil. The fluid is also pale like a fatty emulsion, and in many cases it resembles pus in its physical characters. This change is most likely to occur in old and large cysts, but it is not infrequent in younger and smaller ones, and it is important to bear this in mind because this condition is apt to be mistaken for actual suppuration of the cysts, a much more rare occurrence.

The free fat if long retained is very apt to form crystals of cholestearine, and in fact these crystals are frequently found in the fluid of cysts which otherwise are not strikingly altered.

HÆMORRHAGE occasionally occurs into the cysts, especially when there are papilliform projections. This will cause the fluid to be turbid and deep brown or red in colour. There may also be masses of softened fibrine in the cavity. Sometimes, however, the fluid has a dark brown colour without hæmorrhage.

INFLAMMATION of the cyst wall is not of very frequent occurrence. There may be an acute suppurative inflammation, so that the contents become mixed with pus and assume more and more of the purulent character. With this there is generally an acute inflammation of the surface with fibrinous exudation and adhesion to neighbouring structures. If the suppuration continue there is apt to be perforation of the pus into the abdominal cavity with resulting fatal peritonitis. A chronic inflammation is more common, causing adhesion of the cyst to neighbouring parts, and these adhesions may be very extensive and firm.

PERFORATION of the cyst wall is usually the result of suppuration or gangrene, but may be a consequence of the papillary growths impinging against the wall and causing atrophy. A case is mentioned by Klebs in which the cyst had opened into the rectum in this way. The result is usually peritonitis, but if there has been no inflammation or gangrene, then the simple existence of the fluid in the abdominal cavity need not cause peritonitis.

It is here to be remarked that the colloid ovarian cyst sometimes occurs in combination with the dermoid cyst on the one hand and cancer on the other.

DERMOID CYSTS.—These have already been referred to in describing the TERATOMA. They are of comparatively frequent occurrence in the ovary, and considering the function of this organ it may perhaps be inferred that they arise from the ova by a kind of equivocal generation. The cysts are usually single, but there may be several in the same ovary.

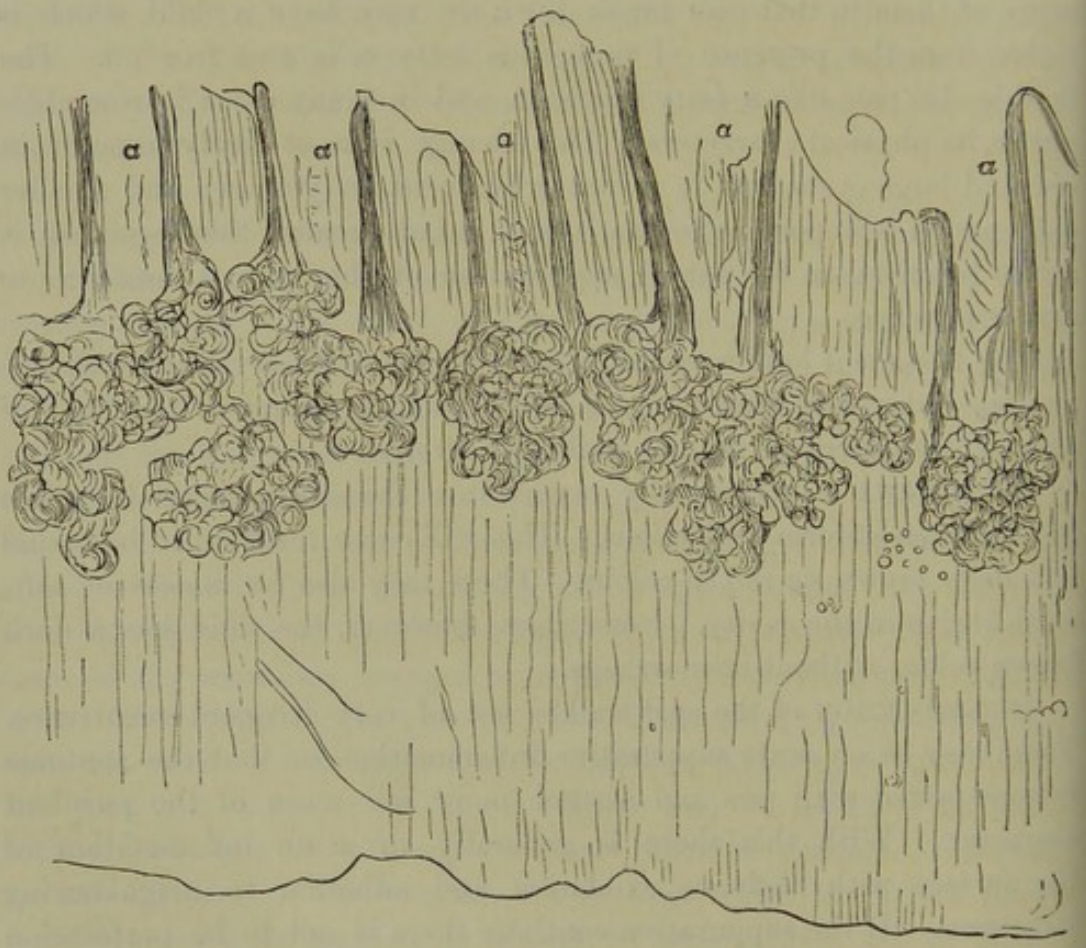


Fig. 304.—Section of wall of dermoid cyst of ovary. A congeries of sebaceous glands with open mouths (*a*, *a*, *a*) occupy the wall. The cyst contained large masses of buttery material with hairs. × 20.

They grow slowly and form globular tumours with a dense connective-tissue capsule. Internally there is an epithelial lining which, in some parts, develops a more complex structure. We have already mentioned how sebaceous glands (Fig. 304), hairs (Fig. 305), bones and even teeth may enter into the constitution of the wall, and a buttery material with hairs and sometimes teeth form the contents.

These cysts not infrequently inflame and may rupture, most frequently into the bladder or rectum, their peculiar contents being discharged and so revealing the nature of the case.

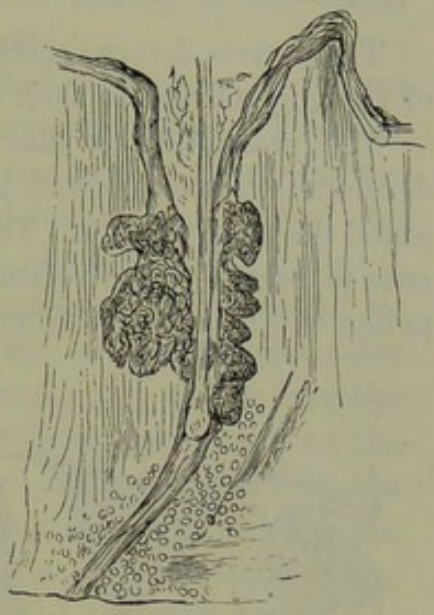


Fig. 305.—Hair in its follicle with sebaceous gland, from wall of same cyst as the former figure. ×20.

Cancer of the Ovary occurs mostly as a cyst with cancerous growths in its walls. There may be a combination of the colloid cyst with cancer, or a partial transformation of the former into the latter; considering the glandular character of the structures forming the colloid cyst, this cannot be regarded as very remarkable. In the ordinary colloid cyst the epithelium has a regular and normal arrangement, and we may call the tumour in that aspect an adenoma; in the cancer the epithelium is distinctly abnormal in its arrangement, being aggregated into indefinite masses. It may even happen that in the midst of the cancer the epithelium is undergoing metamorphosis, so that cysts are developing from it as from the more regular glandular tissue.

Besides these cancerous cysts we may have a solid cancerous tumour in the ovary, presenting the usual characters, but like the ovarian tumours showing a very excessive growth.

Sarcoma is a rare tumour in the ovary. Spindle-celled sarcoma is the more usual form, but round-celled sarcomas also occur. These tumours may also assume very large proportions reaching the size of the head sometimes, and they are not infrequently bilateral. Cysts are frequently present in the midst of them, and these may be simple serous cysts or they may have colloid contents. These latter may arise from glandular structures, and the disease may form a combination of the colloid cystoma and the sarcoma, or they may originate in a softening of the sarcomatous tissue.

For the rest, fibromas and enchondromas have been met with in the ovaries on rare occasions.

CYSTS OF THE BROAD LIGAMENTS—PAROVARIAN CYSTS.

These cysts deserve special mention, especially from a practical point of view, in relation to their diagnosis from ovarian cysts.

The probability is that most of the cysts of the broad ligament develop in connection with the remains of the Wolffian body, commonly called the PAROVARIUM. The exact relations of this body are of importance in regard to the relations of the resulting cyst, and the principal points will be gathered from the accompanying figure (Fig. 306).

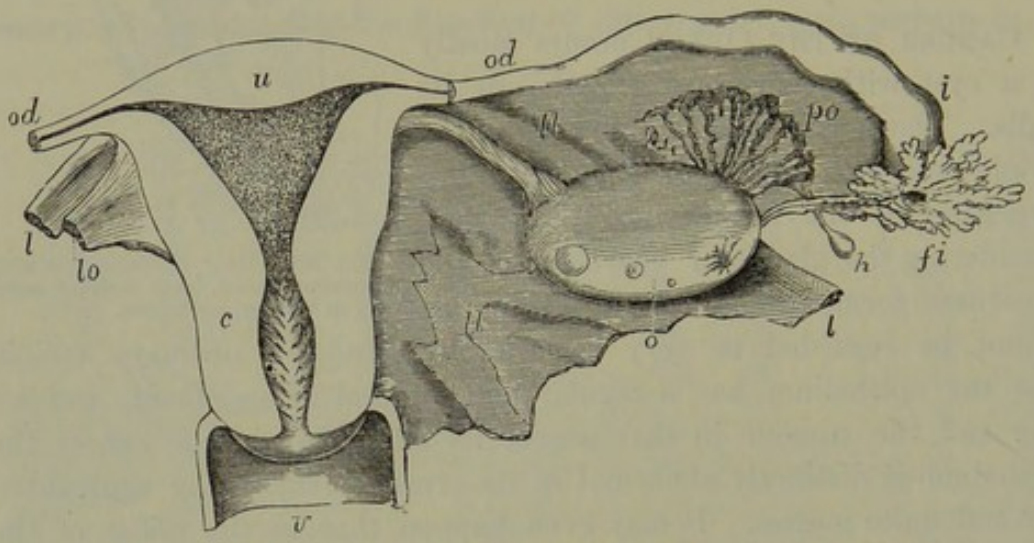


Fig. 306.—Diagrammatic view of uterus and appendages. *po*, parovarium; *od*, Fallopian tube; *fi*, its fimbriated extremity; *o*, ovary, with a ligament to the right proceeding to the fimbriated extremity, and one to the left to the uterus near the origin of the Fallopian tube. (QUAIN.)

The parovarium lies between the two folds of the peritoneum constituting the broad ligament, and under the arch of the Fallopian tube, between the latter and the ovary. When the broad ligament is held up against the light by catching the Fallopian tube, the parovarium can be seen as a series of tubules, converging towards the ovary. In the figure a little tube with a knob at its end (*h*) represents a frequently occurring so-called hydatid, which is one of the tubules with a cystic dilatation at its extremity. This cyst may undergo slight enlargement, but it does not come practically into account as forming the proper parovarian cyst; probably if it enlarges much its very narrow neck is apt to get broken or twisted and the cyst will then shrink. In connection with the anatomical details it is to be further noted that a firm ligamen

unites the ovary to the upper angle of the uterus just below the origin of the Fallopian tube (see figure). The ovary is also united (see figure) to the fimbriated extremity of the Fallopian tube, so that the parovarium is as it were surrounded by a girdle of structures, Fallopian tube above, and continuous with it the ligament passing to the ovary, the ovary itself and the proper ovarian ligament.

One or more of the tubes of the parovarium sometimes undergoes great enlargement and constitutes the parovarian cyst. Whether originating in one tube or in more than one the cyst is nearly always a single one, and it assumes a typically globular form. From the anatomical relations just referred to, it comes about that the cyst as it enlarges stretches the structures named as forming a girdle round it. There is frequently great elongation and dilatation of the Fallopian tube, which may be fourteen or fifteen inches in length and arches over the convexity of the cyst, its fimbriated extremity being spread out on the surface, considerably exaggerated and drawn out. One part of the fimbriated mouth is drawn downwards towards the ovary, which again is found flattened and greatly elongated on the under surface of the cyst. The ligament of the ovary is also elongated and thickened.

The cyst itself is a perfectly homogeneous bladder, consisting of a connective-tissue wall lined with epithelium. Besides this proper cyst wall there is an external coat of peritoneum, which is quite distinct from the proper cyst wall. So loose is the connection between the two that the peritoneal coat can usually be stripped from the cyst wall, so that two globular cysts can be separated, like the external and internal layers of a football. As the parovarium is covered on both sides with peritoneum, forming the folds of the broad ligament, we can understand how in enlarging the cyst retains a distinct peritoneal coat. The elasticity of the peritoneum doubtless allows of its distension, but there must also be some increase of peritoneal tissue as the coat is not thinner than the ordinary peritoneum.

The contents of the cyst are a clear limpid fluid, of low specific gravity, sometimes as low as 1003, and not exceeding 1008. It is very rare to find any considerable secondary alteration of the cyst wall or its contents, but inflammation may occur.

By RUPTURE or PERFORATION (paracentesis) the cyst, being a single one, will be completely emptied, and it is noteworthy that there does not seem to be much tendency to refilling. In one examined by the author with Dr. Gairdner, the cyst, to judge from the symptoms, had been of large size, and ruptured sixteen months before death. It was

found lying in the abdomen collapsed and flattened, and a cicatrix represented the point of rupture. The cyst could be blown up to the size of a child's head, but the corrugated appearance of the internal wall showed that it had been much larger. Here the peritoneal coat, which could be easily stripped, had contracted to suit the diminished size and was smooth on the surface, while the proper cyst wall being devoid of elasticity was thrown into ridges.

It may be useful here to compare the parovarian with the ovarian cyst. The former is a single cyst, the latter never really single, although it may simulate the unilocular character; accordingly the former is completely emptied by tapping, the latter only partially. The parovarian fluid is limpid and its specific gravity never above 1008, while the fluid of the ovarian cyst is mostly more or less glutinous, usually brownish in colour, and of a specific gravity over 1020. It is important also that the parovarian cyst after being emptied may not refill, while in the case of the ovarian cyst if that which has been emptied does not refill, others grow to take its place. When the cyst itself is examined the stretching and enormous elongation of the Fallopian tube are usually very characteristic in the parovarian cyst, although it may happen that an ovarian cyst will grow mainly from the upper part of the ovary, and so cause stretching of the tube. Then there is, in the case of the parovarian cyst, the ready separation of the peritoneal coat, whereas in the ovarian cyst there is no such isolable layer. This arises from the fact that the peritoneum over the ovary is only represented by a layer of endothelium, and not by a membrane distinct from the capsule. The ovarian cyst being the ovary itself with cystic development, it has its external covering formed simply of the exaggerated ovarian capsule. One can sometimes tear this capsule into layers for a certain distance, but no continuous separation of the coats is possible. There is, lastly, the fact that the parovarian cyst is a single simple bladder, whereas even in the case of dropsy of the Graafian vesicles there are several cysts, and in the common colloid cyst there are multitudes of developing cysts and solid glandular tissue.

C.—THE MAMMARY GLAND.

Malformations of the Breast.—One or both mammæ may be absent. It is more frequent, however, to have supernumerary breasts or nipples, sometimes three, four, or even five, instead of two. The supernumerary breasts are usually situated near the axillæ, or under the normal ones. But there are cases in which they have had a very abnormal situation, as in the inguinal region, on the thigh, or even on the back. They are usually small in size, but in some cases they have produced milk during lactation. It may be noted that the occurrence of additional mammæ is not altogether extraordinary, considering that in the lower animals the mammæ are usually more in number than in man.

Inflammation of the Mamma.—This rarely occurs except in connection with lactation. During this process, and especially at its commencement, the structures in the mamma are the seat of very active processes; there is hyperæmia and an active secretion of milk. Under these circumstances inflammation is more readily induced than usual. It may happen that contraction of the arteries from accidental circumstances, such as exposure to cold, may induce inflammation. We know that an inflammation may be induced in animals by ligaturing an artery for a time and then loosening it, and we may believe that partial contractions of the arteries may act in this way. Even a general irritation of the vaso-motor centre by reflex action, when the skin is exposed to cold, may, in the case of the highly excited vascular system of the mamma at the commencement of lactation, induce inflammation. Again, disease of the nipples, such as cracks and ulcers, often induce inflammation in the breasts. We may believe that here the irritant which has caused the lesion in the nipple may extend along the tubes and cause inflammation in the mamma. At the time of puberty, the female breast undergoes a special development, and is also in an active state, and at this period inflammations are also apt to be induced.

The inflammation is usually an exceedingly acute one, and is accompanied by exudation, the interstitial tissue being packed with leucocytes and the breast hardened. This hardening is often local, as the inflam-

mation is usually to some extent limited to certain parts of the breast. But very often the exudation of leucocytes goes on to actual suppuration and the formation of abscess, sometimes with sloughing of the tissue. The abscess so formed may have extensive ramifications in the mamma, especially if the pus does not get vent externally. After evacuation the cavity fills with granulation cells, and finally closes, and a cicatrix is formed.

A CHRONIC INFLAMMATION resulting, after the usual manner of interstitial inflammation, in induration of the organ, has been described, but is not of frequent occurrence.

TUMOURS OF THE MAMMA.

ADENOMA OF THE MAMMA.—This form of tumour is of somewhat common occurrence. It is met with chiefly as an isolated tumour, either in the midst of the gland or in its neighbourhood. There is preserved in the museum of the Western Infirmary a tumour the situation of which was behind the gland, which had to be cut through in order to remove it. The tumour was thus almost like a supernumerary mamma. Tumours of this kind are surrounded by a distinct connective

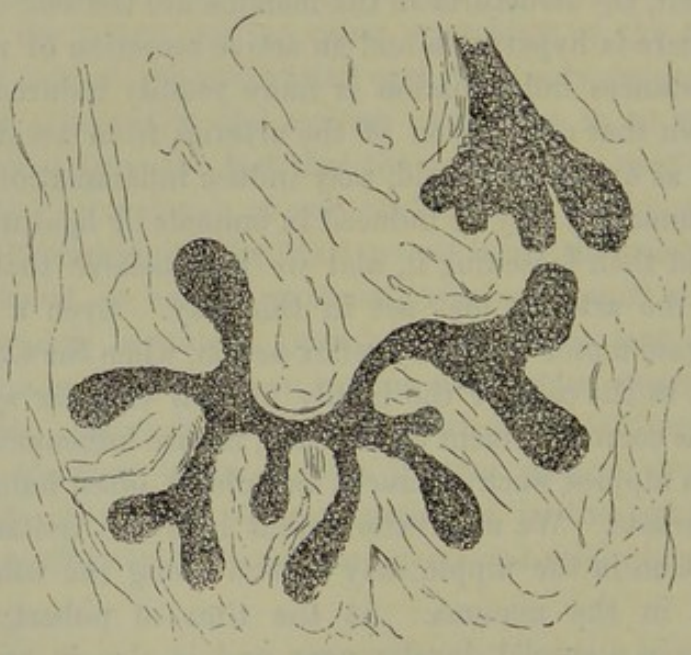


Fig. 307.—Section of an adenoma of mamma. Glandular structures of well-formed outline are shown in the midst of fibrous tissue. ×90.

tissue capsule which isolates them from the gland or from the neighbouring tissue.

Under the microscope the tumour (see Fig. 307) presents a perfectly regular glandular structure, with acini and ducts, but of course without any external communication. Between the glandular elements there is connective tissue which is sparsely nucleated like that of the normal gland.

ADENOID SARCOMA and SARCOMA.—The ADENOID SARCOMA is a form of tumour in which there is glandular tissue with sarcomatous tissue between the glandular structures. Doubts have been expressed as to the actual new-formation of gland tissue in tumours presenting sarcomatous elements, but as we meet with tumours presenting all gradations between the simple adenomas and the typical sarcomas, we can hardly refuse to believe that glandular new-formation does take place in the cases under consideration. When much glandular tissue is present, as in Fig. 308, the tumour is usually isolated, and partially

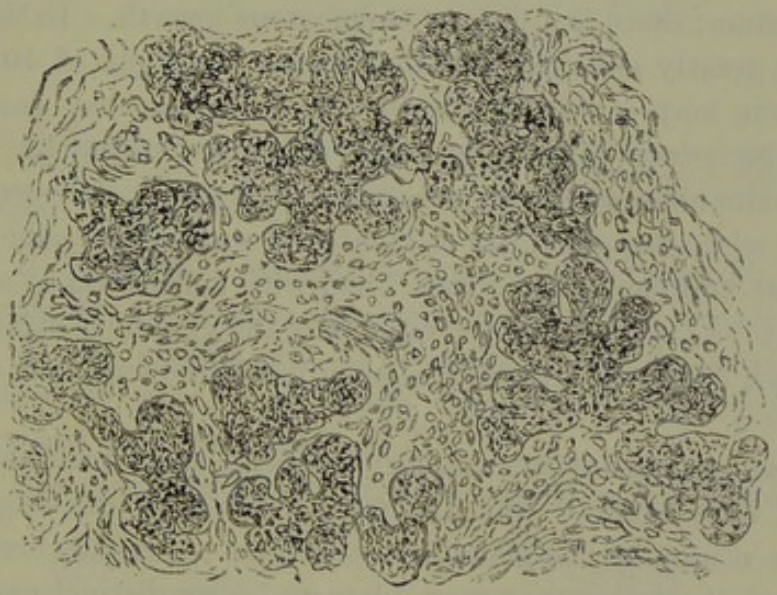


Fig. 308.—Section of an adenoid sarcoma of the mamma. Glandular structures are shown with spindle-cell tissue between. × 90.

separated from the surrounding mammary tissue, and there is sometimes more than one distinct tumour present.

The glandular structures are as in the adenoma, acini and smaller tubules, but they do not conform so strictly in their arrangement to the type of the normal mamma. The sarcomatous tissue evidently arises from the interstitial tissue, and is usually spindle-celled. In regard to this tissue great varieties are presented. The cells may be comparatively limited in number, so that the tissue is a connective tissue with

an excess of spindle cells. From this we have all gradations up to a complete spindle-celled tissue separating the glandular elements.

From cases in which there is a new-formation both of glandular and sarcomatous tissue, it is difficult to distinguish those in which the new-formation is entirely sarcomatous, and any glandular tissue is simply the remains of the normal mammary structure. Tumours are of frequent occurrence in the mamma, in which it may be said at least that the glandular element is very subordinate, and these tumours warrant the designation of true SARCOMA.

Such tumours are not usually isolated or defined from the neighbouring mammary tissue. They sometimes involve a limited part of the mamma, that portion undergoing what may almost be called a sarcomatous degeneration. That is to say, its interstitial tissue becomes converted into spindle- or round-celled tissue, while its glandular structures are variously contorted. But not infrequently the disease affects the whole mamma; there is a diffuse sarcomatous growth. In that case the mamma is greatly enlarged, and may attain a weight of 10 or 20 lbs. The tumour may involve the skin and ulceration may occur. There may thus be a deep ulcer in the midst of a massive tumour.

Under the microscope the sarcomatous elements are seen most prominently, while the glandular elements are somewhat sparse or entirely absent; but here and there a duct lined with epithelium or a misshapen acinus may be found. For the most part the glandular structures seem to be drawn out so that tubes are much more frequent than acini.

In these sarcomas CYSTS are very frequent, and sometimes the cystic formation is so marked that the name CYSTOSARCOMA is given. The cysts take origin in the glandular structures. Perhaps because of obstruction of the latter they may dilate and form distinct cavities in the midst of the sarcomatous tissue. A minor degree of this is very common, glandular structure being represented by elongated spaces lined with epithelium, which is mostly cylindrical (see Fig. 309). Even in these incipient cysts we can often see that the sarcomatous tissue is, as it were, pushing its way into them (see figure), a kind of papillary growth presenting itself in the wall of the space, the growth being covered with epithelium like that lining the space. Sometimes this INTRACYSTIC GROWTH is very marked, and we may have large cysts filled with ingrowing masses of sarcoma. In fact it sometimes appears as if the main growth of the tumour were into greatly dilated gland ducts.

It need hardly be added that the sarcomas and adenoid sarcomas present malignant characters, chiefly in the form of a tendency to local

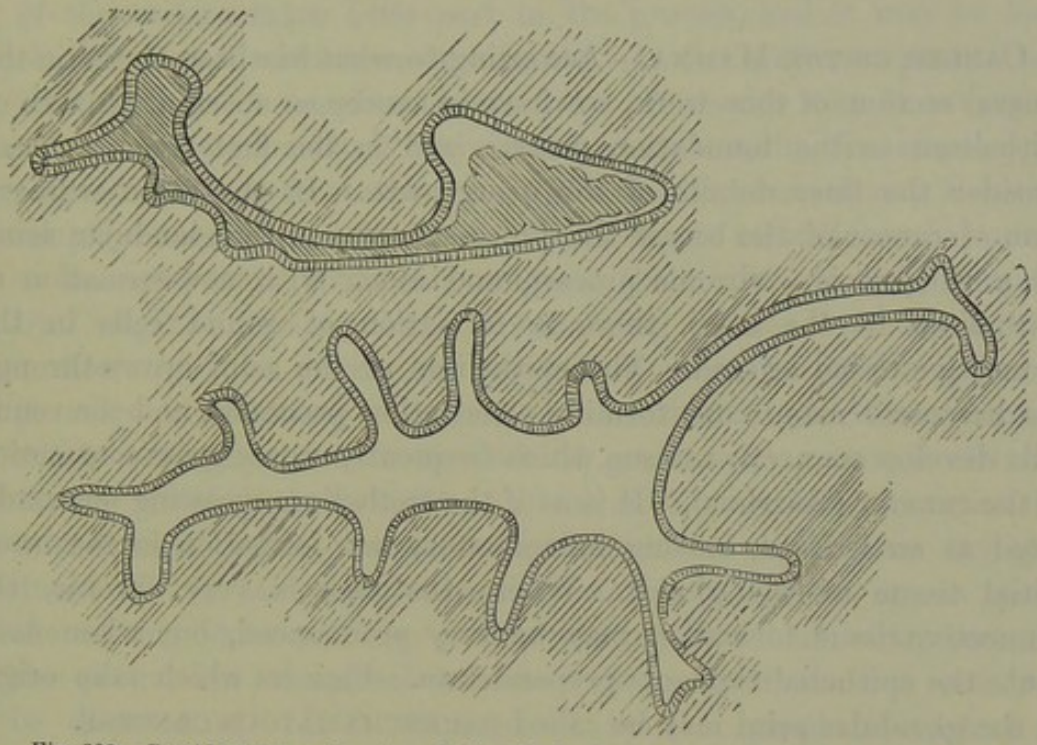


Fig. 309.—Semidiagrammatic view of dilated glandular spaces in a cystosarcoma of the mamma. The spaces are lined with cylindrical epithelium. The tendency to intra-cystic growth is shown, especially in the upper one. These were drawn under the camera lucida so that the outlines are correct. × 62.

recurrence. If an adenoid sarcoma is excised it will probably recur as a pure sarcoma, but the author has seen, in a case of recurrence, an arrangement of the spindle cells as if around distinct centres, which suggested glandular structure. These tumours, on recurrence, also become softer, and the cells more loose.

There are also sarcomas in the mamma which are not related to the

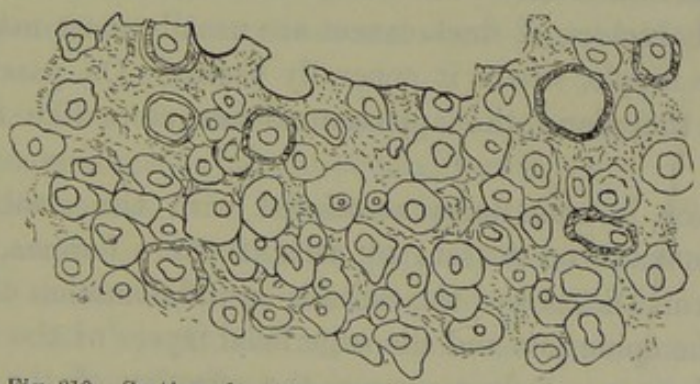


Fig. 310.—Section of cartilaginous part of a tumour of mamma which contained besides spindle-celled and fibrous tissue. × 200.

glandular structure either directly or indirectly. These are usually spindle-celled sarcomas, but they may be considerably mixed, cartilage

even occurring as part of their structure, as in the case from which Fig. 310 was taken.

CANCER OF THE MAMMA.—According to what has been stated in the general section of this work, we have in cancer an aberrant growth of epithelium as the foundation process, and in the first place we may consider the finer details of the overgrowth. In the more ordinary form of cancer of the breast the process begins in the glandular acini. As a rule, it is a chronic process, and along with new-formation of epithelium in the acini, there is formation of round cells in the connective tissue around. The epithelium of the acini grows through the basement membrane, forming penetrating processes, and the round cells develop connective tissue which frequently causes great contraction of the tumour (Scirrhus). It is as if the epithelium, growing outwards, acted as an irritant, causing inflammatory new-formation in the interstitial tissue of the gland. Where the case is very chronic, the connective-tissue formation may be very pronounced, but when more acute the epithelial elements preponderate. Cancers which take origin in the glandular acini may be called PARENCHYMATOUS CANCERS.

But cancers may take origin rather in the ducts of the gland, forming a class called DUCT CANCERS (Thin). These very often begin in the large ducts in or near the nipple. In this case the growing epithelium often distends the ducts, forming cavities which are sometimes lined with cylindrical epithelium, with more irregular epithelium inside. Such dilated ducts may even have the appearance of cysts, so that the tumour may appear cystic This process in the ducts is also associated with irritation of the surrounding connective tissue, so that there are round cells and new-formed connective tissue. The special characters of duct cancer are usually most manifest in the parts near the nipple, where it generally begins. On passing into the substance of the gland the appearances are more like those of the other form.

Duct cancer is sometimes associated with the condition known as PAGET'S DISEASE OR ECZEMA OF THE NIPPLE. Eczema, as indicated in the section on Diseases of the Skin, is an inflammation of the skin, in which both the epidermis and the superficial layers of the cutis are engaged. In the case of duct cancer, the affection of the ducts seems to induce an inflammation of the skin of the nipple and parts around, characterized by the usual formation of round-cell tissue. The superficial or papillary region of the skin may then be replaced almost

entirely by round cells with nests of epithelium in their midst, and the condition is somewhat like that of a granulating wound. The epithelium of the surface takes little part in the process, and it may be lost, so that the granulation tissue is exposed. As the cancerous process begins commonly in the nipple, this condition of eczema may be a very early one, and may precede, it may be for many months, the actual appearance of a tumour in the mamma. It is to be remembered also that a simple eczema may occur in the nipple, due to an ordinary irritant.

In connection with this subject, the views recently enunciated by Creighton deserve notice. According to the observations of this author, there is, during the process of evolution of the gland preparatory to lactation, a great new-formation of glandular epithelium, which gradually, after a number of generations, assumes the condition in which it forms milk. In the involution after lactation there is a reverse process, successive generations of epithelium being produced till it assumes the resting state. All these stages between the resting state and the milk-producing state are characterized by the production of epithelium which is in itself useless, and has to be disposed of. It is disposed of by the lymphatic system, into which the cells pass, and are carried to the lymphatic glands. Creighton regards cancer as the exaggeration of a condition comparable to one or other of the stages of evolution or involution, and therefore primarily a disorder of function. There is an excessive production of epithelium, which bursts through the basement membrane and is grouped outside the acini. In like manner the cells pass to the lymphatic glands, where they give rise to secondary tumours, not by themselves growing and proliferating, but by inducing the lymphatic glandular tissue to assume the characters of cancerous tissue. These views are somewhat theoretical, and stand in need of confirmation.

We have now to consider cancer of the mamma according to the more ordinary division into its several forms.

The commonest form of cancer is SCIRRHUS. The description of scirrhous cancer in the general part of this work is chiefly based on scirrhus of the mamma, and need not be repeated here. It will be remembered that the epithelial masses often form elongated processes (Fig. 311) in the midst of an excessive stroma composed of dense contracting fibrous tissue. The cells are often atrophied so that in some parts of the tumour there is little beyond dense connective tissue. The cancer commonly forms rather a limited infiltration of a part of the gland than

a proper tumour, and as the tissue contracts there is commonly an actual diminution of bulk with great induration. The gland is distorted

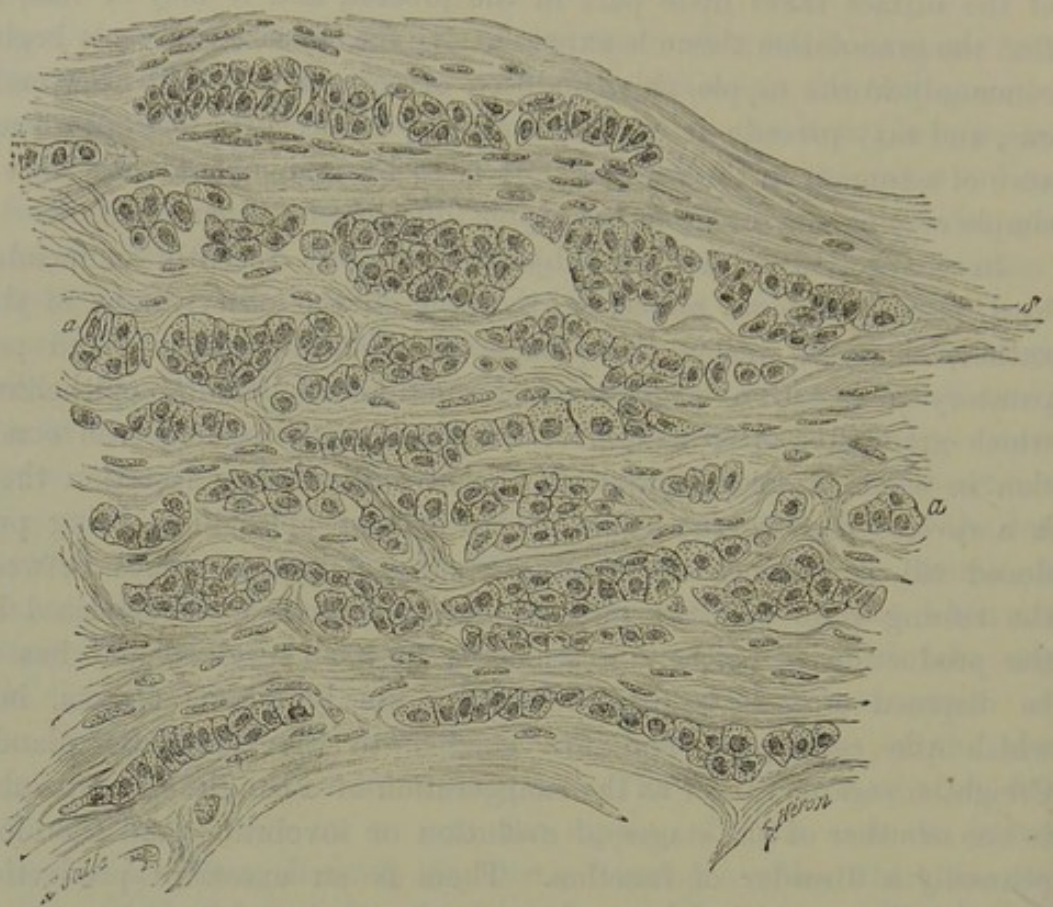


Fig. 311.—Section of cancer of mamma from a recent nodule. Epithelial cells in spaces formed by connective tissue; these are sometimes in single rows, and by multiplication form larger masses. × 200. (CORNIL and RANVIER.)

and puckered towards the affected part. Very often the disease is continuous with the nipple, and by the dragging of the tissue the nipple is drawn in, sometimes even forming an umbilicated depression. The tumour is very irregular in its extension in the gland, and it very often happens that in the midst of hard scirrhous tissue some ADIPOSE TISSUE appears, being the remains of some of the fat which normally surrounds the gland. In like manner pieces of the gland-tissue may crop up amidst the contracting tumour. Not infrequently scirrhus goes on to ulceration of the skin, which usually occurs about the site of the nipple and areola. The ulcer is crater-shaped with dense prominent walls. Sometimes after formation of the ulcer the growth of the cancer becomes more rapid.

When a mamma which is the seat of scirrhous cancer is cut into, either the whole gland or a portion of it is seen to be occupied by a

hard mass of a greyish colour on the cut surface. It is very hard to cut, and the cut surface is commonly concave, the elasticity of the dense connective tissue producing retraction. In the general grey basis there are various whitish or yellowish pieces which represent the remains of mammary or adipose tissue, or the cancerous epithelium in a state of fatty degeneration. If the cut surface be scraped a thickish juice is obtained, which microscopic examination shows to be composed of epithelial cells and their debris. Many of the cells are large and well-formed, while some may contain secondary cells within them or double nuclei (see Fig. 312). There are also free nuclei which have escaped from cells as a result of the mechanical interference in the process of preparing the specimen. Many of the cells contain fatty degeneration, in fact, very often nearly all contain fatty granules, and there are some completely degenerated, showing nothing but an aggregation of fat drops like the compound granular corpuscle.

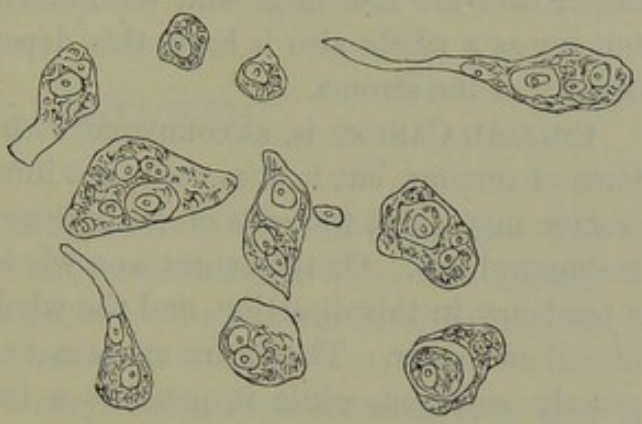


Fig. 312.—Cells in the juice scraped from a scirrhus of mamma. They are of very irregular shape. Most of them contain several nuclei and some daughter cells. ×200.

The lymphatic glands commonly become secondarily affected in scirrhus of the mamma, and the tumour produced here is also a hard cancer with excessive development of the stroma. It is to be observed, however, that in the glands the stroma usually forms a more distinct meshwork than in the mamma, and the epithelial cells form more definite groups.

Medullary Cancer forms the opposite extreme to scirrhus, and there are all intervening grades. In the medullary cancer we have a bulky tumour of soft consistence and rapid growth. There is a well-formed alveolar stroma, and the cells are somewhat loosely contained in it. The tumour involves neighbouring tissues, very readily infiltrating the skin, subjacent muscle, and even the osseous ribs and the pleura. This form is not uncommonly present simultaneously in both breasts. On section the tumour presents a grey brain-like appearance. The juice furnishes numerous cells, mostly small in size but with prominent oval nuclei, also abundant free nuclei which have escaped from

the delicate cells. As the tumour commonly extends to the skin, we may have ulcers with fungating prominence of the tissue. The lymphatic glands are early affected and they also may ulcerate.

Many large tumours of the mamma of comparatively rapid growth do not correspond with the description either of the medullary cancer or the scirrhus. In their minute structure they are more like the scirrhus, and perhaps may be designated ACUTE SCIRRHUS. They have a remarkably firm fibrous stroma, but it forms distinct meshes in which the epithelial masses are contained with considerable regularity. The cancer cells are also large and essentially like those in scirrhus. The tumour as a whole also is hard, this depending on the abundance and density of the stroma.

COLLOID CANCER is, as compared with scirrhus, an exceedingly rare form of tumour, but it does occur not infrequently. The colloid degeneration may affect the cells of an ordinary cancer, producing a partial metamorphosis. Or the cancer as a whole may present, from the first, a tendency in this direction, and the whole tumour have the characters of colloid cancer. The entire mamma is commonly affected, and it is greatly enlarged, while it presents a hard feeling like that of acute scirrhus. On section the tumour presents a flickering gelatinous appearance. Under the microscope there is the usual pronounced stroma with colloid material in the meshes. In the midst of the colloid masses there are often seen groups of cells, the remains of the epithelium.

It is to be added that sometimes cancers occur having a close resemblance to colloid cancers, but in which the metamorphosis is in the stroma, which is the seat of mucous degeneration. We may thus have a large gelatinous tumour which, on microscopic examination, shows epithelial masses embedded in a gelatinous flickering stroma. To this form may be applied the term MUCOUS CANCER.

OTHER TUMOURS of the breast are of uncommon occurrence. We may have an excessive growth of the adipose tissue around the mamma, forming a lipomatosis or LIPOMA CAPSULARE. Even isolated lipomas have been met with. Isolated FIBROMAS have also been seen. MYXOMA of the mamma has been observed in a considerable number of cases. It forms a tumour of considerable size, the interstitial tissue of the mamma generally being converted into mucous tissue, while the glandular structures have atrophied; this form of tumour is apt to be mistaken for colloid or mucous cancer.

The MYOMA has been met with in the nipple.

DISEASES OF THE MALE GENERATIVE ORGANS.

A.—THE TESTICLES.

MALFORMATIONS AND MISPLACEMENTS OF THE TESTICLE. The testicle may be absent on one or both sides, while the vesiculæ seminales and vasa deferentia are perfect. Or the vas deferens may be deficient while the testis is well developed.

IMPERFECT DESCENT of the testis, or CRYPTORCHISMUS, is a very frequent and important condition. The descent of the testis occurs normally before birth, but in a considerable number of cases the organ has not yet appeared externally at birth. In the majority of such cases it comes down within the first week, but it is sometimes delayed for months or a year, or even till puberty. When thus delayed the descent is very often imperfect, so that the gland remains in the inguinal canal or at the ring. On the other hand, the testis may be retained throughout life in the abdomen. The testicle retained in the abdomen or on the way down is usually imperfectly developed, and although apparently of normal size, it does not generally contain spermatozoa in its tubules. It is also more prone to inflammation and the formation of tumours than the normally placed testis, especially when in the inguinal canal where it is exposed to external violence. When it is late of descending the accompanying pouch of peritoneum, which forms the tunica vaginalis, is apt to remain open and so to induce a CONGENITAL HERNIA.

Besides these congenital misplacements, we may have the testis descending into the crural canal, or into the perineum.

INFLAMMATION OF THE TESTICLE. This condition presents itself under a considerable variety of forms, certain of which are difficult

altogether to separate from syphilis and tuberculosis. It is to be remembered that the testicle is bounded externally by a dense fibrous capsule, the tunica albuginea, and that the products of inflammation are apt to be closely confined within this.

ACUTE ORCHITIS is mostly secondary, although occasionally resulting from a blow or other injury. It occurs as a secondary result in gonorrhœa, the specific irritant being apparently propagated along the vas deferens; also in cases of irritation of the urethra by calculi, the passage of instruments, etc., the inflammation in such cases being called sympathetic, and probably brought about by reflex irritation of the vaso-motor centres. In mumps there is also, in a certain proportion of cases, orchitis as a secondary result, the specific irritant attacking the testicles as well as the parotid gland.

The inflammation very often begins in the epididymis, and may remain confined to that region or pass on to the testis. There is hyperæmia and serous exudation producing great swelling, so that the tunica albuginea is tightly stretched, and the organ feels hard and tense. At the same time there is often serous fluid in the tunica vaginalis. There may be resolution without suppuration, the testis returning to the normal condition, or the disease may become chronic, or suppuration may occur. In the latter case an abscess or abscesses form in the testicle, and these may burst externally. In that case the tense albuginea often forces the tissue of the testicle through the opening so that it projects in a fungating form. This, which forms the BENIGN FUNGUS, and is not to be mistaken for cancer, has a red colour and looks like protruding granulations. But it really contains the seminal tubules, and after the subsidence of the inflammation these may be replaced and resume their function. On the other hand, the abscess may dry in and form a caseous mass, which becomes surrounded by a fibrous capsule. This mass may ultimately become calcareous.

CHRONIC ORCHITIS may arise out of an acute attack, remaining after the formation of abscess, or else supervening without that. There is also a spontaneous chronic orchitis which in most cases is either syphilitic or tubercular. The ordinary chronic orchitis is characterized by new-formation of connective tissue in the stroma of the organ, and consequent induration of it. The tubules atrophy and the whole organ is reduced in bulk and hardened. Generally on section it can be seen that the albuginea and the septa which proceed towards the mediastinum, are greatly thickened. At the same time there is frequently adhesion of the tunica vaginalis which may obliterate the sac.

The other form of chronic orchitis which is described is characterized by the occurrence of yellow caseous masses. Such masses may arise from the drying in of abscesses, or in connection with syphilis or tuberculosis, and probably have no independent origin.

SYPHILITIC DISEASE OF THE TESTICLE sometimes occurs as a general induration, having the usual characters of chronic orchitis. The albuginea is thickened and the trabeculæ are enlarged as they converge towards the mediastinum. These thickened structures may be largely composed of granulation tissue, and we may have in addition definite gummata. The gummata may undergo caseous necrosis, and by coalescence of neighbouring tumours we may have considerable masses of caseous material. In the midst of this caseous material the outlines of the seminal tubules can sometimes be made out, indicating that the necrosis has overtaken the proper tissue as well as the new-formed.

TUBERCULOSIS OF THE TESTICLE is characterized by the formation of caseous masses, sometimes of considerable size, and these are surrounded by a grey inflammatory tissue in which tubercles are to be found. The tuberculosis is very often associated with similar disease in the prostate and vesiculæ seminales, and this coincidence points to propagation from the one to the other. The starting point may be at the testis or at the other extremity of the vas deferens. There is also, not infrequently, tuberculosis elsewhere, as in the form of scrofulous glands or phthisis pulmonalis.

As a general rule the tuberculosis begins in the epididymis, mostly in its tubules. The result is great thickening and the formation of a caseous mass, enclosed very often in a firm fibrous capsule. Thus a firm elongated tumour may form behind the testicle. In the testicle also caseous masses form, at first isolated, but afterwards running together into considerable conglomerates. The caseous masses are very dense, but after a time they generally break down, and having burst externally, tedious fistulæ are the consequence.

When the testicle is examined in section the caseous structure is seen to be surrounded by a transparent grey tissue, in which, as already mentioned, tubercles are present. This inflammatory and tubercular structure by its pressure destroys the tubules for the most part, but not altogether, as bits of tubules are sometimes expelled along with the softened caseous material.

TUMOURS OF THE TESTICLE.—These are mostly somewhat malignant in their characters, and there is a peculiar tendency to a mixed structure.

SARCOMAS occur frequently mixed with tissue of other tumours, as the myxoma, enchondroma, etc. Even when the tumour is a pure sarcoma there may be combined the structures of various forms of this tumour, spindle cells, round cells, and mucous tissue. There may, however, be a simple round-celled sarcoma. The sarcomas form usually large tumours of soft consistence and rapid growth. They occur in comparatively young persons, and are prone to metastasis, the secondary tumours occurring mainly in the lungs.

The relation of the sarcomas to the seminal tubules deserves special consideration. The tissue of the tumour, like that of other sarcomas, originates in the interstitial tissue. In many cases the glandular structures undergo atrophy; but in others, changes occur comparable with those we have already considered in sarcomas of the mamma. Cysts are thus of frequent occurrence, and they are so characteristic in some cases that the name CYSTO-SARCOMA is given. These cysts often contain a gelatinous material, although in the larger ones the contents are usually serous. Sometimes the contents undergo fatty degeneration, and we may have cholestearine in the fluid, or even an atheromatous substance. As in the mamma, there may be a papillary ingrowth of the sarcoma into the cyst, forming peculiar intracystic projections. It appears also that there is sometimes an actual new-formation of glandular tissue along with the sarcomatous, in this respect resembling the adenoid sarcoma of the mamma.

CANCER OF THE TESTICLE connects itself with the cystic and adenoid sarcomas. It appears that not infrequently the glandular tissue in these tumours has more of the irregular atypic cancerous character than of the strictly glandular, and in particular the epithelial masses do not possess a membrana propria. These characters are also expressed in the fact that sometimes these tumours extend to the neighbouring lymphatic glands, while others penetrate more readily into the veins.

Proper cancer of the testes is mostly a large quickly growing soft tumour—MEDULLARY CANCER. It involves the whole organ as well as the epididymis, converting them together into a massive tumour. It may also extend along the vas deferens, and on to the lymphatic glands, inguinal, lumbar, and pre-vertebral. From these glands it may extend to the radicles of the portal vein and so produce tumours in the liver, or more frequently to the radicles of the vena cava, producing tumours

in the lungs. In the midst of the tumour we may have cysts formed by mucous or fatty degeneration.

The cancerous tissue is derived from the epithelium of the seminal tubules, and the stroma from the interstitial tissue. It is necessary, however, to mention that tumours may arise in connection with the blood-vessels which have a resemblance in their structure to cancers, but which are properly plexiform angiosarcomas.

OTHER TUMOURS of the testicle are uncommon. We meet with CYSTS, but the chief of them, the spermatocele, will be described afterwards. The testis is also sometimes the seat of the DERMOID CYST. It may be a simple dermoid in the midst of the gland, arising apparently by inclusion of a piece of embryonic skin. But sometimes there is a more complex cyst, like that of the ovary, and deserving the name of teratoma. Such tumours probably owe their origin to the inclusion of a whole fœtus. For the rest, the occasional occurrence of fibromas, lipomas, enchondromas, myomas of the striated variety and even osteomas, has been observed.

HYDROCELE.—By this name is meant the accumulation of fluid in the tunica vaginalis. The fluid is serous and the cause of its accumulation is inflammation. It is not properly a dropsy of the tunica; a general dropsy, affecting the skin of the scrotum very greatly, causes little fluid to accumulate in the tunica vaginalis. The inflammation may be acute, in which case there is fibrine deposited on the surface as well as serous fluid in the sac. More commonly it is chronic, and there is a gradual accumulation of serum.

The fluid distends the sac, and so a bulky tumour is formed which is pear-shaped with its blunt end downwards. The fluid is usually a clear serum, but sometimes it is slightly opalescent. In the true hydrocele this is not from the presence of spermatozoa, but from the existence of fine fat drops, resulting from degeneration of the leucocytes floating in the fluid. There may even be cholestearine crystals formed in this way.

Not infrequently hæmorrhage occurs, most commonly as the result of a blow or other injury, and the hydrocele becomes a HÆMATOCELE. The blood mostly coagulates, and the coagulum through time undergoes various changes, softening into a brown pultaceous material or into a brown turbid fluid, in which are enormous numbers of cholestearine crystals. The blood seems to act as an irritant to the tunica vaginalis, causing often a very great thickening of it. The interior also is rough and

sometimes presents considerable projections. The thickened cyst may contract somewhat so that the tumour is reduced in size. This thickening of the wall, even when the contents are fluid, may cause the hæmatocele to be mistaken for a solid tumour, and castration has often been performed under this belief.

A hydrocele or hæmatocele may be cured by the fluid being absorbed, the result usually being adhesion of the opposed surfaces of the tunica vaginalis and obliteration of the sac.

In the condition named CONGENITAL HYDROCELE the tunica vaginalis retains its communication with the peritoneal cavity. The fluid may come from the peritoneal cavity, or may originate as in an ordinary hydrocele. It can be pressed into the peritoneum through the neck. It will be understood that a congenital hernia may occur along with or alternate with this form of hydrocele.

SPERMATOCELE. ENCYSTED HYDROCELE.—In this affection there is a cyst having in many cases much the external appearance of hydrocele, but containing a fluid in which spermatozoa are abundantly present. In other respects also the condition differs from that in hydrocele, for we have here not merely an accumulation in an existing sac, but a proper new-formed cyst. Hence the name Encysted Hydrocele is often used as equivalent to spermatocele.

The cyst arises in connection with the epididymis for the most part, and probably takes origin in one or more aberrant tubules which have formed blind diverticula from the seminal tubules. They usually arise near the upper end of the epididymis, but it may be at the lower end or from the rete testis. The cysts grow often to a large size, and they sometimes push themselves into the sac of the tunica vaginalis, inverting one layer of the wall against the other. As a rule, the tunica vaginalis is found below and in front of the cyst, this position being connected with the origin of the cyst in the neighbourhood of the testis.

The fluid from these cysts has a peculiar opalescent appearance, which is due to the presence of multitudes of lively spermatozoa. The existence of these shows that the cyst has retained its connection with the seminal tubules. The cyst is usually lined with a ciliated epithelium, but in large ones the pressure of the fluid may cause it to assume the pavemented form.

It will be observed that these spermatic cysts are comparable in their origin to the parovarian cysts.

OTHER FORMS OF HYDROCELE have been described, but they require only a passing notice. There may be an encysted hydrocele without spermatozoa in the fluid. Then there is encysted hydrocele of the cord, sometimes arising by a portion of the communication between the tunica vaginalis and the peritoneum remaining unobliterated and becoming the seat of an accumulation of fluid. There is also diffused hydrocele of the cord, in which there is an œdematous condition of the connective tissue around the spermatic cord. There may even be a hydrocele from a hernial sac, which has got emptied of its contents and shut off from the peritoneum by adhesion of the neck.

B.—THE PENIS AND SCROTUM.

In the PENIS the ULCERS or CHANCRES are the commonest forms of disease. The simple chancre is an ulcer which has its usual seat on the glans or frenum. Sometimes we meet with a deeply penetrating or phagedenic ulcer. The hard chancre is the primary syphilitic sore, and as such we have already considered it.

Another syphilitic manifestation is the CONDYLOMA, which forms warty outgrowths sometimes of considerable size. There may be large groups of papillæ forming a cauliflower-like tumour.

CANCER of the penis occurs in the form of epithelioma. It begins usually in the glans, and the tumour is often covered with prominent papillæ, which give it a highly characteristic warty appearance, like the cauliflower excrescence. It may remain long without ulceration, but usually sooner or later breaks down, and there are sometimes deep ulcerating fissures or fistulæ between the groups of papillæ.

In the SCROTUM, CANCER is somewhat common, and it is so often chimney-sweepers who are affected that the disease is often called chimney-sweepers' cancer. In Glasgow it has been found that workers in paraffin refineries are also liable to this disease. It generally forms a flat tumour from whose surface prominent papillæ protrude. Through time ulceration occurs and the testicle may be exposed.

ELEPHANTIASIS of the scrotum has been sufficiently treated of in the general part of this work.

Lymph Scrotum has already been referred to in connection with the filaria sanguinis. In it there is a varicose condition of the lymphatic vessels of the scrotum with the formation of vesicles in the skin. These frequently burst and discharge a fluid in which the embryo filaria is usually to be found. In some such cases the filaria is also present in the blood, but sometimes not. The lymphatic glands of the groin are indurated, and the dilatation of the lymphatics seems to be due to the obstruction of these vessels in the glands by the embryo filariæ. According to Manson elephantiasis sometimes develops from lymph scrotum, and depends on the same parasite, but this view can hardly be accepted on the present evidence. In lymph scrotum the adult female filaria, and probably the male also, inhabits a lymphatic vessel in the groin, and their embryoes or ova pass off and stick in the glands, thus obstructing the lymphatics.

The Prostate, as we have already seen, is subject to hypertrophy. The common enlargement of old age is due to increase of the muscular substance. This enlargement exists in about 30 per cent. of men above 60 years of age. It develops slowly without any apparent cause, and in this respect has the characters of a tumour. Sometimes the whole prostate enlarges, and it may reach the size of the fist. But sometimes there is a more partial hypertrophy, forming the so-called third lobe of the prostate, which projects inwards at the neck of the bladder, and is sometimes so large as to act like a valve to the orifice of the urethra. The effect of enlargement of the prostate on the urethra is to be noted. If there is a general enlargement the urethra is necessarily elongated in its prostatic portion, and whereas normally this portion measures $1\frac{1}{2}$ inches in length it may come to be 4 inches. At the same time the tube may be narrowed and even distorted. If, for instance, the central part of the prostate is specially hypertrophied, then the urethra, being pushed upwards, has on section a crescentic shape with the convexity upwards; or if one side is larger than the other, there will be a convexity towards the opposite side.

Besides this muscular hypertrophy the much rarer hypertrophy of the glandular structure is to be mentioned. The glandular structure does not commonly increase with the muscular, but sometimes enlarges by itself, so that we have an adenoma of the prostate.

Cancer of the prostate is not of frequent occurrence. The gland enlarges and the disease is apt to extend to neighbouring structures.

Tubercle occurs not infrequently in the prostate and vesiculæ

seminales in conjunction with similar disease in other parts of the urino-genital passages. There is caseous necrosis with ulceration as usual, and this may cause even perforation into the rectum or bladder.

Concretions are of frequent occurrence in the prostate in old persons. They are formed in the gland ducts and are of various sizes, from very minute to the size of a grain of corn. When small they are colourless, but as they enlarge they frequently become blackish or reddish brown in colour. They are round or oval in form and frequently present concentric stratification (Fig. 44, p. 135). They have usually a central cavity. Very commonly these bodies present the character of amyloid bodies, giving a bluish or mahogany red colour with iodine. Sometimes they contain lime salts in their substance. They may pass into the urethra and escape with the urine. While in the prostate they do not appear to produce much disturbance.

DISEASES OF THE BONES AND JOINTS.

A.—THE BONES.

INTRODUCTION.—In considering the diseases of the bones, it is necessary to bear in mind certain matters regarding their structure and life. It is to be remembered that bone grows, not like ordinary tissues by interstitial expansion, but by addition of new tissue to the old. An attempt has indeed been made, on the basis of the architecture of the fine lamellæ of the spongy bone at the ends of the long bones, to show that growth occurs by interstitial expansion; but this attempt is not generally accepted as successful, and it may be said that in the growth of bone, deposition and absorption go on simultaneously, so as to preserve the architecture while the size is increased. Bone is therefore to be regarded as a solid, comparatively unaltering structure. When hypertrophy of bone occurs, this takes place by the action not of the bone itself, but of the periosteum or endosteum. For the most part also, when destruction of bone takes place, it is by agents acting from without. It is to be noted, however, that the bone corpuscles are not altogether inactive cells. They doubtless look after the nutrition of the bone, and although they do not in pathological processes as a rule present any great increase in activity, they are certainly capable of degeneration, in which case they induce changes in the solid intercellular matrix.

In studying the diseases of bone, and more especially in regard to rickets and inflammations, it is important to bear in mind certain facts as to the relation of osseous tissue to cartilage and connective tissue. These three tissues appear to be fundamentally one, and they are to some extent mutually convertible. This fact is sometimes

expressed in the term METAPLASIA, and may be illustrated by the accompanying figures (313 and 314), from a case of fracture of a rib.



Fig. 313.—Longitudinal section of a fractured rib, showing callus, etc.; the section is imperfect at the upper part. *a, a, a, a, a*, the broken extremities of the rib dove-tailing into each other; *b, b, b*, new-formed cartilage constituting part of the callus; *c, c, c*, new-formed bone constituting the external layers of the callus; *d, d, d, d*, new-formed connective tissue constituting the more immediate bond of union between the broken ends. × 11.

As we shall see afterwards, an inflammatory process is concerned in the healing of fractures, the so-called callus being an inflammatory new-formation. As a rule in the human subject, this callus is formed

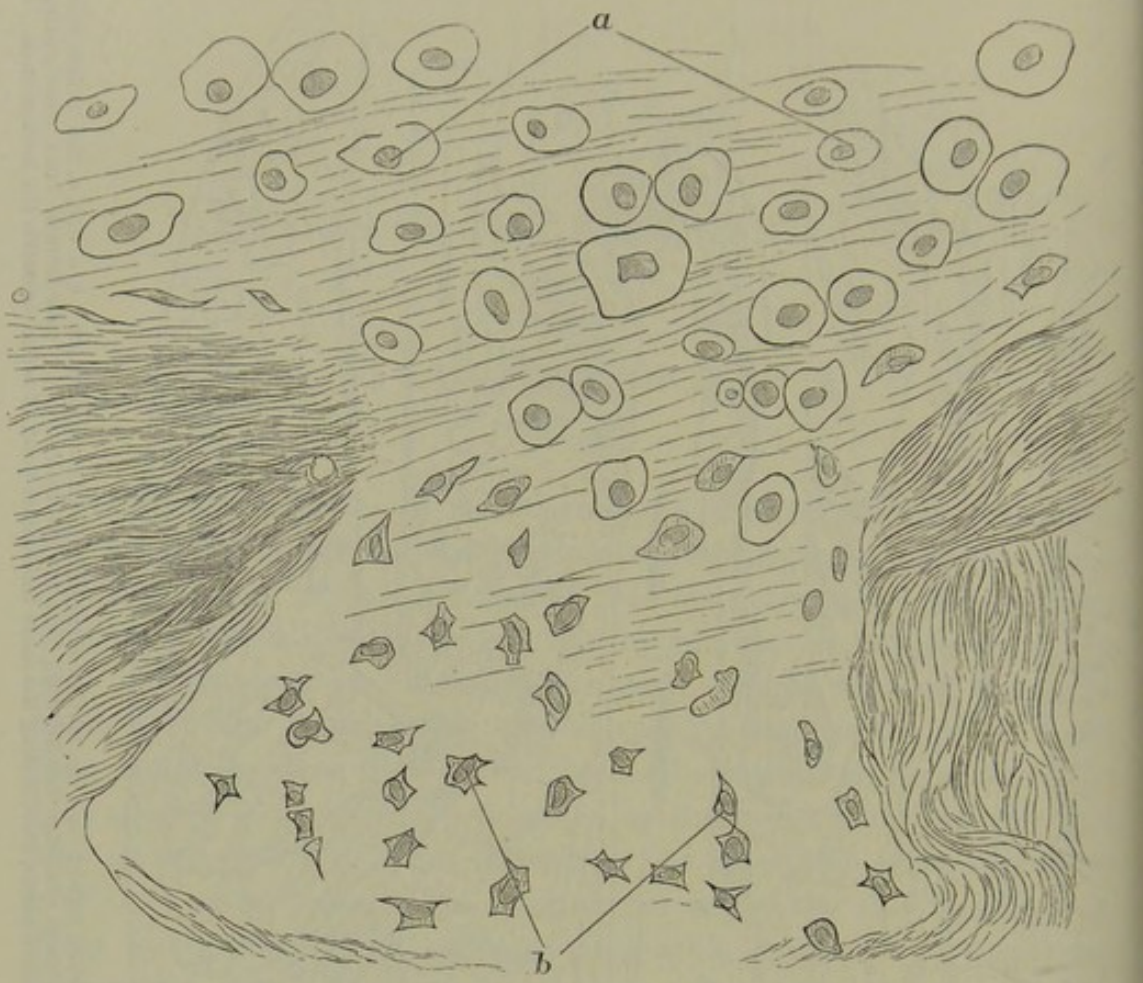


Fig. 314.—From same section as Fig. 313, showing continuity of cartilage and bone in the callus. At *a* there are cartilage cells, and at *b* bone corpuscles, the matrix being continuous and apparently of the same structure. × 350.

of bone, but in animals cartilage enters into its constitution, and in the section of which the figures are representations, the callus was variously composed of bone, cartilage, and fibrous tissue, the existence of one or other being apparently determined by circumstances. In some parts, as at *b*, *b*, in Fig. 313, cartilage and bone exist side by side, and it is sometimes even difficult to say which is actually present, there being obviously transition forms. In this as in other inflammations, the new-formed tissue has originally the structure of granulations, and the granulation tissue may develop bone, or cartilage, or fibrous tissue.

RICKETS OR RACHITIS.

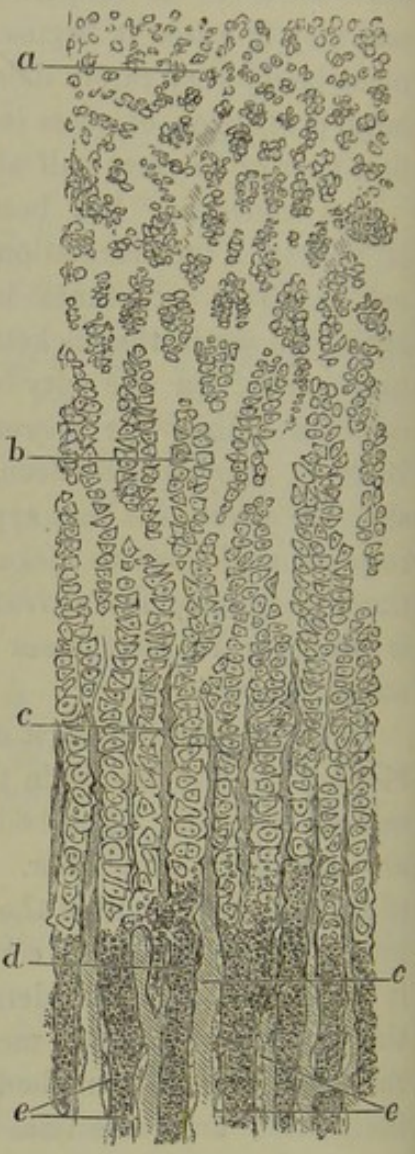
This disease occurs in children during the earlier periods of growth, and so far as the bones are concerned it is a disease of development, the normal process of ossification being interfered with. Cases have been observed of congenital rickets, but these are rare, and in the majority of cases it begins in the first or second year, its commencement being very rarely delayed beyond the fourth or fifth year. In a large proportion of cases its onset seems to be in the latter half of the first year or the first half of the second.

An endeavour has been made lately to make out that rickets is merely a manifestation of hereditary syphilis. This view has not received acceptance in this country. It has been pointed out again and again that rickets is very common in cities where syphilis is uncommon. In the city of Glasgow, for instance, rickets is very common among the poorer classes, but syphilis is very uncommon. It is so also in Aberdeen, Edinburgh, Belfast, and elsewhere. We shall see afterwards that syphilis produces changes in the bones in some respects analogous to rickets, and atrophy of the cranial bones, sometimes designated CRANIOTABES, although formerly regarded as rachitic, is probably in most cases syphilitic; the two diseases, however, are essentially separate.

Rickets occurs amongst children who are injudiciously fed and badly housed, and the disease in the bones is to be regarded as part of a general loss of health. The body is weakened, and, besides the bones, there are other parts that suffer. The state of mal-nutrition may be the effect of an unhealthy state of the mother during utero-gestation, or it may be produced by unhygienic conditions after birth. According to Macewen, it supervenes in a considerable number of cases on an attack of one of the acute fevers, such as measles or scarlet fever, such an attack leaving the child in an ill-nourished condition. There are usually symptoms of indigestion and intestinal catarrh, sometimes with fever, and in a certain proportion of cases there is enlargement of the spleen and sometimes also of the liver and lymphatic glands. The bones, being perhaps the most actively growing parts at this period of life, may be specially affected when the general nutrition suffers.

Rickets has been produced artificially in growing animals by feeding them with small doses of phosphorus, or by giving them lactic acid, by the mouth or subcutaneously. In both cases the diet must be deficient in lime-salts. In the latter case it has been supposed that the lactic

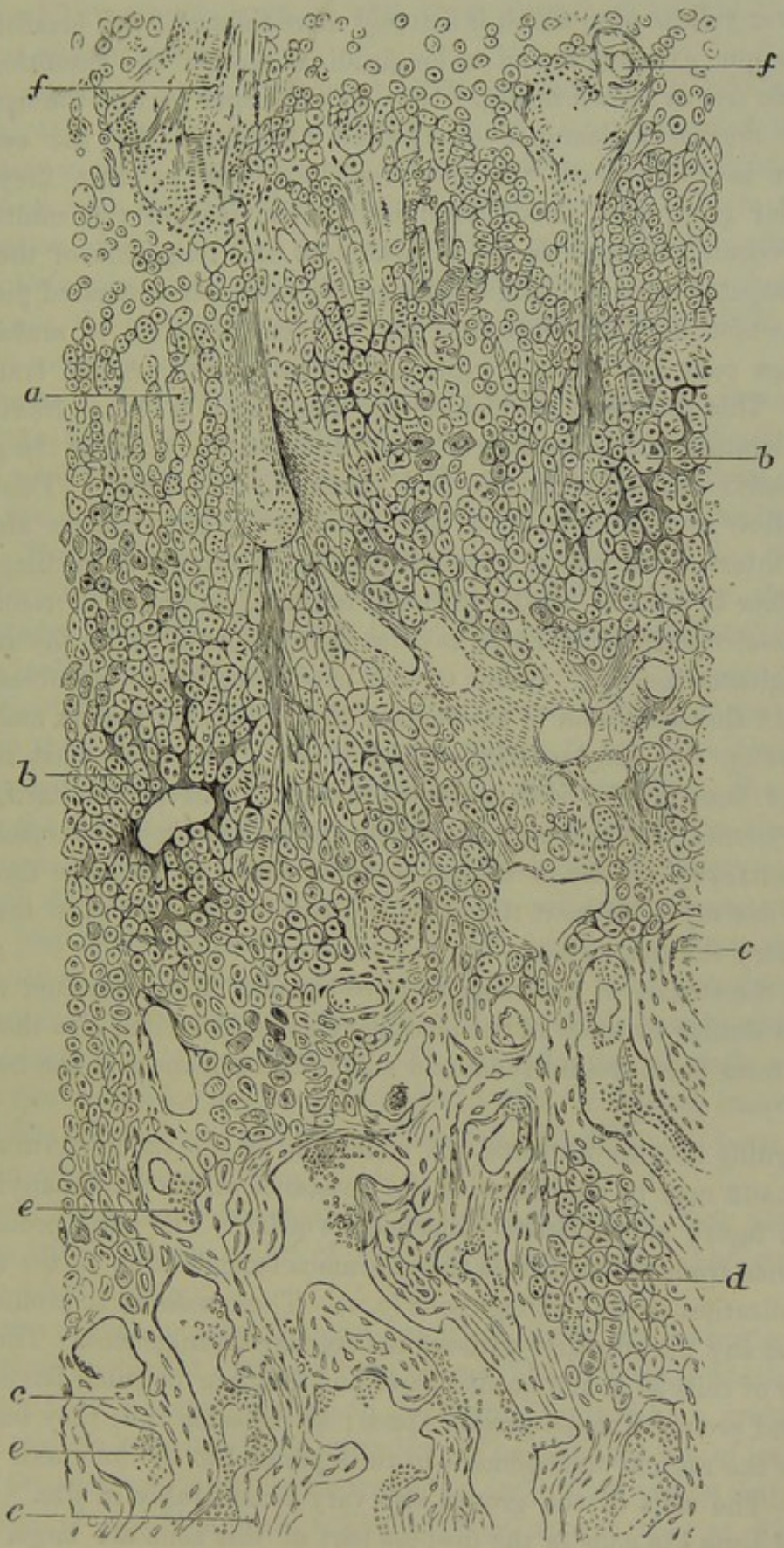
acid, being a ready solvent of lime, prevents its deposition in the bones, and it has been inferred that in the human subject the gastric derangement causes the formation of an excess of lactic acid, which is the cause of the disease in the bones. There is, however, the objection to this view, that rickets is not always accompanied by any considerable gastric disorder, and such a view does not explain its occasional occurrence in the fœtus. Besides, the disease is clearly an error in development, and were it due merely to absence of the lime salts, we should expect the bony matrix to be formed without the lime salts. The very opposite frequently occurs; we have often an impregnation of the cartilage with lime-salts, a calcification of the cartilage (see Fig. 316, *b*, *b*), while true ossification lingers. Rickets can in most cases be cured by supplying sufficient food and proper lodging, and this points to its origin in the opposite of these.



In order to comprehend the processes presented to us in rickets it is necessary to bear in mind the main points in NORMAL OSSIFICATION. If in a growing child a long bone be divided longitudinally, and the cartilage and ossifying border examined, it will be seen that the transition from cartilage to bone with medullary spaces, occurs somewhat suddenly. With the naked eye it can be seen that the deepest layer of the cartilage has a bluish colour, this zone being very narrow. It is succeeded by a still

Fig. 315.—Longitudinal section of bone ossifying from cartilage, *a*, commencement of proliferation of cartilage cells; *b*, cells arranged in longitudinal groups; *c*, matrix of cartilage impregnated with lime, this calcified matrix is continued beyond the ossifying border (*c* on right side); *d*, medullary spaces containing round cells replacing cartilage cells; *e*, *e*, formation of bone at borders of calcified matrix, the osteoblasts each forming a piece of bone and remaining as the bone corpuscle. × 90. (After THIERFELDER.)

Fig. 316.—Longitudinal section of ossifying margin of a long bone in rickets. *a*, proliferating cartilage cells, the area of these very greatly extended and the arrangement quite irregular; *b*, *b*, calcification of the cartilaginous matrix at different levels, but not followed by formation of medullary cavities. The formation of medullary cavities (*e*, *e*) and of bone is occurring quite irregularly, the level being higher at the right (*c*) than at the left (*c*). At *d* the osteoblasts are forming bone. In various places, especially at *d*, pieces of cartilage are seen in the midst of bone, and an apparent transition of the one into the other is seen. × 90. (THIERFELDER.)


f
f
a
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narrower yellow zone which is scarcely more than a line in breadth. On microscopic examination of a longitudinal section the conditions can be made out as shown in Fig. 316. At the upper part of the figure (*a*) is the normal appearance of hyaline cartilage. As the ossifying margin is approached the cells multiply, and at first they form irregular groups, as at *b*. Still nearer the margin the multiplying cells become arranged in rows parallel to the long axis of the bone, the elongated groups being separated by narrower elongated pieces of hyaline matrix. The beginning and end of this zone of multiplying cartilage cells are quite abrupt, and form nearly straight transverse lines. This zone is that which, to the naked eye, is blue. Next occurs an infiltration with lime salts of the hyaline matrix between the groups, the matrix becoming opaque and granular, *c* in figure. This forms the yellow zone as seen with the naked eye. This zone is also suddenly interrupted, and at a definite level the groups of cartilage cells give place to cavities filled with fœtal marrow, consisting of round cells and blood-vessels (*d*). These cavities are still bounded by the calcified cartilaginous matrix. Some of the marrow-cells are osteoblasts, and these fix themselves on to the surface of the calcified matrix and begin to develop the bony matrix around them. Each osteoblast forms a piece of bone around it (*e* in figure), retaining a cavity for itself, which is the lacuna. In this way the cartilaginous matrix is encroached on and destroyed by the new-formed bone, while, at the same time, it is partly destroyed without the new-formation of bone so as to make the medullary cavities larger.

On the surface of the bone we have beneath the periosteum a layer of cells similar to those in the medullary cavities. Here also the osteoblasts form bone around them and add to the thickness of the bone.

Turning now to RICKETS, the condition of the OSSIFICATION FROM CARTILAGE may be studied with the assistance of the accompanying excellent figure copied from Thierfelder's atlas. The most pronounced difference from the normal is the enormous exaggeration of the zone of multiplication of the cartilage cells (*a*, *a*). These seem to be proliferating without any purpose and without the regular arrangement. There are groups of cells as in the normal case, but they are in much larger numbers and occupy a much greater space; at the same time they have not always the normal arrangement in rows parallel to the long axis of the bone. The cells of the groups also vary considerably in size. In the normal bone the cells in the deepest part of this zone are large, but in

rickets while some are large, as at *b*, there are others even at the same level, or deeper, of small size.

Next, in regard to the zone in which the cartilaginous matrix becomes calcified, this also is represented here in the most irregular fashion. Calcification of the matrix occurs, and calcification of the cartilage cells (as at *b* on left), but this occurs quite indiscriminately. There will be calcification of the cartilage high up, as at *b*, while there are numerous groups lower than that uncalcified. In many cases also, whether calcified or not, the cartilage cells lose to a considerable extent their grouping into rows (as below *b* on left).

Then as to the formation of medullary cavities and development of bone, the figure shows how irregularly this occurs. Blood-vessels appear with considerable frequency in the midst of the cartilage, and towards the deeper parts there are medullary spaces with osteoblasts in them. These may even be seen forming new bone, as at *d*. But the medullary cavities do not occur with any greater regularity than the other stages in the process, and it is not always apparent that they have always to do with the formation of the bone. It will be seen in the figure that at a certain somewhat indefinite level, which is lower at the left side than the right, bony trabeculæ appear (*c*, *c*). But it will also be seen that the bone is directly continuous with cartilage, the difference in the two being signalized chiefly by the difference in the cells. It appears also that in the cartilage, which is thus immediately continuous with the bone, the individual cartilage cells are separated by a matrix just as the bone corpuscles are (see figure). In fact it looks very much as if a conversion of cartilage into bone were occurring, and there are even appearances suggestive of the gradual transformation of cartilage cells into bone corpuscles. The examination of such sections as that figured can hardly leave any doubt that an actual transformation of this kind occurs, this being consistent with what has been stated above in regard to metaplasia.

It will be seen in various places, but especially at *d*, that pieces of cartilage survive in the midst of the new-formed bone. The cartilage may be calcified or not.

To the naked eye the changes described above are indicated in a longitudinal section of a rickety long bone. The blue zone which forms a straight narrow transverse line in the normal bone is here greatly increased and its boundaries are irregular. The yellow zone of calcification of the cartilage is still more irregular, and yellow pieces crop up in the midst of the blue zone. Blood-vessels appear also at different

levels. In the area of the blue zone the cartilage is greatly swollen as the enormously multiplying cells take more space than normal.

Under the Periosteum we have a process which may, like that in the cartilage, be described as an enormous preparation for ossification while the process of ossification lags behind. The thin layer of osteoblasts is increased till it forms a layer of considerable thickness. By this layer bone is formed to a very limited extent and very imperfectly. Instead of a proper dense bone, such as should be formed on the surface of the shaft, there is a loose irregular spongy bone. But even the trabeculæ of this spongy bone are not properly formed. Immediately under the thick subperiosteal layer the new-formed bone does not show in its matrix the homogeneous character of the matrix of bone; it is granular, and the lime is obviously deposited without combining with the matrix in the normal manner. It is a calcification rather than an ossification, and the trabeculæ are rather osteoid than osseous. On passing inwards the tissue becomes more strictly osseous however, although hardly acquiring the regular arrangement of the dense bone of the shaft.

Corresponding with the structure described are the naked-eye characters. The subperiosteal layer is seen in the form of a red vascular layer of some thickness. This is so obvious in some cases that, at one time, it was described as if a blood-clot were formed under the periosteum. Beneath this the spongy character of the bone can be seen, while the shaft is considerably thicker than normal and obviously more easily bent.

Deformities of the Bones due to Rickets.—In considering the deformities so often produced by rickets, it is to be remembered that the two chief changes in the bones are, in the first place, enlargement and softening of the epiphyseal extremities of the bones from the affection of the cartilages, and, in the second place, thickening with loss of resistance of the shafts from the periosteal lesion. These conditions do not always go strictly parallel, one or other being frequently the more prominent in a particular bone. The various bones of the body also present very commonly different degrees of rickets although the disease is a general one, and usually affects many bones. Even in bones affected to a similar extent, however, the resulting deformities present very great variations; the deformities consist largely of curvatures of the bones from the application of external forces, and the bones are differently placed in relation to such forces.

DEFORMITIES OF THE LONG BONES.—The most obvious change at the outset is SWELLING OF THE CARTILAGINOUS ENDS of the long bones, giving a clubbed or knobbed appearance to the limbs. This is common to all the long bones, and is the condition generally taken in practice as evidence of the existence of the disease. The bones are also arrested in their growth, so that they are STUNTED while at the same time they are unduly thick.

The remaining deformities occur in the majority of cases in the lower limbs, and are the result of the weight of the body acting on the bones in their weakened condition. Similar deformities are met with in the bones of the arms in cases where external force is frequently applied to them, as where a child in creeping leans on the arms, or where a nurse frequently lifts a child by one arm (Macewen). The deformities consist mainly of curvatures of the shafts of the bones, along with SHIFTING OF THE EPIPHYSES in some cases. In regard to the latter, the extended blue zone at the cartilaginous border being soft allows the epiphysis to change its position according to the direction of pressure, and so at the ankle, the epiphysis is sometimes displaced inwards, and, as it were, overhangs the joint on its internal aspect. The same may occur at the knee-joint, and the internal condyle may exceed in length the external even after the disease has been cured.

The familiar CURVATURES of rickets are due mainly to the weight of the body acting on the softened shafts, and as the pressure acts mainly on the lower limbs the two principal forms are genu valgum and genu varum.

GENU VALGUM, or knock-knee, is a condition in which the thigh and leg form an angle at the knee opening outwards. This deformity depends usually on several alterations. There is generally a curve of the lower third of the femur, with its convexity inwards, the effect of this being that the internal condyle is lower and the external higher than normal. Along with this there is usually the lengthening of the internal condyle already referred to. As a rule the tibia is not bent, the two conditions named taking the chief part in producing the deformity, but sometimes the shaft of the tibia is at an angle with the epiphysis, as if the latter were to some extent overhanging the former. In addition the femur or tibia sometimes shows an anterior curvature, which of course does not increase the valgum condition.

GENU VARUM, or bow-legs, is the converse condition to genu valgum. The shafts of the femur and tibia are curved, with the convexity outwards, but these bones take part in the deformity in very different

degrees, the tibial curve being more frequent and usually more pronounced than that of the femur.

The long bones being soft and flexible are not so liable as normal bones to complete fractures, but they are specially liable to PARTIAL FRACTURES or INFRACTIONS. If the bone is suddenly bent it does not break across, but is partially torn as when an attempt is made to break a green stick. In this case the concave surface of the bent bone gives way and the convex surface does not. The marrow is torn by the broken concave portion, and the broken edges may be projected through the marrow to the opposite internal wall. This kind of fracture has been aptly compared by Virchow to the breaking of a quill. These infractions occur most frequently at the lower part of the tibia, also in the pelvis and ribs, and less frequently in the bones of the arm.

DEFORMITIES OF THE CHEST.—The junction of the cartilaginous and bony ribs is analogous to the ossifying cartilage of a long bone, and undergoes a similar thickening in rickets. These parts of the ribs are therefore knobbed, and there is thus a row of knobs on each side of the chest—the so-called RACHITIC ROSARY. The chest is also liable to deformity from the flexibility of the ribs. During inspiration the lateral aspects of the ribs are drawn inwards from being unable to withstand the atmospheric pressure, so that instead of the natural arch with the convexity outwards, these lateral portions are flattened or even rendered concave. As the ribs take thus a straighter course the sternum is pushed forward, and the characteristic PIGEON-BREAST is produced. It may even be sometimes seen how, in inspiration, the lateral wall of the chest is visibly carried inwards.

DEFORMITIES OF THE VERTEBRÆ.—The vertebræ very often escape in the milder forms of rickets, but in many cases they also are composed of abnormally spongy bone, and allow of the occurrence of curvature. Such curvatures are mostly exaggerations of the normal antero-posterior curves, but lateral curvature also occurs. Any considerable curvature will cause narrowing of the chest, and if this be associated with the pigeon-breast the interference with the circulation and respiration may be serious.

DEFORMITIES OF THE PELVIS.—These are of great importance in the female in relation to the possible occurrence of pregnancy in after life. The chief deformity is produced by the weight of the body acting through the vertebral column on the sacrum. This bone is pushed forward and the pelvis undergoes a corresponding displacement of its parts, the antero-posterior diameter being diminished. The growth of

the bones here also is stunted, and the pelvis therefore remains unduly small.

THE BONES OF THE HEAD frequently undergo very marked deformities. The bones of the face, like the other bones generally, are stunted in their growth so that the face is small. It is also stated that the jaws by the action of the muscles undergo changes in shape by which the lower jaw is shortened and the upper jaw lengthened, so that the teeth of the latter overlap very much those of the former. While these are the conditions in the face the bones of the cranium present striking peculiarities. The flat bones ossify from membrane, and in rickets we have the ossification lingering behind so that at their borders these bones present somewhat broad areas in which there is soft tissue like that under the periosteum. The effect of this is to cause an apparent widening of the sutures and extension of the fontanelles. The closure of the fontanelles is also delayed. The cranium is enlarged in rickets, at least its circumference is greater, and at the same time it is commonly flattened on the summit. The enlargement of the cranium with the stunted condition of the face, causes the well-known overhanging of the brows so often seen.

Another occasional consequence of rickets is the condition designated CRANIOTABES. As we shall see afterwards this is probably most frequently a consequence of syphilitic disease of the bones, but it occurs also in rickets. The bone in rickets is soft, possessing less power of resistance than normal bone. If the child be lying constantly on one spot, or if the contents of the skull be increased, as in chronic hydrocephalus, then the pressure on the bone may cause it to waste. This occurs most frequently when both these conditions are present, and the bone is as it were between two pressures. In this way may occur thinning and actual perforation of the skull, so that in the midst of the bones there will be holes, where the brain is covered by the soft parts alone. From the nature of the case it will be understood that these apertures are mostly in the occipital or the parietal bone, according as the child lies mostly with the back or side of the head downwards.

RECOVERY takes place in rickets by the removal of the insanitary conditions, or by the termination of the period of growth. The ossification advances in the cartilage and under the periosteum. The spongy bone produced under the periosteum becomes dense, and so the bone may be unduly heavy and thick, while it is stunted. The deformities having occurred in a rigid structure are rendered even more fixed by

the completion of the ossification. There is, however, in the course of time an effort on the part of nature to restore the normal architecture of the bones; where they are bent absorption occurs on the convex surfaces and increased new-formation on the concave; there may be considerable restoration of the proper shape in the long bones, but usually much less in the pelvis, head, and thorax.

OSTEOMALACIA AND MOLLITIES OSSIUM.

This disease contrasts with Rickets in respect that it affects the bones after their complete ossification. Like rickets it produces a softening of the bones, but it is a softening which supervenes after they have acquired the normal resistance of fully formed bone. It rarely occurs in children, although at least one case has been reported by Dr. Rehn, in which it was present without a trace of rickets.

It is to be stated at the outset that several distinct conditions are often included under the designation osteomalacia. We must, in the first place, eliminate cases of mere SENILE ATROPHY or others of a similar kind. It often happens in old persons that the medullary spaces increase in size at the expense of the bone, and the bone becomes in consequence less resistant. But the remaining bone is not softer than normal; it often contains even more lime salts than it should do, and is therefore abnormally brittle. Putting aside such cases, however, there are two distinct forms of mollities ossium in which the calcareous constituents of the bone are reduced. It is not possible to separate these two absolutely in their causation, but it may be said that both forms are rare in this country, and that one of them, while it is sometimes met with here, seems hardly to occur on the Continent.

The disease seems to be caused for the most part by defective nutrition, but there are two conditions which specially predispose to it, namely, pregnancy and insanity. It not infrequently comes on during pregnancy, and runs a rapid course. It has also been frequently observed in insane persons, and here the softness of the bones may lead to fractures under comparatively slight violence.

Turning now to the different forms of the disease, there is one which appears to occur most frequently in England, and the classical description of which is that given by John Hunter. It appears to consist in a fatty degeneration of the bone corpuscles with softening of the matrix. The condition, so far as the naked eye is concerned, is thus described

by Hunter: "The component parts of the bone were totally altered, the structure being very different from other bones, and wholly composed of a new substance resembling a species of fatty tumour, and giving the appearance of a spongy bone deprived of earth and soaked in soft fat." In these cases the medulla forms a bright yellow, pink or deep crimson material, and when examined microscopically presents free oil in great quantity with crystals of margarine as well as ordinary adipose tissue.

The other form of the disease is that described by writers on the Continent as OSTEOMALACIA, but it is not so infrequent in this country as has been supposed, the mollities ossium of insanity being probably always of this form. In this form, as shown in Fig. 317, there is a

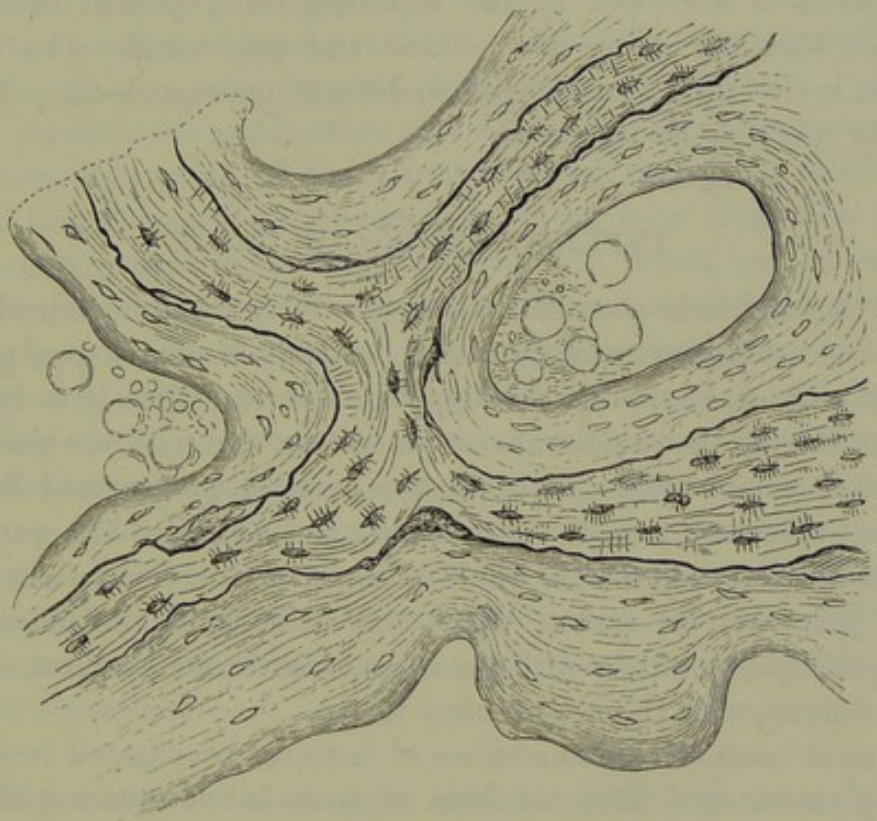

Fig. 317.—A fragment of bone from a case of osteomalacia. The central part shows the usual appearance of bone, while the marginal parts are transparent, being devoid of lime salts, although still showing bone corpuscle. × 90.

direct absorption of the lime salts from the bone. The solution of the lime salts occurs primarily in the portions of the bone next the medullary spaces and Haversian canals, so that, if the bone be examined, the central parts of the trabeculæ are seen to be opaque like normal bone, while the peripheral parts are transparent because deprived of their lime salts. The condition of these parts is like that of bone which has been

decalcified by steeping in an acid, the bone corpuscles are preserved, and the matrix has a homogeneous or fibrous appearance. As the disease advances, the decalcified matrix is encroached upon by the medulla, and the decalcification advances further. The medulla itself is altered; the adipose tissue is largely replaced by round cells sometimes with several nuclei.

The effect of these changes is, of course, to make the bones much softer and more flexible, so that they can often be cut with a knife, or crushed with the fingers. And so in the living body the bones are often bent or crushed. The disease has a particular tendency in some cases to attack the pelvis and vertebræ, but the long bones are also affected. Serious deformities result, especially in the pelvis and vertebral column. The pelvis is narrowed by the acetabula being pushed in on either side, so that the pubes are pointed and prominent. The vertebral column is curved. The sternum sometimes undergoes sharp bendings, and the ribs may be fractured.

INFLAMMATIONS OF BONE.

We have already seen that the proper bony tissue is somewhat inert, and for the most part conducts itself passively in pathological processes. On the other hand, in its development and nutrition it is intimately connected with the periosteum on its surface, and with the tissue lining its various cavities and canals, whether forming proper medullary cavities or narrower canals (Haversian) and spaces. The periosteum, endosteum, and contents of the various spaces in bone, form thus integral parts of the osseous tissue, and in studying inflammation our principal concern will be with the changes in these structures, and their inter-relations with the proper bony tissue.

In most cases the inflammations of bone are propagated from neighbouring structures. Many of them originate in connection with disease of the joints, and many from inflammation of the periosteum. If the inflammation be acute there may be suppuration, but whether acute or chronic, so far as the bone is concerned the most important result is the formation of granulation tissue which, coming into relation with the osseous substance produces various changes there. This granulation tissue replaces the proper medulla of bone, and is often in great abundance under the periosteum, as we shall see in studying periostitis and the healing of fractures, and its effects on the bony tissue is either to destroy it, or to add to it by the new-formation of fresh bone. It is

possible, in theory, to separate these two processes, and to speak of a RAREFYING or DESTRUCTIVE, and a FORMATIVE or CONDENSING OSTEITIS, but the processes so frequently go on together that it will be better to consider them in connection.

In order to understand these processes it is necessary to refer to the state of matters in the original formation and growth of bone. We find in a growing bone that (as already mentioned at p. 798) the medullary spaces are occupied by cells, and that cells of a similar character are present under the periosteum. Many of these cells are evidently busy forming the new bone. They are to be found applied to the surface of the existing bone, and gradually becoming buried in a bony matrix which is apparently formed around them, while they take up the position of bone corpuscles. The cells thus engaged in the formation of bone are properly designated OSTEOBLASTS. But in order to preserve the architecture of the growing bone, there must be at some parts destruction of the already formed tissue. It used to be supposed that this destruction occurred by the bone corpuscles enlarging and causing the surrounding tissue to melt down, but it has now been shown that a special form of cell is engaged in the destruction of the bone, and these cells are properly called OSTEOCLASTS. They are very large cells with a granular protoplasm and many nuclei, or in other words, they are GIANT CELLS or MYELOPLAQUES (see Fig. 320, p. 810). Wherever absorption of bone is going on these cells are to be found, and they appear to adhere to the surface of the bone and cause absorption of the matrix. In this way they dig themselves into the bone and form gaps, in which they are often to be found lying. These rounded gaps in the bone have long been known, and they are usually designated HOWSHIP'S LACUNÆ.

In the granulation tissue of an inflamed bone both osteoblasts and osteoclasts are frequently present. By the action of the osteoclasts in the Haversian canals and medullary spaces, the bone becomes opened out and dense bone is made spongy or spongy bone more open. At the same time the osteoblasts are often at work, and perhaps under the periosteum there are spiculæ of new-formed bone, at the marginal parts of which processes exactly similar to those beneath the periosteum of a growing bone can be seen (see Fig. 318). It happens not infrequently that after the bone has been opened out by the rarefying process, the osteoblasts subsequently set to work, and the bone is restored,

or even considerably condensed as compared with its original condition.

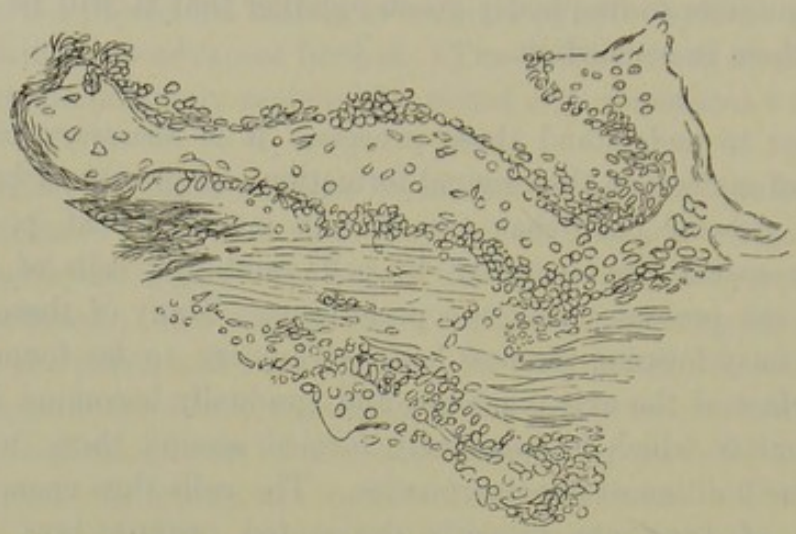

Fig. 318.—New-formation of bone in connection with inflammation. The osteoblasts are getting surrounded by bony matrix and becoming bone corpuscles. × 85.

It is to be added that besides the rarefaction of the bone by the process already described, it appears that the bone sometimes gets channelled for the accommodation of new-formed blood-vessels. We know that the bone corpuscles, with the canaliculi, convey nutritious fluid through the dense bone, and according to requirements these may expand into blood-vessels apparently by the lacunæ enlarging and running together. This, however, as compared with the other, is an insignificant factor.

Caries.—This subject may be conveniently considered here, especially in connection with rarefying osteitis. We have seen that in this latter condition the bone is encroached upon by the osteoclasts, and the lamellæ are thinned. Now, this process may go on to the complete destruction of the bony lamellæ, so as to produce, in fact, a progressive destruction of the bone. This condition is usually associated with either a very acute inflammation or one which has an infective character (tuberculosis, syphilis). As the place of the bone is taken by soft inflammatory tissue, this structure is not able to resist the mechanical wear to which bone is naturally exposed, and so there is an ulceration of the soft tissue generally associated with suppuration. As the soft tissue gives way, the invasion of the bone advances, and so, beyond the actual ulcerating and suppurating surface, the bony lamellæ are greatly thinned and ready to break down. In the majority of cases the caries

is connected with disease of the joints, as we shall see afterwards, but a periosteal inflammation, especially when connected with syphilis, may lead to it.

Before leaving the general subject of osteitis, it will be proper to make some observations on the ABSORPTION OF BONE. We have already seen in the case of rarefying osteitis and caries that absorption of bone takes place by means of the osteoclasts or giant-cells, and it appears further that whenever bone is absorbed, whether it be dead bone or living, the same agents are at work. When, in a simple fracture, a considerable piece of bone is separated from all its attachments and all its blood-vessels torn across, then it will probably die. Necrosis does not occur in every case, as the observations of Macewen on TRANSPLANTATION OF BONE show that pieces of bone removed from one person to another may survive and become incorporated in their new position. But in order to their survival, the pieces must be small, so as to allow of ready penetration of blood-vessels into their medullary spaces. When pieces of considerable size are broken off they do not survive. Similarly in compound fractures pieces of bone are frequently separated from all their vascular connections and may be seen lying in the wound, with a dead white colour and a hard feeling when touched, being evidently dead. Or again, at the end of stumps necrosis of a piece of the bone may occur from osteomyelitis or otherwise. Or, as we shall see afterwards, periostitis may lead to extensive necrosis.

Now, in all these cases, if acute suppurative inflammation be averted, and especially if septic inflammation be kept off, the dead bone may be absorbed. This is sometimes seen very plainly in cases of compound fracture where a piece of dead bone may become visibly eaten into and replaced by vascular granulations. It must occur frequently in simple fractures and at the ends of stumps. It is also not uncommon in necrosis from periostitis, but it will not occur unless the inflammation be moderate in intensity, just as new-formation occurs only in chronic inflammations.

The absorption is effected by the osteoclasts. If a piece of dead bone which has been partially absorbed be examined, its surface will be seen to have a worm-eaten appearance, and, under the microscope, this is found to be due to the existence of innumerable Howship's lacunæ (see Fig. 319). In these lacunæ, or lying beside them, giant-cells are to be seen, and sometimes a regular row of such cells is

visible as if feeding on the bone. Sometimes they are nearly buried in flask-shaped spaces (see Fig. 320).

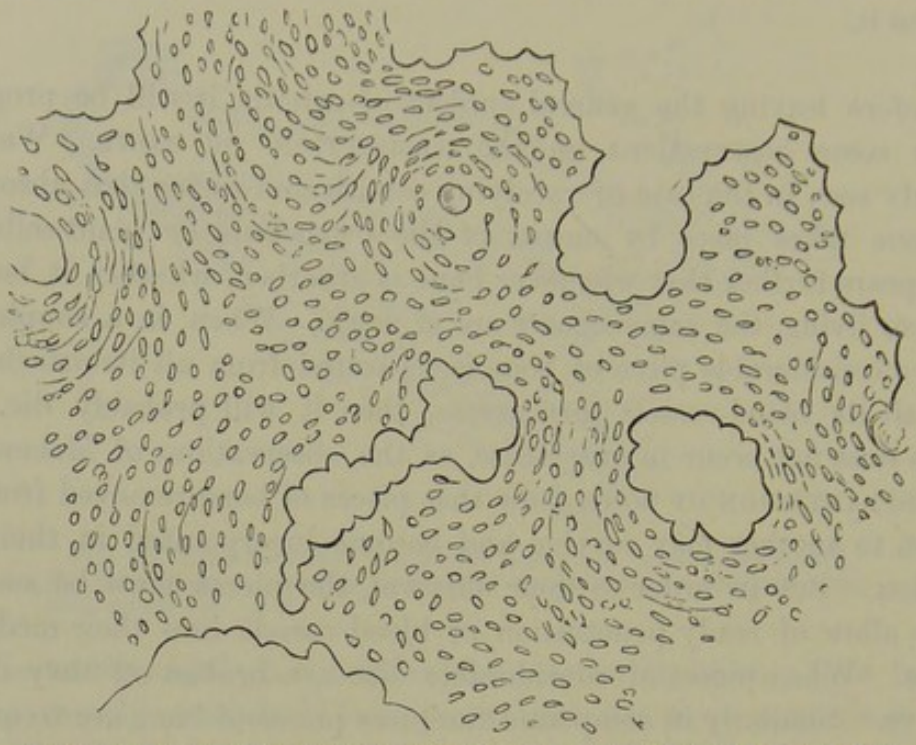

Fig. 319.—Section of a piece of necrosed bone which had been undergoing absorption. The margins of the bone at the medullary spaces and Haversian canals have an eaten-out appearance from the presence of Howship's lacunæ. ×80.

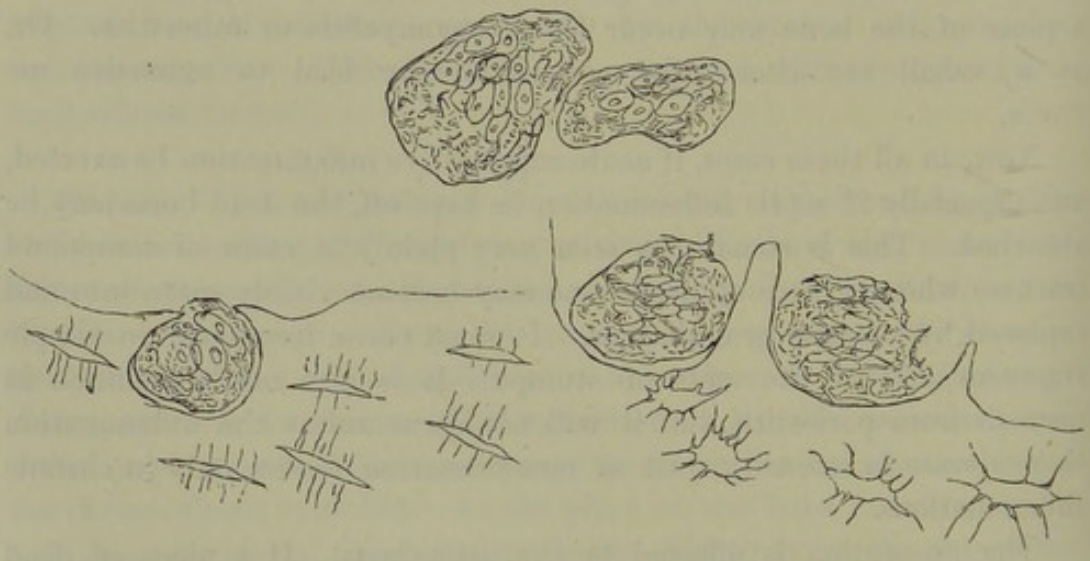

Fig. 320.—Howship's lacunæ with giant-cells (osteoclasts) in them, and free giant-cells; from same piece of necrosed bone as preceding figure. × 350.

The process of absorption occurs not only in pieces of bone which have died in the body, but in pieces of ivory or bone introduced for therapeutic purposes, as in ivory pegs for ununited fracture, bone

drainage tubes, etc. Here also the bone or ivory is eaten into, and Howship's lacunæ with osteoclasts are visible. Such pieces of dead and macerated bone may thus be completely absorbed.

By a similar process LIVING BONE IS ABSORBED. Where an aneurism advances against a bone, as the sternum or vertebræ, and erodes it, the destruction of the bone is produced, as in the other case, by osteoclasts. So is it also when a tumour advances against a bone and erodes it, although it is necessary to exclude from the category the case of certain tumours which, as we shall see afterwards, may originate in the bone itself, and cause destruction of the bone by softening occurring around the bone-corpuscles which give origin to the tissue of the tumour.

It is necessary to add to all this that although osteoclasts in the form of giant-cells appear to be the chief agents in the destruction of bone, both dead and living, and both in the physiological growth of bone and under the command of pathological processes, yet that absorption may be produced by other agents. We have seen how in osteomalacia there is destruction without giant cells, and we have also seen how by canalization there may be rarefaction of the bone without giant cells.

We may now enter more specifically on the individual FORMS OF INFLAMMATION in which the bone is involved, and it will perhaps illustrate the matter if we take up first the processes concerned in the healing of fractures.

HEALING OF SIMPLE FRACTURES.—As we have seen, this occurs mainly by the formation of callus, and we have to consider how this callus is formed. At the time of fracture the periosteum is torn and, to some extent, raised from the surface. The marrow is also torn across. Blood is effused, but it generally gets diffused, and if it exercises any influence on the further course of events it is by keeping the parts separate and interfering with the healing process. The blood, however, usually offers little obstacle, and is either absorbed or displaced by the new-formed tissue. The periosteum around the broken ends becomes vascular and swollen, and by an inflammatory process is converted into granulation tissue. A similar process occurs in the medulla, and here too the tissue is replaced by inflammatory structures. More slowly, a rarefying osteitis causes the enlargement of the

Haversian canals and medullary spaces, and these also are filled with granulation tissue.

The next process is the new-formation of mature tissue, and the amount of tissue formed and its kind are determined by circumstances. If the bones are kept very fixed then there is comparatively little inflammation, and the amount of granulation tissue produced is small. The granulation tissue under these circumstances forms new bone, in the way already described (formative osteitis). In the periosteum, in the marrow, and between the ends of the bone, the osteoblasts set to work and produce bone. This bone is at first in the form of narrow trabeculæ, and the CALLUS thus formed consists of soft tissue in which are narrow trabeculæ of bone. According to its situation the CALLUS is called EXTERNAL, INTERNAL or INTERMEDIARY. The external callus encloses the broken ends in a sheath, the internal forms a rod uniting them, the intermediary, formed in the widened canals and spaces of the bone itself, passes from one broken end to the other and so unites them in detail. If the bone has not been kept rigidly fixed the amount of granulation tissue and of callus is large, and especially the external callus, in which a large number of narrow trabeculæ of bone are formed. When the rigidity is very imperfectly preserved, then, instead of the granulation tissue forming bone, it develops into fibrous tissue and cartilage. This occurs almost uniformly in the fractures of animals, but is sometimes seen also in man, especially in fractures of the ribs where it is difficult to prevent a certain amount of movement. Fig. 313, p. 793, was taken from a case of multiple fractures in an insane person, in whom the existence of the fractures was unknown, and no attempt made to keep the bones at rest. We have already seen that cartilage, connective tissue, and bony trabeculæ are all represented.

When the bone has become fully united the parts of the callus not necessary for the preservation of the continuity of the bone are disposed of. The intermediary callus becomes, for the most part, the permanent bond of union, while the external and internal disappear except in so far as they are needed to fill up gaps where the bones have not been exactly in apposition. Sometimes the bones are considerably out of position, and a large amount of new bone remains permanently as the bond of union.

PERIOSTITIS.—The periosteum is inflamed under somewhat various circumstances. CHRONIC PERIOSTITIS is a frequent consequence of inflammation in joints and of necrosis of bone; it occasionally results even

from ulcers of the skin when situated immediately over a bone which has little more than the skin covering it, as for instance the tibia. The periosteum is the seat of granulation tissue which, as time goes on, is developed into mature tissue. In some cases, and especially in old rheumatic affections of the joints and under ulcers of the skin, the new-tissue formed is cicatricial connective tissue, so that the bone is covered with a dense hypertrophied periosteum. In the majority of cases, however, and this applies to most inflammations of the joints, the inflamed periosteum produces new bone and the osteoblasts add irregular outgrowths of bone to the surface. In this way we have localized thickenings of the bone which are sometimes designated hyperostoses, or periostoses (see Fig. 321). The new-formation of bone may even extend out a considerable distance from the bone, and we may have the joint locked by projecting bony outgrowths, which sometimes coalesce, forming a synostosis.



Fig. 321.—Hyperostosis in the bones of the leg and foot in elephantiasis. (Virchow.)

Suppurative Periostitis occurs in two forms. There is a rare form in which a rapid suppuration occurs with gangrene of the periosteum and acute inflammation around. With this malignant periostitis there are sometimes associated pyæmic lesions in the lungs and elsewhere. In this disease micrococci are found in the pus which forms beneath and around the periosteum, as well as in the blood-vessels in the metastatic inflammations. The disease is thus an infective one, although the mode of entrance of the organisms is just as obscure as in the case of ulcerative endocarditis.

Simple Acute Periostitis occurs mostly in weakly children as the result of a blow or other injury, and it takes place most frequently in the bone which is most exposed to such injuries, namely, the tibia. The inflammation affects the subperiosteal layer and the subjacent bone chiefly. At first there is swelling from inflammatory infiltration of the periosteum, and, if the inflammation does not resolve, then suppuration

ensues. The pus collects between the periosteum and the bone and raises the former over a certain area. The bone thus denuded of its periosteum dies, as the nutrient vessels passing into the bone are severed. The subsequent events connect themselves with the necrosis of the bone, and will be considered afterwards under that heading.

OSTEOMYELITIS.—This name is given to inflammation of the bone-marrow, and it occurs very rarely as a spontaneous or independent disease. There are cases of MALIGNANT OSTEOMYELITIS which are strictly comparable to malignant periostitis, and in which also micrococci have been found. A general pyæmic condition may develop also in this disease. TRAUMATIC OSTEOMYELITIS arises as a septic inflammation in connection with compound fractures and amputations. The marrow becomes swollen from inflammatory hyperæmia and infiltration, and ultimately abscesses may form. This disease is of importance for two reasons. The suppurating marrow may induce necrosis of the bone, or it may be the starting point of a pyæmia, the infective organisms getting into the open-mouthed veins of the bone and extending inwards.

NECROSIS OF BONE.

This name implies the death of a portion of bone, and we have already considered some of the ways in which it may be brought about. It may be by periostitis or osteomyelitis, or by direct violence. We have seen also how in some cases the piece of dead bone is absorbed. But in many cases absorption does not occur, chiefly where an acute inflammation exists around. Whether absorption occurs or not, the first occurrence is the SEPARATION OF THE DEAD BONE FROM THE LIVING, and this is effected by an inflammatory process. The dead bone by its mere mechanical presence sets up an inflammation around it. By means of a rarefying osteitis the Haversian canals and medullary spaces enlarge, and the bone immediately around the dead piece being replaced by granulation tissue, the necrosed portion becomes a SEQUESTRUM. The process of absorption may, as we have seen, proceed to attack the dead piece, which may completely disappear. But this presumes that the sequestrum is itself non-irritating, and that the granulation tissue is not stimulated to suppuration. In many cases these conditions are not fulfilled. The acute inflammation which caused the necrosis may continue, or a septic inflammation may extend from a wound communicating with the dead piece of bone, it may be after the

opening of an abscess in periostitis or otherwise; in either case suppuration may occur in the granulations around the sequestrum, and this is fatal to the absorption of the dead bone.

In these cases we have a considerable area of inflammation around the sequestrum, and in this area of inflammation we have both new-formation and destruction of bone. The surrounding bone is opened out by rarefying osteitis. At the same time the periosteum or endosteum produces new bone, so that the bone as a whole is thickened and the sequestrum is covered in by a mass of soft bone like callus. The commonest cause of necrosis is periostitis, and the sequestrum in that case is on the surface of the bone, and the periosteum is raised in the original suppuration. This raised periosteum produces a shell of new bone as just mentioned, and if the necrosis be considerable this shell of new bone may exercise the function of support instead of the bone. In this shell there are very commonly apertures through which the pus of the original suppuration has passed, and through which the pus of the existing suppuration finds exit. Such an aperture is called a CLOACA, and it is usually by enlarging the existing cloacæ that the sequestrum is removed.

PHOSPHORUS-NECROSIS.—This condition occurs chiefly in persons who are employed in workshops where lucifer matches are manufactured, and who are thus exposed to the vapour of phosphorus. The vapour acts locally, on the jaws chiefly, and it is said that persons with carious teeth are particularly liable to be affected. The phosphorus produces an inflammation mainly of the periosteum, resulting in a great new-formation of cancellated bone on the surface of the jaw. This bone may afterwards become condensed by the ossification encroaching on the medullary spaces. After a time the inflammation leads to suppuration, and the pus forms between the new-formed bone and the original bone of the jaw. From this results a necrosis of the jaw which may involve the entire bone, and be accompanied also by necrosis of the new-formed bone. The resulting suppurations are usually fatal in their results, but after removal of the sequestrum healing may occur.

From the observations of Wegner it appears that phosphorus acts as a general stimulant to the structures concerned in the formation of bone. The phosphorus vapour acting directly stimulates so violently as to produce the inflammation and necrosis just described, and this result has been produced also in rabbits exposed to the vapour of phosphorus. When given in small doses internally, phosphorus produces in growing animals a distinct stimulation of the process of formation of bone. In

such cases the bone produced at the ossifying border of the cartilage is not a spongy bone, but a dense layer, and there is also an unusually dense bone produced beneath the periosteum. It is noteworthy that in growing animals to whom small doses of phosphorus were given, while insufficient quantities of lime were supplied, there was a great production of osteoid tissue, somewhat like that produced in rickets.

SYPHILITIC AFFECTIONS OF BONE.

These lesions have nearly always their seat of origin in the periosteum, although the subjacent bone may be simultaneously involved. The condition may be briefly described by stating that gummata are produced, while inflammation occurs around. The existence of the gummata is sufficient indication that the lesions are of the tertiary stage.

Gummata of the usual structure are produced in the internal layers of the periosteum, and there is thickening of the periosteum around. This membrane being tightly stretched over the tumour, the swelling is hard to the feeling, but often with a certain elastic resistance. The gumma undergoes caseous metamorphosis in its central parts, but advances peripherally, and as it advances against the bone it causes erosion of it. The advance is in the first instance along the vessels, and as erosion occurs around them a worm-eaten appearance is produced in the bone. Beneath the gumma, which has most frequently its seat on the bones of the skull, especially the frontal bone, there may be thus considerable loss of substance, so that even the entire thickness of the skull may be penetrated. The caseous material often undergoes softening and suppuration ensues. If great care is not taken in evacuating the abscess at an early date, there may be very obstinate and even extending ulcers produced. Without ulceration the gumma may undergo resolution, and a cicatricial depression result, or after ulceration healing may occur.

Along with these processes immediately related to the gumma, there are in the neighbourhood conditions referable to inflammation. The bone around is condensed by new-formation filling up the medullary spaces, and there is sometimes a thickening of the bone by inflammation of the periosteum. This is much less common in the skull than in the long bones, especially those of the legs, where it sometimes leads to a very striking hypertrophy of the bone, whose surface is exceedingly rough from the loss of substance in some parts, and the irregular new-

formation in others. The bone around the syphilitic defect or ulcer is dense bone, and in this respect contrasts very markedly with that around the ulceration in caries.

HEREDITARY SYPHILIS leads to certain important changes in the bones which have been described chiefly by Wegner. These changes consist mainly in a stimulation of the ossifying structures of the bone, while the proper process of ossification is imperfectly effected. In certain respects, therefore, they show some analogy to the changes in rickets, but differ from them, as we shall see, in detail. They also differ in respect that the principal changes in syphilis are CONGENITAL ,and are to be seen in their typical form in the long bones of still-born syphilitic fœtuses. These changes may even be used to diagnose the existence of congenital syphilis.

In the cranial bones there are frequently changes, mainly affecting the periosteum, but they are by no means constant, and are to be distinguished from those in the long bones which are more distinctive of syphilis. These changes in the periosteum consist in slight inflammatory processes, leading to thickenings with softening of the bone. They are of importance as being probably the cause of CRANIOTABES, which appears to be a frequent concomitant of hereditary syphilis. This condition is brought about when a child with bones affected as above is in the habit of lying with one part of its head resting on a support; in that case the bone is apt to give way, and the brain to be covered merely by soft parts.

In the long bones the changes occur at the ossifying margin of the cartilage. We have already seen that in the normal bone the border of ossification is a narrow line, the transition zone occupying little space and forming a straight transverse line. In congenital syphilis this is altered, and for convenience of description Wegner distinguishes three stages; these may be followed in the bones divided longitudinally, so as to show cartilage, ossifying border, and bone, in section.

In the first stage the ossifying border is not linear, but forms a zone about the twelfth of an inch in breadth, and of a whitish or reddish white glancing appearance. In this zone microscopic examination shows an excessive proliferation of the cartilage cells, which, with the matrix, have become calcified as if in preparation for ossification, but this process has not been completed.

In the second stage the zone is about twice the breadth of that in the first stage, being occupied as before by calcified and pro-

liferated cartilage. The boundaries of this zone in both directions are very irregular, the calcified cartilage on the one hand sending papillary-like projections into the hyaline cartilage above, and being encroached upon by the irregularly ossifying margin below. Blood-vessels occur in the midst of the cartilage, and these are often surrounded by fibrous tissue instead of the proper fœtal marrow. In this dense tissue a direct ossification may occur, a formation of bone without the agency of the fœtal medulla.

In the third stage we have again the calcified zone, which, however, is more brittle than formerly. Above it the cartilage is swollen and blue as in rickets, and beneath it there is a zone not represented in the previous stages. It has a greyish red or yellow appearance, resembling granulation tissue or pus, and is exceedingly soft so as almost to dissolve the continuity of the bone. This zone actually consists of granulation tissue, and appears to be the result of a reactive inflammation induced by the condition of the zone above. This, the calcified zone, shows no longer well-formed cartilage cells; these have shrunken and become ill-shaped like the cells in caseous material. It appears, indeed, as if the calcified cartilage had become necrosed, and by its irritation had set up the inflammation in the medulla beneath. This condition has suggested the question, whether the separation of the epiphyses, which is sometimes met with in young children, may not be due to congenital syphilis.

It is to be noted that, so far as known, these affections of the bones have their origin during intra-uterine life, although they may continue and perhaps develop further after birth. It is even possible that future observation may show that they can originate after birth.

In regard to the bones affected, the order of frequency given by Wegner is, lower end of femur, lower ends of bones of leg and forearm and upper end of tibia, upper ends of femur and fibula much more seldom than upper end of radius and ulna; and most rarely the lower end of the humerus. It may be inferred that the disease is usually multiple, being present in several bones simultaneously; and the various stages may be seen in the same person, the disease being variously advanced in different parts.

TUBERCULAR OR SCROFULOUS DISEASE OF BONE.

This connects itself in a majority of cases with similar diseases of joints, under which heading it will again be considered. But apart from the joints we may find it in the bodies of the vertebræ, in the bones of the carpus and tarsus, etc. The disease manifests itself as a rarefying osteitis with caseous necrosis. The opened-out spongy tissue is filled with granulation tissue, and in the midst of this tissue tubercles of regular structure are to be found. The tubercles in the midst of the granulation tissue indicate the true nature of the disease, and it is therefore proper to recur to the older designation, tuberculosis of bone, rather than to use the term scrofulous disease.

In many cases the disease goes on to suppuration, but it is a chronic process, and the abscesses which result are cold abscesses; these, in the case of the vertebræ, may attain a considerable size. The destruction of the bone and substitution of soft granulation tissue causes the structure to lose greatly its power of bearing pressure. As the bodies of the vertebræ are exposed to considerable pressure, they very often become in this disease crushed together, and an acute curvature (antero-posterior) is the result. Although the disease is tubercular, it is capable of healing, and in that case the granulation tissue forms new bone, often dense, so that the structure is firmer and heavier than it was originally. If collapse of the vertebræ has occurred, then the healing will make permanent the loss of substance, and confirm the curvature.

SPINAL CURVATURES.

Introductory.—The spinal column is composed of vertebræ whose bodies are separated by elastic fibro-cartilages. The vertebræ articulate with each other at four other points, two on the upper and two on the lower surface of the arch. The vertebræ are also bound together by firm ligaments in front of and behind their bodies. The effect of these various connections is that, even when the spine is separated from all its attachments except the ligaments, it retains its form to a large extent, and its natural conformation may be studied after its removal from the body.

When seen in profile the spine presents the well-known antero-posterior curves, the convexity being forwards in the cervical and lumbar regions, and backwards in the dorsal. These curves are capable of considerable variation in the movements of the body. The whole of

the curves may be obliterated and converted into a general convexity backwards by stooping forwards, as when, with the arms extended and the legs straight, an attempt is made to touch the toes with the tips of the fingers. By arching the body backwards the dorsal curve may be partially obliterated, and a general convexity forwards produced. It appears, therefore, that the spine is capable of considerable antero-posterior movement. These antero-posterior movements imply a considerable degree of compressibility of the intervertebral cartilages. The combined cartilages occupy about a fifth of the entire length of the spinal column, and their compressibility may be inferred from the fact that during the retention of the erect posture the entire length of the column gradually diminishes, so that the stature is usually half-an-inch to three-quarters less at night than in the morning. This is believed to be due chiefly to the compression of the cartilages, which recover at night when the recumbent posture is assumed. The antero-posterior movement of the spine is freest in the cervical and lumbar regions, and most limited in the dorsal.

The spine is capable to a much more limited extent of lateral movement. The articulating processes, being situated on either side of the arches, prevent any considerable lateral deviation, as they become locked against each other when that occurs. If the surfaces of these processes were horizontal, facing one another above and below, then they might allow of freer lateral movement, but the more they assume the perpendicular position, and the more they face inwards and outwards, the greater is the impediment to lateral movement. It will be found that on passing from above downwards the articulating surfaces assume more and more of a perpendicular position. In the cervical region they are oblique, and face slightly inwards and outwards; in the dorsal they are more perpendicular and face nearly forwards and backwards, while in the lumbar region they are nearly perpendicular, and face each other nearly inwards and outwards. In this way it occurs that while lateral movement is limited in all regions it is almost impossible in the lumbar region.

For a similar reason, twisting of the spine on its axis is possible to a very limited extent.

The question of the existence of a natural lateral curvature has been matter of dispute. It is generally stated that there is a slight lateral deviation to the right in the upper dorsal region, and this is usually ascribed to the more frequent and forcible exertion made with the right arm; but the existence of this curve has been seriously questioned

(Adams). The late Dr. Foulis in 110 post-mortem examinations found lateral deviation in no less than 58 cases. He did not observe it specially in the upper dorsal region or towards the right, and concluded that it was due to the positions habitually assumed by the persons at their various trades. We may perhaps conclude that normally there is no lateral curvature, but that a very slight permanent deviation is often assumed when a frequently repeated position of the body predisposes to it.

Forms of Spinal Curvature.—The function of the spine is to support the structures attached to it, and to hold the head erect, the latter function being in man the more prominent one. Any single curvature of the spine will have the tendency to remove the head from the erect position, and tilt it backwards or forwards or to one side, and in order to preserve the erect position there is required a curvature in the opposite direction. The natural antero-posterior curves are in this sense mutually compensatory, the lumbar restores the position lost by the sacral curve, and the cervical that of the dorsal. When abnormal curvatures occur there is a tendency to a similar compensation, so that the curvatures may be divided into primary and secondary. It will not be necessary to consider in detail the secondary curvatures; their amount and direction may be inferred from those of the primary ones. It may be stated, however, that there are, frequently, several secondary or compensating curves, the spine presenting several sinuosities in order to reach the stable position for the head.

1. Antero-posterior Curvature.—There are two quite distinct forms of antero-posterior curvature, the curve in the one form being rounded, and mainly an exaggeration of the natural curvature, and in the other sharp or angular.

(*a*) Angular curvature, or Pott's disease of the spine.—This depends on disease of the bodies of the vertebræ. For the most part it is a local tuberculosis of one or more of the bodies with the caseous necrosis and caries described above. The result is usually a slow suppuration with psoas, lumbar, or other abscess. The softened bodies of the vertebræ give way under the superincumbent weight, and the spine is bent at a sharp angle, the spinous processes becoming unduly prominent behind. The affection of the bodies may be unsymmetrical, and if collapse be more at one side than the other the angular curvature will not be exactly antero-posterior. This form of curvature is more

rarely due to traumatic causes, as crushing of the bodies by heavy weights falling on the head or back, or by a fall from a height. This may lead immediately to an angular curvature, or may be the starting-point of a necrosis and suppurative inflammation. Even tubercular disease of the bodies seems often to have its starting point in an injury, such as a fall or twist of the spine, such injury leading to this result only in predisposed persons. In the majority of cases Pott's disease occurs in children, tuberculosis of bone being commonest in early life.

If healing of the disease of the bodies occurs, the carious bone becomes firm, but the loss of substance by the collapse of the bodies is not recovered, and the bone is fixed permanently in its abnormal position. The new-formed bone may be even firmer than the old, and if several bodies have been diseased there may be anchylosis of them, so that a piece of the spine is absolutely fixed.

It is worthy of special notice that angular curvature is much more obvious in the dorsal region than elsewhere, as it here increases the natural posterior curvature. In the cervical and lumbar regions, where the natural convexity is forwards, there may be a rounded posterior curvature produced, or, even with extensive disease, there may be very little posterior curvature visible externally.

The spinal cord is not generally injured by angular curvature, but in some cases it is crushed and interrupted. It may be so even during the process of healing, the sclerosis or condensation of the vertebræ sometimes causing further shrinking and increase of the curvature.

(*b*) Kyphosis or Posterior Curvature.—This is mainly an exaggeration of the normal curvature with the convexity backwards in the dorsal region, and is due chiefly to muscular weakness or a habit of stooping. It is most frequent in children and old people, leading in its most exaggerated form to hump-back, and in a lesser degree to round shoulders.

(*c*) Lordosis or Anterior Curvature.—In this condition the convexity of the curve is forwards, and the tendency of it is to throw the head backwards. It is most common in the lumbar region, and in the majority of cases is due to rickets. Rickets when it affects the pelvis causes the sacrum to assume a more horizontal position than normal, and in order to retain the erect position the lumbar anterior curve is exaggerated. It may also be produced by congenital dislocation of the hip-joint (stated by Adams to be of considerable frequency), and anchylosis of the hip. There may be also, but rarely, a direct lordosis in the lumbar region from rickets, the natural curvature being

increased by reason of the softness of the bones. In the dorsal and cervical regions lordosis is very uncommon.

2. LATERAL CURVATURE or ROTATORY CURVATURE.—In the introductory section we have seen that the mechanism of the spine allows of exceedingly limited lateral deviation. But it often happens that from habitual faulty positions at work or otherwise there is a frequently repeated tendency to lateral deviation. In that case, as a direct displacement is not possible, there may be, especially in persons constitutionally weak, a deviation with partial ROTATION of the vertebræ. The faulty position may be merely the result of a bad habit, of standing on one leg for instance, so as to cause obliquity of the pelvis; or it may be from sitting in a constrained position at study or manual labour, so that either the pelvis is oblique or the arms are used particularly in one direction so as to displace the centre of gravity to one side; or there may be a hysterical contraction of the muscles of the scapula lasting for a long period and altering the centre of gravity; or there may be an obliquity of the pelvis from one leg being shorter than the other, as sometimes in rickets. There is also softening of the bones in rickets, and very severe curvature may occur when this is associated with obliquity of the pelvis.

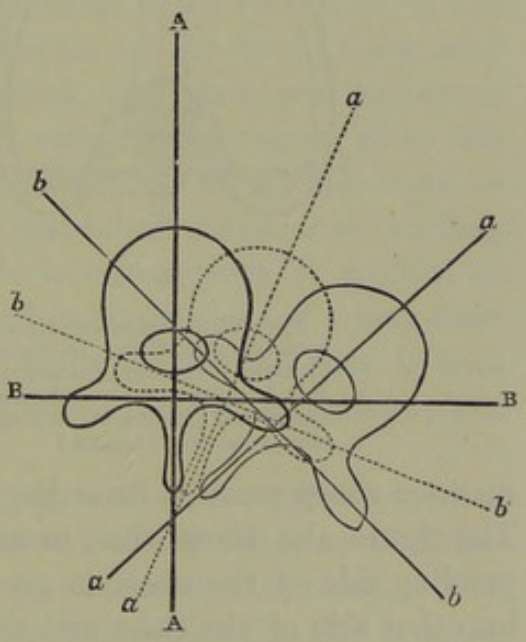

Fig. 322.—Diagram showing rotation of vertebra in lateral curvature. The various lines show the positions of the body and transverse processes in the different degrees of rotation. The axis of rotation is behind the tip of the spinous process, where the three lines meet. (ADAMS.)

The mechanism of this rotation will be understood from the accompanying diagram (Fig. 322). The dark outline indicates the natural position of the vertebra, the dark straight lines indicating the natural axis and the direction of the transverse processes. When rotation occurs the body moves round so as to present to one side in the direction of the lines *aa* and *aa*, while the spinous process deviates very little. In the figure the centre of rotation is just behind the tip of the spine, and there is a slight deviation of it; but the centre of rotation may be at the tip of the spine, and with very marked rotation of the vertebræ, there may be no deviation of the spines.

Lateral rotatory curvature is met with chiefly in the dorsal and lumbar regions, being, as a rule, much more extreme in the former, probably from the greater mobility there. There is usually curvature in both these regions, the two curves being in opposite directions, and one of them in a certain sense secondary. It is not possible, however, to distinguish rigidly between primary and secondary curves, as the two form nearly *pari passu;* a slight deviation to one side will result in a similar curve to the opposite side, and they will increase together.

We have seen above in connection with Fig. 322 that the plane of the transverse processes is altered by the rotation of the vertebræ. An examination of that figure will show that the transverse process on the side of the convexity is considerably displaced backwards, and in actual cases it may be felt projecting under the skin. If the curve be in the dorsal region the rib will be similarly displaced, and its angle especially will project. As shown in Fig. 323, the rib in that case commonly

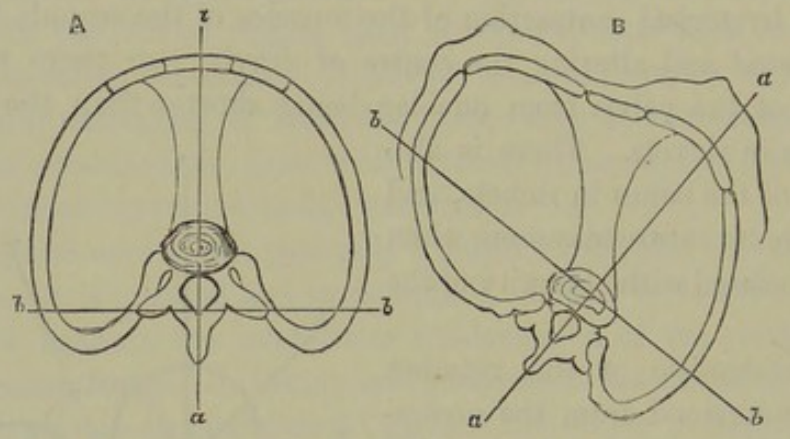

Fig. 323.—Diagrammatic section of normal chest and that with rotatory curvature. In the latter it is seen that the body of the vertebra is rotated into the right side of the chest, the rib on this side turning at an unduly sharp angle. The prominence of the transverse process on this side and of the breast on the opposite side is shown. (ADAMS.)

makes a sharp curve at its angle, so that it is greatly flattened laterally. The figure also shows that, in such a case, the capacity of the corresponding side of the chest is greatly diminished. The body is rotated into that side of the chest and the ribs are flattened towards the vertebræ, these conditions sometimes attaining to such a degree that the bodies of the vertebræ approach the internal surfaces of the ribs. There is consequently great reduction in the capacity of this side of the chest, the lung being correspondingly compressed and curtailed in its movements. It will be seen also that posteriorly there is prominence of the angles of the ribs on the side corresponding with the convexity of the curve, while anteriorly the breast on the opposite side is prominent.

TUMOURS OF BONE.

Osseous Tumours.—In view of the fact already illustrated on more than one occasion, that inflammatory processes in and around bone lead frequently to new-formation of osseous tissue, it is not remarkable that there are certain bony growths which stand, as it were, on the borderland between tumours and inflammatory growths. Some of these have been mentioned at p. 192 under the designations hyperostosis and periostosis. In these cases there is always some form of irritation inducing the new-formation, and the new-bone takes origin from the periosteum, so that it is applied to the surface of the existing bone forming outgrowths from it. The irritation may have its origin in an inflammation of the bone, of the periosteum, or of the joints, and we shall see afterwards that diseases of joints, especially chronic rheumatic inflammations, are frequently accompanied by new-growth of bone.

Various names have been applied according to the circumstances of these bony outgrowths due to irritation of the periosteum. The name osteophyte is given when there are numerous small elevations of the surface without any considerable thickening of the bone; these may have a figured appearance on the surface, and they are sometimes loosely adherent to the bone, coming off with the periosteum when it is removed. Hyperostosis is a general enlargement of a whole bone, or a considerable part of it, with roughness and tuberculation of the surface, such as occurs sometimes in a long bone in consequence of syphilis or elephantiasis (see Fig. 321, p. 813). Such a hypertrophy of a long bone has hardly the characters of a tumour, but when a small bone is thus enlarged it acquires much more of the appearance of an independent separate growth.

Exostosis is a more definite tumour of bone, an outgrowth with a limited basis, but even some of these have intimate relations to irritations of bone. This applies especially to multiple exostoses, which are of occasional occurrence. In the case from which Fig. 324 is taken (Virchow) the patient, a boy ten years of age, had suffered, during the course of three years, from repeated attacks of rheumatism affecting the joints and muscles. The result was the formation of sixty-five exostoses on various bones of the body. Exostoses also occur not infrequently at the insertion of tendons, growing into the latter and sometimes even separate from the bones. These are connected in their origin with the contraction of powerful muscles, occurring chiefly

where such muscles are inserted, and sometimes induced by specially violent exercise of the muscles.

The more simple exostoses have been already considered at p. 191.

The name Osteoid Chondroma has been given by Virchow to a form of tumour which merits a more special description. The tumour is composed essentially of tissue such as we find in the deep layer of the periosteum of a growing bone, or in callus, its main constituents being osteoblasts. The cells are smaller than cartilage cells and mostly round, but they do not possess a capsule. There is a dense intercellular substance which has a somewhat fibrous appearance. In the midst of the tissue bits of true cartilage may be found. Being formed of tissue analogous to that which is preliminary to ossification it frequently undergoes calcification and even true conversion into bone. The tumours form, mostly, under the periosteum of the long bones and their seat of election is the lower end of the femur or the upper end of the tibia, originating probably in the layer of osteoblasts there, and they may grow to large dimensions. They thus form club-shaped expansions of the long bones (Fig. 325). On section the tissue is found to be dense, and it is found to be osseous or calcareous on passing deeply, where it is incorporated with the bone. The medullary cavity of the bone is often filled with new-formed bone. This form of tumour sometimes presents a tendency to become sarcomatous, and even without that it may recur after removal.

Sarcomas in connection with bone are a very important group of tumours. As the sarcomas are of a connective-tissue structure, so they originate from connective tissue. The marrow and the periosteum being connective-tissue structures we may have sarcomas originating from them, but the bone also is a connective tissue, and there seems no reason to doubt that it also may give origin to sarcomas. We may therefore distinguish sarcomas according as they have a central (myelogenous), interstitial (osseous), or peripheral (periosteal) origin.

Of the Myelogenous Sarcomas the most characteristic is the myeloid or giant-celled sarcoma, already sufficiently considered. But we also meet with central round-celled sarcomas or even spindle-celled sarcomas. The central sarcomas originating in the medulla of the cancellated tissue or in that of the shaft of a bone, usually destroy the external shell of bone as they grow. In this way they frequently reach the surface and may even work themselves into surrounding tissue. In some

Fig. 324.

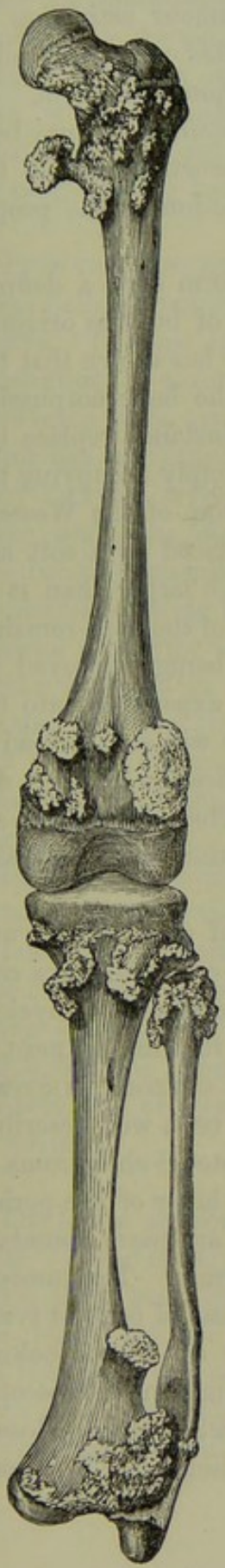

Fig. 325.

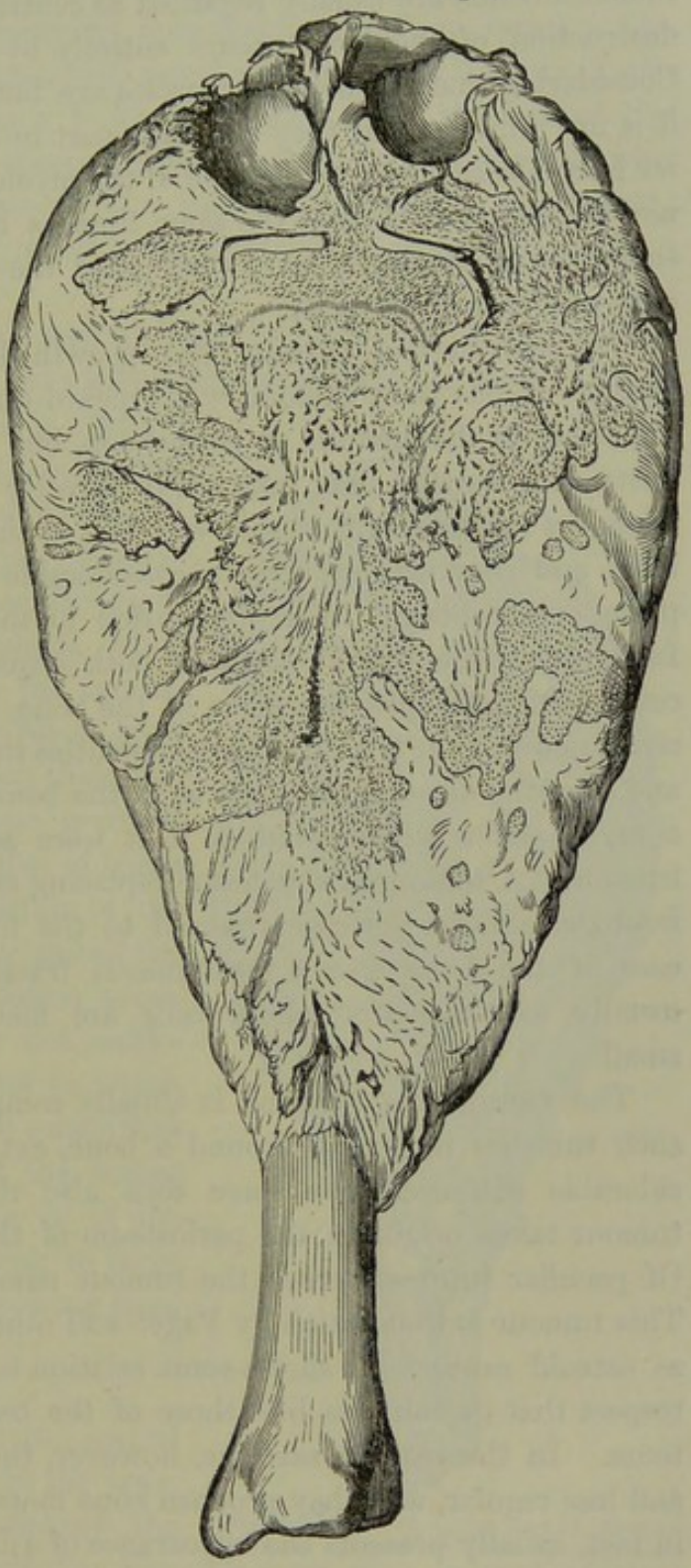

Fig. 324.—Multiple exostoses of femur, tibia, and fibula. These are grouped towards the ends of the diaphyses. At its lower end the fibula is flattened by the exostoses growing out from the tibia. From a boy 10 years of age. One third the natural size. (VIRCHOW.)

Fig. 325.—Osteoid chondroma of the tibia, divided obliquely. At the upper extremity the tumour has surrounded the cartilages of the knee, and new-formed cartilages have been produced. Internally the bone is condensed by the new-formation of bony masses. From a boy 13 years of age. (VIRCHOW.)

tumours which are usually regarded as central, it is not certain that the destruction of the bone occurs entirely by the tumour acting on it. Considering that the bone corpuscles are but modified medullary cells, it is not unlikely that they also take part in the tumour formation. As we have already seen in the case of the myeloid tumour, there may be a new-formation of bone at the same time as the destruction, and so the tumour may acquire a bony shell after the destruction of the proper external shell of the bone.

The sarcomas of INTERSTITIAL growth do not form such a definite group. It has been customary to regard sarcomas of bone as originating either in the medulla or periosteum, but Ziegler has shown that the tissue of a sarcoma may take origin directly from the bone corpuscles. Tumours taking origin in this way will in the first instance replace the bone, and they may grow to a considerable size, simply occupying the place of the bone. In a preparation in the museum of the Western Infirmary the entire humerus of both arms is replaced by a soft sarcoma, which occupies the place of the bone, although larger than it in circumference. It is only at the extremities that any of the bone remains, and here the appearance is not as if the bone were being destroyed by a myelogenous tumour, but as if it were actually expanding into the tumour. A tumour of soft tissue replacing the bone will readily lead to fracture, and in the case referred to the first indication of any disease of the bone was a spontaneous fracture. These sarcomas are usually soft tumours whose cells are mostly round and generally small.

The PERIOSTEAL sarcoma is usually composed of spindle cells, and such tumours may grow around a bone, extending outwards for a considerable distance. We have seen also that sometimes a myeloid tumour takes origin in the periosteum of the jaw, forming an EPULIS. Of peculiar interest here is the tumour named the OSTEOID SARCOMA. This tumour is that which by Paget and others has been well described as osteoid cancer. It shows some relation to the osteoid chondroma in respect that its cells are like those of the ossifying layer of the periosteum. In the osteoid sarcoma, however, the cells are more abundant and less regular, and they produce bone more uniformly. The tumour, in fact, usually presents the appearance of a dense mass of bone of ivory hardness, on the surface of which there is a layer of fibrous-looking tissue. This layer is often comparatively thin, and on microscopic examination it presents spindle cells or round cells which are so closely adherent to each other that they are with difficulty isolated. The bone

is formed by the direct transformation of these cells, and one has sometimes the opportunity of observing remarkable transition forms. The tumour, like the osteoid chondroma, mostly originates at the end of one of the long bones, and forms a bulbous swelling there, the end of the bone, with its medullary spaces, being completely transformed into a hard, heavy, osseous tissue. The tumour enlarges by incorporating neighbouring parts, and it not infrequently extends by metastasis.

PRIMARY CANCER is very rare in bone, but tumours of a glandular or epithelial structure have been met with, destroying the bone in their growth. In some cases this is really a penetration of a cancer into bone, but there seem to be actual cases in which a cancer has originated in bone. SECONDARY CANCER is much more frequent. There are some cancers which, when they become generalized by the cancerous material getting into the blood, have a special proclivity to develop their metastatic tumours in the bone marrow. We may thus in a great number of bones have a cancerous transformation of the medulla, and as the tumour grows the bone is destroyed. A condition sometimes develops in this way not unlike OSTEOMALACIA in the manner in which the bone becomes softened. We may thus have cancerous softening of the bodies of the vertebræ, of the ribs or of the long bones, the tumours being in large numbers, and everywhere growing from the medulla.

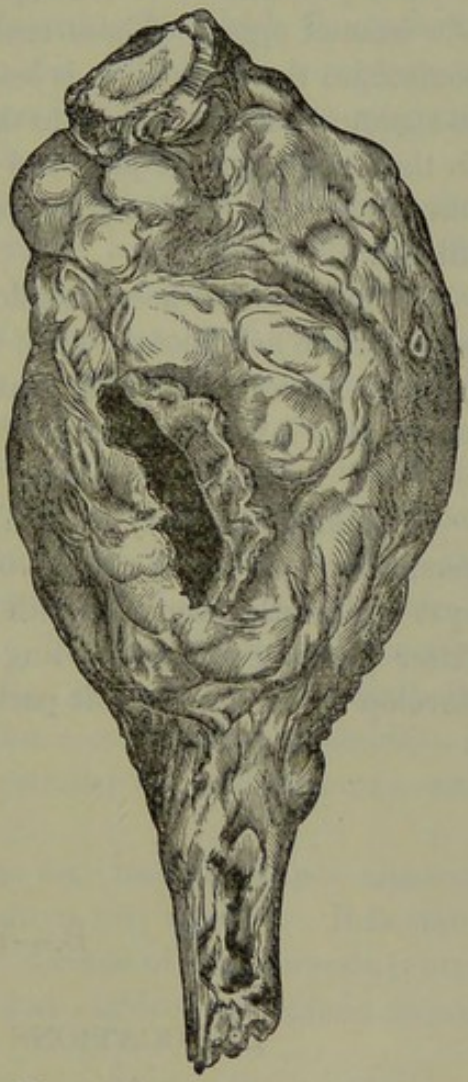

Fig 326.—Cyst of upper end of fibula. The upper part of the bone is expanded into a cyst which contained a reddish serous fluid.

The bones are sometimes the seat of CYSTS. These mostly occur in the jaws, where they may greatly distend the bone, but in the case represented in Fig. 326, the fibula was at its end distended into a bulky cyst which contained merely a serous fluid.

The CYSTS OF THE JAWS, originating as they do for the most part

near the alveolar processes, are probably related to the teeth. Some of them are single, UNILOCULAR CYSTS, and have their origin in teeth which have not undergone the usual eruption. A tooth or pieces of hard substance (dentine) are usually present in the wall of the cyst. Others are MULTILOCULAR and develop out of a gland-like tissue, the cells of which undergo colloid degeneration, and in this way form cysts. In its original structure the tumour might be called an adenoma, and a considerable portion of it is sometimes composed of solid glandular or epithelial tissue. According to Eve the tumour arises by penetration downwards of the epithelium of the gums, and he relates this to the normal penetration of this epithelium in the fœtus in order to form the enamel organ. These multilocular cysts are mostly innocent, but sometimes the epithelium is less regularly arranged, and they approach in structure and tendencies to the cancers. Both forms of cysts originate in the interior of the jaws and distend them; those in the upper jaw have a special tendency to pass into the antrum which they may fill out.

FIBROMAS have been occasionally observed growing from the periosteum in the neighbourhood of the mouth and nose, and they sometimes project inwards into the nares or mouth as fibrous polypi. The MYXOMA is a very rare form of tumour.

PARASITES are very rare in bone. The CYSTICERCUS cellulosæ has been observed, but the ECHINOCOCCUS more frequently. The hydatid cyst has mostly been met with in the bones of the pelvis or in the tibia. After growing and distending the bone it may burst through it and develop further in the soft parts around.

B.—THE JOINTS.

DISLOCATIONS AND MISPLACEMENTS.

CONGENITAL DISLOCATIONS.—Children are sometimes born with the joints in faulty positions, some of these being really traumatic and others of more obscure origin. The traumatic cases arise for the most part during parturition, either from the natural forces engaged in delivery, or by dragging on the part of attendants. The HIP-JOINT is

not infrequently dislocated in this way, and usually the displacement is on both sides at once. The head of the bone is usually displaced upwards so as to rest on the dorsum of the ileum above and behind the acetabulum. Through time the head makes for itself a new joint, and the acetabulum fills up. Congenital dislocations of other joints are exceedingly rare.

TALIPES or CLUB-FOOT.—These names are applied to distortions of the feet, or more rarely of the hands; the bones assume certain abnormal positions in which they are retained by the contraction of muscles. A certain proportion are CONGENITAL, and these seem to arise in utero by a faulty distribution of the impulses by which the muscles are made to contract. One or more muscles are kept in a continuous state of more or less rigid contraction, while the others are not, and the consequence is that the foot is held in a distorted position.

The NON-CONGENITAL forms are, in the great majority of cases, due to infantile paralysis. In this disease, as we have seen, some muscles are paralysed, while others are not. It has been generally stated that the deformities are due to contraction of the unparalysed muscles which are not opposed in the normal manner by the paralysed ones. This appears to be the explanation in some cases, but it does not account for the occurrence of talipes in cases where nearly all the muscles of the foot are paralysed. Such cases indicate that the faulty position may arise to some extent because the muscles are not able to keep the foot in its proper position, so that it tends to fall into the attitude it would assume if there were no muscles. These positions are also variously modified by the use made of the foot in walking, the parts being brought against the ground in the position most suitable to stability in the maimed condition of the limb. In a similar way club-foot may occur in pseudo-hypertrophic paralysis.

Besides paralysis, it seems that spasm may lead to talipes, although the explanation of the local spasm is often very obscure. It is stated that mimicry sometimes leads to it, or disease of the nervous centres or reflex irritation. It is undoubted that children sometimes acquire a talipes after a convulsive attack.

The FORMS OF TALIPES do not call for detailed description here. There are four principal forms, some of which may be combined. In TALIPES VARUS the toes are inverted, and the inner margin of the foot is raised upwards; the tibiales anticus and posticus are the muscles which are chiefly contracted. In TALIPES VALGUS, which is one of the

rarer forms, the foot is turned outwards, and the outer border is raised, there is usually also some elevation of the heel; the peronei, extensor longus digitorum and gastrocnemius are the muscles chiefly engaged. In TALIPES EQUINUS the heel is raised and the foot extended, so that the person walks on the distal extremities of the metatarsal bones; the gastrocnemius is the muscle contracted. In TALIPES CALCANEUS the heel is depressed and the foot flexed at the ankle, this deformity being the reverse of the preceding one; the contracted muscles are chiefly the tibialis posticus, the peronei and the extensors.

By long retention of the fixed position the bones become variously modified in shape, undergoing atrophy where exposed to prolonged pressure. Where the cartilage is no longer used in the movements of the joints it also atrophies. The bones frequently acquire adhesions in their new positions, and the ligaments, by elongating or shortening, accommodate themselves to the new position. New ligamentous attachments are sometimes formed, and the bones may become joined together by anchylosis.

TRAUMATIC DISLOCATIONS.—We have here to do with cases in which the bone is pushed out of its place by some external force acting on it. The bones are kept in their places mainly by the ligaments of the joints, but no inconsiderable aid in this regard is given by the muscles which act on the bones. As a general rule when external pressure is exercised on a bone at a joint, the muscles are so braced as to enable the bone to retain its place in spite of the external force. But if unexpectedly, or when the muscles are generally relaxed as by alcoholic stupor, a force is exercised on a bone, then it may be displaced, although the force under ordinary circumstances would be insufficient to produce this effect. The bone may even be displaced by the action of the muscles themselves, where a certain group acts very vigorously while their antagonists are relaxed. There are indeed persons who can voluntarily produce dislocation of almost all the more movable joints, and that by mere muscular efforts. In order to this we must suppose a certain laxness of the ligaments, but there is also a power acquired by education of strongly contracting certain muscles, while others which usually contract along with them are relaxed. We know that for the most part the muscles in their contractions are co-ordinated, and most people are unable to contract individual muscles apart from their co-ordinates, but there are exceptional persons who possess this power, some in a limited degree and others very remarkably. Many persons, for instance, cannot shut

one eye without the other, and most persons when they shut one require to make an active effort at opening the other, in order to prevent it shutting too. But there are persons who can close the eyelids of one eye as easily as they can close the fingers of one hand.

In traumatic dislocation there is usually tearing of the ligaments to some extent, and in the case of some joints much laceration is necessary before dislocation can occur.

When the bone is dislocated, the same contraction of the muscles which normally aids in preventing dislocation, generally offers serious obstacles to the return of the bone to its normal place. If restoration does not occur soon then the bone acquires adhesions in its abnormal situation, the adhesions being the result of chronic inflammation set up by the irritation of the bone. The displaced bone generally comes to press with its head against a neighbouring part of the bone with which it formerly articulated, and the adhesions attach it to the periosteum in its new position. Friction by degrees wears down to some extent the opposed piece of bone, and as new bone is produced around by the irritation there may be a kind of hollow joint formed. By the wearing of the bone the cancellated tissue would be exposed, were it not that dense bone is produced on the surface so as to cover in the spongy tissue. A smooth hollow surface may thus be produced, and a tolerably perfect joint, although cartilage is not formed to cover it, but only a layer of smooth polished bone. The head of the displaced bone also loses its cartilage, and may even get worn away considerably. If the bone remains permanently displaced the old hollow of the joint becomes filled up, bone growing when the friction of the opposing bone is no longer exercised.

SPONTANEOUS DISLOCATIONS are mostly due to inflammatory changes in the joints or their ligaments, or to the contraction of cicatrices in the neighbourhood. It will be understood also from what has gone before, that the sudden contraction of one set of muscles while the rest are relaxed may cause dislocation. If spontaneous dislocations are unreduced there may be changes in the joints similar to those in traumatic cases, but there are frequently primary inflammatory changes, which are more prominent than those secondary changes.

ANCHYLOSIS.

By this name is meant fixation of a joint by union of the opposing bones by means of firm adhesions. The expression "false anchylosis" is sometimes used to designate the condition in which the joint is fixed, not by adhesion between the bones, but by rigidity and shortening of the surrounding soft parts.

For the most part anchylosis is the result of inflammations of joints, where the cartilage has been destroyed and healing has subsequently occurred. In the process of healing the inflammatory tissue on the opposing surfaces develops into connective tissue, and as the two surfaces have to a considerable extent coalesced, fibrous tissue unites them permanently. In this fibrous bond of union there are often bony plates, and occasionally the union is effected by bone itself. This, however, is a very unusual occurrence, as even slight movement of the joint is sufficient to prevent the formation of bone. The fixation of the joint, however, is often so firm as to resemble an actual coalescence of the bones.

An interesting discovery was made by Meier of Zurich, in regard to the ARCHITECTURE of the cancellated tissue of bones. The bony trabeculæ of the spongy tissue do not form an irregular net-work, as they seem at first sight to do, but they are arranged according to a definite architectural plan. They form, in fact, pillars, which are directed towards the surfaces on which pressure is exercised in the various movements of the joints. Each bone has its own architectural structure, and the structure corresponds exactly with what mathematicians make out as to the direction of pressure in the various bones. When anchylosis occurs, or after the healing of fractures, the lines of pressure may be changed. If these occur in growing bones, the architecture readily undergoes a corresponding change. But even in adults, by thickening of the lamellæ in some parts and absorption at others, there is a gradual adaptation of the structure to the changed circumstances.

INFLAMMATION OF JOINTS—ARTHRITIS.

This is a somewhat extensive subject, and includes the great bulk of the diseases to which the joints are liable, especially if we include scrofulous or tubercular disease of the joints.

In most cases of arthritis the inflammation affects, more or less, all the structures which enter into the construction of the joint. The

irritant is usually present in the joint itself, and is distributed over it with the synovial fluid by the movements of the joint. We may expect, therefore, that the synovial membrane and the cartilage, as they cover the surface, will in most cases be primarily affected. The cartilage, being non-vascular, is less liable to inflammatory changes than the synovial membrane, which in most cases is primarily and chiefly engaged, especially in acute inflammations. But in chronic cases the irritation extends beyond these structures to the ends of the bones, to the neighbouring periosteum, and even to the ligaments.

Simple Acute Arthritis.—This condition is produced most directly by the opening of joints and the occurrence of septic decomposition in their fluids. But it also occurs sometimes by exposure to cold, from injuries, and from the extension of phlegmonous inflammations from surrounding parts.

The inflammation resembles closely that of the pleura and pericardium in its anatomical details. The synovial membrane and cartilages are covered with fibrinous exudation, and the cavity contains serous fluid in which flakes of fibrine are visible. This fluid is sometimes very considerable and distends the joint. In this stage the disease may resolve and the joint return to its normal condition. On the other hand, especially if the joint has been laid open and exposed to decomposition, the inflammation goes on to suppuration. The synovial membrane becomes swollen and dull, being infiltrated with inflammatory cells, and gradually converted into granulation tissue. If the inflammation is very acute, we may have suppuration by the mere exudation of leucocytes without much change in the synovial membrane. When the disease has gone on to the formation of granulation tissue it is now in a subacute condition and is apt to be prolonged. The inflammation also extends beyond the synovial membrane. In the cartilage the cells undergo active proliferation, and the matrix breaks down; thus softening occurs, and ulcers form. There is inflammation of the bone, a rarefying osteitis with caries. The ligaments also take part in the inflammation, they are softened and, with the synovial membrane, take part in the formation of granulation tissue. The periosteum is inflamed and new bone is formed, so that irregular projections occur near the ends of the bones. With all this there is, of course, usually an abundant purulent discharge from the joint, which may weaken the patient and prove fatal, perhaps with amyloid disease.

If the inflammation subsides the various masses of granulation tissue develop into connective tissue, and, by the contraction of this, great

rigidity of the joint may be produced. The granulation tissue lining the joint does also to a great extent coalesce, and the result is a partial or complete obliteration of the joint. The bones thus become finally united by fibrous or osseous adhesions, and a permanent anchylosis is the result.

Pyæmic arthritis has already been partly considered. In this disease a virus is deposited in the joint and spread over the surface by the synovial fluid. The result is an acute inflammation with fibrinous exudation, but generally going rapidly on to suppuration. It is remarkable that when the joint is full of pus there is sometimes very little structural change in the synovial membrane, the whole condition being almost confined to the blood-vessels from which an excessive exudation has occurred. The inflammation usually affects several joints simultaneously. It is to be added that occasionally in typhus, dysentery, diphtheria, scarlet fever, etc., a similar acute arthritis occurs.

Acute rheumatic arthritis is, like pyæmic arthritis, due to an irritant which is present primarily in the blood and affects the structures of the joints like other connective-tissue structures. The result is an acute inflammation accompanied by serous and fibrinous exudation into the joint. The synovial membrane is injected and swollen, and if the inflammation is of sufficient intensity and duration the cartilage, and even the bone, take part in it. The cartilage cells undergo proliferation, and may burst into the cavity of the joint. The bones show inflammatory proliferation in the medulla in the usual fashion. As a rule these changes do not reach an extreme degree, and suppuration is hardly known to occur.

Gouty Arthritis.—In this disease uric acid, in the form of urate of sodium, is deposited in the tissues of the joints. It is first deposited in the cartilage, and, according to Charcot, always, to begin with, at the middle of the articulating surface, that being the point furthest removed from the blood-vessels. The urate is sometimes in the form of stellate crystals (Fig. 327), the cartilage cells forming the middle points of the bunches of crystals. But the salt is also deposited in the matrix and often in the form of irregular needles. It is also frequently deposited in the synovial membrane, and in the bones, ligaments, and soft parts around the joints. Sometimes the salts are deposited even under the skin, forming visible projections (the so-called tophi or chalk-stones).

This deposition seems to lead to an acute irritation of the structures of the joint, chiefly an intense hyperæmia, often with serous exudation. It never goes on to suppuration, however. When recovery takes place it frequently leaves a chronic inflammation, resulting in changes analogous to those in chronic articular rheumatism.

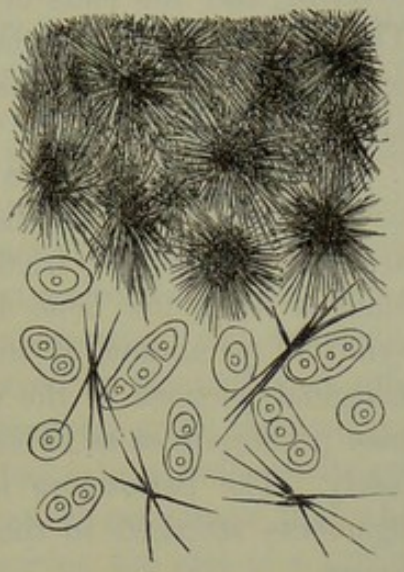

Fig. 327.—Cartilage of joint in gout, with crystals of urate of soda. The salt is in stellate crystals which are nearly continuous at upper part of figure, which corresponds to surface of joint. × 200. (CORNIL and RANVIER.)

CHRONIC RHEUMATIC ARTHRITIS. — As a rule this disease affects many joints, but as the changes are virtually the same as in ARTHRITIS DEFORMANS, and the two conditions run into one another, we may describe them together. In arthritis deformans the disease is partial, being confined perhaps to a single joint, and the lesions attain a much greater development than in general articular rheumatism. It is also much more a disease of old people, and is met with chiefly among the poor. In both these diseases the nature of the irritant is entirely obscure.

The inflammatory phenomena appear first in the synovial membrane and the cartilages. The synovial fringes enlarge by a slow process of inflammation, and the villous projections increase in number and become more prominent. Not uncommonly pieces of cartilage develop in the fringes, originating in the cartilage cells which exist normally there, and these pieces of cartilage being usually pedunculated act very much like free bodies in the joint and may become loose. The cartilage also sometimes undergoes ossification in whole or in part. At the same time there is an increase of the synovial fluid, but without any formation of fibrine or pus.

The cartilage cells undergo proliferation and the matrix presents a peculiar fibrillation, so that the cartilage assumes a soft velvety condition, and readily undergoes destruction from the friction of the opposing surfaces. It is stated by Rindfleisch that the fibrillæ of the matrix undergo mucous degeneration, and that mucus may be found in the synovial fluid.

The bone beneath the cartilage also undergoes considerable alteration, especially when the cartilage gets worn away. To prevent the cancellated tissue from being opened, there is formed, as the cartilage is

destroyed, a layer of dense bone, which is smooth and polished, and takes the place of the cartilage. This forms a much less efficient covering, and the ends of the bones work roughly against each other. This layer of bone may also be worn down, and so considerable atrophy of the head of the bone may result, a layer of dense smooth bone being always reproduced.

At the borders of the articular surface there is often considerable new-formation of bone, the result of the inflammation where the parts are not exposed to friction. It appears from the observations of Ranvier that the bone here develops largely from cartilage. The synovial membrane, at the edge of the joint, covers in some of the marginal portions of the cartilage, and being thus protected, the cells may proliferate so as to lead to new-formation of cartilage, which may ossify. The periosteum may also produce new bone, and even the ligaments attached to the periosteum may be the seat of bony processes.

With all this there is considerable thickening of the ligaments by inflammatory new-formation of connective tissue, and often fibrous union between opposing parts of the joints. Indeed, if the joints are kept at rest, there may be a complete union of the parts around the joints opposite each other, leading to anchylosis.

Without anchylosis there is stiffness of the joints, whose movements are greatly curtailed. There is frequently great deformity from the thickening of the tissues and new-formation of bone.

An extreme degree of arthritis deformans is sometimes seen in the hip joint, when it gets the special name of MORBUS COXÆ SENILIS. Here the wearing down of the head of the bone is sometimes very extreme, so that ultimately the articulating surface may lie between the trochanters. As new-formation of bone occurs simultaneously at the borders of the articular surface, a kind of artificial head is produced, and the appearance is presented as if the neck were atrophied and the head displaced. In like manner an apparent widening of the acetabulum may occur. The original articular surface is worn away, but by the formation of new bone by the periosteum around, a wall is formed, giving the appearance of the borders of a widened acetabulum.

SYPHILIS does not frequently attack the joints, but rheumatic attacks in syphilitic persons may have some relation to the specific virus. According to Lancereaux, there may be in the secondary stage an inflammation like that of acute or subacute rheumatic arthritis,

and, in the tertiary stage manifestations like those of chronic arthritis.

Scrofulous or Tubercular Arthritis.—Besides these names, this disease is often called strumous synovitis, gelatinous degeneration of the joint, tumor albus, fungous caries, etc. The disease occurs mostly in delicate children, but as it is associated with the formation of definite tubercles we must regard it as taking origin in the specific tubercular virus. It is sometimes said that the tubercular formation is secondary, and that there is first a chronic inflammation of a scrofulous kind going on to caseous degeneration, and so leading to the formation of tubercles. A case observed by the author is quite opposed to such a view. There was in this case a great thickening of the synovial membrane, which was converted into a bulky, soft, grey tissue, which overlapped the cartilage, and was so prominent that when the joint was opened for the purpose of excision the idea of a tumour was suggested. There was not a trace here of caseous material or of pus, and yet the thickened synovial membrane consisted essentially of an immense aggregate of tubercles with inflammatory tissue around them. The tubercles were of typical form, with large giant cells.

The disease begins usually in the synovial membrane, and consists in a formation of tubercles and a chronic inflammation with great production of granulation tissue. The soft, pulpy granulation tissue gives the synovial membrane a gelatinous appearance, from which one of the names of the disease is taken. There is also a slow enlargement of the joint from the increased bulk of the synovial membrane.

The ends of the bones constituting the joint are affected simultaneously or soon after, and here the characters presented are those of a rarefying osteitis. The medullary spaces become filled with granulation tissue and enlarged by destruction of the bony lamellæ. In this granulation tissue there are also tubercles. In this way there is, as it were, a pad of granulations under the articular cartilage.

The cartilage also at the sides is partly encroached on and overlapped by the altered synovial membrane which advances over it. In this way it is partly enclosed between two layers of granulation tissue, and it gradually becomes eaten into. The granulations, chiefly those of the medulla, extend into the cartilage, and their encroachment is assisted by proliferation of the cartilage corpuscles, which enlarge and cause softening of the matrix around.

By the absorption of the cartilage the whole joint may be converted

into a cavity lined with granulation tissue, and the ligaments also are frequently transformed in a similar way.

Generally suppuration results, and the joint becomes filled with pus. Abscesses also not uncommonly form around the joints. Through time the pus generally finds its way outwards, and is discharged by an aperture in the skin. A fistulous canal is the result, forming a communication between the cavity of the joint and the surface, and this canal is also lined with exuberant granulations, which pout out at the opening in the skin. Among the granulations here, as elsewhere, tubercles are found.

The rubbing of the two ends of the bones, which are now covered by granulations, leads to an ulcerative destruction of these soft structures. The inflammation extends more deeply in the bone as the superficial parts are ulcerated, and so we have progressive caries. For some distance beneath the surface the medullary spaces are filled with granulations and the bony trabeculæ thinned. It will be understood from this how the disease is apt to recur unless the whole carious portion be removed, for tubercles are present in the granulation tissue filling the medullary spaces, and unless they be removed a fresh extension may occur.

In an early period of the disease, before suppuration has occurred, there may be recovery; but after the occurrence of suppuration, there is seldom a spontaneous restoration, which at best is a slow process. If recovery takes place the granulating surfaces unite more or less, and the joint being partly or completely obliterated, a fibrous union may come about, leading, it may be, to anchylosis.

DISEASES OF THE SKIN AND ITS APPENDAGES.

INTRODUCTION.

THE diseases of the skin are exceedingly manifold, and the names applied to them somewhat complicated. In the present section no attempt will be made to give a complete description of the appearances presented in each affection. So far as the naked-eye appearances are concerned, these are sufficiently described in the text-books on the practice of medicine or on diseases of the skin. We shall endeavour here to summarize the pathological conditions and group together the various diseases according to the nature of the lesion. It will be necessary first to refer to the normal structure of the skin.

NORMAL STRUCTURE.—The CORIUM or TRUE SKIN is a very vascular dense membrane composed of interlacing fibres of connective tissue, with numerous elastic fibres. It is richly supplied with nerves, and possesses bundles of smooth muscle. It has also a rich system of lymphatic vessels. In the corium we may distinguish a superficial or papillary layer and a deeper one. Many of the diseases affect the papillary layer especially.

The EPIDERMIS on the surface of the corium is in several layers (Fig. 328). Most superficial is the horny layer (*a*) composed of flat cells, which are little more than scales, and have lost their nuclei. Next comes the stratum lucidum (*b*) composed of flat transparent cells. This is followed by the stratum granulosum, also composed of flat cells which are granular. Most deeply situated is the stratum mucosum or rete Malpighii, composed of cells which, in the deepest layer, are cylindrical, but towards the surface become polygonal and flattened. In the deeper layers the cells are serrated at the margins, so as to give the appearance of prickles by which the cells fit into each other. The stratum lucidum and stra-

tum granulosum are thin, and for practical purposes the epidermis may be divided into the horny and Malpighian layers. The Malpighian layer extends between the papillæ of the corium, forming interpapillary processes.

The SEBACEOUS GLANDS may be regarded as modified prolongations of the Malpighian layer. They are mostly connected with hair follicles into which they open, but sometimes large glands are connected with small hairs and small glands with large hairs, while there are glands not connected with hairs at all. The SUDORIPAROUS GLANDS are usually situated beneath the skin, their ducts passing through corium and epidermis, having a spiral course in the latter. The HAIRS are composed of horny epidermis, and are placed in follicles. In the latter two layers of epidermis can be distinguished (Fig. 328), the outer root

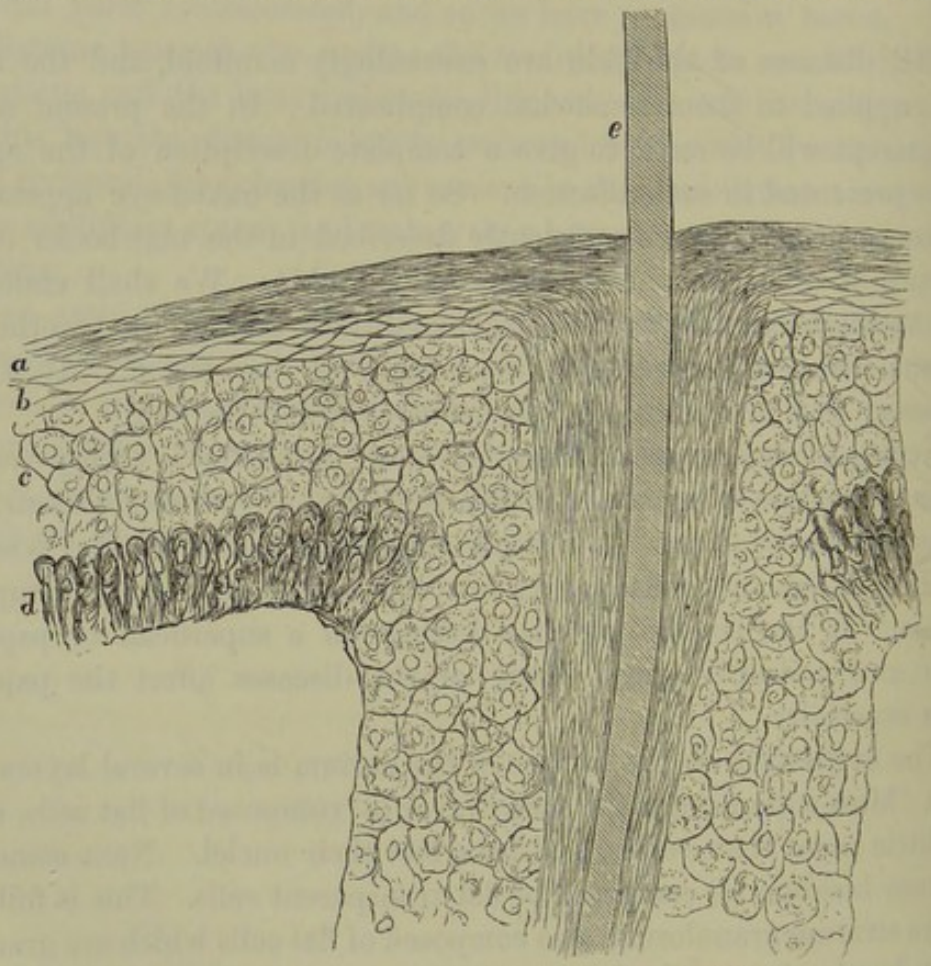

Fig. 328.—Section of epidermic layer of skin with a hair and its follicle. *a*, horny layer; *b*, stratum lucidum; *c*, Malpighian layer with (*d*) the deepest layer of cylindrical cells; *e*, hair, whose sheath presents two layers, one continuous with the horny and the other with the Malpighian layer. × 350.

sheath corresponding with the Malpighian layer, and the inner root-sheath corresponding with the horny layer. At the bottom of the

follicle is a papilla continuous with the corium, and on this is set the bulb of the hair. The NAILS are composed of compressed horny epidermis. Beneath the nail are still two layers of epidermis, a horny layer of loose cells, and a Malpighian layer covering well-formed papillæ.

The exposed position of the skin renders it very liable to the influence of agents acting from without. It is also liable to be influenced by irritants circulating in the blood, in which case the skin affection will probably be an insignificant part of a general condition. The skin again is liable to be affected by states of the nervous system. From these remarks it will be inferred that the inflammations of the skin are the most important morbid conditions, and these will call most largely for description.

HYPERÆMIA, HÆMORRHAGE, ŒDEMA OF THE SKIN.

The skin is very liable to variations of its blood supply. An active HYPERÆMIA hardly occurs as a pathological condition except as part of an inflammation. Passive hyperæmia, on the other hand, is exceedingly common as a result of general venous engorgement, especially in disease of the heart, where it leads frequently to CYANOSIS.

HÆMORRHAGES are frequent and of various kinds. As to their causes little need be added to what is stated at p. 45. The skin is liable to hæmorrhage by traumatic rupture of its vessels, but still more, perhaps, by alterations in the state of the blood affecting its vessels. In scurvy, in purpura, in small-pox, in typhus, etc., the skin is the seat of hæmorrhage much more frequently than any other structure.

The blood escaping from the vessels collects in the serous spaces of the corium for the most part, but may pass to the subcutaneous tissue, where the fat is sometimes considerably infiltrated. When the blood has escaped from a small vessel and infiltrates a limited area so that a bluish spot is seen on viewing the surface, the term PETECHIA is given. As these small hæmorrhages depend on the state of the blood the petechiæ are nearly always multiple. When the blood infiltrates a larger area, then the term ECCHYMOSIS is used. Sometimes the blood collects between corium and epidermis, and then a hæmorrhagic VESICLE is the result; but this can only happen if the deeper layers of the epidermis have been killed so as to allow of their separation from the corium. When there are numerous small hæmorrhages forming a large number

of petechiæ, then it is customary to use the term purpura, or to speak of a purpuric condition.

The blood effused in the skin undergoes changes like those already described at p. 47. The affected area is first dark blue, and the colour does not disappear on pressure. After a time, as the blood-colouring matter is dissolved, the colour gets fainter and changes in hue, while the discolouration becomes more extended. If blood has collected between the layers of epidermis, it comes to the surface and is disposed of as the epidermis is shed.

ŒDEMA of the skin, apart from inflammation, is chiefly related to disease of the heart and kidneys. Its general pathology has been considered at pp. 53 and 54. The exuded fluid collects in the lymph spaces and is carried off by the lymphatics. A condition of the skin has been recently described under the name MYXŒDEMA. It appears to occur in connection with Bright's disease, and differs from ordinary œdema in respect that the fluid occupying the spaces contains a considerable amount of mucine. The œdematous parts are much firmer than in ordinary œdema and do not pit on pressure.

ATROPHIC CHANGES IN THE SKIN.

SIMPLE ATROPHY is not uncommon in the skin. The most frequent example of it is afforded by SENILE ATROPHY, resulting in the wrinkled skin of old people. In this case the connective tissue of the cutis loses in bulk, especially the papillary layer. Very often the remaining fibres have a strikingly granular appearance under the microscope, but there are sometimes patches in which the fibres have assumed a glassy or colloid character, so as to give rise to the designation colloid or hyaline degeneration. The epidermis is also thinner and dry, and there is often desquamation in the form of dry scales or larger membranous pieces. The hairs are atrophied, as their papillæ have taken part in the general atrophy of the papillæ of the skin. The hair-follicles are shortened and the sebaceous glands on this account may be brought close to the surface, almost opening directly on it. The secretion may accumulate in the sebaceous glands so as to form small or large CYSTS.

A general atrophy also occurs in emaciated persons, and it may closely resemble the condition in senile atrophy.

There are further conditions variously named PARCHMENT SKIN, xeroderma, general atrophy, hide-bound skin, which are of rare occurrence, and are not very well understood in their exact relations. The

skin is thinned and hardened, especially the epidermis, so that the body seems covered with stiff parchment, which often looks as if too small for the surface to be covered, so that the movements of the limbs are impeded. It is sometimes mottled with pigmented spots, sometimes white. The disease generally begins in early life and extends gradually over the skin. This condition will be considered subsequently under the tropho-neuroses.

Of the LOCAL ATROPHIES the most familiar is that which occurs after PREGNANCY. It is well known that white lines are found in the abdomens of persons who have been pregnant. Similar lines occur in persons whose abdomens have been distended by tumours, by ascites, or even by accumulation of fat. The white lines have a cicatricial appearance, and they seem to owe their origin to the connective-tissue fibres of the cutis being dissociated by the stretching. Somewhat similar white lines or striæ sometimes occur idiopathically, especially over the buttocks, trochanters, pelvis and thighs.

The HAIRS are liable to atrophy, and two forms may be distinguished according as either the hair itself or its pigment diminishes. ALOPECIA or BALDNESS is atrophy of the hair itself. All through life a continuous falling out of the hair is occurring, and is due, as we have seen before, to an atrophy chiefly of the bulb. But the papilla remains, and a healthy new hair is produced on the site of the old one. In old people, however, the new hairs are not usually reproduced of normal size, and they become gradually finer and finer, till there are only the finest woolly hairs on the bald part, or even none at all. It is well-known that this condition frequently occurs in comparatively early life —PREMATURE ALOPECIA. The cause seems to be an atrophy of the papilla and sometimes of the skin itself. Besides being produced in this way, baldness may be secondary to syphilis, to inflammations and to certain parasitic diseases; in these cases it depends on interference with the nutrition of the sheath and papilla.

Special attention has been paid to ALOPECIA AREATA, in which baldness occurs in circular patches. These patches are not entirely bald, but are covered with fine woolly hairs, and the papillæ are not destroyed. The nature of this disease must still be regarded as obscure. Some regard it as of parasitic origin, and Eichhorst states that, as the fungus is mainly in the hair sheath, it is usually left behind when the hair is extracted, and so is overlooked. Others assert that it is due to changes in the nerves which command the nutrition of the skin, and is a tropho-neurosis.

CANITIES OR GREYNESS OF THE HAIR is also for the most part a natural atrophy of old age. But it also sometimes comes on prematurely. It depends for the most part on a deficiency of pigment in the individual hairs at their original formation, so that the pigment granules between the cells in the cortical layers of the hair are diminished. But there may be a temporary blanching of the hair from air getting infiltrated among the cells of the cortex. Cases of sudden permanent blanching have received no satisfactory explanation.

The NAILS are liable to atrophy, which may be congenital or acquired. In the course of acute illnesses, such as fevers or maniacal attacks, the formation of the nails is often diminished, and the illness is marked for a time by a transverse depression, which, with the growth of the nail, proceeds from the root outwards, and disappears in due course. The nails also atrophy sometimes in consequence of various parasitic or inflammatory skin diseases. The nail substance may be simply thinner and more delicate than normal, or it may be brittle and split or crumble readily.

INFLAMMATIONS OF THE SKIN.

These include a very great variety of diseases, and the nomenclature is exceedingly complicated. In the skin, as elsewhere, inflammation is produced by the action of irritants, and the form of the inflammation will depend greatly on the nature and source of the irritant. But it depends perhaps just as much on the nature and condition of the skin itself, the same irritant producing very different effects in different persons.

As illustrative of many points in the pathology of inflammations of the skin, we shall refer to the very simple case of the results of a FLEA-BITE. The results are not the same in every person, because different persons are variously susceptible to the irritant. When a flea penetrates the epidermis it introduces an irritant, which has an immediate effect on the sensory nerves. This is followed in certain persons by an œdema of the superficial layers of the skin, leading to the formation of a flat elevation called a WHEAL. By rubbing, the poison is dispersed in the

serous spaces around the puncture, and the wheal is enlarged up to a certain point. The wheal is preceded by a slight hyperæmia, and at its periphery there is still some redness of the skin, but this is generally insignificant. After a short time all trace of the irritation subsides; the inflammation has been very slight and transient. But the irritant still remains, and next day more permanent changes show themselves. At the place of the puncture there is a conical elevation, which at first is solid, forming a PAPULE, but after a time presents a clear cavity containing fluid, a VESICLE. Both of these conditions are again due to inflammatory exudation. The exudation is from the vessels of the papillary layer of the skin, and it consists of serous fluid, with leucocytes. This may confine itself to the papillæ, or it may pass among the epidermic cells, loosening them out, in either case forming a solid elevation or papule. But it may so dissociate the epidermic cells as to form a cavity in which it collects, thus producing a vesicle. The vesicle does not form, as might be supposed, between the epidermis and cutis, but among the deeper layers of the epidermis itself, the softer cells of the Malpighian layer becoming separated so as to leave a space. According to Ziegler, this is always by necrosis and destruction of some of these cells.

The papules and vesicles thus formed are often very persistent, remaining with trivial alterations for days or even weeks. As a rule, the vesicles dry in, and only papules are left, but the vesicles are sometimes renewed at intervals. The elevations ultimately subside, but a piece of epidermis is discharged from the surface, a DESQUAMATION, and the skin is restored to its normal condition.

CAUSATION OF CUTANEOUS INFLAMMATIONS.—From what has gone before, it will be apparent that in the case of all inflammations we have to look for an irritant. But the illustration just given shows that the same irritant produces very different effects in different persons. We have seen that in some persons a flea-bite produces an exudation leading to the formation of a wheal, but in many persons it does not. In some persons a wheal may be produced by a very trivial irritation. A simple scratch with the finger-nail will, in some, cause a raised line such as in others is produced by the lash of a whip. Then it is remarkable that in the same person at one time a wheal will be produced by a simple scratch and at others it will not. These differences apparently depend on variations in the state of THE NERVOUS SYSTEM at different times and in different persons. In URTICARIA there is a formation of

wheals in various parts of the body without any special external irritant. Such attacks are usually brought on by eating shell-fish, walnuts, or other special forms of food. These substances appear to produce their effects through the nervous system, inducing, by reflex action, a peculiarly sensitive state of the skin. The wheals occur especially in parts of the skin which are irritated by rubbing or by the contact of the clothes, and there may be very striking œdema of the eyelids, for instance, where the feeling of itchiness has induced the person to rub them more than other parts.

In almost all forms of inflammation the state of the nervous system and individual peculiarities have a most important bearing on the form and intensity of the process. But there are some forms of inflammation in which the condition of the nervous system has even a more direct bearing on the causation. Where the trophic centres of parts of the skin are interfered with, a trivial irritation may lead to necrosis or severe inflammation.

Inflammations owe their immediate origin to direct or indirect irritation of the skin. The irritant may be circulating in the blood and carried to the skin as to other structures. This applies to the cutaneous eruptions in the acute specific fevers and in syphilis; in these cases we may designate the eruptions as symptomatic. On the other hand, the irritant may come from without, as in the case of erysipelas, scalding, etc., and the inflammation is localized according to the extent of the irritation.

FORMS OF CUTANEOUS INFLAMMATIONS.

It is somewhat difficult to classify the various inflammations of the skin, but for convenience we shall consider them in four groups:—(1) Symptomatic Inflammations; (2) Inflammatory Skin Eruptions; (3) Traumatic and Non-infective Inflammations; (4) Septic and Infective Inflammations.

1. SYMPTOMATIC INFLAMMATIONS.

This class embraces the inflammations occurring in the acute fevers. Of the former, some are very trivial so far as the actual lesion in

the skin is concerned. Thus, the eruptions in measles, scarlatina, typhoid and typhus fevers, consist of little more than an inflammatory hyperæmia, with slight exudation. The action of the irritant on the epidermis is evidenced in many cases by the subsequent occurrence of desquamation, which implies that the cells have been so injured as to lead to their premature necrosis and discharge.

In SMALL-POX there is a much more severe inflammation. As the changes here afford an excellent example of the more pronounced inflammatory lesions of the skin, and may be regarded as typical of the anatomical conditions in inflammatory skin eruptions in general, they merit a more careful study. In this case the virus evidently lodges in the skin and multiplies there, leading to pronounced local changes. The fine particles, which we saw in a previous page to be the direct vehicles of the virus, are present in the small-pox eruption, especially in the earlier stages of the process, and it is evidently the products of their action that irritate the skin.

The effects of the irritant are seen mainly in the epidermis, which shows changes chiefly in the more plastic Malpighian layer. Many of the cells undergo a kind of coagulation necrosis, their nuclei being lost and their substance converted into a hyaline material. These necrosed epidermic cells allow of spaces being formed among their layers,

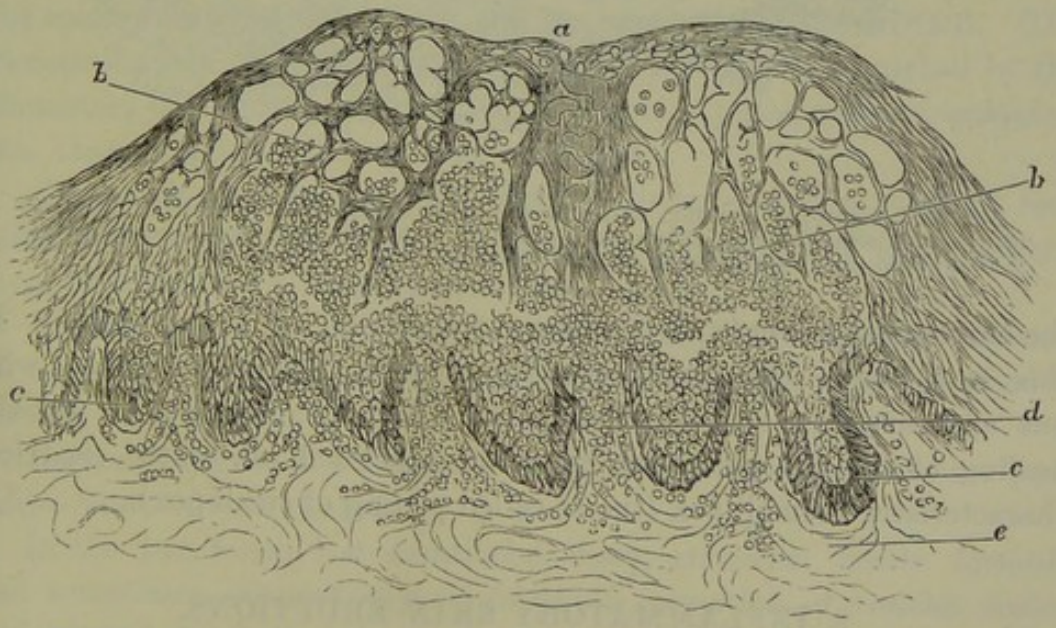

Fig. 329.—Section of a small-pox vesicle. Superficially there is a network formed of the altered epidermis. In the meshes of this (*b*, *b*) are pus corpuscles. For the most part the Malpighian layer in its deepest cells (*c*) is preserved, but at some points, as at *d*, it is broken through and the pus is infiltrating the skin. *a*, umbilication of the vesicle, due to a sweat-gland, the coils of which are distinguishable. × 140. (After RINDFLEISCH.)

in which exuded fluid collects. In this way a vesicle is formed, but it does not consist of a single cavity. As shown in Fig. 329, the epidermic cells or their remains form a network of fibres and partitions which divide the vesicle into compartments or loculi (*b* in figure) in which a serous fluid containing the fine particles already referred to is contained. As the inflammation increases in intensity leucocytes are exuded, and these accumulate, as seen in the figure, both in the superficial layers of the cutis (*d*) and in the loculi of the vesicle. By the aggregation of these the vesicle becomes a pustule. In the figure it is seen that while the papillary layer of the skin (*d*) is somewhat infiltrated with leucocytes, yet it is not destroyed, and the interpapillary processes of the Malpighian layer of the epidermis (*c*) still persist. Sometimes no further destruction occurs than this; the pustule dries in and a crust is formed, and under it the Malpighian layer forms new epidermis, so that when the crust is shed healing occurs without any loss of substance. But more commonly the action of the virus causes death of the superficial layers of the cutis as well as of the epidermis. This is shown in Fig. 330, where an injection thrown into the arteries runs into

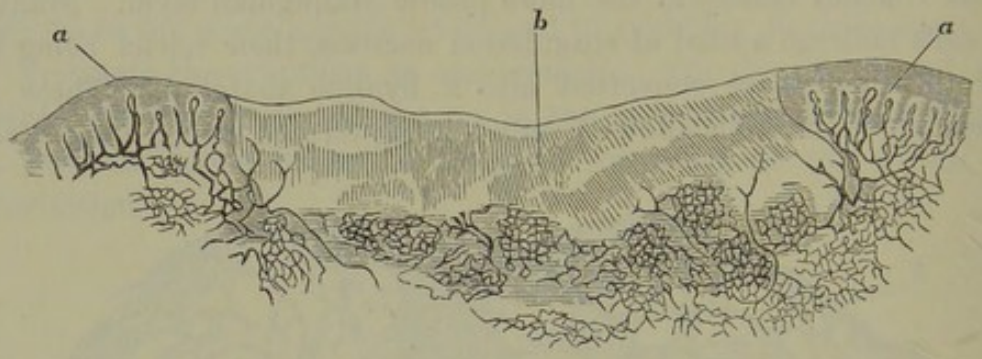

Fig. 330.—Small-pox eruption with necrosis, from an injected specimen. The normal skin at either side (*a*, *a*) has its vessels fully injected, while the necrosed part (*b*) is uninjected and homogeneous. × 50. (RINDFLEISCH.)

the surrounding skin (*a a*), but does not penetrate into the slough (*b*). In this case, when the crusts are torn, little sloughs infiltrated with pus are revealed, on the removal of which ulcers appear. By the healing of the flat ulcers we have the depressed reticulated cicatrices characteristic of small-pox (the so-called pitting of small-pox).

2. INFLAMMATORY SKIN ERUPTIONS.

We include here all simple inflammations of the skin which do not depend on any traumatic or infective cause.

(1) ERYTHEMA AND ROSEOLA.—These names are applied to mild inflammatory conditions in which the chief, and sometimes the only apparent, change is hyperæmia. The inflammatory nature of the condition is, however, often indicated by the existence of more or less swelling, due to œdema of the superficial layers of the skin (erythema nodosum and papulosum). The attacks are frequently evanescent, but are often followed by desquamation, which also evidences the inflammatory nature of the condition.

These very mild inflammations are frequently somewhat generalized, and appear in many cases to be, like urticaria, related to special conditions of the nervous system, especially, perhaps, of the vaso-motor nerves. They may also be produced by external irritants, especially in susceptible persons.

(2) ECZEMA.—This name is applied to localized inflammations of the skin, usually of a sub-acute or chronic character. The mere fact of their local nature would indicate that the irritant here comes from without; but external irritation is hardly ever the entire explanation of the attacks. In no other disease do individual peculiarities and special states of the organism play a more important part. The external irritant may be very various, such as medicinal ointments, stuffs used by the patient in his occupation, as in dyeing, parasites which induce scratching, etc. The intensity of the inflammation depends on the susceptibility of the patient and the character of the irritant. The various degrees of intensity are, to a great extent, distinguished by the characters of the eruption, so that we have papules, vesicles, pustules, etc., characterizing different cases of eczema.

If the irritation be very mild there is little beyond a patch of redness, with raised papules, depending on infiltration of the papillary layer of the skin—ECZEMA PAPULOSUM.

In cases where the irritation is more violent, there is partial necrosis of the epidermis, and vesicles form in the manner already described—ECZEMA VESICULOSUM.

A greater degree of inflammation will convert the vesicles into pustules—ECZEMA PUSTULOSUM.

In the two forms last mentioned there are often crusts formed, and sometimes, without any considerable formation of vesicles, scales and crusts form, so that the eczema is nearly dry and the surface scaly —ECZEMA SQUAMOSUM. On the other hand the vesicles may break, and as fresh exudation passes to the surface there may be a continual dis-

charge—ECZEMA MADIDANS. The surface thus exposed is often very red and infiltrated, so the name ECZEMA RUBRUM is given.

These forms are not to be rigidly distinguished, and several of them may be present in the same case, there being papules, vesicles, pustules, crusts, and a weeping surface represented on the same patch.

In what has gone before the conditions referred to have been chiefly those in sub-acute eczema. When the disease becomes chronic there are more permanent changes which may be compared to those in catarrh of mucous membranes. The inflamed surface usually keeps on discharging serous fluid, not always to the same extent. The epidermis is softened, and, to a considerable extent, lost, so that the cutis is exposed or covered with irregular crusts. The cutis itself is red and it is thickened both by the serous exudation and by accumulation of round cells. The skin, in fact, shows more or less the characters of a chronic inflammation with the usual new-formation of connective tissue.

When the inflammation subsides, there is, in the milder forms, a complete restoration. But where considerable infiltration of the skin has occurred there may be a very imperfect restoration of the papillæ, the skin, as a whole, having somewhat of a cicatricial character. Hence the smooth homogeneous appearance sometimes presented. The part is also not infrequently the seat of pigmentation.

(3) PSORIASIS.—The nature of the irritant is in this case quite unknown, but it is probably to be found in some special condition of the blood. We know, at least, that remedies introduced into the blood (arsenic, and, according to Napier, chrysophanic acid administered internally) frequently cure the disease.

The lesion is mainly of the epidermis, and especially of its Malpighian layer. The papillary layer of the cutis is hyperæmic and partly infiltrated with leucocytes; the papillæ are also described as enlarged, but these alterations are comparatively trifling, as, after death, very little indication of them is to be found. During life the hyperæmia gives the corium a red colour. In the middle regions of the Malpighian layer of the epidermis there is an abundant new-formation of epidermic cells. This new-formation is so great that there is no time for the cells to become horny before they pass to the surface. Hence the epidermis on the patch is entirely composed of Malpighian layer, and, these cells being soft, they adhere as they dry much more readily into considerable scales than the horny cells do. For a similar reason, as they dry they shrink much more than the horny cells, and air insinuates itself

in interstices between them. It is the finely divided air which gives the scales the peculiar silvery appearance characteristic of this disease (Rindfleisch). When the scales are removed the papillary layer of the skin is seen to be red and readily bleeds.

(4) Pityriasis Rubra.—In this disease we have a more or less general affection, and it is not improbable that it depends on a lesion of the trophic centres of the skin. It is characterized by an excessive discharge of scales consisting of masses of epidermic cells. These scales pass off from slightly raised and reddened surfaces, which in the earlier periods are limited in size, but extend till often they cover nearly the entire body. In the earlier periods the cutis presents little more than hyperæmia with excess of leucocytes in its papillary layer, but when the disease has lasted for some time there is thinning of it with flattening of the papillæ. The sebaceous glands and hairs as well as the sweat glands, are usually atrophied. There is often a very excessive discharge of epidermis, and the disease may lead by debility and marasmus to a fatal issue.

(5) Lichen Ruber.—The designation lichen is frequently used to denote a simple papular eruption, and in this sense lichen simplex is nothing but eczema papulosum. Lichen ruber, on the other hand, is a diffused papular eruption, depending like pityriasis rubra on some obscure general cause. There is an inflammation of the skin, generally beginning in patches, but sometimes extending till nearly the entire body is covered. There are individual red papules on a red basis. As the disease goes on the skin gets infiltrated and thickened, so that the movements of the joints are hindered, and fissures are formed at the folds of the skin. On the face the lines of expression are obliterated. The nails are usually thickened. In its details the disease seems to consist in an inflammatory infiltration of the papillary layer of the cutis and the Malpighian layer of the epidermis. The cells of the rete Malpighii are enlarged and increased in number, and the interpapillary processes are enlarged. The papillæ show abundant accumulation of round cells, especially around the vessels. There is often accumulation of epidermic cells in the hair-follicles.

(6) Prurigo.—This also is a diffused affection of the skin, which somewhat resembles urticaria, except that it is more permanent. Like urticaria it seems to depend on some condition of the nervous system,

induced especially among children by neglect of sanitary conditions and defective nutrition. Numerous small papules appear on the skin and they are intensely itchy. The papules are due to an inflammatory thickening of the papillæ and rete Malpighii. There are round cells and a serous fluid exuded, so that when the head of the papule is removed by scratching a drop of fluid appears. The papules are often induced to bleed by scratching, and it is probably from this that they frequently leave a brown stain. The irritation produced by scratching may also lead to eczema.

(7) PEMPHIGUS.—This condition is characterized by the formation of large vesicles or bullæ filled with fluid, which is at first clear, but usually becomes more or less purulent. As the bullæ usually occur at intervals over a considerable surface, the disease is to be ascribed to some general cause, and in some acute cases the existence of an irritant in the blood is suspected. There arise at first patches of a red colour and slightly raised. The epidermis is then separated from the cutis by fluid accumulating beneath it. There is not here, as in small-pox, an exudation among the cells of the Malpighian layer, but for the most part the whole epidermis is raised, and the bleb is not divided by septa into loculi. If the bleb remain unruptured a layer of epidermis forms on the surface of the cutis. But if it burst, then the exposed cutis discharges for a time; by and by, however, a crust forms, under which the epidermis grows. In some cases the blebs are imperfectly formed and neighbouring ones coalesce, so that a considerable surface is affected. When these blebs burst there is little tendency to new-formation of epidermis, and the skin continues discharging fluid as well as crusts produced by the fluid drying in. This form is designated PEMPHIGUS FOLIACEUS.

(8) ACNE.—This name is applied to inflammations of the sebaceous glands and their neighbourhood, chiefly in connection with accumulation of the secretion in the gland. There are two forms in which the accumulation of sebum occurs, named respectively comedo and milium, but it is chiefly in connection with the former that acne occurs.

In COMEDO a sebaceous follicle is filled with secretion, which forms a solid plug in the gland. The end of the plug presents at the surface, and has a black or dark blue colour. It has been usually supposed that this colour is simply due to dirt, but Unna has asserted that there is a true pigment concerned, whose composition is allied to that of ultra-

marine, and whose colour is destroyed by aqua regia. The plug can be readily pressed out by squeezing the skin around the gland; it emerges as a worm-like structure with its dark head. The plug consists of shed epidermis and sebum, with occasionally a small parasite, the acarus folliculorum.

In MILIUM there is an accumulation of the secretion with closure of the orifice of the gland. The accumulated secretion forms a rounded solid globe, which can be felt in the substance of the skin, but over which the epidermis passes unbroken. It is, in fact, a small retention cyst, and it contains the secretion of the gland mixed with epidermis, so that on cutting into it a whitish globular body is discharged. The cause of the closure of the duct is obscure.

In acne there is a more or less acute inflammation of the sebaceous glands, usually in connection with comedo. There is redness and swelling around, and pus is usually formed, and mingles with the substance of the comedo. Sometimes there is not a proper suppuration, but the substance of the plug is softened by the inflammatory exudation. The inflammation is due to the irritation of the plug, especially when by long stagnation it has become foul.

The name ACNE MENTAGRA, or SYCOSIS, is given to cases where there is inflammation of the sebaceous glands in connection with the hairs of the beard. There is a sycosis of parasitic origin, but in the simple form there is suppuration in and around the hair-follicles of the nature of acne.

A more chronic inflammation of the sebaceous glands of the face, with special hyperæmia of the vessels around, has received the name ACNE ROSACEA. There is very little tendency to suppuration, but great thickening of the skin occurs, so that sometimes there are large lobulated and red protuberances, especially on the nose, on the surface of which many comedones are seen. This disease is not uncommon in women, especially about puberty and at the climacteric period. In men it is often associated with dissipated habits.

3. TRAUMATIC AND NON-INFECTIVE INFLAMMATIONS.

(1) BURNS AND SCALDS.—We include here the lesions produced by the application of excessive heat to the skin, whether the heated substance applied be in the solid, liquid, or gaseous form. The heat acting as an irritant damages or kills the tissue, and so we have signs of inflammation frequently associated with necrosis.

Burns have been distinguished into three degrees, according to their intensity, and we have to consider the exact condition of the skin in each. The three degrees are characterized by these three phenomena—hyperæmia, vesication, sloughing.

In the FIRST DEGREE the heat is only sufficient to produce a hyperæmia of the skin. Exposure to the rays of the sun, or to hot water of a temperature of 100° F. and upwards, causes such a relaxation of the arteries as to induce considerable congestion. The inflammatory nature of this hyperæmia is shown by its continuance for some time after removal of the cause, and by the occasional occurrence of some œdematous swelling of the skin. After a time there may be desquamation.

The SECOND DEGREE is produced by the action of a temperature of 140° to 185° F., or by the evanescent action of a still higher temperature. The effect is to cause a necrosis with swelling of the epidermic cells of the Malpighian layer, and an inflammatory exudation from the papillary layer of the skin. The changes in the rete Malpighii are similar to those already described as occurring in the formation of the small-pox vesicle, but they are more rapidly produced and the layer of cells is more homogeneously affected. The exudation, passing out from the papillæ, separates the epidermic cells from the surface of the papillæ, and a vesicle is thus formed. Usually the interpapillary cells of the rete Malpighii escape destruction, but when the action is more intense they also may be killed. The inflammation soon subsides, and from the remaining cells of the rete Malpighii new epidermis is reproduced ; there may be already a complete coating of new epidermis before the vesicle bursts. But sometimes the vesicle bursts early, and the inflamed surface of the skin is exposed ; or nearly the whole of the rete Malpighii may have been destroyed, even the interpapillary processes. In these cases the covering over of the surface with epidermis may be delayed, and the surface may even become like a granulating wound, discharging pus.

In the THIRD DEGREE there is necrosis not only of the epidermis but of the true skin to a greater or less depth. The temperature is over 140° F., and if very high may have acted for a very short time. As a general rule the necrosed tissue lies as a dry crust on the surface. An inflammatory process occurs around it, with exudation, going on usually to suppuration. In this way the slough is separated, and a granulating wound is left, which heals in the usual way, leaving a cicatrix, the character of which varies with the depth of the slough.

Severe burns sometimes LEAD RAPIDLY TO DEATH with symptoms of collapse. The explanation of this is not easy, but there are two conditions which affect the body in general which probably are the chief agents. When a part of the skin is exposed to a high temperature, the red corpuscles in the vessels perish, and they do so even in parts where the circulation persists. If the heat has acted for some time, then the blood in the vessels may have been frequently renewed and large numbers of corpuscles may have been destroyed. The red corpuscles yield their hæmoglobin, which, as we have seen at p. 11, acts as a poison. Besides this, the mere destruction of large numbers of corpuscles may seriously interfere with the respiratory functions. Again, the vessels of the skin are dilated after the occurrence of the burning. If the surface affected be large there may be, as a result of this, a serious loss of heat and reduction of temperature in the body as a whole. At the same time the dilatation of so many arteries may reduce the blood-pressure to a considerable extent. The combined action of these conditions seems to bring about the collapse after burns.

If the person survives for some time after the burning, there are frequently found inflammations of internal organs, the lungs, kidneys, serous membranes; also fatty degeneration of the heart and of the liver. These are to be ascribed with great probability to the alteration of the blood.

It is much more difficult to account for the occurrence of the DUODENAL ULCER after burns. When several weeks elapse before death, there is found in about 20 per cent. of the cases one or more ulcers, usually situated in the duodenum near the pylorus, but sometimes in the pyloric region of the stomach. It may be a superficial hæmorrhagic erosion or a deeply penetrating ulcer.

(2) FROST-BITE AND CHILBLAIN.—These conditions are produced by the action of excessively low temperatures. We can distinguish three degrees here also.

The common CHILBLAIN is an example of THE FIRST DEGREE. If portions of the body are exposed to a low temperature and then heated, a chronic or subacute inflammation is induced. This occurs especially in the fingers and toes. There is passive hyperæmia sometimes amounting almost to stasis, so that the part has a livid hue. There is also serous exudation, so that the part is swollen and œdematous; there may be red corpuscles as well as leucocytes in the exudation. Sometimes ulceration occurs.

The SECOND DEGREE includes the LESS SEVERE cases of FROST-BITE. The skin has been frozen and too rapidly thawed, the result being such an injury to the tissue as to cause an acute inflammation. The epidermis is raised in blisters which often contain a bloody serum. There may even be sloughing of the superficial layers of the cutis, and by the separation of the slough an indolent ulcer forms.

In the THIRD DEGREE, forming the MORE SEVERE cases of FROST-BITE, there has been prolonged exposure to very intense cold. The consequence is the complete freezing of part of the body, especially in regions removed from the heart, as the fingers and toes. The tissues are stiffened by freezing, and the blood coagulated, so that sometimes parts can be broken off like glass. When the parts are thawed gangrene sets in. The whole frozen part does not die, but there is partial recovery with inflammation. The gangrenous part is separated in the usual way, generally with decomposition (moist gangrene).

(3) BOIL AND CARBUNCLE.—These names are applied to localized acute inflammations of the skin with partial necrosis. The boil or FURUNCULUS occurs for the most part in persons who are debilitated or exhausted, but in addition to this we have to look for some local irritant. The fact that it begins in the neighbourhood of a hair-follicle or sebaceous gland seems to suggest that accumulation of secretion may afford the irritant. The boil would thus be related to the acne pustule, the more intense inflammation in the former being related to the state of the patient. The inflammation manifests itself in hyperæmia and exudation, so that a localized redness and swelling are the result. A piece of skin in the very centre of the inflamed area dies, and a small abscess having formed, the slough is by degrees discharged along with the pus.

The carbuncle or ANTHRAX is similar in its general characters to the boil, but a much larger piece of skin is involved. The slough is therefore of much larger extent. It sometimes happens that the whole piece of skin in its entire thickness dies and is separated as a dry leathery slough. More frequently the necrosis is less extensive in the superficial layers, but more extensive in the deeper parts, and the slough is discharged through numerous small apertures.

(4) WOUNDS AND EXCORIATIONS.—The phenomena connected with the healing of wounds and the formation of granulations have been considered in previous pages. When merely a portion of the epidermis is

removed by an injury, forming an EXCORIATION, it is restored with remarkable celerity. The cells at the margin and those of the deeper layers divide and form new cells which fill in the gap. In the case of a deeper wound the epidermis also shows great vigour, and it sometimes advances beyond the line of the other healing processes.' Dr. Macewen has pointed out to the author that the new-formed epidermis may advance over a blood-clot filling up a wound. The epidermis here has a remarkably transparent hyaline appearance and is continuous, not with the Malpighian layer, but with the layers superficial to that. The character of the cells here and their transparency suggest that they may be derived from the stratum lucidum. It may, indeed, be suggested that this layer in the normal skin is composed of young epidermis, and that the loss on the surface is supplied by new-formation here and not in the Malpighian layer.

(5) ULCERS.—By this name we understand losses of substance in the skin which are mostly in process of enlargement. The margin of the ulcer is inflamed and infiltrated with inflammatory products. The enlargement takes place by a gradual molecular necrosis of the inflamed structures, and it implies the continuous action of an irritant. The irritant is mostly an infective virus, and the majority of the ulcers will be again referred to under the next heading. The VARICOSE ULCER, however, does not belong to this category. The original lesion here is a prolonged venous hyperæmia, leading to œdema and infiltration of the skin. The nutrition of the skin is seriously compromised, and a trivial external injury may cause the epidermis to give way. The exposed and inflamed skin forms granulations, but these also, from the persistent venous engorgement, are readily destroyed by slight injuries, and the ulcer advances, while the inflammatory infiltration of the skin outside extends. The granulations will only proceed to healing in the usual way when the venous hyperæmia is removed.

In the case of infective ulcers there is also usually a granulating surface which is gradually destroyed by the action of the virus. When the virus has been destroyed, then the ulcer proceeds to healing like a granulating wound.

4. INFECTIVE INFLAMMATIONS.

We include here those forms of inflammation of the skin which can be traced to the action of specific viruses. The syphilitic inflammations

might be considered here, but they will be taken up afterwards by themselves.

(1) Lesions from Cadaveric Poisons.—In the juices of the dead body when in process of decomposition, there are innumerable bacteria of different kinds. Some of these may attack the skin of the dissector or pathologist, and find a lodgement there. The organisms themselves are of very various degrees of virulence. If the subject has died of a septic disease, then the organisms which have during the life of the patient been active factors in the production of the disease, may remain specially virulent after death. The fluid in the abdomen after septic peritonitis, such as that which occurs in one form of puerperal fever, teems with micrococci, and this fluid is peculiarly virulent when applied to the skin. So is it also with septic pleurisy, etc.

Besides degrees of activity in the virus, there are various degrees in the susceptibility of different persons, and of the same person at different times. The frequent exposure to the cadaveric viruses creates a certain immunity, so that a person will be more secure against them when frequently engaged in post-mortem work than when making only an occasional examination. A state of exhaustion of the body renders one much more susceptible, and makes the inroads of the virus when once implanted more vigorous than when in ordinary health. The inference from this is, that the best treatment for this condition is to leave off work and at once seek rest and fresh air.

The virus very often finds access to the skin without any breach of surface. When a wound is made during dissection it is usually washed thoroughly and sucked, while bleeding is encouraged; in this way the virus may be washed away. But if it gets into the hair-follicles or sweat glands it may lodge and multiply undisturbed.

The immediate effects are usually an acute localized inflammation of the skin, resulting in the formation of a small pustule. The virus may have attacked at several points, and there is a crop of pustules, usually on the back of the hand or forearm where the epidermis is thin, the left hand being more frequently affected than the right, as it is most frequently exposed in separating and holding the organs. In many cases nothing more than the pustules is produced, and in the case of the regular pathologist a crop of pustules in the spring may be his annual experience. The pus contains micrococci, some of them free, but some in the substance of the pus corpuscles (see Fig. 331).

Sometimes, however, there are more severe local effects, and sometimes the virus travels farther inwards. Instead of dying away, the

pustule, after partially disappearing, sometimes leads to an acute inflammation in a larger area around, so that a boil is the result. The inflammation is often so acute as to lead to a necrosis of a piece of skin, so that suppuration is set up and a slough is ultimately discharged. In this case there is a cicatrix left when healing occurs. In other cases it is what has been called a blind boil which develops after the pustule. There is a more chronic inflammation of the skin with considerable thickening and elevation. The surface of these elevations is often irregular and somewhat warty in appearance—the PATHOLOGICAL WART. These, however, not infrequently develop without a previous pustule, the virus acting slightly but continuously from the first. In all these cases the forces of the tissues seem sufficient to keep the virus local, although there may be some general disturbance of the body, perhaps from the absorption of the products.

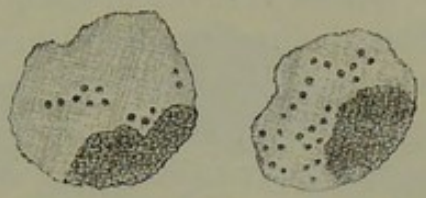

Fig. 331.—Pus corpuscles with micrococci in them from a cadaveric pustule. × 1500.

In some cases, however, the virus propagates itself upwards towards the trunk. It may be that an erysipelas starts from the local inflammation, extending upwards along the lymph spaces of the skin. In other cases the axillary glands become inflamed without any intervening lesions, the virus passing up the vessels and only producing mischief after lodging in the glands. Here suppuration is common. An inflammation of the skin resembling erysipelas may spread from the glands, as the virus, checked in its upward course towards the trunk by the gland, passes outwards to the lymph spaces around. This course of events is shown in the exquisite account which Paget has given of his own case in his *Clinical Lectures and Essays*. The inflammation may travel along the connective tissue of the skin and subcutaneous tissue, and may even reach the pleura. In the skin its effects may be very severe, resulting in sloughing and profuse suppuration like that in erysipelas. It may even lead to septic infection or pyæmia.

(2) ERYSIPELAS.—This is an acute infective inflammation of the skin. The virus depends on bacteria in the form of micrococci which extend more or less abundantly in the lymph spaces and vessels of the skin (see Fig. 332) and subcutaneous tissue. The result is a more or less severe inflammation. At first there is an inflammatory hyperæmia, which advances as the virus propagates along the lymph spaces. This, with a moderate exudation of fluid and leucocytes, may be all the

phenomena. But sometimes there is much more intense inflammation. The skin is infiltrated with leucocytes to such an extent that it is softened and opened out with pus. The epidermis is raised by exudation so that vesicles or pustules are formed. Sometimes the lymph spaces are occupied with fibrine. Besides suppuration, there is often necrosis of portions of the skin so that sloughs are separated with the pus.



Fig. 332. — From the skin in a case of erysipelas. The upper illustration shows a lymphatic vessel at the border of a sebaceous gland, filled with micrococci. The lower shows a straight vessel similarly filled. × 350.

(3) PHLEGMONOUS INFLAMMATIONS. — These have very much the characters of the severer forms of erysipelas, for which, indeed, the name phlegmonous erysipelas is used. The term phlegmonous is applied to inflammations of the skin of a very acute character, associated with sloughing. Such inflammations may be produced directly by the presence of virulent decomposing material in the skin and subcutaneous tissue, as where urine is extravasated and decomposed. But the condition may be more directly allied to erysipelas, depending on the gradual extension of micrococci in the lymph spaces. This occurs mostly around septic wounds, and may be followed by abscesses at some distance from the wounds.

Sometimes the virus is of such an intense nature that gangrene rapidly develops, being preceded only by an œdema. To this condition the name MALIGNANT ŒDEMA is sometimes given.

(4) SPLENIC FEVER or ANTHRAX.—This disease, as we have seen, depends on a special bacillus. There is usually a local affection to begin with, and the disease may remain local. The local affection has the characters of a phlegmonous inflammation of the skin and subcutaneous tissue. Sometimes the appearances of malignant œdema are produced. From these local manifestations the condition is sometimes called MALIGNANT PUSTULE. As a general rule the bacillus penetrates to the blood, and the patient dies from the general specific fever.

(5) INFECTIVE TUMOURS.—Of these, LUPUS, LEPROSY, and GLANDERS have been sufficiently described in the general part of this work. Syphilitic diseases will receive special description in the next section.

The name FRAMBŒSIA is given to a disease which evidently depends on a virus which acts on the skin. There are prominent irregular swellings produced which have the general appearance of exuberant granulations. These have been compared in appearance to strawberries and raspberries. The local names YAWS (African for raspberry) and PIAN (mulberry) also suggest these resemblances. The disease is

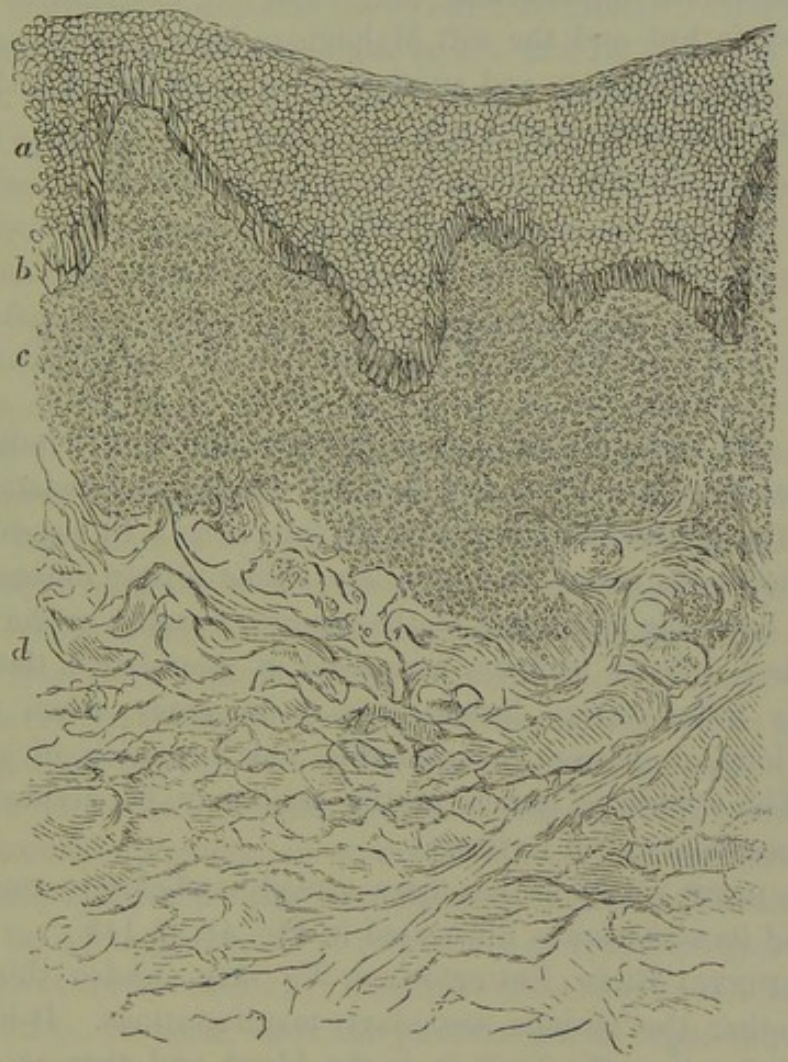

Fig. 333.—Section of skin in framboesia, from a part where the disease was not very far advanced. The papillary layer of the cutis is seen to be replaced by granulation tissue while the epidermis is preserved on the surface. × 75.

endemic in the West Indies and Africa; it also occurs in Peru, where it is called VERRUGA. It is contagious, and in many respects so much resembles syphilis that some authors have regarded it as the same disease.

It begins as a small raised spot, usually on the face, on the upper or

lower extremities, or near the organs of generation. The spot enlarges and gradually assumes the red irregular appearance which has suggested its names. It may continue for months or years, and, neighbouring areas coalescing, it may affect a large portion of the cutaneous surface.

The structure of these growths closely resembles that of the syphilitic chancre, as may be seen by comparing Fig. 333 with Fig. 48, p. 149. The cutis is converted into granulation tissue, whose bulky masses form the irregular prominences characteristic of the disease. The epidermis may be continuous over even the most prominent of these masses (see figure), and may even be exaggerated; but the horny layer is lost and the soft Malpighian layer alone remains. The epidermis may give way, and an ulcer form, from which a thin fluid is discharged, not usually a true pus.

SYPHILITIC LESIONS OF THE SKIN.

In the first part of this work it has been sufficiently indicated that syphilis depends on a virus, and that the various manifestations in the skin are the results of the action of this virus. In regard to these lesions it has been stated that they are either simply inflammatory, or that they have the characters of the gumma, forming in the latter case more or less definite tumours composed of granulation tissue. Even the purely inflammatory lesions have a tendency, when they have persisted long, to present considerable new-formation of granulation tissue. The syphilitic lesions of the skin may be divided into the primary, secondary, and tertiary.

1. The HARD CHANCRE has been already sufficiently considered at p. 149, and its structure is illustrated in Fig. 48, p. 149.

2. SYPHILITIC SKIN ERUPTIONS.—We may, under this heading, group together the various secondary manifestations. It is to be remembered that here the virus is in the blood, and that, as a rule, the manifestations occur over the skin as a whole, although circumstances may determine a certain local selection. The eruptions are for the most part symmetrical, and they present a peculiar tendency to occur in round patches. These patches, by healing in the centres and extending at the periphery, frequently assume a circular or serpiginous shape.

The syphilitic eruptions of the secondary stage are somewhat similar in character to the simple inflammatory eruptions, and they are commonly designated by similar names. There is, however, more tendency in the syphilides to the development of granulation tissue in the skin, and hence the papular forms of eruption are more frequent. The syphilitic eruptions present very various characters, and there is no form which is constantly present at a particular stage. In the earliest periods there is usually a generalized hyperæmia of the skin (SYPHILITIC ERYTHEMA or ROSEOLA). A more local development of elevated papules, generally in groups, constitutes the SYPHILITIC LICHEN. In these papules, the corium, especially its superficial layers, and to a certain extent the epidermis, are infiltrated with round cells; generally there is desquamation of epidermis, and this is sometimes very prominent. Occurring in the palms of the hands and soles of the feet this desquamation is so characteristic as to give rise to the designation SYPHILITIC PSORIASIS, the papules after a time coalescing and so merely producing a generally raised surface.

The CONDYLOMA (*plaque muqueuse, mucous tubercle*) is a further development of the papule. It occurs usually in situations where two surfaces of the skin are in contact and are thus kept moist, as in the neighbourhood of the genital organs, in the axilla, beneath the mamma, etc. We have here a very marked and extensive infiltration of the papillary layer of the skin with round cells, so that an elevated surface is formed. Sometimes there is a special elongation of the papillæ so that a warty surface is produced, giving rise to the pointed condyloma. Sometimes the condyloma breaks down on the surface and an ulcer forms.

The syphilitic papules sometimes develop into pustules or vesicles. The pustule forms by the epidermis being raised from the surface, while a fluid inflammatory exudation occurs between it and the corium, which latter remains infiltrated with round cells. The pustule or vesicle and its infiltrated basis may enlarge so as to produce a broad bleb on a red raised base (SYPHILITIC PEMPHIGUS). The blebs often dry in and form raised crusts (RUPIA). In these cases the pustules are as if on the surface of condylomata. This is still more the case in PEMPHIGUS NEONATORUM, which is one of the manifestations of hereditary syphilis. Here the corium is affected somewhat as in the condyloma, but the infiltration has more the characters of granulation tissue. In the condyloma the structure of the skin remains to a great extent, but it is infiltrated with round cells which are mostly leucocytes. In pemphigus neonatorum, however, the tissue is replaced by a vascular tissue in which are many

large cells, the condition approaching to that of the gumma. On the surface of this the epidermis is raised, forming a vesicle or pustule.

The Gumma.—This is not of very common occurrence, and is, as we have seen, a special tertiary manifestation. It begins as a hard swelling in the cutis. It increases in size and raises the surface, sometimes forming a tumour of considerable dimensions. It is peculiarly prone to ulcerate, and after ulceration has occurred it may go on extending, the infiltrated edges gradually giving way. The structure of the gumma has been described and illustrated at p. 151.

TROPHO-NEUROSES OF THE SKIN.

We include under this heading lesions of the skin in which, by reason of disease of the nervous system, such changes occur in the nutritive processes as to lead to definite anatomical results. The existence of separate trophic nerves for the skin has not been anatomically demonstrated. But there are evidences, especially in pathological processes, that trophic centres exist, and that fibres convey impulses of this kind to the cutaneous surface. The ganglia of the posterior roots of the spinal nerves and the similar Gasserian ganglion seem to contain trophic centres, and the trophic fibres are either identical with the sensory ones or run along with them.

(1) Herpes.—This disease is typically of nervous origin. It is commonly accompanied by neuralgia, and in its site it nearly always follows the distribution of a single nerve stem. It appears, for instance, in the course of an intercostal nerve, or occupies one side of the face in the area of distribution of the fifth.

The eruption in the skin is in the form of vesicles which somewhat rapidly pass through a series of changes. There is first a group of slight elevations occupying a reddened patch of skin, and each of these rapidly develops a vesicle; in a few days the vesicle dries up into a crust, under which fresh epidermis is formed. In its details the eruption is inflammatory. There is hyperæmia and œdema of the papillary layer of the skin. The serous exudation collects in the Malpighian layer of the epidermis, separating its cells just as in the case of the small-pox eruption. The vesicle is divided by a network composed of the elongated and contorted epidermic cells, which often present clear

spaces or vacuoles in their substance. In the serous contents of the vesicles there are leucocytes, and these may accumulate till the fluid approaches to the nature of pus. The papillary layer is also frequently the seat of infiltration with round cells. Occasionally there is hæmorrhage, and the papillary layer of the skin may be destroyed, so that when healing occurs by granulation a cicatrix may be the result.

The nervous origin of herpes has been abundantly established. Direct injury to a nerve, as by a gunshot or other wound, may cause it. It is to be presumed that, in this case, the inflammatory process in the wound irritates the nerve, and the cutaneous inflammation may be regarded as due to the irritation of trophic fibres. Spontaneous herpes, and especially herpes zoster, has been found associated with inflammations of the intervertebral or Gasserian ganglia, but it has been questioned whether the trophic centres have actually their seat there.

The herpetic eruption may arise from disease of the spinal cord and brain. In the case of the cord it is chiefly in locomotor ataxia that we meet with herpes, and the eruption is accompanied by the severe pains characteristic of that disease. We know that in locomotor ataxia it is the posterior columns of the cord that are affected, and this would indicate that the cutaneous trophic-centres or fibres run in these parts, while the coincidence of neuralgic pains also indicates a sensory locality. It is here again to be presumed that the lesion producing the herpes is an irritative one as indicated by the violent coincident pains.

But we may have herpetic eruptions from disease in the brain. There are cases recorded in which one half of the body was affected, and in some of these there was a hemiplegia due to a coarse lesion in the brain. It is clear that there must be trophic fibres and centres in the brain as well as in the cord, and their irritation may lead to herpes. There are also a few cases on record of universal or nearly universal herpes, as if a general centre for the whole body were irritated.

(2) Glossy Skin.—This name was applied by Paget to a condition which he observed in connection with injuries or wounds of the nerves. There is here again indication of irritation of the nerves, as there is always neuralgic pain, described by Mitchell as burning pain. The condition also occurs sometimes after an attack of herpes (Paget), and it may be associated with eczema. It may also follow disease of the spinal cord (Mitchell).

The disease occurs mainly in the hand, and especially in the fingers. The affected fingers "are usually tapering, smooth, hairless, almost

devoid of wrinkles, glossy, pink or ruddy, or blotched as if with permanent chilblains" (Paget). The most striking peculiarity is the shining, glossy appearance of the surface as if it had been varnished. The comparison to chilblains is usually applicable, but sometimes the appearance is rather that of highly polished scars, and the condition resembles that in morphœa. In the affected part the hairs mostly disappear, and the nails undergo peculiar changes. The latter become greatly curved, much more than in cases of phthisis, while the skin at the root of the nail becomes retracted, leaving the sensitive matrix partly exposed. The disease affects mainly the fingers and toes, but it may extend to the palm of the hand or the dorsum of the foot. The histological details in this condition are unknown.

(3) MORPHŒA AND SCLERODERMA.—These names are applied to denote conditions which are sometimes regarded as of a different nature, but the presumption is that they are virtually the same disease.

The nervous origin of the disease has been brought prominently forward by Hutchinson on the ground that it usually occurs in defined patches, often distinctly following the distribution of particular nerves. But sometimes the disease is more extensive, and it may be almost universal. The same may be said, however, as regards herpes, and it does not invalidate the supposition of its nervous origin.

When the disease is in the form of patches it is often described as MORPHŒA or ADDISON'S KELOID. The patches have the characters of induration and stiffening of the skin; they are mostly white and ivory-like, but may have a yellowish or mottled appearance. The greatest peculiarity is the hardness, as if the skin were frozen. The skin is sometimes bound down to the parts beneath, the induration extending to the subcutaneous tissue, and even deeper, and in that case there may be considerable interference with motion and even deformity of limbs from contraction of the skin.

In the more diffuse form of SCLERODERMA proper, extensive tracts of skin are sometimes involved, such as the greater part of the face, the arms, etc. In a case observed by the author, the face, chest and both forearms and hands were affected, and dry gangrene had occurred in the fingers, which had a stiff black appearance.

In its anatomical details the skin presents characters which may be summarized as atrophy with chronic inflammation. The papillæ are mostly flattened, and the cutis thinner than normal, but it is composed of more homogeneous connective tissue than usual, having

somewhat the characters of cicatricial tissue, and less fibrous than that of the normal skin. This condition extends somewhat to the subcutaneous tissue where the fat is to a considerable extent atrophied, apparently by the encroachment of the connective tissue. The hairs are also atrophied in the affected areas, and there is said to be alopecia when the patches extend to the hairy scalp. The evidence of chronic inflammation is the existence of abundant nuclei in the altered skin. These are usually aggregated around the blood-vessels, but they are also seen around sebaceous glands and under the rete Malpighii.

It will be seen from the above that the changes here are to a great extent comparable to those which occur in muscle after destruction of its trophic centres; there is atrophy with chronic inflammation.

An endeavour has been made to associate this disease with stasis of lymph, and relate it to elephantiasis. Some also regard it as allied to leprosy. We have already seen that both elephantiasis and leprosy are diseases probably dependent on specific irritants, and that they are endemic in particular localities, whereas this is in no sense true in regard to scleroderma.

Allied to scleroderma in the general characters of the lesion in the skin is the condition commonly designated SCLEREMA NEONATORUM. In this disease the skin, usually of the lower extremities, is hard and swollen, so that movement of the limbs is curtailed. When it persists for some time the skin may be like parchment. In the earlier stages the skin is œdematous, while in the later there is thickening from new-formation of connective tissue. The disease occurs, as the name implies, in new-born children, being sometimes congenital. The children are weakly and usually die in a few days.

(4) BEDSORES.—Besides the ordinary bedsores which occur in persons who lie long in one position, especially when cleanliness is not attended to, there are some which are obviously related to nervous lesions. The ACUTE DECUBITUS is met with in connection with lesions of the spinal cord or brain, usually in severe cases, such as cerebral hæmorrhage or injury to the cord. The appearances presented in the skin are those of an acute phlegmonous inflammation with sloughing. At first there is simple œdema and hyperæmia, but vesication follows and deep ulceration. The sloughing may extend to the muscles, tendons, etc., sometimes laying bare the bones. These acute bedsores imply a grave lesion of the trophic fibres, and there are indications that these

follow the course of the sensory fibres. Bedsores have been observed, for instance, in unilateral lesions of the cord where there was paralysis of motion on one side and anæsthesia on the other; in that case the bedsores are on the anæsthetic side.

HYPERTROPHIES AND TUMOURS OF THE SKIN.

The CALLOSITY is an exaggeration of the horny epidermis occurring where the parts are exposed to unusual friction. It is a true hypertrophy, being a direct provision of nature to protect the true skin from the excessive friction to which it is exposed. The best example of the callosity is in the horny hands of workmen, but it is often seen in the feet, at points which are peculiarly exposed to pressure.

The CORN (CLAVUS) is closely related to the callosity. Here, also, there is friction, but it is associated with compression. It occurs chiefly in the foot where there is a concentric pressure from ill-fitting boots, and friction against either the boot or a neighbouring toe. There is, as in the former case, an excessive new-formation of horny epidermis, but, by the concentric pressure, the layers of epidermis have their directions changed, and growing against each other are projected inwards towards the cutis. There is thus an ingrowing kernel of hard horny epidermis which has given rise to the name of corn. The cutis is irritated and undergoes atrophy. Around the kernel the epidermis is always thickened, the condition being like that of the callosity.

ICHTHYOSIS.—This is a disease which apparently owes its origin to a congenital defect in the structure of the skin. The disease itself is sometimes manifest at birth, but if not it begins in the earlier years of life, gradually extends over the whole body, and continues during life.

It consists, anatomically, in an exaggeration of the horny layer of the epidermis, which is sometimes greatly thickened. The thickened horny layer forms scales of larger or smaller size, sometimes producing merely a furfuraceous exfoliation, but in more severe cases giving rise to large plates like fish scales. From this latter appearance the name of the disease is derived. The scales do not consist entirely of epidermis, but contain sebaceous material, which iss ometimes so abundant

as to give the scales a polished appearance like mother-of-pearl. The large scales may be fixed in their peripheral or middle parts, and project considerably at their edges, so as to give an imbricated appearance. The milder forms of the disease, in which there is little more than an excessive scaliness of the surface, are often included under the designation ICHTHYOSIS SIMPLEX or XERODERMA, while the more severe forms in which there are prominent scales are distinguished by the name ICHTHYOSIS CORNEA or ICHTHYOSIS HYSTRIX.

In the milder forms the cutis is not markedly affected, but in some cases the papillæ are greatly elongated. The substance of the corium is often atrophied, and the subcutaneous fat deficient.

The COMMON WART may be variously regarded either as a tumour or a hypertrophy of the skin. There are warts which have distinctly the characters of tumours, presenting specialities of structure and growth which entitle them to that designation. But the common wart, consisting for the most part of local exaggeration of the normal structures and occurring in numbers in the same person, has more doubtfully the characters which we ascribe to a morbid growth. A group of papillæ are elongated, and the epidermis over them thickened, so that the characters are those of a hard papilloma. The HORN is of similar structure to the wart, but the papillæ are usually more elongated, while the horny layer of the epidermis forms a more consistent mass which grows into a prominent outgrowth.

The TRUE KELOID is an elevation of the skin which has in its marginal parts branching processes extending out. There is evidently considerable contraction and dragging on the part of the central tumour and of the radiating processes, so that the skin is puckered around as in the case of a contracting cicatrix. The lesion has many of the characters of a definite tumour. It is composed in the fully developed state of dense connective tissue which may be unduly cellular. The new-formation has its seat in the deeper layers of the cutis, and it is stated that the papillary layer is intact. In the earlier stages it consists mainly of spindle cells, and Virchow therefore regarded it as a sarcoma. The analogy to the sarcomas is supported by the fact that the tumour recurs on removal. The most common site of keloid is the front or back of the chest, but it is found in other parts.

The name FALSE KELOID is sometimes used to designate a condition which occurs IN SCARS. A localized thickening, usually in the midst of

a large cicatrix, as from a burn or an ulcer, presents itself, and there are raised processes passing out from it as in the true keloid.

Soft warts and pigmented moles (*nævi pigmentosi*).—These are very often congenital, or they occur very early in life, and usually remain stationary throughout life. They are smaller or larger elevations of the skin, either colourless or pigmented, and frequently beset with hairs. They present a somewhat peculiar structure, especially considering that they exist unchanged for many years. They are covered by epidermis which shows little difference from the normal. But instead of the normal tissue of the cutis beneath the epidermis there are masses of cells separated by connective tissue. The cells in these nests are usually large and resemble epithelial cells or large sarcomatous cells. The presumption is that these structures are really survivals of the fœtal condition, and their importance in relation to tumours has already been referred to at p. 175. In their structure it will be observed that these warts are much more like tumours than the ordinary warts, and that their tissue conforms to that of the cellular tumours, probably the sarcomas.

Molluscum contagiosum.—This name is applied to little growths of the skin, occurring chiefly on the face and showing a preference for the eyelids, but sometimes extending so as to be almost universal over the body. It will be inferred that the growths are multiple. The individual ones have been compared to pearl buttons, which they resemble in their circular shape and central depression, but they are usually pink in colour. There is considerable elevation of the little growth, and, although generally sessile, it sometimes becomes pedunculated and may even drop off.

In the centre of the elevation a depression is visible which is the orifice of a sebaceous gland, and the tumour consists of an enlarged sebaceous gland. A section of the growth shows the exaggerated lobules of the gland, while within there is an irregular cavity containing white sebaceous material which sends prolongations into the gland lobules. The lobules of the gland consist of epithelium, the peripheral cells of which are cylindrical. In the midst of the sebaceous material are found peculiar glancing bodies compared to swollen starch granules.

The disease depends on some virus, and, as the name implies, it is contagious. It generally occurs in groups in the same person, as if spreading, and several members of the same family, or several persons

living together, are usually affected simultaneously. It is usually seen in children, but occurs also in adults.

FIBROMA MOLLUSCUM.—This condition is to be carefully distinguished from that just mentioned. We have here also multiple growths, but they are definite fibrous tumours having their seat of origin in the cutis. When small they may lie embedded in the cutis, but as they increase in size they become prominent and may finally assume a pendulous condition. They are sometimes present in enormous numbers, the individual growths varying in size from very small tumours up to those having even the bulk of a man's head.

The epidermis is usually unchanged on the surface of the tumour. The tumour consists of connective tissue in which there may be an excess of small spindle-shaped cells. To the naked eye all the characters of a hard fibroma are presented.

It appears from the observations of Recklinghausen that these multiple fibromas of the skin are often associated with multiple fibromas of the nerves. The structure in the two cases is the same, namely a soft connective tissue, rather more cellular than normal. The fibromas of the nerves are often described as neuromas, but as they contain no new-formed nerve-tissue they are false neuromas. From these observations there seems reason to suspect that the tumours in the skin have their origin in the nerves of the skin, and that they also are primarily false neuromas. Looking to this probable origin of these tumours they may perhaps, along with those of the nerves, be grouped as MULTIPLE NEUROFIBROMAS. In several cases of this kind a distinct hereditary tendency has been observed, and some of the tumours are often congenital.

ELEPHANTIASIS.—This condition has been already described at p. 181. It may be added here that a condition somewhat resembling elephantiasis and designated lymph-scrotum is sometimes brought about by obstruction of the lymphatics. There is dilatation of the lymphatics and formation of vesicles, and there may be, after a time, a thickening of the skin, but without the attacks of acute inflammation characteristic of elephantiasis. This condition (which has been named elephantiasis lymphangiectodes) is usually the result of the filaria in the lymphatics, and has already been referred to (see p. 296).

XANTHOMA, or XANTHELASMA.—This name is applied to slight

elevations of the skin of a yellowish colour. They occur mostly on the eyelids, where they appear as firm yellow patches, which are usually quite flat, but may be slightly tuberculated. They consist of firm connective tissue in which finely divided fat granules are abundantly present. The latter give the opaque yellow character to the lesion.

Of the remaining simple-tissue tumours, the LIPOMA is common, originating in the subcutaneous tissue. The MYXOMA is not infrequent, and the ENCHONDROMA and OSTEOMA very unusual. The ANGIOMA of the skin is common as the congenital nævus (see p. 199).

SARCOMA.—This form of tumour is of somewhat frequent occurrence, and we may have round-celled or spindle-celled growths, which sometimes assume considerable dimensions. We have already seen that sarcomas sometimes originate from soft warts or moles, and when they do so they frequently present a similar structure to that described above, namely masses of large round cells in a stroma. To this form the name ALVEOLAR SARCOMA is applicable. Sarcomas originating from moles are peculiarly apt to be pigmented.

Sarcomas rarely occur as secondary tumours in the skin, but a case is known to the author where multiple tumours composed of round-celled tissue formed at intervals in the subcutaneous tissue and some of them disappeared. These were either round-celled sarcomas or lympho-sarcomas.

CANCERS.—The EPITHELIOMA of the skin forms the majority of the flat-celled epitheliomas, and it has been already referred to at p. 224.

In the skin, two forms of epithelioma have been distinguished, one in which the cancer cylinders tend to penetrate deeply into subjacent structures, and the other in which there is rather a tendency to extend along the surface. The one form is sometimes called infiltrating cancer, the other flat cancer.

The infiltrating epithelial cancer has its most familiar seat in the lower lip. Beginning as a slight thickening, it gradually extends, producing a knotted, thick appearance. The surface ulcerates, and a scab forms. On making a section through such a tumour an appearance is presented as of a wart growing inwards, and the material of which it is composed has a brittle, crumbling appearance. Under the microscope, it is seen at the margin that the epidermis is growing downwards, the growing cells having the characters of those of the rete mucosum (see

Fig. 334). The growth is in cylinders, and as it progresses there seems to be a mutual pressure of the cylinders causing great compression of

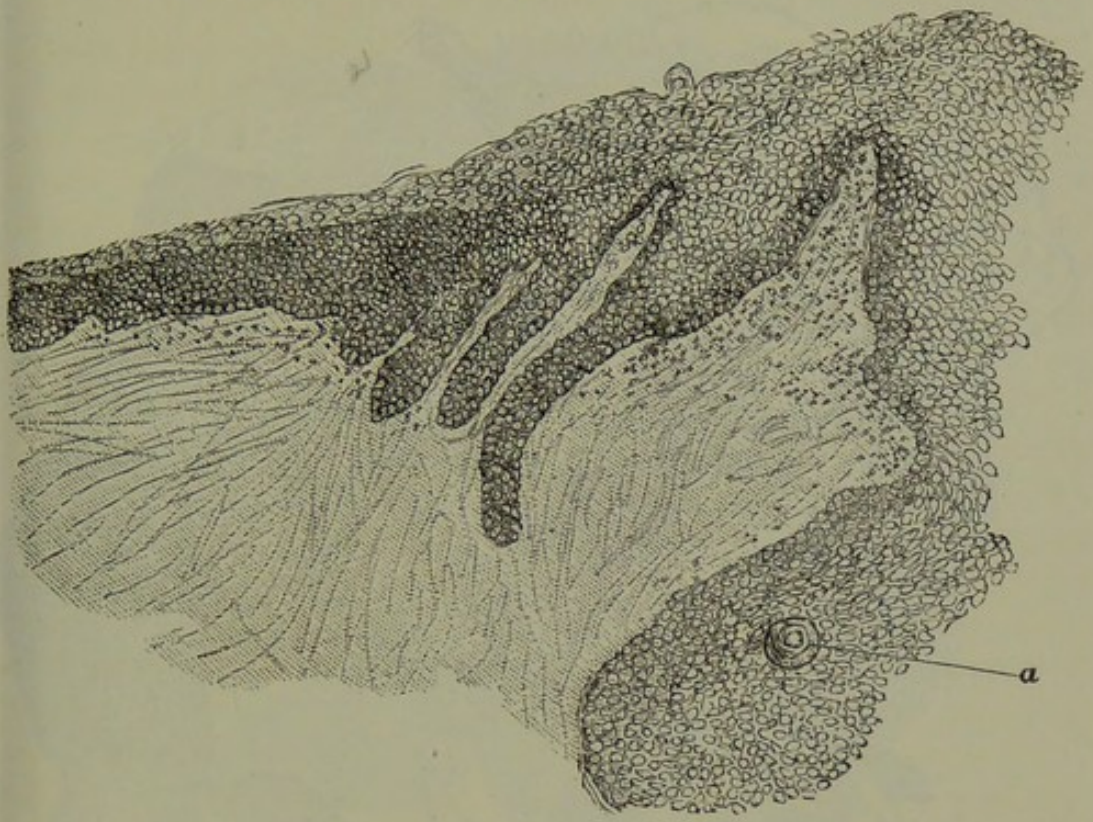

Fig. 334.—Section of an epithelioma at its marginal part. The epidermis is seen to be penetrating inwards into the cutis. At *a* a small laminated capsule is indicated. × 100.

the central cells. To this cause, and perhaps also to a tendency to degeneration on the part of the cells, is due the formation of the peculiar glistening epithelial globes, or laminated capsules, which are so prominent in many cases (Fig. 335). These globes consist of epidermic cells wrapped round a common centre, and when they are disintegrated the cells may retain their curved shapes. The epithelial cylinders may penetrate very deeply and usually cause great irritation, evidenced by the presence of round cells in the tissue, as in Fig. 336.

In the scrotum the cancer is very much as it is in the lips, having the infiltrating character. It is met with principally in chimney-sweepers, but also in Glasgow among workers in paraffin refineries. At the edges of the scrotal cancers there is often some enlargement of the papillæ.

In other parts of the skin it is generally the flat form which is met with. The epithelioma tends to spread laterally rather than deeply, so that it may come to cover a considerable surface, which is often circular in form, with raised warty-looking edges. On examining these edges

under the microscope it is often seen that there are series of elongated papillæ. The central parts are ulcerated, but even here there is an

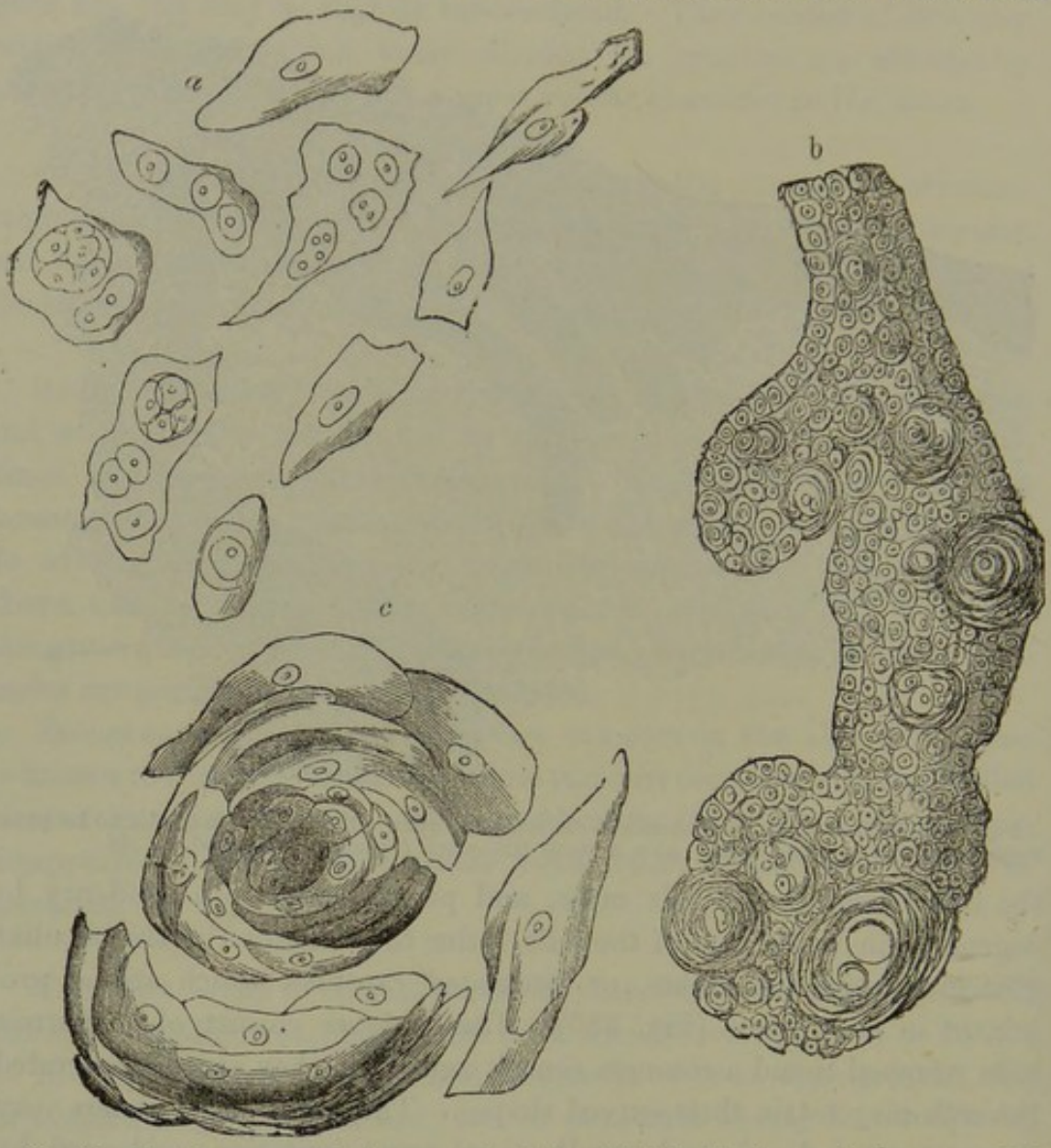

Fig. 335.—Parts from an epithelioma. *a*, isolated epithelial cells; *b*, a cylinder composed of epidermis, and with many laminated capsules; *c*, a laminated capsule opened out so as to show the cells composing it. From a fresh preparation with the addition of dilute acetic acid. × 400. (BILLROTH.)

appearance as if papillæ had been cut off at their bases. Sometimes these flat cancers appear to take origin in the sebaceous glands, and to grow rather by an exaggeration of them than of the surface epithelium. All flat cancers of the skin grow slowly, and sometimes they cicatrize in their central parts while slowly extending at their edges.

In the flat form ulceration very often overtakes to a large extent the new-formation, so that the lesion presents itself as an ulcer with infiltrated margins, and is often called RODENT ULCER. Sometimes healing

occurs in the central parts, a cicatrix forming, while the ulcer extends peripherally. At other times the ulcer goes on extending. In these



Fig. 336.—Portions of three cylinders of an epithelioma, embedded in round cells produced as a result of irritation of the cutis. × 200.

cases with the ulceration there is a great new-formation of inflammatory tissue, and this may greatly obscure the epithelial elements, which, however, are to be found in nests of large flat cells. The flat ulcerating form occurs mostly in old people, and does not usually lead to secondary tumours in the lymphatic glands. The rodent ulcer occurs on the face, especially on the eyelids and side of nose.

ORDINARY CANCER is of rare occurrence in the skin, but cases have been observed to which the names scirrhus and soft cancer have been given. PIGMENTED CANCERS are of occasional occurrence, and they are of importance on account of their tendency to form secondary tumours, first in the lymphatic glands and then throughout the body. They are, however, much less frequent than melanotic sarcomas with which they are apt to be confused.

PARASITIC DISEASES OF THE SKIN.

We have already seen that certain forms of inflammation are associated with the presence of micro-organisms, especially the infective inflammations. We saw also that leprosy depends on a specific bacillus. These do not require further treatment here.

FUNGI are present in three forms in the skin. It has already been indicated that many are of opinion that the same fungus is at the basis of all three forms, and that this fungus is the oidium lactis. But if this be the case it seems strange that the three varieties keep perfectly distinct, and when the diseases are communicated from person to person they do not interchange.

1. TINEA FAVOSA or FAVUS.—This is a disease chiefly of the hairy scalp, although it occurs on other parts of the skin and also in the nails. On the scalp it forms crusts which at first are isolated and about the size of split-peas. They are circular in shape, pale yellow in colour, and dimpled in the centre through which a hair or hairs generally pass. When removed the crusts are usually seen to be somewhat cup-shaped, the convexity of the cup being next the skin, the latter presenting a corresponding depression. If the cups be divided with a knife they are seen to have a porous appearance, the interstices being filled with air, and they are brittle, so that they can easily be broken down in water.

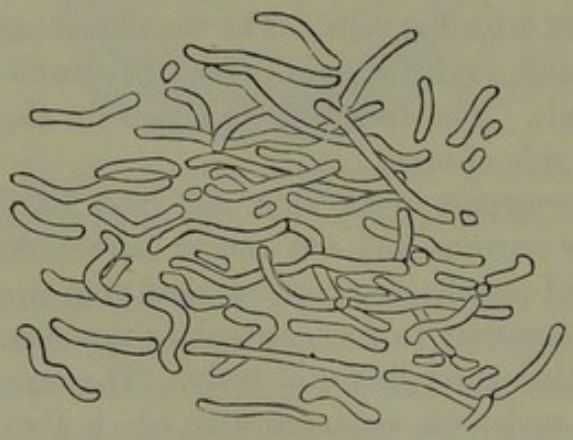

Fig. 337.—The fungus in favus. Short threads are shown. × 350.

The crusts are formed of fungus along with epidermic scales and their debris. The fungus is the ACHORION SCHOENLEINII, in the form for the most part of short tubes (Fig. 337) with rows of conidia spores. The proper mycelium is not jointed, but the receptacula are. The fungus appears to begin its growth in the hair follicles, enveloping the hair and passing into it. It also passes into the hair sheath and epi-

dermis around, separating the cells and destroying them. It has its seat thus in the first instance beneath the horny layer which may be continuous over it. It does not invade the true skin, but the crust may cause inflammation around it which may go on to suppuration and ulceration. As a rule, however, it only affects the epidermic structures, the hairs being largely destroyed where the crusts are developed.

When it attacks the nail, it forms a yellow crust, the tissue of the nail being opened out and softened by the fungus penetrating between the horny cells.

2. TINEA TONSURANS.—This is also a disease chiefly of the scalp, but

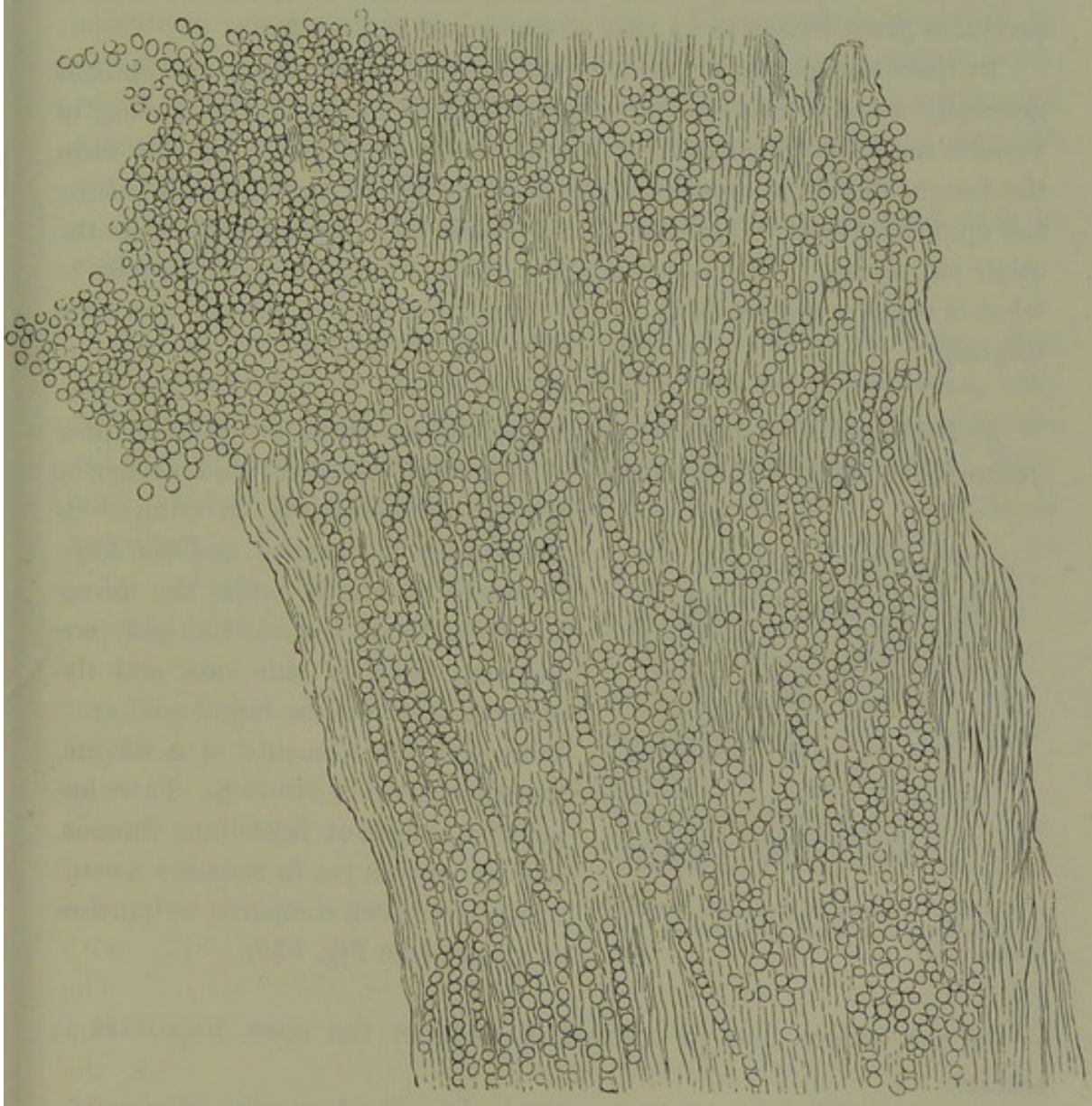

Fig. 338.—Hair from tinea tonsurans. The shaft is penetrated and broken up by spores. × 350.

the same fungus attacks the beard and the parts of the body devoid of hair. The disease is therefore divisible into three forms, TINEA TONSURANS PROPER, TINEA SYCOSIS, and TINEA MARGINATA.

In tinea tonsurans, or RINGWORM, there are circular patches on the scalp, in which the hairs are short and small, as if the hair had been badly cut. The fungus, called the TRICHOPHYTON TONSURANS, is here chiefly in the form of spores (see Fig. 338) which infiltrate the hair and its sheath, as well as, to a less extent, the epidermis around. The mycelium is only represented by short threads. The hair shaft is greatly penetrated by the spores, which break it up.

In tinea sycosis, or RINGWORM OF THE BEARD, the fungus is again chiefly in the form of spores in the hairs and hair-follicles, but here it produces great irritation so that pustules and papules form.

In tinea marginata, or RINGWORM OF THE BODY, there are patches generally more or less circular or crescentic in shape, and consisting of vesicles on a raised surface, or simply scaly elevations. In this form the fungus develops mycelium abundantly, whose threads pass among the epidermic cells. The spores are much less abundant than in the other two forms. The name ECZEMA MARGINATUM has been given to what is really a severe form of the condition which we are now considering.

3. PITYRIASIS VERSICOLOR.—In this disease there are patches of a yellowish or dark brown colour with a scaly surface, and occurring chiefly on the trunk in adults. If the surface be scraped and the scaly products examined under the microscope (best with the addition of liquor potassæ, both in this case and the others), there will be found epidermic cells with the elements of a fungus, the MICROSPORON FURFUR. There are usually abundant mycelium threads, and the spores are in rounded masses which have been compared to bunches of grapes (see Fig. 339).



Fig. 339.—Fungus in pityriasis versicolor. Threads are seen with groups of spores. × 500 (DUHRING.)

Of the lesions due to ANIMAL PARASITES the most important is scabies.

SCABIES.—This disease is characterized by the formation of papules,

vesicles, pustules and other signs of inflammation due to the effects of the ACARUS SCABIEI or SARCOPTES HOMINIS. The female of this insect penetrates into the substance of the epidermis. It forms a tunnel for itself as it penetrates, and in this it deposits ova and fæces, the latter in the form of brown granules. It usually passes through the horny layer into the rete Malpighii, sometimes approaching the surface of the papillæ. It opens up the epidermis and causes irritation, evidenced by intense itching.

The inflammatory conditions are the result partly of the irritation of the acarus and its embryoes, which, as they develop from the ova, begin to travel along the tunnels, and partly the effect of the scratching induced by the itching. The primary lesion is a papule on which a minute furrow is visible to the naked eye. The papule is produced by the opening up of the epidermis and swelling of the papillary layer, which is infiltrated with serous fluid and round cells. Vesicles and pustules are produced when the inflammation is more severe, and are met with chiefly in children and persons with delicate skins.

The ACARUS FOLLICULORUM is an insect sometimes met with in comedones.

The LARVÆ OF INSECTS are occasionally met with in the skin. The ova are deposited in the skin, and the larvæ having developed, may traverse the skin and subcutaneous tissue for a considerable distance till they present at some part and are squeezed out or extracted. They may produce considerable inflammations in the form of boils or swellings.

ADDENDUM.

ACTINOMYCOSIS.

THIS disease should have been considered under the heading of PARASITIC FUNGI, but was overlooked.

The disease occurs chiefly in cattle, and occasionally in pigs, but it has been met with in a certain number of cases in man. It depends on the existence of a fungus whose exact botanical position is unknown. The fungus is in the form of short threads which are clubbed at their extremities. These threads, which are perhaps conidia, are arranged in a radiating fashion, many springing from a common centre, with their clubbed extremities outwards. They thus form peculiar radiating groups of a globular or oval form, which, being made up of club- or wedge-shaped pieces, present a peculiar glandular or knobbed surface, like that of a mulberry. The club-shaped fibres are united in the centre by a matted mass of fibres, which may be the mycelium. It is from these radiating structures that the fungus has received its name of Ray-fungus or Actinomyces (ἀκτίς, a ray), and the disease that of Actinomycosis.

The radiating clumps are individually of very small size, like grains of dust, but they are usually united into larger masses as the heads in a cauliflower (Ponfick). These larger masses are the characteristic indications of the disease, appearing to the naked eye as yellow sulphur-coloured granules in the midst of the structures about to be described.

The disease was first described and named by Bollinger in 1877, he having distinguished it in cattle, in which it seems somewhat common in certain localities. Its occurrence in the human subject has been established, chiefly by the observations of Israel and Ponfick.

In cattle it mostly appears as a tumour-like swelling of the jaw, most commonly the lower jaw. It grows outwards to considerable dimensions, forming a simple or lobulated tumour. After a time the skin gives way, and a prominent projecting mass protrudes, which discharges a thick pus with pieces of slough. In this discharge are visible little sulphur-yellow granules, which are somewhat firm in consistence, and have a greasy feeling. These are the fungus masses already described. The new-formation may extend from the jaw to the tongue, pharynx, larynx, œsophagus, stomach, and intestinal wall.

The disease is communicable by inoculation from one animal to another. The rabbit and dog seem to be incapable of inoculation, but cattle are highly susceptible. It may be produced by inoculation into the subcutaneous or intermuscular tissue, and produces its effects in a very striking manner when inoculated into the peritoneal cavity. When introduced into the blood it produces typical new-formations in the lungs.

In man the disease is induced apparently by accidental inoculation, usually by a wound in the mucous membrane of the mouth (as from extraction of a tooth) or pharynx, but possibly by a wound in the skin. When so induced it produces swellings, as in cattle, but these do not usually grow to such bulky tumours, as they break down more readily so as to form abscess-like cavities which open externally and give rise to fistulæ. The disease may remain local, affecting, it may be, the jaws and surrounding parts. On the other hand, it may extend slowly till it involves the bodies of the vertebræ or the pleura. In such cases the introduction is probably by the pharynx. In these internal parts it produces a slow inflammatory process with exuberant granulations and chronic suppuration. When it affects the vertebræ, which it seems to do with peculiar frequency, these become carious, and a chronic abscess forms which may gradually extend to the surface and open in the lumbar region or the groin. In these cases the person becomes slowly emaciated, and dies after months or years from exhaustion, sometimes with amyloid disease. In some cases there has been a metastasis, so that abscess-like formations have occurred in various organs, and the case has been like one of pyæmia. In all these situations the sulphur-yellow granules are found, and they are to be recognized in the pus of the abscesses, etc.

Looking more closely to the anatomical details in this disease, it is clear that we have to do with a specific irritant. The most direct effect of the action of this irritant is the formation of granulation tissue. In

cattle this is so abundant that a bulky tumour is produced, which, from its structure, might be taken for a round-celled sarcoma. In man the granulation tissue is not so exuberant, although produced abundantly, and when the abscesses find their way to the surface the granulations pout at the opening like those of a sinus leading from a scrofulous joint. Looking to this great new-formation of granulation tissue and to its tendency to break down, Ponfick has suggested that the disease should be placed among the INFECTIVE TUMOURS. The granulation tissue here resembles that in the infective tumours, not only in its exuberance and tendency to break down, but also in its tendency to form connective tissue in an irregular way. In the midst of the masses of granulations there may be strands of coarse connective tissue.

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