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ANIMAL PHYSIOLOGY:

THE

STRUCTURE AND FUNCTIONS

OF THE

HUMAN BODY.

BY

JOHN CLELAND, M.D., F.R.S.,
PROFESSOR OF ANATOMY AND PHYSIOLOGY IN GLASGOW UNIVERSITY.

WITH 158 ENGRAVINGS.



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PREFACE.

THE principal object of this book is to supply to readers previously unacquainted with anatomical details as complete an account as possible of the functions of the body. In doing this, the author has kept constantly in view the desire of the Publishers to supply the information required for the Advanced Course of the Directory of the Science and Art Department; and at the same time has sought to furnish to the junior student of medicine a compendium of physiology which may assist him in obtaining a clear idea of the principles of the science, and prepare him for the perusal of works of more elaborate character.

Necessarily such a book is, to some extent, a compilation; but it is hoped that, in grouping of facts, and in directing the reader's mind to just conceptions and conclusions, this manual may be found to be something more than a mere collection of details.

With a few exceptions, the Illustrations have been engraved from pencil sketches, the majority of them original, and others taken from sources which are acknowledged; and the author takes this opportunity of thanking the Engraver, Mr. STEPHEN MILLER, of Glasgow, for the care which he has bestowed on them.

J. C.

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ANIMAL PHYSIOLOGY.

CHAPTER I.

INTRODUCTION—FUNCTIONS OF ANIMALS—NUCLEATED CORPUSCLES.

1. The world around us is divisible into the organic and inorganic worlds; the organic world including all bodies which either are or have been alive, and the inorganic comprising all others.

Physiology is the study of the healthy operations which take place in living beings; and when the word is used without qualification, it is customary to consider that special reference to the physiology of the human body is intended: still, in its widest signification, it refers to all living beings, both animal and vegetable.

It is a science which goes hand in hand with **Anatomy**, the study of the structure of living beings; for, as is the case with an artificial mechanism, so also with the body, an acquaintance with its structure is required to explain the way in which it works.

Anatomy and physiology are not, however, co-extensive. On the one hand, there is much physiology which has little apparent connection with anatomy; and, on the other, in the present state of science, there is much anatomy which can be studied without special reference to physiology. In fact, when the anatomist rises above the mere description of the particular objects before him, he examines structures from two points of view, one of which is the physiological, and has regard to their fitness to serve some purpose useful to the being to which they belong, while the other is called the *morphological* view, and looks to the structural affinities of

parts in the same or in different species; for example, the relations of the human limbs one to the other and to those of other animals.

There is one department of observation in which the studies of the anatomist and physiologist become identical, namely, **Development**; in it series of forms are met with, important as such to the anatomist, even in a strictly morphological respect, while by the physiologist they are viewed as phenomena of action of the most remarkable kind, peculiar to living beings.

When physiological investigation diverges from anatomy, it comes into close connection with other branches of science. For not only have living bodies a structure, but they consist of components subject to the laws which govern matter in the inorganic world. Thus the body consists of chemical constituents, and many of the processes taking place within it are of a chemical nature. Its materials are also subject to the ordinary laws of physics: scattered through it are varieties of mechanical appliances; special parts are set aside for optical and acoustic purposes; and others exhibit electrical phenomena of a very remarkable description. The study of physiology is therefore very dependent on both chemistry and physics. Its connection, however, with these subjects is of a different nature from its connection with anatomy; for anatomy and physiology are two closely associated departments of **Biology**, or the science of life; while the bond which joins biology to chemistry and physics is simply this, that living bodies, being composed of matter, are subject to the laws of matter, besides exhibiting additional laws peculiar to themselves and termed *vital*.

In the following pages attention will be principally directed to human physiology, but occasional reference will be made to peculiarities of function in other animals; and while matters which are peculiar to man will be pointed out, it will become apparent that all the larger facts of function, as well as structure, are common to man and other animals. Indeed, our knowledge of human physiology is largely dependent on experiments on dogs, rabbits, horses, birds, and even frogs. It will also be our business to enter into various anatomical details, to give the student a knowledge of the

structures principally implicated in the physiological processes to be explained; and, in particular, it will be necessary to describe the *textures* or *tissues* of the different parts, which in great measure require the aid of the microscope for their examination. This is the department of anatomy termed **Histology.**

2. Living bodies are termed **Organisms**, because they are composed of **organs**, or parts devoted to different purposes; and the purpose to which any organ is devoted is called its **function.**

Organs are of various degrees of complexity. In organisms of the higher or more complicated description, bodies comparable with organisms of a very simple or rudimentary kind exist as *textural elements.* Such textural elements enter into the formation of more complex *textural organs* (*e.g.*, arteries in animals, and vascular bundles in plants), which are distributed as component parts of a variety of *special organs*, such as eye, ear, liver, brain, etc., often the only parts alluded to when the term special organ is used.

3. All organisms are in great part composed, particularly their more active portions, of chemical combinations of a complex kind, called **organic matter**, together with which there are always, in addition, various mineral constituents and water entering into their composition. The most distinctive character of organic matter is that it is combustible, becoming black when heated over a flame; and, as this blackness is due to carbon, it disappears on further exposure to heat and air, leaving the ash or non-volatile mineral constituents which are always associated with organic matter.

Organic matter is divisible into two groups of substances, which are distinguished as *nitrogenous*, and *non-nitrogenous* or *carbonaceous;* the first containing carbon, hydrogen, oxygen, and nitrogen, and the second having no nitrogen in their constitution. The products of the complete combustion of carbonaceous matters are carbonic acid and water, while nitrogenous substances yield ammonia in addition.

The attraction of both carbon and hydrogen for oxygen is very great. Carbonic acid, consisting of one equivalent or combining proportion of carbon and two of oxygen, is the compound which is formed when carbon is freely exposed to

oxygen at a high temperature; and, when oxygen and hydrogen gases are mixed, and a light applied to them, they combine with explosion, producing water, which consists of two equivalents of hydrogen and one of oxygen. Ammonia consists of one of nitrogen and three of hydrogen; and, in the complete combustion of organic matter, this hydrogen may be obtained partly from the organic matter itself, and partly from water, the oxygen of which is used in the formation of carbonic acid. In less perfect combustion, cyanogen in a state of combination may be evolved instead of ammonia, by the nitrogen of the organic matter combining with part of the carbon, in the proportion of one equivalent of carbon to one of nitrogen.

The combustibility of organic matter depends on its contained oxygen being less than sufficient to combine with its carbon and hydrogen to form carbonic acid and water, and on the complexity of its molecules. While substances found native in the inorganic world consist of elements grouped in pairs, in which the number of equivalents of the one substance bears a simple proportion to the equivalents of the other, organic substances present groups of three, four, or more elements gathered together in common union, with many equivalents of each combined in one molecule, often in proportions by no means simple; and more especially are the molecules of the nitrogenous constituents of the textures complex.

The oxidation of organic matters may take place by other means besides a burning heat. Thus it occurs in the form of putrefaction at much lower temperatures, especially when aided by abundant moisture. So also, oxidation of organic matter and the resolution thereof either into carbonic acid, water, and ammonia, or into products of less complete decomposition, take place in the interior of organisms during life, and are sometimes alluded to under the name of combustion.

4. The organic world is divisible into two kingdoms, the animal and the vegetable. The power of building up the complex molecules of organic matter from the separate elements, or such simple combinations as carbonic acid, water, and ammonia, is peculiar to vegetables, while intelli-

gence is confined to animals. All vegetables, however, do not possess the building power; it is apparently a property belonging exclusively to green parts: and all animals do not possess intelligence; but, on the contrary, it may be assumed to be entirely absent from the lowest forms, while it appears in obscure and gradual dawnings in others.

In the region of the minute and simple beginnings of life, the animal and vegetable kingdoms touch one another, and there may even be a common territory including beings which have no claim to be classed in one rather than the other. But, growth and reproduction being the highest functions of vegetable life, while intelligence is the highest aim exhibited in the animal series, vegetable and animal forms rapidly diverge as they become complex, so that those of a highly developed description in the one kingdom cease to have any resemblance to those of the other.

5. **The functions of animals** may be enumerated as nutrition, reproduction, sensory functions, and movement. The first two of these, being equally characteristic of animals and vegetables, are sometimes termed functions of *organic life;* while those varieties of the other two which constitute sensation and voluntary movement are distinguished as the functions of *animal life.* In all, except the very simplest and minutest creatures, special parts or groups of organs are devoted to each of these different functions; while, in addition, there is a large amount of structure, whose office is to give protection or mechanical support to the rest of the body.

Nutrition includes the various processes necessary for the growth of the body and the maintenance of its substance. Every living part of every living being undergoes change in the particles of which it is composed, attracting and assimilating to itself materials around it, and parting with others which undergo decomposition; and these processes of waste and repair are in proportion to the activity of the part, every manifestation of life being accompanied with chemical and other changes. Thus a living being is a vortex, the particles of which are continually changing, while the form continues; and vital energy is a force correlative with mechanical, chemical, and other forces found in the inorganic world.

It follows from this that every part of a complex body, like that of man, requires a supply of nourishment to be brought to it, and a channel of escape for waste products; and to meet these requirements there are many different organs. The immediate source of nourishment of all the tissues is the blood, but to recruit the supply of this fluid new materials have constantly to be taken in; and to fulfil this end, the alimentary canal receives the food and digests it, that is to say, reduces the newly received materials to such a condition that they can be taken up by processes of absorption from the cavity of the canal, and carried to the blood. To complete the elaboration of the blood, and free it from impurities constantly resulting from waste, a variety of organs are engaged, of which the principal are the lungs, spleen, liver, kidneys, and skin. Lastly, to convey the blood to and from the tissues which it nourishes and the organs in which it is purified, a system of ramifying vessels is required, and a heart with muscular force sufficient to propel the blood through them.

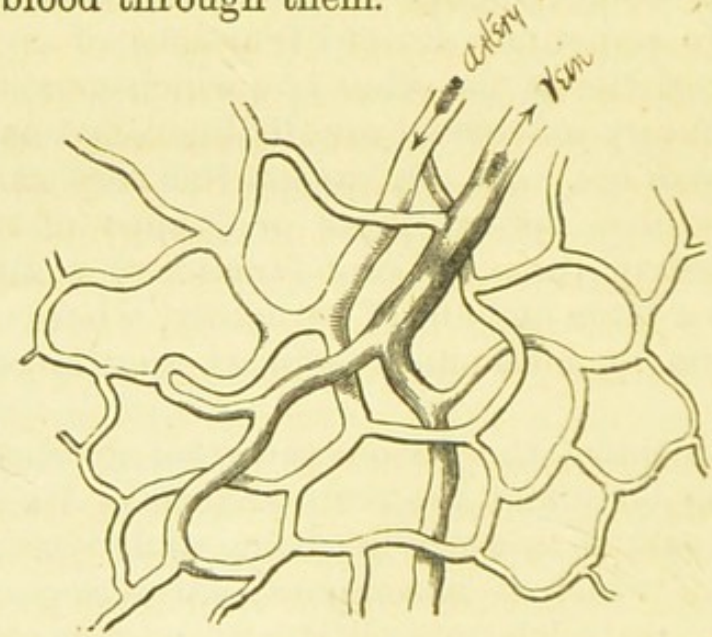


Fig. 1.—Diagram of Capillary Network, with termination of an Artery and commencement of a Vein.

It may be here mentioned that the system of blood-vessels is completely closed in all vertebrate animals, the blood being distributed from the heart by arteries, circulating through the tissues in a network of minute vessels called capillaries, and returning to the heart by veins. But the

capillaries, which have an average diameter of only $\frac{1}{2000}$ of an inch, have walls of extreme tenuity, which allow, with the utmost freedom, the transition of materials outwards and inwards between them and the surrounding textures.

Reproduction is the function by means of which new individuals are developed from portions of pre-existing living beings; and, although it is not generally so diffused throughout the body as the function of nutrition, but is delegated to special parts, yet it may be remarked that in many low forms of animal life, and some even of the higher vegetable forms, a large amount of reproductive power pervades the entire organism. Also, in the higher animals there exists an ill-understood connection between the reproductive organs and the nutrition of the body generally, which is of a two-fold description; the nutrition of the body being importantly modified by the condition of these parts, and the minute peculiarities of all parts of the body being capable of transmission to the offspring.

Sensation is a psychical, and not a physical condition; but it is associated and bound up with changes in the body, the seat of which is the nervous system. The mind is not influenced by external objects, save when these irritate nerves or organs of sense into a state of activity, and the active condition, travelling along nerve-trunks, reaches the part of the brain with which the mind is specially and inscrutably linked. And not only is an active condition of the brain necessary to influence the intelligence by external objects, but a like active condition accompanies all emotion and every operation of the mind.

Movement of a voluntary description is accomplished by muscles receiving, through nerves, their stimulus to action from the brain, which in turn is stimulated in an unknown way by the will. Thus, the central nervous system is both the terminus to which messages from the organs of sense are sent, and that from which commands to the voluntary muscles proceed.

All sensory function, however, is not sensation, and all movement is not voluntary. The nervous system may receive an influence from without, and transmit it to groups of muscles, without intervention of any act of consciousness.

This is what is called *reflex action* (p.178), and in such a case the part irritated, from which the nervous impulse starts, is still said to have *sensibility*, and the nerve to be sensory, although there is no sensation, and the movement is involuntary. Also, the property of response to irritation is not confined to the nervous system; structures may alter their shape or undergo other change on application of a stimulus, and this property is termed *irritability*. The active part of change of shape or movement probably in all cases consists in contraction, and is hence called *contractility*.

Irritability and contractility, although they may well be included under the terms sensory function and movement, are not, like sensation and voluntary movement, confined to animals. They are found in the vegetable world also; and it may be maintained with probability, that they are properties of every living part of every living being.

6. The expression **living parts of living beings,** has been already twice used, and will attract the student's attention to the fact that every part of the texture of the body does not equally exhibit the phenomena of life. In a large majority of the different textures, a considerable or even the greater part of the bulk is composed of mere deposited matter, which, although it undergoes both structural and chemical changes, offers no sufficient evidence of the possession of properties peculiar to living beings; but, imbedded in this, or in other instances forming the principal mass of the texture, there is always to be found a set of elements which exhibit some or all of the four functions—nutrition, reproduction, contractility, and irritability.

These living elements of texture always consist of material belonging to one chemical group of substances; namely, those which are termed sometimes the **proteids,** but which may probably be more conveniently distinguished as the **albuminoids,** albumen and fibrin being among the most familiar examples of them. The substances of this group are the most complex combinations of carbon, hydrogen, oxygen, and nitrogen; and, as they are found in nature, contain also phosphorus, sulphur, potash, and soda.

Very frequently the expression **protoplasm** is used to in-

dicate, without much definition, the varieties of albuminoid substance found in the growing stages of the living elements of texture, and in the lowest forms of life.

The generalization has been long known, and may be safely made, that the phenomena of life are never exhibited without the presence of albuminoid substance.

The simplest form of living element in both animal and vegetable texture, or at least one of the simplest forms, and the most important, is the *nucleated corpuscle*, which is remarkable not only for the remarkable part which it plays, but for its resemblance to some of the simplest kinds of animals, the genus Amœba.



Fig. 2.—Species of Amœba. After Pritchard.

7. **Amœba** is the name of a family of animals which are microscopically minute, and inhabit both salt and fresh water. They consist of a mass of protoplasm unlimited by any envelope, containing granules, and usually a clear, rounded, firmer body, the *nucleus*, with a still denser speck in its interior, the *nucleolus*. This mass of protoplasm moves about by throwing out temporary processes in different directions, and changing its form by virtue of its contractility. In fact, the powers of assimilation, reproduction, irritability, and contractility, appear all to be present in one common mass. There are other families in which such a mass as constitutes the amœba is surrounded by a membranous covering or a hard shell.

8. **The Nucleated Corpuscles** found in the textures of the higher animals present many varieties of appearance, but in their young and active condition they have this much resemblance to amœba, that they present a mass of protoplasm with one or more nuclei, which may contain nucleoli. Some are surrounded with a membranous envelope, others have none, and with regard to a great number of them it is extremely difficult to say whether they have a membrane round them

or not. The membrane, when present, is called a *cell-wall*, and the structure of which it is the limit is a *nucleated cell;* and in consequence of the circumstance that the mass of protoplasm was the last part of the corpuscle to have due attention attracted to it, and that the outline of the corpuscle was often mistaken for a membrane, even when no membrane existed, the importance of the cell-wall was formerly overestimated, and the word cell is even yet often used to indicate structures without a cell-wall, which are better designated as corpuscles. The cell-wall is probably in all instances a deposit round a pre-existing corpuscle.

At an early period of embryonic existence, the body may be said to consist entirely of nucleated corpuscles; and even after birth, the younger the animal the more abundant are these elements in the textures, and the more easily exhibited under the microscope. They are found in numbers wherever there is much growth; and in rapidly increasing tumours they exist in greatest plenty. They are also the germs from which the more complex elements of texture take origin. Thus nerves and voluntary muscular fibres originate by metamorphosis of nucleated corpuscles, which, in becoming more highly developed, lose the reproductive power, while they gain, in the one case, nervous activity, and in the other greatly increased contractility. Both of these tissues in early development present long bands of albuminoid substance, with a row of nuclei in each.

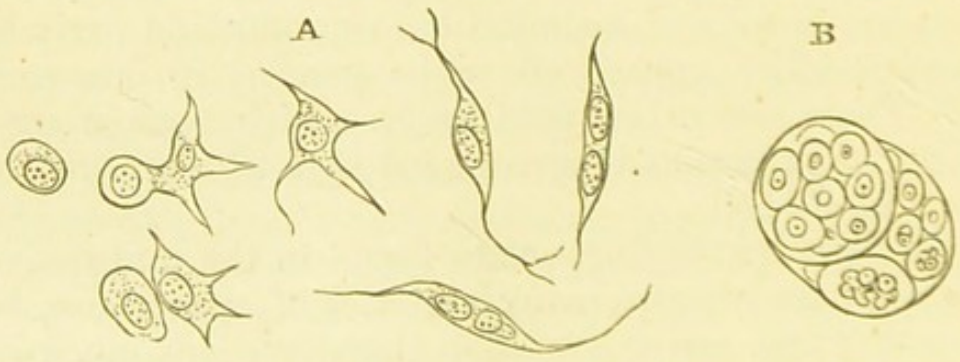


Fig. 3.—Multiplication of Nucleated Corpuscles. A, Corpuscles from connective tissue of a fœtal lamb, some of them dividing. B, Endogenous multiplication within a brood cell from a tumour.

Nucleated corpuscles multiply by division, which is termed *fissiparous* when the parts into which they divide are of

similar magnitude, *gemmiparous* when buds are separated from a parent mass, as occurs frequently in vegetables. When a corpuscle divides within a cell-wall, which remains unruptured, the process of multiplication is called *endogenous*. The nucleus seems to play an important part in the multiplication of corpuscles, being, at least in many instances, the first part to divide.

At present the weight of evidence appears to be in favour of every corpuscle being derived from a parent. Certain physiologists hold a contrary opinion; but there is no well determined instance of these structures originating otherwise within the body.

The varieties of nucleated corpuscles found in different situations will come under notice in the description of the individual textures.

CHAPTER II.

THE CONNECTIVE TISSUES.

9. The most widely distributed texture in the body is that which is termed connective tissue. It is the substance which connects the integument everywhere with the deeper structures, and it makes partitions between these structures and between the elements of which they are composed. Thus every muscle has a filmy sheath, which, when separated, is seen to consist of a felted white substance, sending in processes into the muscle, dividing its substance into bundles, and these into still smaller bundles by finer investments. The same substance separates the bundles of every nerve, and surrounds the blood-vessels; it is found in great quantity among fat and beneath the integument, and it forms in fact a continuous web in which all the structures throughout the body are imbedded.

This tissue, looked at with the microscope, exhibits two elements: first, a matrix, which, in those places where it is most closely mixed up with other textures, is often homogeneous or nearly so, but which, in the denser specimens obtained from distinct masses, assumes the appearance of extremely fine fibres of indefinite length, disposed in irregular felted fashion, leaving spaces, from which the tissue gets the name *areolar;* secondly, nucleated corpuscles, called in this instance connective-tissue-corpuscles.

A drop of dilute acetic acid added to the specimen under the microscope, causes the fibres of the matrix to swell up and become indistinct, bringing the nuclei of the corpuscles clearly into view, and also a variable admixture of isolated fibres on which the acid has no effect. The fibres on which acetic acid has no action are called *elastic* fibres, and will be further referred to; those which are swollen up by the acid are called

white fibres, and constitute the bulk of all white fibrous tissue. White fibres become completely dissolved by prolonged boiling, being converted into *gelatin*, a nitrogenous

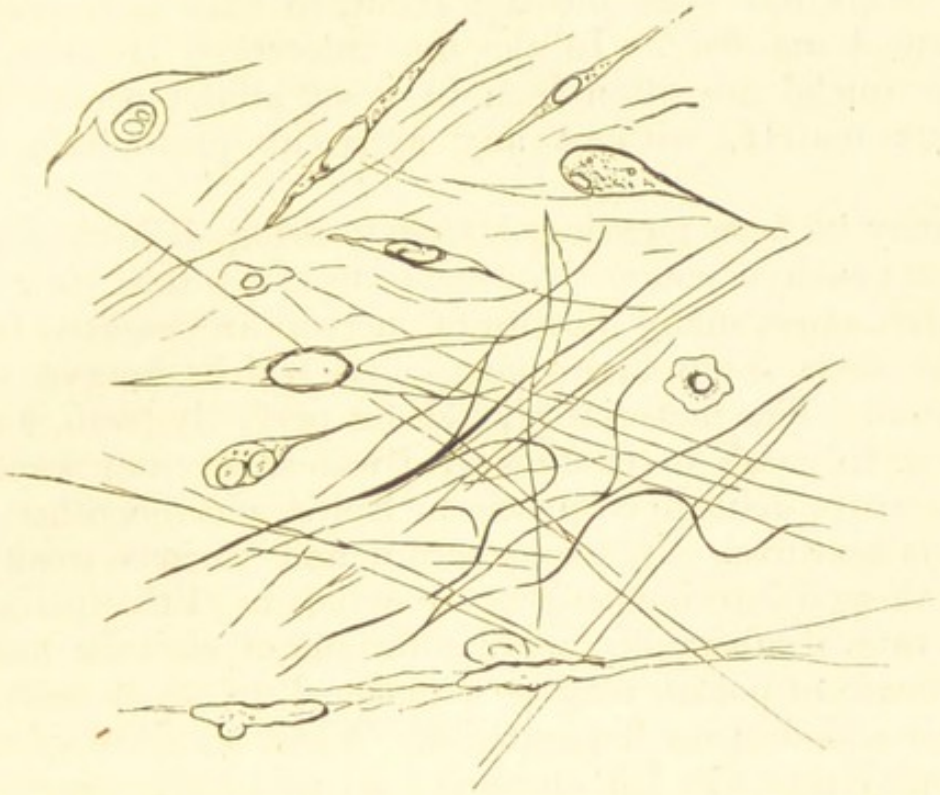


Fig. 4.—CONNECTIVE TISSUE FROM THE ORBIT OF THE OX, exhibiting corpuscles of various shapes, felted white fibres, and a few slightly curled elastic fibres.

substance of simpler chemical constitution than the albuminoids, and characterized by dissolving in hot water and forming a jelly on cooling. Albuminoid textures, on the contrary, are coagulated by boiling; and thus it is that when meat is boiled, the flesh or muscular fibre is hardened, while the connective tissue between the muscular fibres is softened and ultimately dissolved. This cannot be illustrated better than by comparing a raw fish with one which has been cooked. In the raw fish the semi-transparent and comparatively soft segments of muscle are united by firm septa, tough and strong; in the cooked state they are opaque and hard, but fall separate, because the septa dissolve into gelatin.

The *connective-tissue-corpuscles*, being of albuminoid substance, resist boiling, and their examination is sometimes facilitated by that means. They often present a stellate appearance, sending out branches or processes in different

directions. In the web of the frog's foot, and in other transparent textures capable of being examined microscopically in living animals, they have been seen not only changing their shape but even moving about, so that they may well be termed *amœboid*. In the fine interstices between other tissues, nuclei are often seen in great abundance in homogeneous matrix, without any apparent protoplasm about them.

It may be here mentioned, that to bring delicate textural elements such as connective-tissue-corpuscles into view under the microscope, many niceties of method are resorted to, and among these there are some points which deserve special attention. The material should be perfectly fresh, and not allowed to come in contact with water, as water swells up and destroys delicate corpuscles. Spirit, on the other hand, shrivels textures. By using serum and various weak solutions, these deleterious effects are avoided. Principal among preservative substances, weak solutions of chromic acid and bichromate of potash may be mentioned, to which spirit may be daily added in small quantities. Water added to specimens previously treated with chromic acid no longer destroys the corpuscles. In examining nucleated corpuscles, staining with an ammoniacal solution of carmine is often of the greatest service: the specimen should be washed after being stained, and should then be put up for the microscope in glycerine. Very often the beauty of the specimen is greatly increased by addition, after glycerine, of a little nitric acid. This must, however, be carefully washed away again, before it has had time to destroy the carmine staining.

10. White Fibrous Tissue.—The term connective tissue is a very general one, and the varieties to which we have already referred are the homogeneous and areolar; but there are others which are more markedly fibrous, and constitute the group of white fibrous tissues, namely, fascia, aponeurosis, tendon, and ligament.

Fascia is the name given to strong, felted arrangements of white fibrous tissue spread out in sheets. An *aponeurosis* is a sheet of white fibrous tissue arranged in parallel fasciculi, or in two or more sets of decussating fasciculi, and having in consequence a shining appearance. *Tendon* is white fibrous

tissue used for the attachment of muscles, and may either be arranged in the form of aponeurosis or in solid bands; it has a satin-like lustre of considerable brilliancy. When tendons rupture during life, they snap straight across. *Ligament* is white fibrous tissue used for binding bones together; it is not so lustrous as tendon; and when it gives way, which is very seldom, it does not snap but tears. In all these fasciculated forms of connective tissue, the corpuscles are elongated, and lie in the direction of the fibres. In tendon they are flattened, and have been seen in specimens from young animals to lie in sheets between bundles of the fibrous substance. Tendon and ligament are quite inextensible, and all white fibrous tissue, even when by injury to its texture it is gradually stretched, is destitute of resiliency.

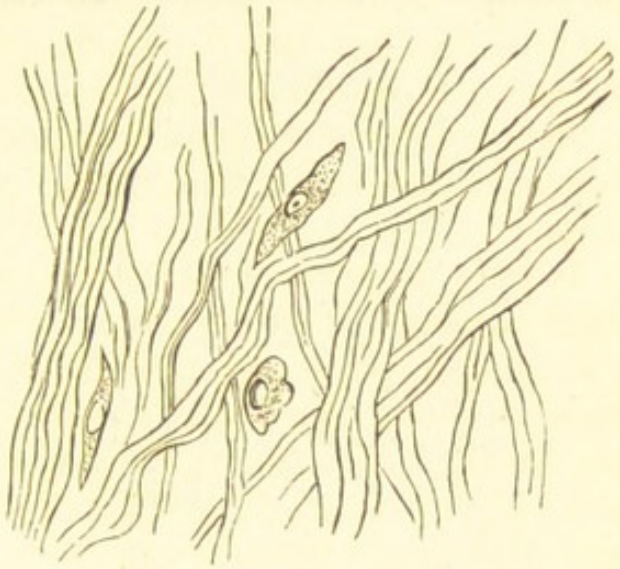


Fig. 5.—APONEUROSIS, human.

11. Elastic Tissue occurs both in the form of fibres and thin homogeneous membranes. It gets its name from being highly extensible and resilient, and is most widely distributed in the fibrous form. In the human subject there is only one set of ligaments which consist of nearly pure elastic tissue, namely, the ligamenta subflava, which join together the arches of the vertebræ, and get their name from the yellow colour peculiar to elastic fibres. They facilitate, by their resiliency, the resumption of the erect posture when the back has been bent forward. In quadrupeds two other notable instances of pure elastic tissue may be mentioned. One is the ligamentum nuchæ, a strong band extending from the back of the skull, and attaching it to the withers or dorsal spines; the other is in the form of an aponeurosis, which lies on the abdominal wall, and aids the support of the viscera. On examining fibres from any of these sources, it is seen that they may be of considerable breadth, that loosened

from their attachments and teased out they curl up at the ends, that they refract light very strongly, and that they are unaltered by acetic acid. Elastic tissue is not easily altered

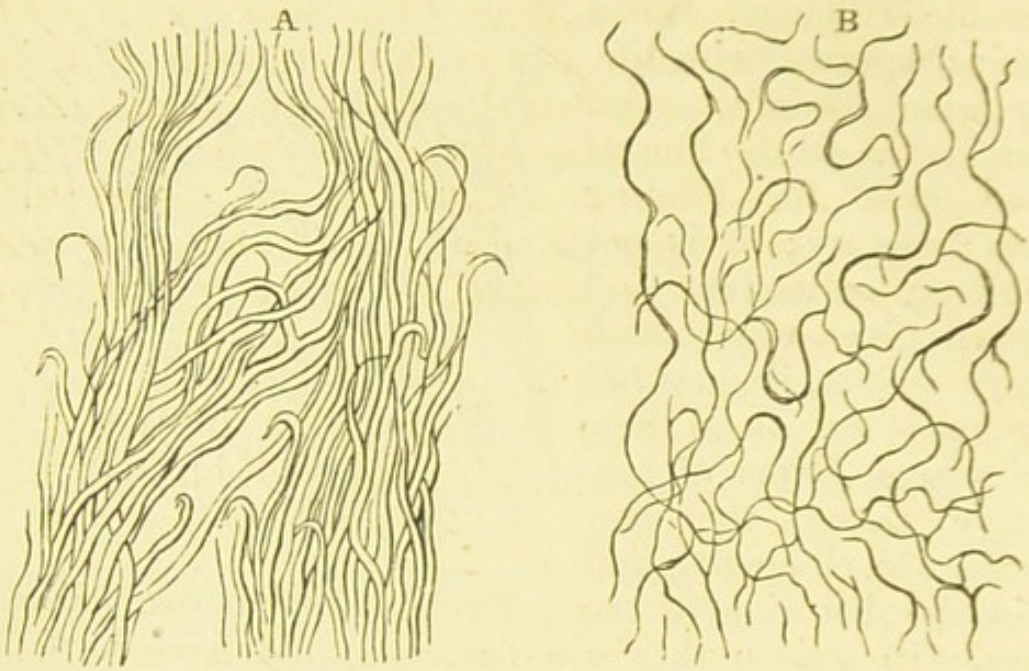


Fig. 6.—Elastic Tissue. A, From ligamentum nuchæ of sheep. B, From pleural surface of lung.

by even prolonged boiling, and yields no gelatin. In many places, as, for example, underneath the pleura, isolated elastic fibres are exceedingly abundant, of great length, curling naturally, and crossing one another in all directions.

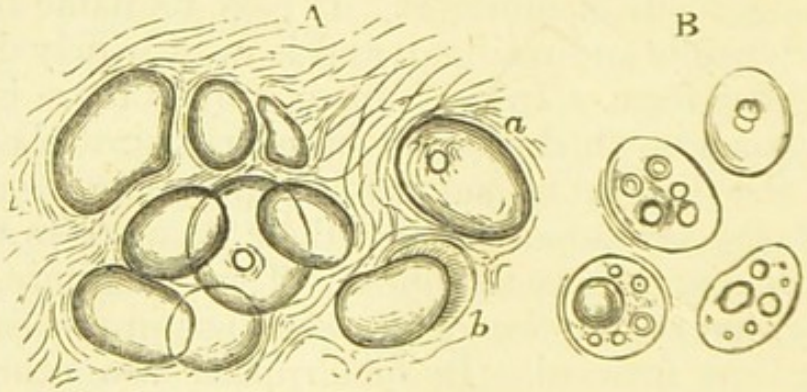


Fig. 7.—Adipose Tissue. A, The usual appearance of fat-cells, *a*, shows a nucleus on the side of a fat-cell; *b*, cell filled partly with water, partly with oil. B, Scheme of the mode of accumulation of oil in young fat-cells.

12. Adipose Tissue is the term technically used for the fat of the body, because fat in its proper acceptation means a solid oil, such as tallow. Adipose tissue consists of a number

of minute vesicles, varying in diameter up to $\frac{1}{200}$ of an inch, filled with oil, and imbedded in groups in connective tissue. Sometimes a nucleus can be detected at the side of the vesicle. The mode of development appears to be that one or more minute globules of oil occur at first in the interior of a connective-tissue-corpuscle, and that the oil goes on accumulating, pushing before it the substance of the corpuscle, which subsequently is so altered in appearance and consistence, as to form the wall of the vesicle or adipose cell. Adipose tissue, and the connective tissues generally, are but scantily supplied with blood-vessels.

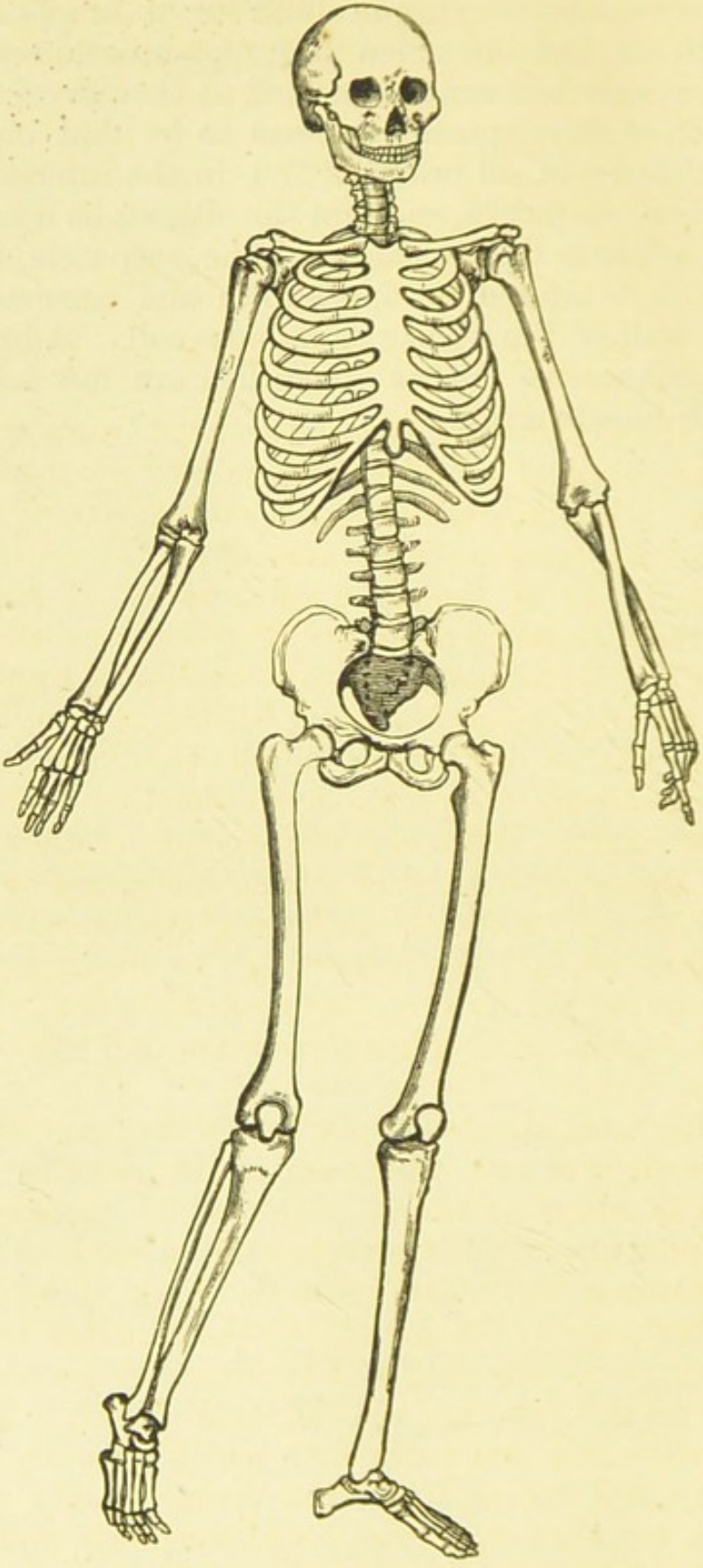


Fig. 8.—The Skeleton.

CHAPTER III.

THE SKELETON.

13. By the skeleton is meant the hard framework of the body. It consists of bones, cartilages, and ligaments.

What is called the backbone, or, more properly, the *vertebral* or *spinal column*, may be said to be the central part of the skeleton. It is composed of a series of bones called *vertebræ*, the fore parts or *bodies* of which, united by means of *discs* of flexible tissue, constitute a pillar of support, while what are termed the *arches*, lying behind this pillar, form a protective cylinder round the spinal cord, have *spinous* and *transverse processes* projecting from them, and glide one on another by joints. There are twenty-four of these movable vertebræ, the seven highest of which, belonging to the neck, are called *cervical*, while the following twelve carry ribs and are called *dorsal*, and the remaining five are termed *lumbar*. They are succeeded by the sacrum and coccyx, which form the lower part of the vertebral column, and will be further alluded to.

Springing from the dorsal portion of the vertebral column are twelve pairs of ribs, which are further prolonged in front by means of *costal cartilages*. The costal cartilages of the upper seven pairs of ribs are prolonged forwards to the breast-bone or *sternum*, to be fitted into its sides; those of the succeeding five pairs are each fixed to the cartilage next above; while those of the eleventh and twelfth ribs are pointed, and terminate in the muscular wall of the abdomen. The circles formed by the ribs and parts with which they are connected are called *costal arches*, while the series of ribs and costal cartilages, together with the dorsal vertebræ and sternum, constitute the *thorax* of the skeleton.

14. Articulating with the upper end of the sternum, in the

human subject, are the collar bones or *clavicles*, which unite the shoulders with the skeleton of the trunk. The clavicle has no existence in many mammals, such as the horse, the ox, and the sheep; while in others it is rudimentary and without function, as in the cat and the dog; and in all such instances the shoulder and fore limb are united to the rest of the skeleton by mere muscular connections; but in the animals in which it exists—for example, squirrels and monkeys—it is the fulcrum on which the arm moves when stretched out from the body or approached to the middle line. The outer end of the clavicle articulates with the *scapula* or shoulder-blade, and the two bones together form the *shoulder-girdle*.

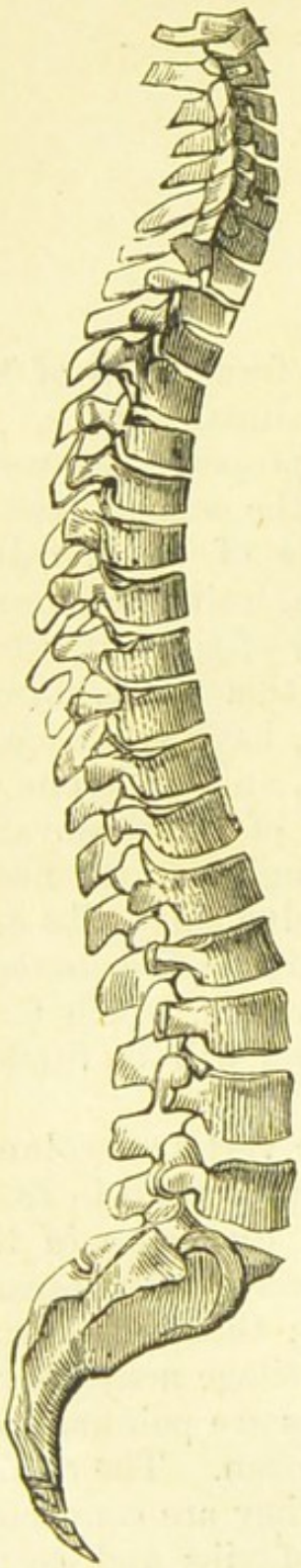


Fig. 9.—Vertebral Column.

The joints at the outer and inner ends of the clavicles permit the shoulder-blades to be moved upwards, downwards, forwards, or backwards at will, while they continue to glide on the conical walls of the upper part of the chest. The part of the shoulder-blade with which the clavicle articulates is called the *acromion*, and is the expanded extremity of a spine which arises from the back of that bone, and is directed outwards and upwards. At a little distance from its outer end, the clavicle is likewise united by strong ligaments to another process of the shoulder-blade called the *coracoid*, against which it rests when the shoulders are pushed upwards.

The *humerus* or arm bone articulates by a rounded head with a surface of the scapula called the *glenoid fossa*, distinct from both acromion and coracoid processes, and this articulation is the shoulder joint. It permits greater freedom of motion than any other

joint in the body, owing to the smallness of the scapular surface, compared with the globular humeral surface, on which

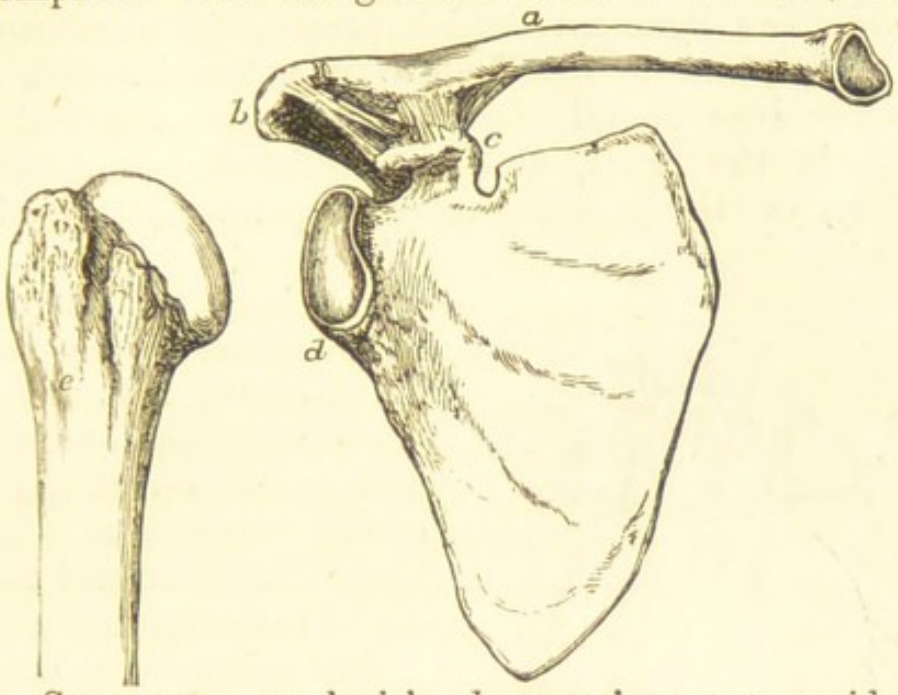


Fig. 10.—SHOULDER. *a*, clavicle; *b*, acromion; *c*, coracoid process; *d*, glenoid fossa of the scapula; *e*, humerus.

it moves, and the looseness of the ligamentous capsule which unites the two bones; but the coracoid and acromial processes overhang the joint sufficiently to add greatly to its strength; for it is against them that the humerus is in great measure pushed in all positions in which great pressure is made against it.

In the forearm there are two bones named *radius* and *ulna*. The ulna, the inner of the two, is strong above and slender below, and admits of no movement save in a hinge fashion on the humerus, with which it articulates by means of a cavity which looks forwards, and is bounded below by the *coronoid process*, above by the *olecranon* or prominence of the elbow. The radius,



Fig. 11.

Fig. 11.—RADIUS AND ULNA. *a*, olecranon process of ulna; *b*, coronoid process; *c*, orbicular ligament, embracing the head of the radius; *d*, triangular ligament, uniting the radius to the styloid process of the ulna.

which is much slenderer above than at its lower end, and supports the hand, is bound to the ulna at its upper end by an *orbicular* ligament, which permits it to rotate within its grasp, and is fastened to it below in such a way that it revolves round that bone as on a pivot, carrying with it the hand, and accomplishing *pronation* and *supination*, or the turning of the palm downwards and upwards.

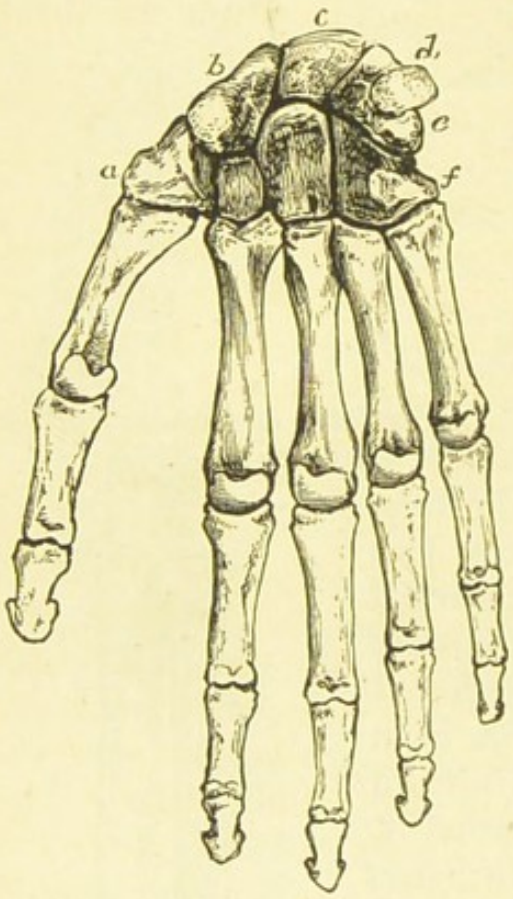


Fig. 12. — FRONT VIEW OF THE BONES OF THE HAND. *a*, trapezium; *b*, scaphoid, and, beneath it, the trapezoid; *c*, semilunar, and, beneath it, os magnum; *d*, pisiform; *e*, cuneiform; *f*, unciform.

The hand consists of eight little *carpal* bones arranged in two rows, five *metacarpal* bones, which form the skeleton of the palm, and the *phalanges* or finger bones, of which the thumb has two, and the other digits three each.

The bones of the upper row of the carpus are named— beginning at the outer or thumb side — the *scaphoid*, *semilunar*, and *cuneiform* bones, and the *pisiform*, smaller than these, and articulated in front of the cuneiform. The bones of the second row are called *trapezium*, *trapezoid*, *os magnum*, and *unciform*, the unciform supporting the metacarpal bones of the ring and little fingers, and the others supporting one metacarpal bone each.

The movements of the wrist are accomplished partly by movement of the upper row of carpal bones on the radius, and partly by one row of carpal bones moving on the other. There is little perceptible movement allowed between the carpal bones of the second row; but it is not without importance that they are separate bones; for when we lean or push with the palm, and the wrist is over-extended, the members

of this range, as well as the metacarpal bones, present the concavity of an arch towards the object pressed on, and have the ligaments which support them in that position thrown into a state of tension, which, being recovered from as soon as the pressure is removed, gives elasticity to the movements of the limb. The utility of the hand depends in great measure on the opposability of the thumb to the other digits, and this results from freedom of movement between the trapezium and first metacarpal bone, and from the number of muscles attached to the thumb.

15. The fifth or lowest lumbar vertebra rests on the broad upper end of a curved wedge, the *sacrum*, which consists of five other vertebræ fused together in one bone; and at the lower and narrow end of this bone are four more of a rudimentary description, corresponding with the *caudal* vertebræ or bones of the tail in other animals, but usually named by the human anatomist, collectively, the *coccyx*.

On its sides, in the upper two-thirds of its extent, the sacrum is closely united to the two *pelvic* or *innominate* bones, which, together with it, enclose a basin or cavity, called the *pelvis*. Examined in early life, each innominate bone is seen to consist of three parts, which meet at the articular cup, called the *acetabulum*, for the head of the thigh bone. The expanded upper part is called the *ilium*, the lower part is called the *ischium*, while the part which meets with the opposite bone in the middle line is the *os pubis*, and the union is called the *symphysis pubis*. The expanded ilium obviously corresponds with the shoulder-blade in the upper limb, and the pair of innominate bones with the shoulder-girdle, notwithstanding that the shoulder-girdle is but little connected with the trunk, while the innominate bones take an important part in bounding the visceral cavity.

From the upper end of the sacrum a prominent ring of the innominate bone can be followed round to the symphysis pubis, constituting the brim of the true pelvis as distinguished from the part of the abdomen between the blades of the iliac bones. In the erect posture of the body this ring lies at an angle of 60° with the horizontal, so that the sacrum presses downwards on it. But the sacrum is so

placed that its upper end is thrown in front of the rest of it, and that its hinder surface, which is narrower than the anterior, looks upwards; it would, therefore, fall down into the pelvis were it not supported by a pair of exceedingly strong *posterior sacro-iliac ligaments;* and it is through these ligaments much more than by direct pressure that the weight of the body is conducted from the sacrum to the pelvis.

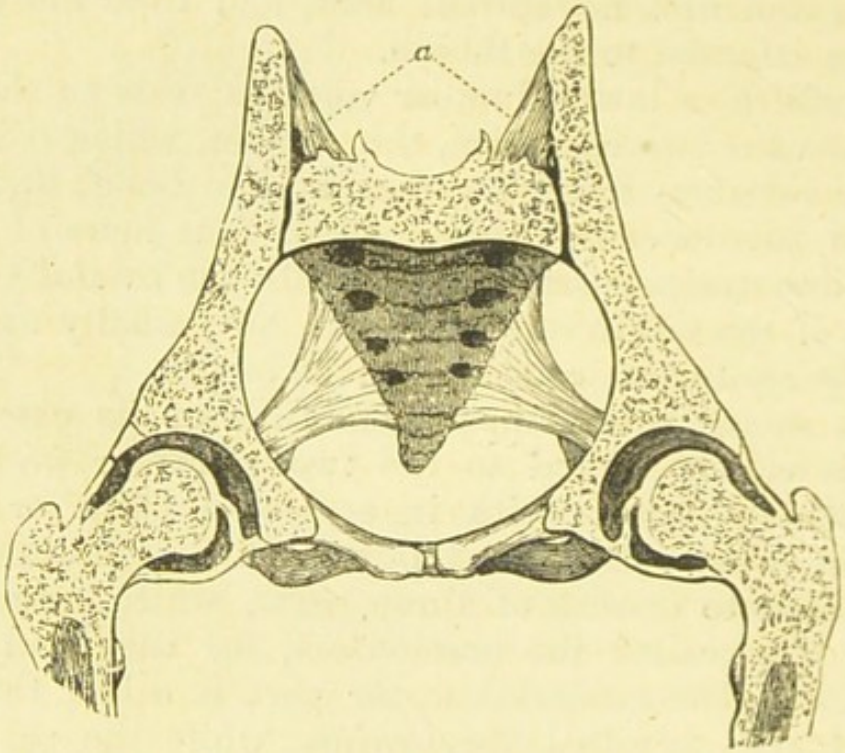


Fig. 13.—Section of Pelvis, showing the suspension of the sacrum between the haunch bones. *a*, the posterior sacro-iliac ligaments.

16. The thigh-bone or *femur* corresponds with the humerus of the upper limb; in front of the knee is the *patella* or knee-cap, which is a *sesamoid* bone or ossification within a tendon, and not at all correspondent with the olecranon of the elbow: in the leg the *tibia* and *fibula* are the bones corresponding with the radius and ulna in the fore-arm: and in the foot there is a close correspondence of all the bones with those of the hand.

The parts of the foot are called the *tarsus*, *metatarsus*, and *phalanges*. The phalanges and metatarsal bones are arranged quite like those of the hand, the great toe being similar to the thumb in having only two phalanges. The bones behind the metatarsals are the *internal*, *middle*, and *external cuneiform*

bones, supporting the three inner metatarsals, and the *cuboid*, supporting the fourth and fifth. These four bones obviously correspond with the four carpal bones of the lower range in the hand: but behind them are three others, the *scaphoid*, lying behind the three cuneiform bones; the *calcaneum*, a very large bone projecting back from the cuboid, and forming the heel; and the *astragalus*, resting on the calcaneum behind, pressing against the scaphoid in front, and articulating with the leg-bones above; and the dissimilarity of appearance of the tarsus as compared with the carpus, is due to the large and unequal development of these three bones. The scaphoid, however, corresponds with the bone of the same name in the hand, and the astragalus with the semilunar, while the calcaneum represents the cuneiform and the pisiform together; and it is owing to the great development backwards of the calcaneum to form the heel, that the hollow by which tendons and other structures pass from the back of the leg to the sole of the foot is turned inwards so as to lie between the heel and inner ankle.

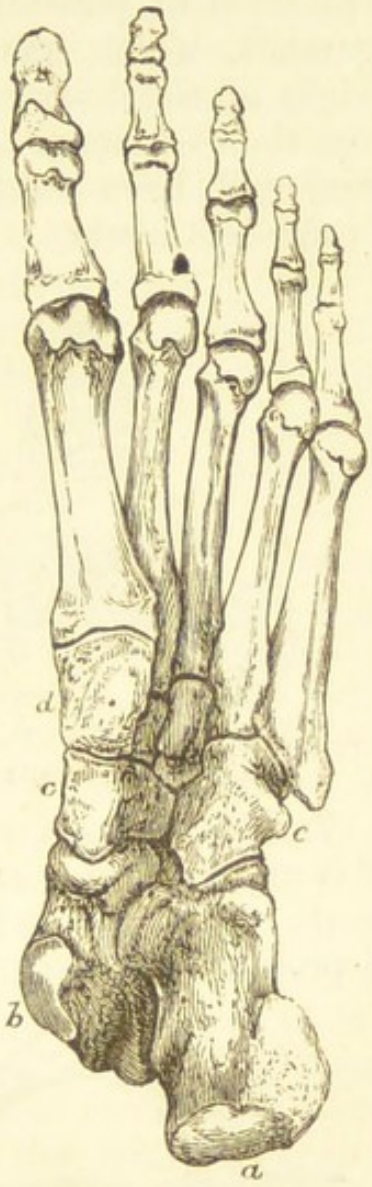


Fig. 14.—Foot from below. *a*, calcaneum; *b*, astralagus; *c*, scaphoid; *d*, internal cuneiform; *e*, cuboid. The middle and external cuneiform are seen between the cuboid and internal cuneiform.

The same principle of conduction of pressure through tense ligaments, which we have noted in the hand and the pelvis, is resorted to again in the foot. The foot may be conveniently regarded as consisting of two arches supported behind by a common pier, the back part of the calcaneum. To the inner and principal arch belong the three inner toes, and the keystone of this is the astragalus, the fore part or

head of which, lying between the calcaneum and scaphoid, is retained in position by a strong *inferior calcaneo-scaphoid* ligament, which has frequently to bear nearly the whole weight of the body. The outer arch is continued forwards from the calcaneum to the cuboid and two outer toes, and is prevented from falling flat by strong *calcaneo-cuboid* or *plantar* ligaments.

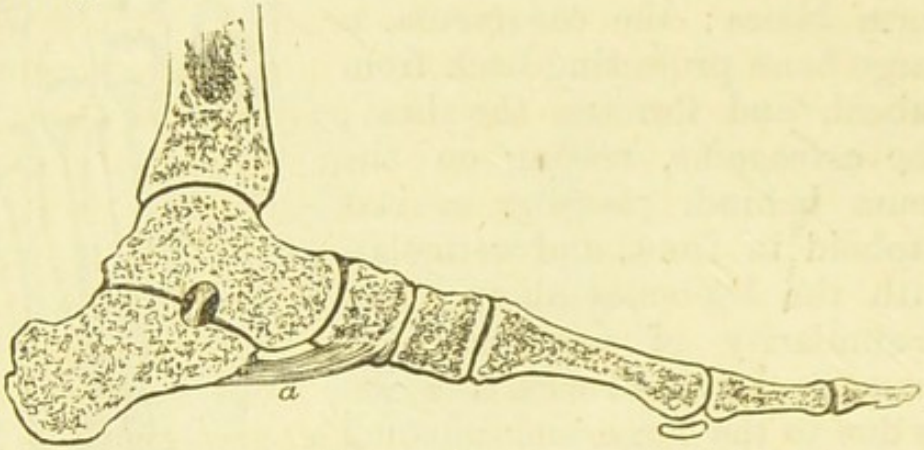


Fig. 15.—Section of Foot, showing, *a*, the inferior calcaneo-scaphoid ligament supporting the head of the astralagus.

17. The first and second cervical vertebræ are termed the atlas and axis, and are specially modified to facilitate movements of the head, which rests on them. The atlas, instead of presenting a body in front and an arch behind, has the

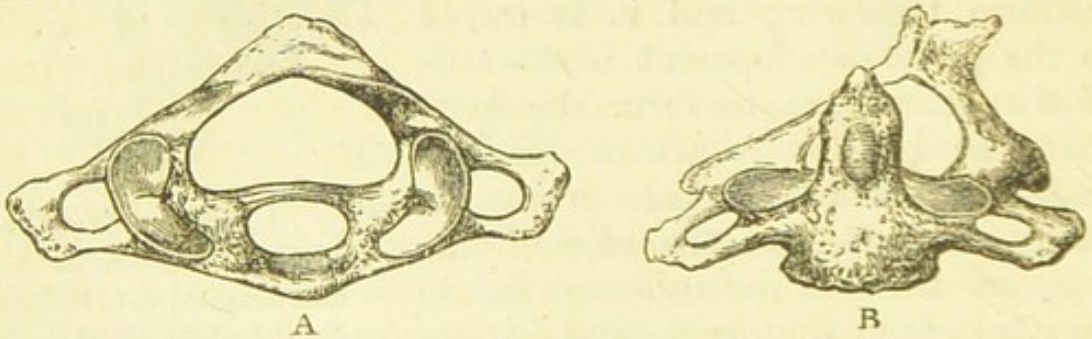


Fig. 16.—Atlas and Axis. A, Upper surface of atlas; above is the ring for the spinal cord, and, separated from it by the transverse ligament, is the ring for the odontoid process below; to the sides of this are the surfaces which articulate with the skull. B, Front view of the axis, with the arch seen in perspective behind the odontoid process.

hollow of its arch prolonged forwards, between the articular portions which carry the skull; and in the recent state, the anterior part of this hollow is converted into a separate ring by a transverse ligament. Through this anterior ring pro-

jects a process which surmounts the body of the axis, namely, the *odontoid* process, and round this the atlas, carrying with it the skull, revolves as on a pivot. The motion, however, is limited by two lateral bands, the *check* ligaments, which pass out from the top of the odontoid process to be attached to the sides of the *foramen magnum*, the opening in the skull by which the cranial cavity is made continuous with that of the spinal column. By the study of development and the anatomy of different animals, it is well ascertained that the odontoid process is really the body of the atlas, which has become fastened to the top of the body of the axis, and remained separated by a joint from the other parts of the bone to which it in one sense belongs.

18. The skull consists of cranium and face. The *cranium*, or part enclosing the brain, is counted as having eight bones. But it is right that even a tyro should understand that various of these bones consist of different elements which have become fused together at an early age, while some of what are considered as distinct bones are also fused together in every adult. The word "bone" is, therefore, used somewhat arbitrarily in speaking of the bones of the skull. The *occipital* bone forms part both of the base and the roof, and is pierced by the foramen magnum. The other bones of the roof are the two *parietals* and the *frontal*, which in the child is divided down the middle like the parietals. The frontal not only forms a large part of the vault of the skull, but also the roofs of the *orbits* or sockets of the eyeballs. In the base of the skull, a complex bone, the *sphenoid*, formed by the junction of many elements, and primarily divisible into an anterior and posterior part which are distinct in most animals, extends forwards from the occipital, with which it is thoroughly united in the adult, and reaches the orbital plates of the frontal; while the interval between the orbits is filled in by the upper part of a delicate and likewise complex bone, the *ethmoid*, which is pierced with foramina for the filaments of the nerves of smell, and takes much greater part in the formation of the cavity of the nose than in completing the cranial walls.

Lastly, on the sides of the skull, and projecting into its base between the sphenoid and occipital, are the *temporal*

bones, which contain the organs of hearing in their interior. The part of the temporal which lies above the *external auditory meatus*, or opening of the ear, is termed the *squamous* portion; the thick process behind is called *mastoid;* the pyramidal projection into the base is the *petrous* portion; and a plate which forms the inferior limit of the opening of the ear, and of the cavity into which it leads, is the *tympanic plate.* Enclosed by this plate, within what is called the tympanic cavity, are three little ossicles, which will be described with the organ of hearing.

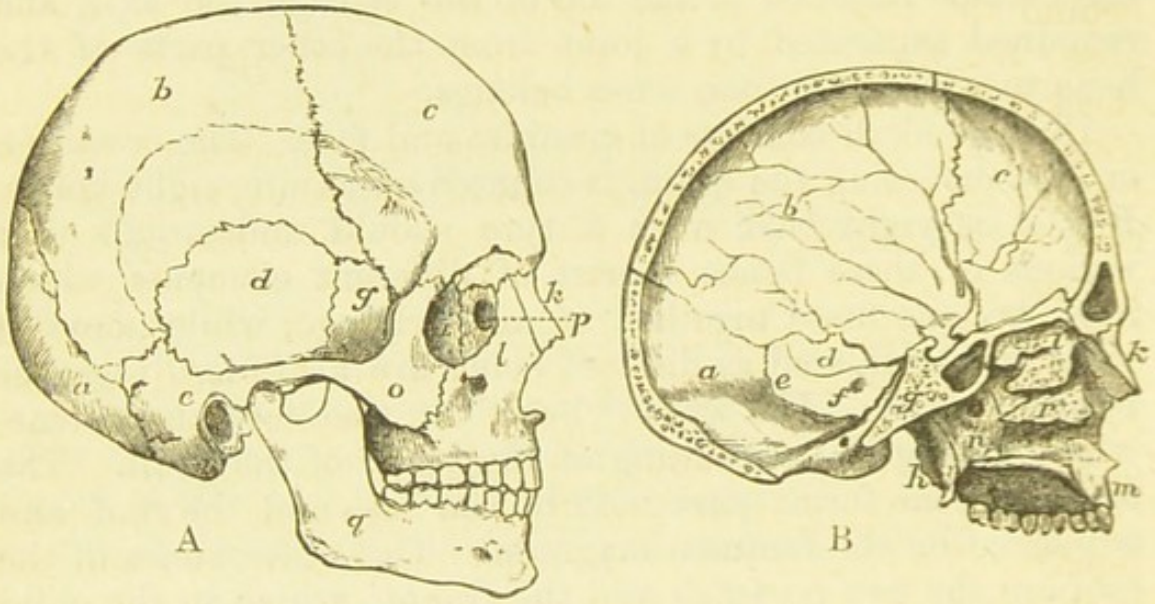


Fig. 17. — Skull. A, Profile view. B, Vertical section. *a*, occipital bone; *b*, parietal; *c*, frontal; *d*, squamous portion of temporal; *e*, mastoid portion; *f*, petrous portion; *g*, sphenoid; *h*, pterygoid process of sphenoid; *i*, ethmoid; *k*, nasal; *l*, superior maxillary; *m*, pre-maxillary part of superior maxillary; *n*, palatal; *o*, malar; *p*, lachrymal; *q*, inferior maxillary; *r*, inferior turbinated.

19. Of the *face bones*, the largest is the *inferior maxilla*, or lower jaw, and this is the only one which is movably articulated. The remaining part of the face consists mainly of the walls of a passage, the interior of which is divided into the right and left nasal fossæ by a mesial bone called the *vomer*, together with a mesial plate of the ethmoid. The floor of this passage constitutes the palate. Much the larger part of this division of the face in the human subject is formed by the *superior maxillary* bones, which carry all the upper teeth, and represent two pairs of bones in the

skulls of other mammals, namely, the superior maxillaries and the pre-maxillaries. Behind the superior maxillaries are the *palatals*, which form the back part of the palate, and, by means of ascending portions, join together the superior maxillaries and what are called the *pterygoid* processes of the sphenoid bone, two processes projecting downwards from the base of the skull. It may also be mentioned that the inner parts of these processes, namely, the internal pterygoid plates, are separate bones in most animals. The superior maxillaries send up a pair of processes to the frontal bone, behind the two *nasals*, the bones forming the ridge of the nose; but they get a much stronger support from a pair of cheek bones, the *jugals* or *malars*, which project outwards from them, and each of which sends one process up to the frontal to complete the outer wall of the orbit, and another backwards to form an arch with what is called the *zygomatic* process of the temporal. The other bones of the face are two little plates called *lachrymals*, grooved for the nasal ducts, the passages by which the tears are carried from the eyes into the nose; and the *inferior turbinated* bones, a pair of thin curved laminæ which project into the nasal fossæ.

20. Peculiarities of the Human Skeleton.—The most remarkable peculiarities of the skeleton of man, as compared with other animals, are connected with the maintenance of the erect posture.

The foot has a broad sole, and is arched both from behind forwards, and also from side to side, so as to give elasticity to the step.

The straight position of the knee is characteristically human, no other animal but man being supported on extended knee joints; for though birds are also bipeds, they have the knees flexed in standing. The human knee joint is so constructed that, when fully extended, it remains in that position without muscular exertion, so long as the weight of the body presses down on it. And this can easily be demonstrated; for the patella is situated in the tendon of the extensor muscle of the knee, and when it is loose, that muscle is evidently relaxed: now, when one stands with the knees straight, the patella can be felt with the hand to be hanging perfectly slack; but as soon as the foot is lifted

from the ground it becomes tightened, because then it is only by muscular effort that the knee is kept straight.

The femur in man is longer than in other animals; and by the length of this bone, when we stoop with bent knees and resting on the balls of the toes, the pelvis is thrown sufficiently backwards to balance the bending of the body forwards (fig. 27). If the thigh bones were short, it would be difficult to pick an object off the ground.

The pelvis also is short, expanded, and strong: the pillars of bone which convey the weight from the sacrum to the thigh-bones are stouter than the corresponding parts which have no such function in other animals; and the expanded blades of the iliac bones both give surface for the attachment of the large *glutei* muscles by which the trunk is extended on the top of the thigh-bones, and also help to support the viscera above them.

The bodies of the vertebræ increase rapidly in size from the cervical to the last lumbar, so as to bear the accumulated weight which they support; and the transverse processes of the thoracic and lumbar regions are thrown remarkably back on the arch, so as to bring the bodies as much as possible forward into the visceral cavity; a circumstance which will at once strike any one who compares even in a cursory fashion the lumbar vertebræ of a rabbit, sheep, or ox, with those of the human subject. In the thoracic region, the ribs, with the exception of the two last pairs, being attached by distinct articulations to the sides of the bodies of the vertebræ and to the transverse processes as well, have a direction backwards as well as outwards given to them, by which, before arching forwards, they include in their circuit two great fossæ at the sides of the column, which contain a large part of the lungs.

Even the peculiarities of the human skull are closely connected with the adaptation to the erect posture. It has already been pointed out that in quadrupeds the head is suspended by a strong elastic ligamentum nuchæ; and it is, in addition, supported by muscular action; but, in man, the head is balanced on the top of the atlas when he stands erect. This is an arrangement altogether peculiar to man, and is accomplished, in the first place, by the bones of the

face being comparatively light, and, secondly, by changes in the form of the cranium, connected with the large size of the brain. These changes consist mainly in the base of the skull in front of the foramen magnum being shortened and curved downwards, and in the roof being greatly elongated and arched, so that the part of the occipital bone behind the foramen magnum, which in a quadruped looks backwards, is turned downwards, and a large part of the brain is thus made to lie further back than the condyles by which the occipital bone articulates with the atlas.

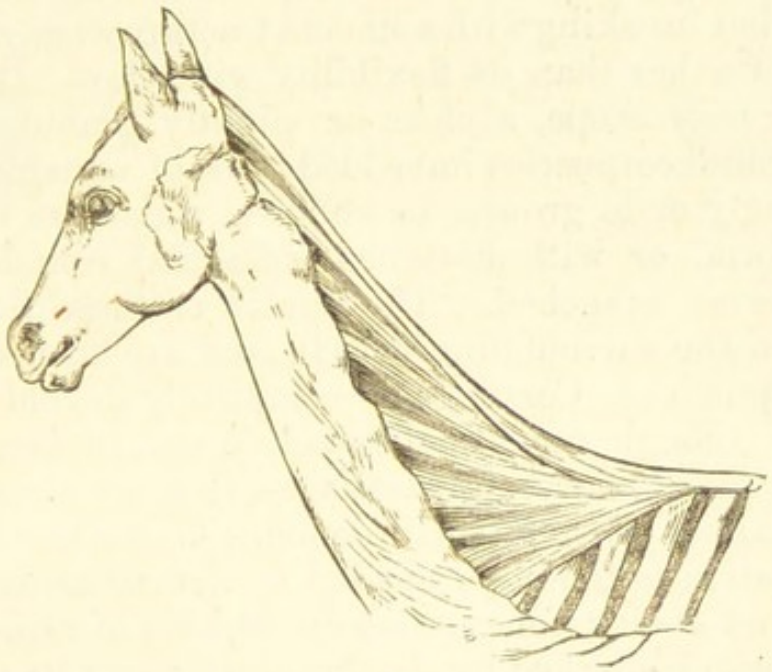


Fig. 18.—Ligamentum Nuchæ of the Horse.

The elongation of the face downwards may be mentioned as a human peculiarity, as well as the want of projection forwards. This elongation is partly in connection with the development of spaces, in which the voice reverberates and acquires resonance, but cannot be altogether accounted for by that consideration. Rather, it is a physiognomical peculiarity of man, like the presence of a chin, well developed in the higher varieties of the race, but not in subservience to any special function.

In the skeleton of the upper limb there is no mechanism altogether peculiar to man; the completely developed clavicle, freely moving shoulder joint, pronation and supination of the forearm, opposability of the thumb, and com-

plete power of handling and fingering, are all found among the lower animals.

21. Skeletal Textures.—The textures found in the skeleton are bone, cartilage, and the fibrous tissues. The fibrous tissues have been already considered. Bone, which is the prevalent texture in the adult skeleton, makes its first appearance always either in cartilage or fibrous tissue, more frequently in cartilage; therefore, it is convenient to explain the nature of cartilage first.

Cartilage, in its most frequent form distinguished as *true* or *hyaline* cartilage, is a firm texture capable of a marked amount of flexion, but breaking with a smooth fracture when it is sought to bend it further than its flexibility will allow. It presents, under the microscope, a clear or slightly granular matrix, with nucleated corpuscles imbedded in it, of variable size, and lodged, singly or in groups, in hollows, which are either of a rounded form, or with flattened sides and rounded angles, and are never branched. The limits of these hollows are denser than the surrounding matrix, and are termed capsules of the corpuscles. Cartilage is completely devoid of blood-vessels, for though occasional vessels occur in large masses, as, for example, in the costal cartilages, they are always lodged in canals along with a small amount of connective tissue. But the matrix is freely permeated by nourishment from the vessels round about; for cartilage is capable of rapid growth, and its growth is marked by changes throughout its substance. In growing cartilage, the corpuscles are seen in groups in every stage of multiplication. One will be found with two or more nuclei; another partially divided into two or more parts, with septa springing up between them; while, in other instances, the septa are completed, and exhibit various thicknesses of matrix between them, towards which the divided corpuscles still present flattened sides. The matrix of cartilage is converted by prolonged boiling, not into gelatin, but into *chondrin*, a closely allied substance, which, like gelatin, dissolves in hot water, and forms a jelly on cooling; but which differs slightly in composition, and has some distinctive chemical reactions. This is the more remarkable, as bone yields by boiling, not chondrin, but gelatin.

The coating of cartilage on surfaces of bone which glide

one on another, is termed *articular* cartilage, and has the peculiarity that, towards the surface, the corpuscles are in groups flattened parallel to the surface, while in the deep parts they are in vertical groups.



Fig. 19.– Costal Cartilage.



Fig. 21.—Reticular Cartilage, from the Epiglottis.



Fig. 20.—Articular Cartilage. Vertical Section.

A peculiar variety of cartilage, called *yellow* or *reticular*, which occurs in the epiglottis and a few other places, depends on the matrix being pervaded with a densely felted substance similar to elastic fibrous tissue, but more brittle.

Plates of matted fasciculi of fibrous tissue, with elements of cartilage sometimes interspersed, occur in various positions, but particularly as movable discs between the articular surfaces of certain joints, such as the knee, and combine the elastic resistance of cartilage with toughness which endures the action of rubbing, and are named *fibro-cartilages.*

22. Bone is a more complex tissue than cartilage; its complexity depending on the impermeability of its matrix to fluids, and the consequent necessity of canals for nutrition. The matrix consists two-thirds of mineral matter, principally phosphate of lime with some carbonate of lime, and the remaining third of animal matter; the two being so intimately blended that they form a homogeneous mass, translucent in thin sections. When the animal matter is removed by calcination the form of the bone still remains; and when the mineral matter has been gradually dissolved by dilute hydrochloric acid, the animal matter retains the same bulk and microscopic structure as before, presenting the consistence and flexibility of cartilage, but yielding gelatin by boiling.

The only microscopic structures common to all bone are the *bone-corpuscles*, which are nucleated corpuscles characterized by a multitude of fine processes, and are imbedded in hollows of corresponding shape and size, called *lacunæ;* while their processes occupy exceedingly fine *canaliculi*, which radiate from the lacunæ, those of one lacuna inosculating with those of others, so that fluids may be conveyed from one lacuna to another.

Bony tissue is found, however, in two different forms, the cancellated and the compact. *Cancellated* or spongy tissue, such as one finds in the bodies of the vertebræ, the tarsal bones, and the ends of long bones, consists of minute spicules and occasional laminæ of bone with the spaces or meshes between them filled with fine connective tissue, copiously supplied with blood-vessels, and loaded more or less with adipose matter. *Compact* or solid bony tissue, such as is found in the shafts of the long bones, is traversed by blood-vessels, and presents a remarkable microscopic arrangement connected therewith. The passages for the blood-vessels, named *Haversian canals*, after Havers, who first mentioned

them, vary from $\frac{1}{1000}$ to $\frac{1}{200}$ of an inch in diameter; they enter from the surface of the bone by multitudes of minute oblique openings visible with the naked eye, and run for the most part longitudinally, connected however by numerous short canals, which have a more transverse direction. The

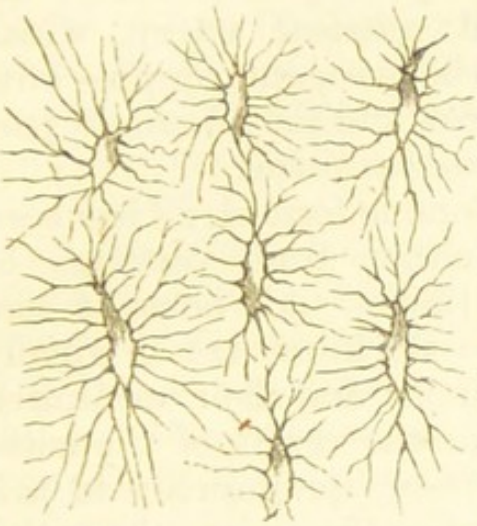


Fig. 22.—Lacunæ and Canaliculi.

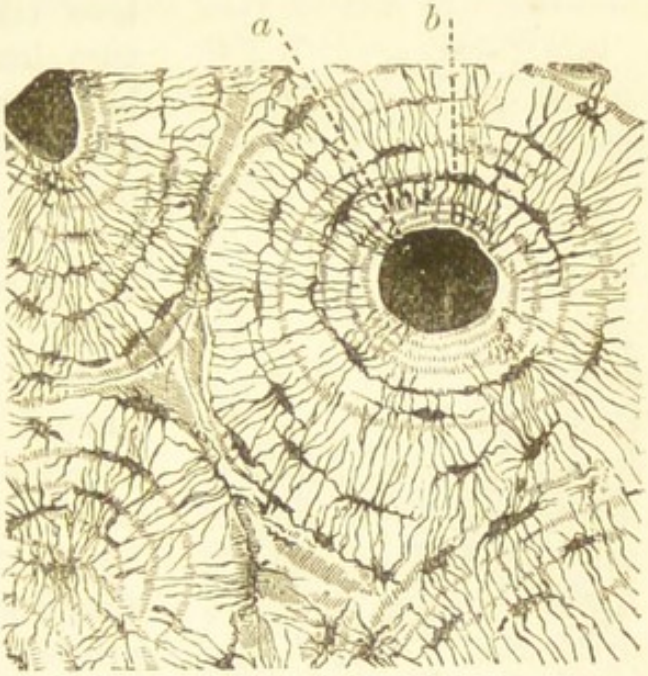


Fig. 23.—Transverse Section of Compact Osseous Tissue. *a*, Haversian canal; *b*, Lacunæ in concentric rings.

tissue is arranged in concentric laminæ around the Haversian canals, so that circles of lacunæ are seen surrounding the transverse sections of the canals, and such an arrangement of concentric rings is called an Haversian system. The whole compact tissue is made up of such systems, the interstices being filled with fragments of similar laminæ which were formerly complete, but of which the other portions have been absorbed so as to leave gaps or absorption-spaces, subsequently filled up by new systems developed concentrically from the circumference inwards, till they have closely grasped the blood-vessels in the centre.

The arteries for the supply of bone subdivide in the fibrous membrane by which each bone is surrounded, the *periosteum*, and from this membrane small branches pass all over the surface into the openings of the Haversian canals. The veins emerge by comparatively few orifices of larger size,

which, in long bones, are found near the articular extremities. The marrow cavities in the shafts of long bones may be looked on as of the same description as the cancellations in the spongy tissue at the extremities of the same bones, with which they communicate. The marrow is vascular connective tissue of a delicate description, loaded with adipose cells, and has usually a special artery, the so-called *nutrient* artery, which pierces the bone, and supplies both the marrow and the innermost part of the osseous tissue.

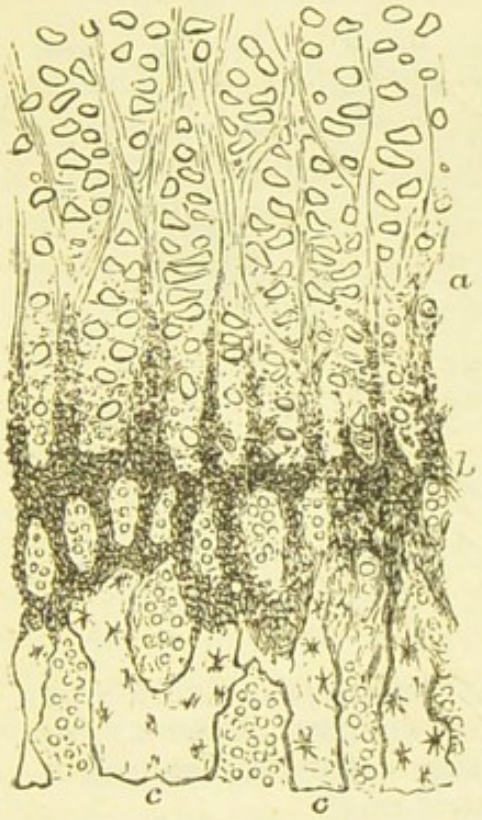


Fig. 24. — Vertical Section through the plane of ossification at the upper end of the femur of an infant. *a*, Cartilage, with corpuscles in vertical columns, and altered matrix between; *b*, granular deposit spreading in spicules; *c*, true bone.

23. Bone is formed, as has been stated, either from cartilage or fibrous tissue. All bones of considerable thickness are originally cartilaginous, and their ossification begins in the centre of the mass. The first step preliminary to this process of ossification is the multiplication of vessels within canals, and the absorption before them of a certain amount of cartilaginous matrix. When a section is made through the plane of contact of a centre of ossification and the surrounding cartilage, the cartilage-corpuscles are seen arranged in rows placed vertically to the plane of ossification; and between these rows there project into the matrix opaque spicules, which consist of granules of calcified matter, distinct one from another, and reflecting the light. By a further deposition of granules, the cartilage-corpuscles become hid from view and closely surrounded; and in some instances mineral deposit takes place also within the capsules. By still further deposition of mineral matter, the matrix becomes homogeneous and transparent, and within the ossifying border spaces are formed by absorption. Within these spaces there

is a free growth of corpuscles (termed osteoblastic) and blood-vessels. Whether the corpuscles are derived from those of the cartilage, or from the connective tissue round the vessels, is not settled; but they become imbedded in a new deposition of calcified matrix, which leaves them with freely intercommunicating branches, and are thus converted into true bone-corpuscles.

The first deposit of bone is dense and irregular: if the spaces formed in this by absorption accumulate, cancellated tissue is the result; but if they become filled with a new deposit of bone, this deposit takes place in concentric rings, gradually closing round the blood-vessels, and compact tissue is produced.

In cancellated, as well as in compact tissue, there is continual deposit and reabsorption of bone; but in the compact tissue, the osseous substance is in such proportion to the vascular, as to surround the vessels; while in the cancellated, the vascular connective tissue, or red marrow, is in such quantity as to surround the osseous spicules.

When bone is developed from fibrous tissue, there is no granular stage in ossification; but bony tissue is laid down at once, as in spaces formed by absorption.

24. While cartilage is capable of rapid growth, as has been already stated, by multiplication of its corpuscles and expansion of its matrix, bony tissue is capable of very little expansion, and increases in bulk by addition to its surfaces, where it is in contact with cartilage or fibrous tissue. Thus, a ring of silver fastened round the wing-bone of a young pigeon becomes gradually imbedded and covered in by the new depositions of bone on the surface, while, by the absorption which is at the same time going on internally, it may even come to lie in the enlarged cavity of the bone. John Hunter found, that if two holes were bored in a bone of a young animal, at a measured distance one from the other, afterwards when the bone had grown longer, the holes remained separated by the same interval as at first. Even apart, however, from the circumstance that subsequent observers on repeating Hunter's experiment have obtained a different result, it must be admitted that osseous tissue has some power, although limited, of interstitial expansion, seeing that

the body of the lower jaw elongates by that means sufficiently to make room within it for the permanent teeth, and an expansion of the same sort takes place in the frontal bone between the frontal eminences and the margins of the orbits. But the principal elongation of the bones of the limbs is provided for by the extremities of the bones being furnished with separate *epiphyses* or supplementary centres of ossification, between which and the shaft there remains, as long as the growth of the bone continues, a thin plate of cartilage, which is as rapidly growing interstitially as it is converted into bone at its surface. So, also, the bones of the skull expand principally by additions at their edges, and when premature obliteration (synostosis) of any suture occurs, it causes arrest of growth at right angles to the suture, compensated for by additional growth in other directions, producing a variety of anomalous forms of skull.



Fig. 25.—Tibia at 18 years of age, showing the superior and inferior epiphyses.

25. The Joints or Articulations, by which the different bones are joined together, may be divided primarily into movable and immovable.

All the bones of the skull, with the exception of the lower jaw, are united together by *immovable* articulations or *sutures*, many of them rendered firmer by the dovetailing of complicated serrations of the articulating edges. Such articulations are serviceable for purposes of growth, as has been already explained.

Movable articulations are divisible into complete or perfect, and incomplete or imperfect.

Incomplete joints are those in which the opposed surfaces of bone are united by intervening substance of a yielding description; and the most notable example of this mode of union is found in the vertebral column. The arches of the vertebræ are united by pairs of complete joints, but their bodies, the parts through which the weight of the trunk is principally conducted, are joined by intervertebral discs,

consisting exteriorly of rings of oblique fibres, and more deeply of pulpy tissue, rich in corpuscles like cartilage-corpuscles. These discs are so many elastic pads which are useful in preventing shocks, and while little movement is allowed by them between each pair of bones, the amount permitted in the whole column is very considerable.

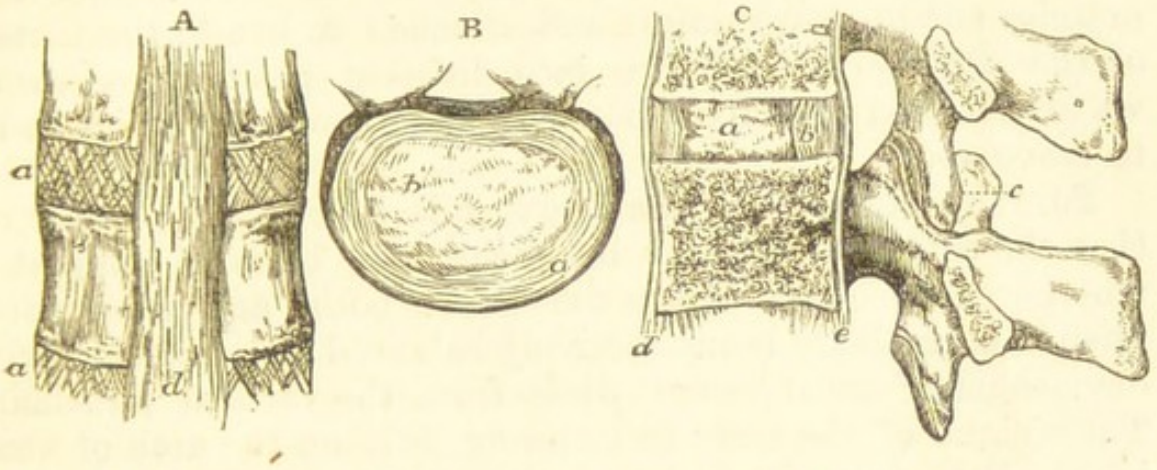


Fig. 26.—Lumbar Intervertebral Disc. A, front view. B, horizontal section. C, section from before backwards. *a*, fibrous rings; *b*, pulpy tissue; *c*, articular surfaces in contact; *d*, anterior common ligament; *e*, posterior common ligament.

Complete joints are those in which the surfaces of bones coated with articular cartilage glide one against the other, while the ligaments which bind them together are placed round about. Internal to the ligaments there extends from the circumference of one articular surface to that of the other, a delicate *synovial membrane*, so called because from it there exudes sufficient fluid, termed synovia, to moisten the surfaces of the shut cavity which it encloses.

In the complete joints, the movements allowed vary greatly both in character and degree. In many, as, for example, between the individual bones constituting the second range of the carpus, and between some of the tarsal bones, the movement is extremely slight (arthrodia), and the principal advantage gained appears to be elastic resistance to pressure, by the weight being thrown upon tense ligaments. Others, in which the movements are extensive, may be rudely compared with joints made by mechanicians. Thus, the shoulder and the hip may be termed ball and socket joints, there being in each a rounded surface which moves in all directions against a

cup; the elbow and the ankle furnish examples of hinge-joints, permitting angular movement in only one path, that of flexion and extension; and in the articulation of the first and second vertebræ, we have an instance of a pivot-joint, the odontoid process of the axis or second vertebra, being the pivot round which the atlas or first vertebra revolves.

26. Mechanics of the Skeleton.—By the contraction of muscles passing over joints and attached to bones, the parts of the skeleton are thrown into different positions, so that we are enabled to support ourselves in different attitudes and to move about.

For the support of the body, it is first of all necessary that the centre of gravity be within the basis of support, whether that consist of one foot or of both; and to accomplish this the body is instinctively balanced by compensatory deviations of its different parts from the vertical position. The weight of the body in standing falls on the arch of the instep, the piers of which are the heel and the balls of the toes. When the feet are together and the knees straight, both the tibia and the femur are thrown forwards further at their upper ends than their lower, and over-extension of the knee is prevented by the construction of that joint; while the weight transmitted from the vertebral column is received by the haunch bones at a point further back than where these bones articulate by the hip-joints with the thigh bones. The leg is prevented from falling forwards over the foot at the ankle joint by the action of the muscles of the calf, the *soleus* and *gastrocnemius*; and this is probably the only instance, in the standing posture, of a considerable weight being permanently supported by muscular power. At the hip-joint the weight, being behind, makes tense the ligaments in front; and the muscles passing over the back of that joint, while they may be felt to be rigid during their activity in recovering the body from stooping, are flaccid when the erect position is attained. The vertebral column is balanced by being curved in different directions in the loins it is thrown forwards; where it supports the chest it is curved well backwards; it turns forwards again in the upper part of the chest and at the root of the neck; and on the top of the column the head maintains its position by

balance. Thus it will be observed that in preserving the erect posture, the muscles principally act in steadying the body, but have little of its weight thrown on them; and this is exceedingly important, as muscular contraction is a vital action involving expenditure of force, and very exhausting.

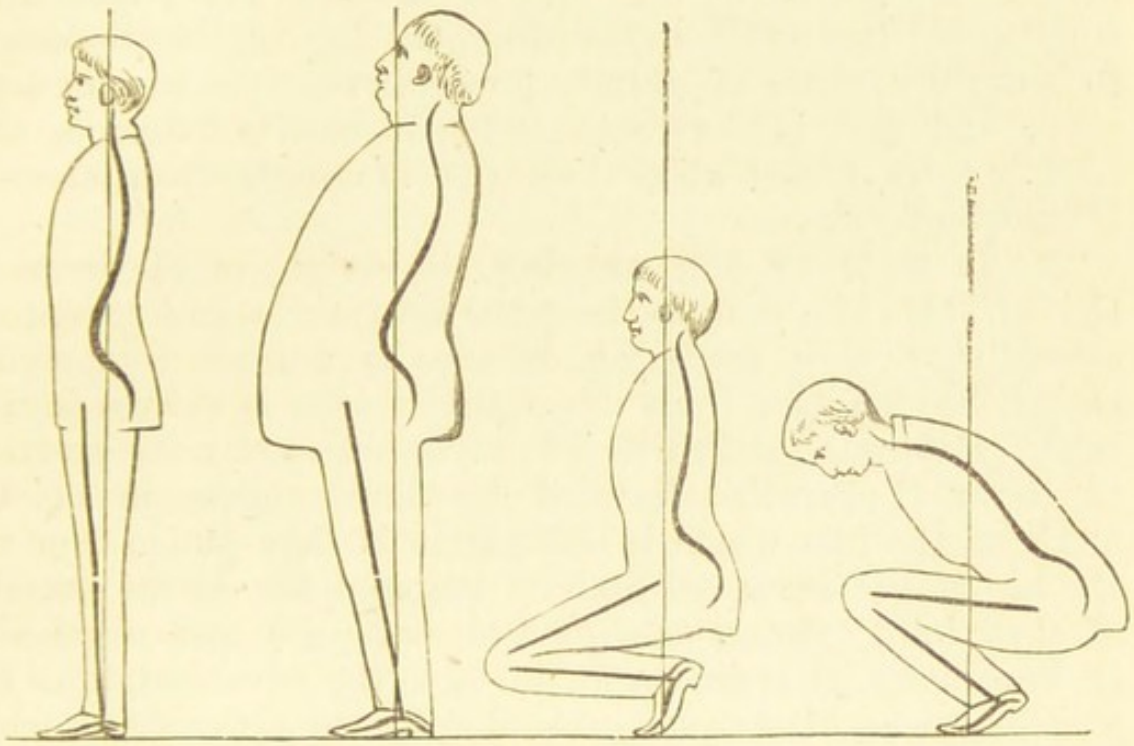


Fig. 27.—Illustrates the preservation of the centre of gravity within the basis of support.

The body is supported with still less muscular effort in the position called standing at ease than at attention. In standing at ease the weight is borne principally on one foot, while the other assists lightly as a prop. The limb on which support is made has the knee straight, and is inclined above towards its own side, so as to bring the weight of the trunk over the foot; the haunch of the other side is allowed to drop to a lower level than its fellow, sending the lower end of the vertebral column into an oblique position; and the trunk is kept vertical by the column being thrown into a spiral curve.

When a heavy weight is carried in front of the body, the trunk is thrown sufficiently back to bring the centre of gravity of the whole mass within the basis of support; for this reason portly persons, in whom the weight of the abdominal region is greatly increased, hold themselves

particularly erect. When the upper part of the body is bent forward, the lower part is carried backwards; and if the knees be bent, the projection forwards of the legs is balanced by the bending backwards of the thigh. When the knees are completely bent, the heel is raised from the ground, because the joints at the balls of the toes are required to supplement the ankle in bending the leg sufficiently down to bring the centre of gravity forwards over the base of support; and that is the reason why, in such a position, the heel is more raised when the trunk is upright than when it is stooped forwards.

27. **In walking and running** the weight of the body is thrown from one limb to the other alternately, and, except in exceedingly slow marching, balance is not yet completely established on one limb when the weight is shifted to the other. Before the limb which is advanced reaches the ground, the body is propelled forwards by the straightening of the ankle of the foot which is behind; it is then pulled over on the hip of the advanced limb by the muscles on the outside of that joint (*gluteus medius* and *minimus*), and, especially in long steps, it is drawn forwards to the advanced limb by a strong mass of muscles extending between the pelvis and inside of the thigh (the adductors).

The difference between walking and running is twofold. First, in walking the heel is brought to the ground, while in running it is not; yet the foot, at the moment when it is used to propel the body in running, is as advantageously placed as in walking; for the leg is so much sloped forwards that the angle between it and the foot is quite as sharp as it ever is in walking. Secondly, whereas in walking the whole propulsive action is from the foot, in running, the knee and hip-joints being both greatly bent, a vast additional impulse is given by their simultaneous extension. So also in **leaping,** all the joints of the lower limb are flexed in preparation for the leap, and the impetus given by their sudden extension propels the body through the air. But leaping differs from running, in that the limbs are extended together instead of acting alternately.

28. In the movements of the skeleton, all the three orders of levers are employed. In extending the fore-arm, as in box-

ing, a lever of the first order is illustrated; the hand being the weight, the extensor of the elbow the power, and that joint the fulcrum placed between the weight and power. But when the elbow is straightened in raising the body on the hands, then the superincumbent weight falls at the elbow, between the extensor muscle, which is still the power, and the hand, which is now the fulcrum; and the second order of levers is illustrated. When a weight held in the hand is raised by bending the elbow, the flexor muscles in front of the joint are those which act; and, as they are situated between the fulcrum and weight, a lever of the third order is brought into action.

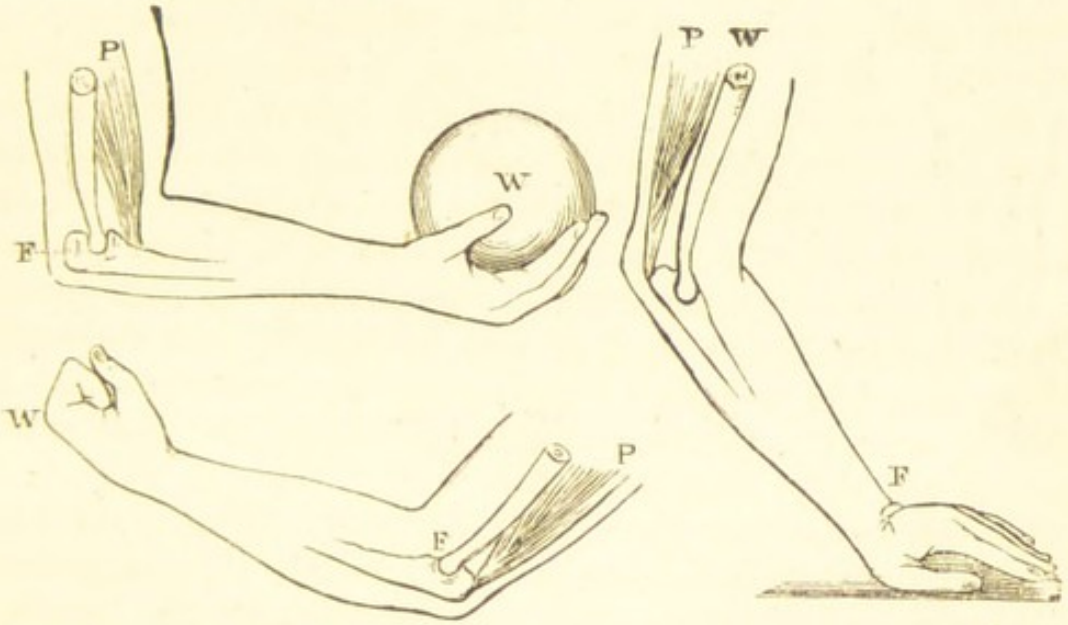


Fig. 28.—THE THREE ORDERS OF LEVERS, illustrated at the Elbow.

The muscles of the calf (the gastrocnemius and soleus), passing down to the tendo Achillis, are concerned in actions illustrating all three kinds of lever. When the foot is raised and the toes depressed, as in working a pedal, the weight is at the toes, and the ankle-joint is the fulcrum of a lever of the first order; when we rise on tip-toe it is the muscles of the calf which raise the heel, the fulcrum is at the toes, and the weight of the body falls on the ankle after the fashion of a lever of the second order; and, lastly, in the slighter action of the same muscles, when the heel is kept to the ground by the weight of the body, the force which prevents the body falling forwards is applied at the upper attachments, while the ankle is the fulcrum,

and the forward inclination of the body above is the resistance, so that the mechanism is that of a lever of the third order.

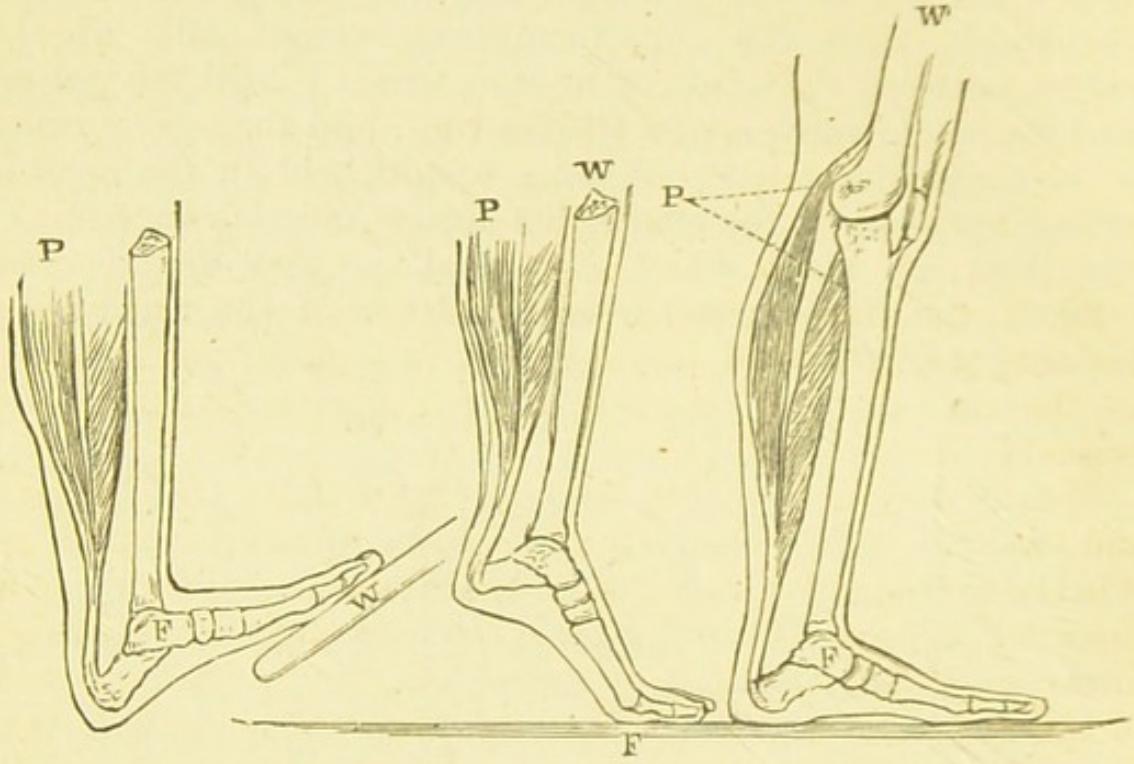


Fig. 29.—THE THREE ORDERS OF LEVERS, illustrated in the Foot.

CHAPTER IV.

MUSCLES.

29. The active element in which the force resides by which not only the bones and joints are set in motion, but likewise all the movements of the organs are accomplished, is called muscular fibre.

Muscular fibre presents two great varieties, the *striped* and the *unstriped*. The striped is the more complex, and, as it is the variety of which all the muscles consist, and over which the will has control, it is likewise termed voluntary muscular fibre; while the unstriped or smooth variety, being employed in the viscera, blood-vessels, and other structures subserving the purposes of organic life, and beyond the control of the will, is termed involuntary or organic muscular fibre. There are, however, various instances in which striped muscular fibre is not under the direction of the will, the principal being the heart; and there is a circumstance other than the relation to the will, on which more probably the kind of fibre used in each structure depends, namely, that striped muscle contracts suddenly when irritated, and becomes suddenly relaxed, whereas the unstriped contracts slowly and is relaxed slowly. The heart is required to contract rapidly, and striped muscular fibre is used in its construction. The mode of contraction of striped muscle is exemplified by the immediate response of the muscles of the skeleton to the impulses of the will; while the contraction of unstriped fibre may be seen by watching the enlargement and diminution of the pupil, occasioned by altering the focus of the eye or the amount of light admitted to it (p. 242). But birds, which probably require more rapid action of the iris in connection with their extraordinary keenness of vision, have the muscular tissue of the iris composed of striped fibres; and in mam-

mals the muscles of the tympanum, which are stimulated precisely in the same way as the iris, are of the striped description.

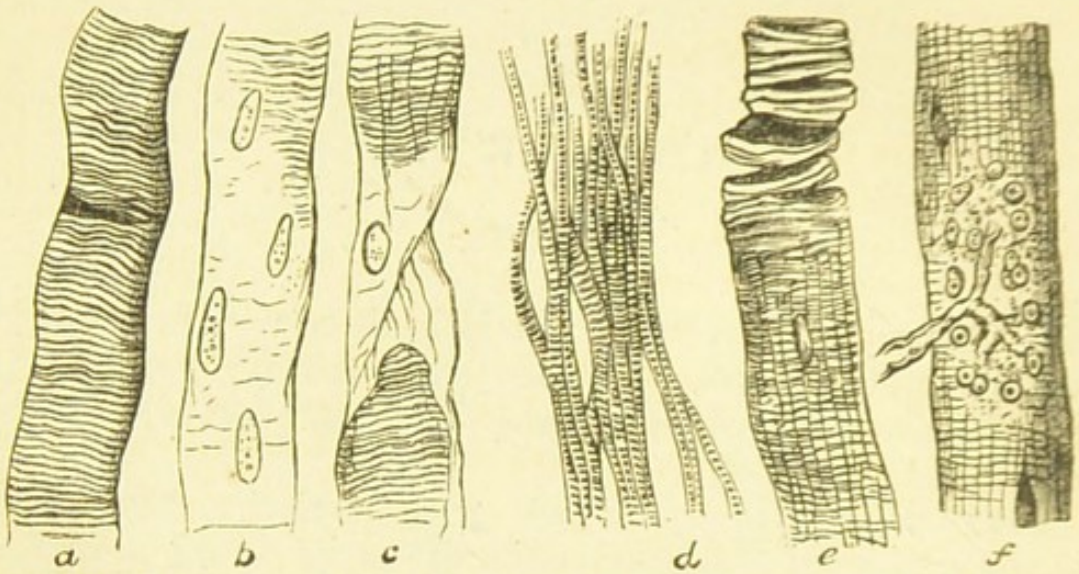


Fig. 30.—Striped Muscular Fibre. *a*, undisturbed fibre; *b*, treated with acetic acid, to show the nuclei; *c*, the striated substance torn and the sarcolemma uninjured; *d*, fibre teased out to show the fibrillæ; *e*, fibre broken into discs above, and showing fibrillæ below; *f*, termination of nerve, after Kühne.

30. **Striped Muscular Tissue** consists of very long fibres which, in their best developed varieties, approach $\frac{1}{400}$ of an inch in diameter. In most instances each fibre exhibits a delicate sheath or *sarcolemma*, which, in its resistance of reagents, resembles elastic tissue. The sarcolemma is filled with substance which is closely striped or striated transversely, the striation depending on a regular alternation of parts of different refractive properties. By careful manipulation this striated substance may be separated up into a bundle of fine threads called *fibrillæ*, each of which exhibits the same alternation of parts which causes the striation of the fibre, and may be looked on as a series of dark or highly refractive parts, the *sarcous elements* of Bowman, connected by means of a less dense material. By other modes of manipulation the striped fibres may be partially cleft across, so as to present the appearance of a series of discs; and there is no sufficient reason for supposing that the division into fibrillæ is more natural than this division into discs. To the interior of the sarcolemma are adherent a number of elongated nuclei; and it is impor-

tant to observe that in the frog, and also in early fœtal development of mammals, the nuclei are imbedded in the middle of the striated contractile substance. The fibres of the heart have no sarcolemma.

31. Unstriped Muscular Tissue is often arranged in bands of indefinite length like the striped fibres; but even when this is the case, it consists of a series of elongated fusiform corpuscles varying usually from $\frac{1}{600}$ to $\frac{1}{300}$ of an inch in length, and known as *fibre-cells*, although possessing no proper cell-wall. These fibre-cells are flat, with long tapering extremities, an elliptic or rod-like nucleus in the middle, and at each end of the nucleus usually a few granules. They are of dense consistence, and adhere one to another tenaciously by means of a material acted on by nitric acid.

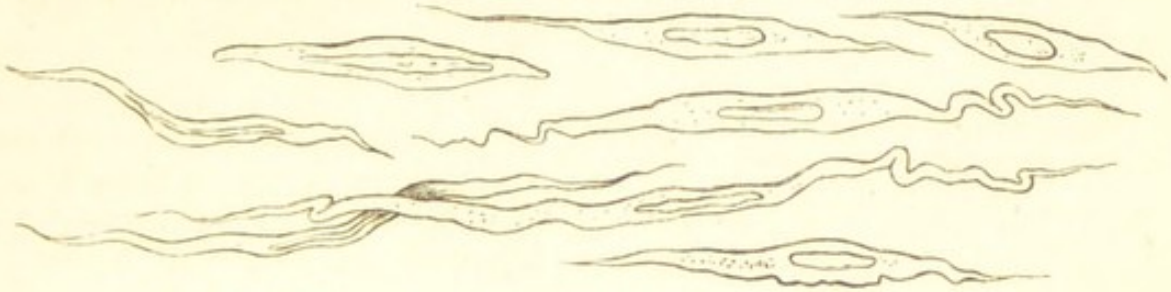


Fig. 31.—Fibre-Cells of Unstriped Fibre.

32. New muscular fibres of both the striped and unstriped variety, would appear to be capable of being developed from connective-tissue-corpuscles. In both varieties the connection with the nervous system is effected by filaments of nerves entering the interior of the fibre; in striped fibres the filaments end in swellings or expansions in or on the striated substance, and in unstriped fibres certain observers trace them to the nuclei of the fibre-cells.

33. Muscular substance consists in greater part of muscle-fibrin, a description of albuminoid material which, in the form in which it is found after death, is termed *syntonin*, and is distinguished from other varieties of fibrin by being soluble in dilute hydrochloric acid. It would appear, however, that during life the muscle-fibrin is in a fluid condition, and differs from the syntonin found after death; and it has, therefore, been distinguished as *myosin*. That a slight decomposition sets in soon after death, seems certain from the circumstance that dead muscle has an acid reaction, whereas muscle which

is still contractile is neutral or slightly alkaline, except after being thrown into a state of spasm.

Although muscle-fibrin is the principal solid constituent of muscle, there are numerous others which occur in small quantity in solution, some of them containing nitrogen and others not. The nitrogenous substances referred to are all of them much simpler in chemical constitution than the albuminoids, and the most important of them is called *kreatin*, of which it is sufficient to note that it and its allies are of a composition less complex than gelatin, and more complex than urea. Among the non-nitrogenous substances found in muscles may be mentioned grape sugar, and another variety of sugar called inosite, also lactic, butyric, and other acids. These various substances, both those which contain nitrogen and those which do not, are probably formed by processes of decomposition incident to activity of the muscular fibre, for their quantity is greater in muscle whose irritability has been exhausted by electric stimulus, than in muscle which has been at rest. Thus the hind limbs of a frog have been separated from the animal, and one of them has been subjected to severe electric stimulus, while the other has been left at rest; and the muscles of the stimulated limb have yielded a notably larger amount of substance soluble in alcohol than those of its fellow (Helmholtz).

34. During life, however, muscular action is sustained by the combustion not of nitrogenous material but of non-nitrogenous. This has been proved by a variety of experiments, in which persons have been kept for days on a weighed diet of known composition, and their urine and other excreta have been daily analysed; and it has been found that on days on which they took violent exercise, they lost no more nitrogen than on days when they were at perfect rest. By other experiments it is known that the amount of carbonic acid given off by the lungs is greatly increased by exercise. A muscle may, therefore, be compared with an engine which consumes in its work, not its own substance, but fuel. This fuel is carbonaceous material, which is converted with the aid of oxygen into carbonic acid and water; while it is in the intervals of rest that the proper substance of the muscle, consisting of albuminoid material, undergoes growth and repair.

35. Although the normal stimulus to muscular contraction is derived through nerves, the muscles may be excited to contract by various other stimuli, mechanical, chemical, and electrical, and by heat and cold. Isolated muscular fibres, both striped and unstriped, have been made to contract under the microscope. The irritability of muscular fibre is, therefore, inherent in itself, and not due to its nervous connections. Complete contraction sustained for a short time is followed by a condition of exhaustion or temporary loss of irritability; but the duration of contractile power may be greatly increased in the pathological spasm termed tetanus, the condition which constitutes lockjaw when it affects the muscles of mastication. However, a certain slight amount of habitual contraction of a continuous description, distinguished as *tonicity*, exists in a number of muscles, possibly in all; and we shall find it illustrated in the coats of arteries, and in the circular muscles called sphincters, which keep the orifices around which they are situated closed; for example, the pyloric orifice of the stomach.

The irritability of muscle continues for some time after the death of the animal, and in some cold-blooded animals may continue for days. The properties of living muscle can therefore be studied on parts separated from the bodies of animals. A block of living muscle placed in the circuit of a galvanometer exhibits a remarkable description of electric tension so long as it is quiescent. A galvanometer is an instrument which indicates the presence and direction of electric currents in a wire by means of the deviations of a magnetic needle placed over an insulated coil. If the circuit of the wire be completed by making contact with the transversely cut extremities of the block of muscle, or with points equally distant from the centre, no current is exhibited; but if the contact be made with any other points, the galvanometer indicates the passage of a current through the wire from the point nearest the centre of the block of muscle to the other; and this current is strongest when one point of contact is at the centre of the block, and the other at one extremity. If, however, the muscle be made to contract, the condition of electric tension ceases.

36. Some time after death, at a period said to vary from ten minutes to eighteen hours, or longer, a state of rigidity of the muscles sets in, termed *cadaveric rigidity* or *rigor mortis*. It begins in the face, and extends successively to the trunk and upper and lower limbs, and disappears from the parts in the same order, after lasting for a period varying from a few hours to several days, and longest in those instances in which it has set in latest. It is longest delayed and most marked in strong subjects who have been cut off in full vigour. It never sets in till after the disappearance of irritability, and that circumstance is sufficient to show that it is not, as has sometimes been supposed, a contraction of the muscles. Rigor mortis is often so intense as to render it impossible to alter the attitude of the limbs without tearing the muscles or damaging the bones; but it never alters the position in which the body is lying; for example, it does not raise the jaw when it has dropped in death; and in this it differs obviously from muscular contraction. The use of muscles is to produce movement by their contraction; and when two opposing groups are both made spasmodically rigid, as may happen in tetanus, the stronger overcomes the other. But so far from this being the case in rigor mortis, it is known to every undertaker that a body stiffens in whatever position it is placed in. No doubt some apparently well authenticated stories are on record of movements of the limbs taking place in persons who had died of yellow fever; but, however difficult such cases may be to account for, the very circumstance that the movements were neither spasms nor mere twitchings, but of a combined description, shows that they were not a variety of rigor mortis, and did not originate in the muscular texture, but in the nerves; and the explanation of them must be sought in some irritation of the central nervous system, probably by a product of decomposition, before irritability had ceased in the muscles. It appears, then, that rigor mortis produces no change in the length of the muscles; and there seems good reason to accept the hypothesis that it is a phenomenon due to chemical change which coagulates the myosin; but it must be admitted that we are not yet properly acquainted with the chemical distinctions of muscle prior to, during, and subsequent to rigor mortis.

37. Unstriped muscle is, for the most part, found diffused among the other tissues of organs, into the formation of which it enters, or lying in strata. Striped muscle, for the most part, is gathered into definitely limited organs called muscles, which have a distinct origin and insertion, and usually a certain amount of tendon in their construction. The extent of action of a muscle depends on the length of its fibres, while its strength of action is in proportion to the number of them. When therefore a muscle consists of few fibres running lengthwise from origin to insertion, it is useful rather for the extent of the movement which it serves, than for the force which it gives to it. But when great resisting power is required in a muscle, its tendons extend through its substance, and its muscular fibres are short and numerous, passing obliquely from one prolongation of tendon to another: thus in the soleus, one of the muscles of the calf already referred to (p. 51), the fibres are arranged in four oblique sets, and are none of them more than about an inch in length; so that the muscle is incapable of approximating its attachments more than an inch, but can exert in its limited range an enormous force, and is thus well adapted to sustain the weight of the body in standing.



Fig. 32. — Deep surface of soleus muscle.

CHAPTER V.

FREE SURFACES, EPITHELIUM, SECRETION, AND INTEGUMENT.

38. The free surfaces to be noted in the study of the body are of three descriptions :—

First, the external surface of the body is covered with integument.

Secondly, the surfaces of hollows and passages communicating freely with the outside, such as the alimentary canal and the ducts of glands, are lined with *mucous membrane*, so named from the mucus with which it is lubricated, thrown out from its surface, or supplied by glands.

Thirdly, the surfaces of cavities and canals which have little or no communication with the outside, have a smoothly polished appearance, and from them transudes, in the case of empty cavities, a sufficient amount of fluid to moisten them. This group of surfaces includes *serous membranes*, which are shut sacs of delicate membrane, extending over the surfaces of viscera, and lining the opposing walls of the cavities which contain them, so as to allow free gliding movement; thus the abdominal viscera and the opposed walls of the abdomen are invested with the peritoneum, the lungs and ribs with the right and left pleura, and the heart with the pericardium. The *synovial membranes* lining the cavities of joints are similar to serous membranes, but are not continued over the faces of the articular cartilages. Synovial *bursæ*, provided for the free gliding of muscles or integument over bone, such as the bursa on the front of the knee, the distention of which with fluid constitutes the common affection called housemaid's knee, are similar sacs with more slender walls; as also are the sheaths, called *thecæ*, in which a number of tendons glide. So also the interior of blood-

vessels and lymphatics are polished and smooth, and the interior of the heart is lined with membrane very similar to the pericardium round it.

39. Epithelium.—All the free surfaces now alluded to agree in one point, namely, that they are clothed with one or more strata of nucleated corpuscles. Such investments are termed *epithelium*, and the corpuscles which compose them *epithelial cells*.

Epithelia, in which the cells are arranged in a single layer, are termed *simple*, while those in which there are several layers, are distinguished as *stratified;* and stratified epithelia are named according to the character of the superficial layer, without regard to the numerous shapes of corpuscles in the deep layers.

In *squamous* or *pavement epithelium* the cells are flattened like scales. The surface belonging to the third group above described, including serous and synovial membranes, and the interiors of vessels, are all clothed with simple squamous epithelium of delicate microscopic character. The cuticle, which will be more particularly described anon, and the mucous membranes of the mouth, eyelids, and urinary

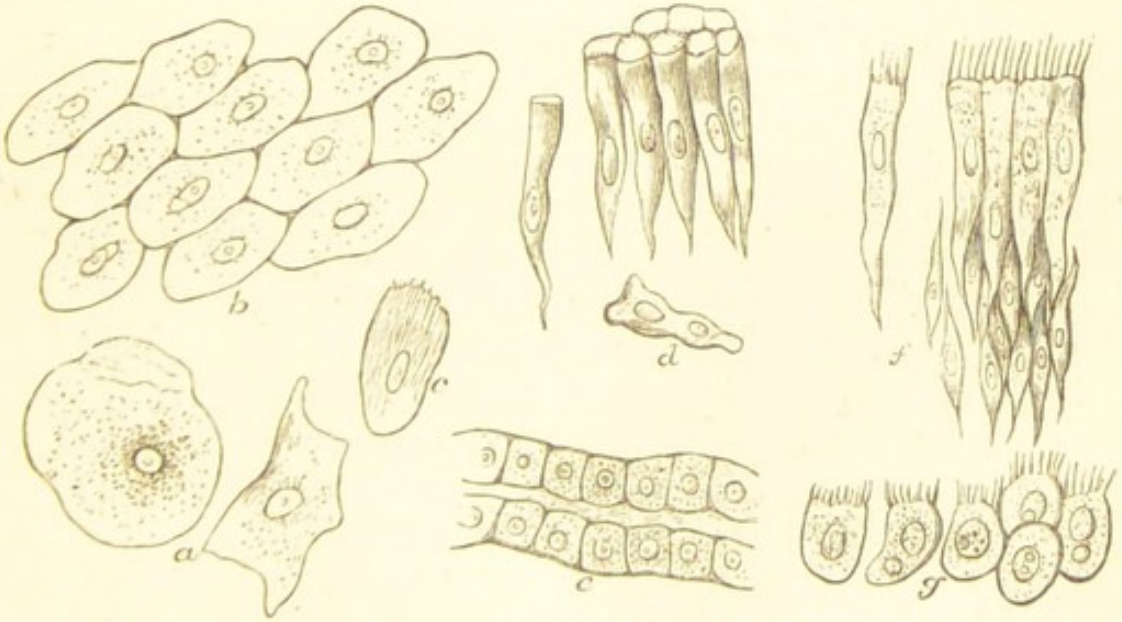


Fig. 33.—Varieties of Epithelium. *a*, separate squamous cells from mouth; *b*, from serous membrane; *c*, fluted cell from deep part of epidermis; *d*, columnar cells of intestine; *e*, cubical cells of kidney; *f*, ciliated columnar stratified epithelium of windpipe; *g*, ciliated spherical cells from choroid plexus of brain.

bladder, afford instances of stratified squamous epithelium. The microscopic examination of the more delicate simple squamous epithelia, is facilitated by treating the surface to be examined with a solution consisting of one grain of nitrate of silver in an ounce of distilled water, and, after a few minutes, washing it and exposing to the light. Oxide of silver is deposited, first in the lines of contact of the edges of the cells, and, on a little further exposure, also in their substance, particularly in the nuclei.

Columnar epithelium has the cells elongated in a direction vertical to the surface, and lying together like rods or prisms. It is found in the whole length of the alimentary canal, from the entrance into the stomach and onwards, and in the majority of ducts of glands. In glands and their ducts, there are also various transitional forms between columnar and squamous, as, for example, the cubical; and the terms *spheroidal epithelium* and *glandular* are used for the various irregular polygonal forms of corpuscle engaged in secretion in the salivary and other glands.

Ciliated epithelium is neither the mere mechanical protection which squamous epithelium is, nor the secreting structure which columnar and others often are, but has the property of keeping the moisture on its surface in a perpetual current. This it does by means of minute hair-like processes, termed cilia, projecting from the free aspect of its cells, and perpetually in motion. In a suitable fluid these cilia will continue to move for hours under the microscope, after the cells to which they belong have been detached from all other texture; and therefore both the power of movement or contractility, and the stimulus thereto, must be inherent in themselves. The character of the movement is always the same; it is so rapid that it cannot be observed in detail till it begins to get slower, but the general effect is something like the undulation of a field of corn swept by the wind, or still liker the vibration of hot air over a furnace seen against the light. When the rapidity abates, each cilium is seen to be slightly flattened, and to bend over to one side, and recover with a feathering curve. The movement is at all times in one direction, and that direction is in every case toward the orifice of the passage, when there is one. Ciliated

epithelium, with the cells of a columnar form, is found clothing the respiratory passages, including the lower part of the nasal cavity, the larynx, trachea, and bronchial tubes; it also lines the Eustachian tubes, and parts of the reproductive passages, both male and female. Ciliated epithelium of spheroidal character is common in the invertebrate and lower vertebrate animals, and is found in the ventricles of the human brain.

40. Secretion.—It has been pointed out that epithelial cells are in some instances devoted to secretion, and it will be convenient in this place to explain the nature of that function. Secretion is the preparation and separation of any substance from the economy; and the substance may either pre-exist in the blood and be merely extracted therefrom, or it may be a new substance elaborated by the secreting organ. Thus, in the perspiration there is little which does not pre-exist in the blood, while in the bile the most important ingredients not only are not constituents of the blood, but are poisonous when absorbed into it. In probably all instances, nucleated corpuscles of the description of epithelial cells are agents in secretion. The water contained in some secretions may escape from the blood in part by mere percolation, but the solid constituents are selected or manufactured by the secreting corpuscles or cells.

A certain amount of serous or mucous secretion may escape from the general surface of serous or mucous cavities; but for the production of special secretions there are **glands** provided, which are organs composed essentially of recesses opening off from epithelial surfaces and lined with secreting cells, which obtain the material on which they act from a copious supply of blood-vessels round about. The recesses of which glands consist may be either tubules or saccules, which may open singly on a free surface, constituting simple glands, or may be gathered into groups, forming compound glands, which, whether tubular or saccular in the secreting part, pour their secretion into tubules converging to a common duct. Compound sacculated glands have the primitive saccules arranged in lobules, and these in larger lobules; and such glands are therefore termed lobulated.

With respect to the mode of action of the secreting cells

or nucleated corpuscles, it may be remarked that, in the instance of one of the salivary glands (the sub-maxillary) in



Fig. 34.—Lobule of Liver of Oyster.



Fig. 35.—Lobule of Parotid Gland of Embryo Lamb five inches long.

the rabbit and the ox, branches of nerve have been traced under the microscope to the individual corpuscles, and it has been found that stimulation of the *chorda tympani* nerve supplying the gland excites secretion, and that the corpuscles of a gland so excited have a different appearance from those of a gland which has been at rest, losing the sharply defined transparent and slightly striated appearance which they have when at rest, the contour lines becoming indistinct, and the substance altered, so as to be capable of being stained more uniformly with carmine (Heidenhain and Pflüger). So also the secreting cells of the glands of the stomach have been found to have a different appearance during digestion from what they have in an unfed animal, but no appearance of multiplication of the cells at these times can be detected. It therefore appears that the secreting cells act by undergoing, under nervous stimulation, a



Fig. 36. — Secreting Corpuscles of sub-maxillary gland of the ox with nerve-fibres ending in them. After Pflüger.

change of condition, during which they have powers of attraction, elaboration, and transmission of substances. The active condition of the cells is not, however, proved to be in all instances occasional, and excited only by nervous stimulus. While saliva and gastric juice are poured out in response to occasional nervous irritations, the secretions of the kidneys and skin never wholly cease in health; and it is possible that in these organs the corpuscles have a certain amount of continuous activity, comparable with tonicity in muscles.

41. **The Integument.**—The integument combines the functions of protection, sensation, and secretion, and consists of two parts, the epidermis and the cutis vera.

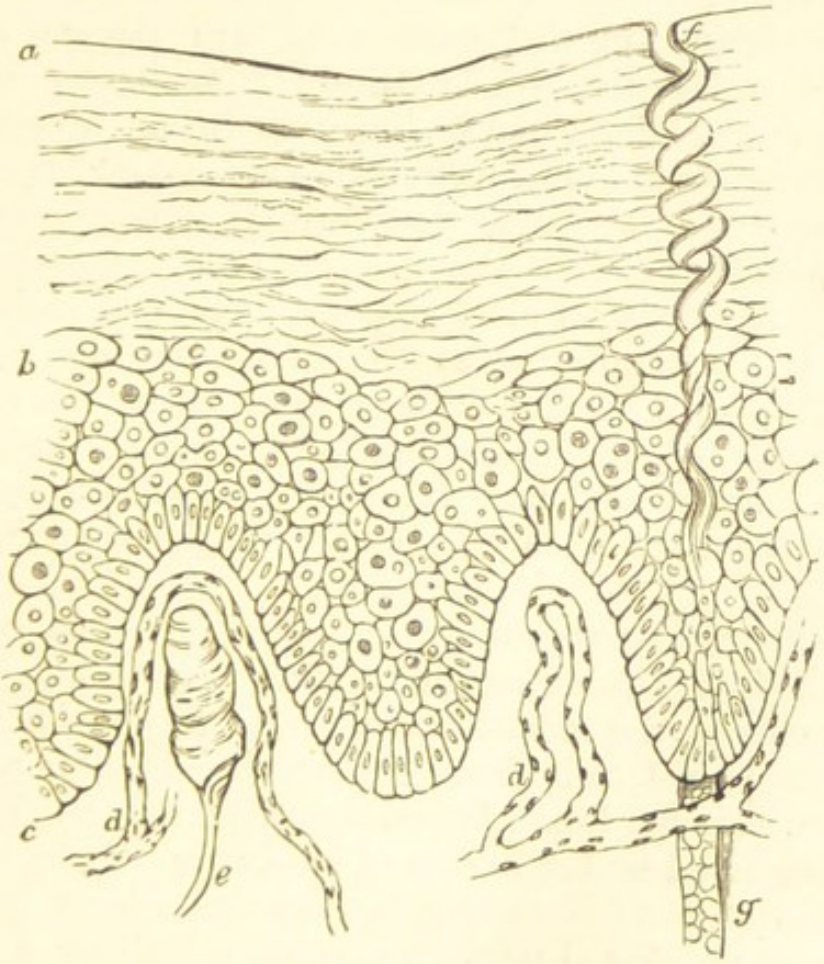


Fig. 37.—INTEGUMENT OF HAND, vertical section magnified. *a c*, epidermis; *a b*, horny layer; *b c*, rete mucosum; *c*, elongated corpuscles of deepest layer; *d d*, capillary blood-vessels in two papillæ; *e*, nerve fibre, ending in a touch corpuscle; *f*, duct of sweat gland, spiral in the horny layer; *g*, the same, beneath the integument.

The *epidermis*, *cuticle*, or *scarf-skin*, is a stratified squamous

epithelium. When very thin sections vertical to the surface are made through it, and examined under the microscope, it is seen to consist of two parts, which are very different in appearance: a deep part consisting of delicate texture, and a superficial which is horny. The difference may be made very striking by acting on the specimen with a drop of an ammonia solution of carmine, which takes no effect on the horny part, but stains the deep part, and particularly the nuclei, it being the property of that solution so to act on all growing nucleated corpuscles.

The deep part of the cuticle is likewise called the mucous layer (*rete mucosum*, or Malpighian layer), and it presents several strata of cells. Those which lie deepest, resting on the cutis vera, are always somewhat elongated vertically, while those immediately superficial to these are small, and the remaining strata exhibit cells larger and more flattened the nearer they are to the surface. It appears, therefore, that whatever may be the mode of origin of the deepest or elongated cells, the other layers consist of elements, the history of each of which is, that it has originated as one of the minutest cells, and passes gradually to the surface as it enlarges, undergoing both change of shape and chemical composition, until it becomes incorporated with the horny part of the cuticle, and is ultimately shed from the surface in the shape of a small scale.

The superficial or horny part of the cuticle consists of flattened cells closely adherent one to another, receiving additions from the mucous layer on the deep side, and casting off its oldest cells from the surface in a perpetual insensible desquamation. Its cells may be separated and their nuclei displayed by the action of a solution of caustic potash. The explanation of blistering is, that the mucous layer, acted on by some unwonted irritation, pours out a serous discharge, which, being pent up by the impermeable horny part of the cuticle, separates it from its connections.

The cuticle, besides the mechanical protection which it gives the body, furnishes likewise, by the impermeability of its horny layer, and the intervention of living parts between the surface and the vascular channels within, a protection

against the absorption of poisons, so that these, as is familiar to every one, may be handled with impunity when the cuticle is perfect, and yet may be introduced into the system by a very small wound. The surface of the body is not, however, to be supposed incapable altogether of absorbing substances from without. Fluids left in contact with the cuticle, and even solid substances rubbed into it, are gradually absorbed. Probably such absorption takes place principally in the orifices of the sweat glands, but even these are lined with thin prolongations of the horny cuticle, which therefore cannot be regarded as totally impermeable.

A variable amount of pigment exists in the deep cells of the cuticle, and it is on this that all duskiness of skin depends, the greatest amount of pigment being in the cuticle of the negro. Among the chemical changes, however, which take place in the epidermal cells as they approach the surface, is the disappearance of the pigment; and the horny layer is pale which is raised by a blister from the negro's skin. The red tints of the skin are not dependent on pigment, but on the blood shining through from the blood-vessels in the cutis vera.

42. The *cutis vera*, *derma*, *corium*, or true skin, has a white fibrous basis. Its surface is thrown into papillæ or finger-like prominences, the largest of which are about $\frac{1}{100}$ of an inch in length. In the papillary part, it is impossible to detect separate fibres; while in the deeper part, the white fibrous substance is arranged in interlacing bands, the spaces between which get larger as the subcutaneous tissue is approached, into which the skin gradually blends. In the deep part also, elastic fibres curl and twine in all directions, and there is a copious network of connective-tissue-corpuscles with long processes. The superficial part is much more vascular than the deep; for close to the surface of the cutis is spread one of the richest networks of capillary blood-vessels in the body, with a loop of blood-vessel in every papilla. It is from these blood-vessels that the epidermis receives its nourishment. The epidermis is moulded to the papillary surface of the cutis; and in the hands and soles of the feet, which have the papillæ disposed in thickest rows, the trace of this arrangement is left on the surface of the cuticle, in the form of the

ridges with furrows between them which characterise those parts.

43. The sensibility of the skin is due to the presence of nerve terminations, which are of different descriptions and at different depths. The largest of these are termed *Pacinian bodies*, and are especially found in the subcutaneous adipose tissue of the fingers and toes (fig. 38). They are grape-shaped structures of such size that they can be recognised by the practised dissector with the naked eye as minute grains, being upwards of $\frac{1}{16}$ of an inch in length; and they consist each of a dilated end of a nerve fibre, with layers of tough nucleated tissue round about. They are not peculiarly integumentary structures, for the site in which above all others they are found easily and abundantly, is the mesentery of the lower bowel of the cat. Within a number of the papillæ of the cutis vera smaller bodies are found, termed *touch-corpuscles* of Wagner (fig. 37). These are of such size, that each one fills the greater part of the papilla in which it is contained: the structure consists of a firm nucleated core, round which the nerve is coiled. Still smaller *end-bulbs* (of Krause) are found in or beneath the papillæ in places where the skin is delicate, as on the lips and over the white of the eye, and appear to resemble the Pacinian bodies in having the nerve ending in the interior. Lastly, it is to be noticed that, independently of all these modes of nerve termination, nervous filaments have been found ramifying between the cells of the epidermis, and possibly terminate in individual cells; and, although this is the most difficult method of nerve-termination to trace, there can be little doubt that it is the most important.

44. The glands of the skin are of two descriptions, the sudoriparous and the sebaceous.

The *sudoriparous*, or sweat glands, are in great numbers all over the body. In the palm of the hand there are as many as 2500 in every square inch of skin, but in the lower limbs and back there have been estimated to be not more than 600 in the square inch. On the palm, particularly when it is warm and slightly moist, the orifices of these glands may be easily seen with a simple pocket lens arranged in a row on every ridge. Each gland consists of a tubule,

the secreting part of which is coiled up into a ball about $\frac{1}{50}$ or $\frac{1}{100}$ inch in diameter, imbedded in the subcutaneous tissue, and supplied freely with blood-vessels, while the duct passes vertically up through the corium. Sometimes there are two tubes in one coil, uniting to form one duct. In the



Fig. 38.—Sweat Glands and Pacinian Corpuscles. *a*, Papillary surface of corium; *b*, secreting portions of the sweat glands; *c*, corpuscles of Pacini.

palm of the hand and the sole of the foot, where the epidermis is thick, the sudoriparous ducts, in passing through the horny layer, are thrown into a fine spiral like a cork-screw, which may be accounted for thus: the ducts in the deep part of the cuticle are lined with horny epithelium, which is incapable of contraction, while round about them are growing epithelial cells of the rete mucosum, which, as they

approach the surface, in process of conversion into the horny layer, become flattened; the horny wall of the duct, as it is carried to the surface with the structures in which it is imbedded, having therefore to be accommodated in a shorter vertical depth than it occupied at first, is pressed by the shrinking structures round it into an oblique position, and the regular continuance of this process gives rise to a spiral.

The *sebaceous* glands (fig. 41) are for the most part connected with hairs; and large hairs have usually several of them opening into the necks of their follicles, but frequently it happens, particularly in the face, that a very large sebaceous gland opens into the neck of the follicle of a very small hair, showing that these glands not only serve to lubricate the hair, but the integument as well. The sebaceous glands consist of one or more small groups of saccules opening into a common duct, lined with epithelium, and filled with oily matter.

45. The perspiration is the combined product of both sets of glands, but principally is derived from the sudoriparous. The sebaceous glands secrete nothing but oil, and they are not the exclusive source of the oil of the skin; for not only may particles of oil be detected in the interior of large sweat glands, but oil is secreted by the palms of the hands, which have no sebaceous glands. In connection with this it may be mentioned that the ceruminous glands, which secrete the wax of the ears, are simply large sweat glands. The most abundant solid constituent of the perspiration is common salt, chloride of sodium; and besides other salts, there is always a small amount of urea in it. Carbonic acid is likewise given off by the skin, although the amount of it is insignificant compared with what escapes by the lungs. The total amount of perspiration is obviously exceedingly variable; but in experiments made by enveloping the body in a water-tight bag with apertures for breathing, it has been found to be little short of two pounds per diem. One obvious use of the perspiration, and probably the principal purpose which it serves, is the protection of the body from too great heat, whether of external or internal origin, by the cooling effect of its evaporation from the surface, as will be further referred to (p. 149). Its flow, like that of saliva, is probably

under the control of the nervous system; certainly it is no mere filtration dependent only on the amount of blood sent to the surface, for the skin may be hot and dry, particularly in fevers, and a cold sweat may burst out when the surface is pale from deficient flow of blood to the surface, as in the recovery from fainting.

Considering the function of the perspiration as a moderator of the temperature of the body, the results which are obtained by varnishing the bodies of animals with an impermeable coating are not only interesting, but exceedingly difficult to explain. In such experiments, when the varnishing is complete, the temperature rapidly falls, and the animals die after periods varying from a few hours to days; the smaller animals, those in which the total surface bears the largest proportion to the body, being those which succumb soonest. Why the temperature falls is not understood; but whatever the cause of death, such experiments show the importance, in a sanitary point of view, of removing accidental accumulations of all kinds from the surface of the body.

46. **Epidermal Appendages.**—For purposes of protection there occur in different animals a variety of special growths from the cuticle; and those which occur in the human subject are nails and hairs.

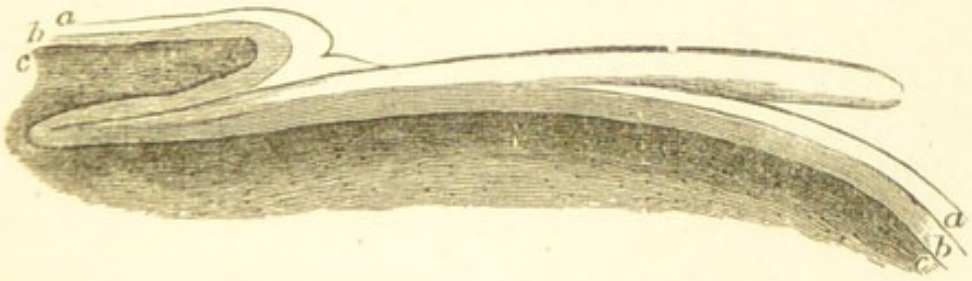


Fig. 39.—Nail and its Matrix, longitudinal section. *a*, Horny layer of epidermis; *b*, mucous layer; *c*, corium.

A Nail is simply a thickening of the outer layer of the cuticle growing from a bed or matrix, which is in the form of a fold at the back part. In this fold there are two surfaces of skin looking one toward the other, and thus the root of the nail receives additions from above and below, as well as behind. It is pushed continually forwards by new growth at the bottom of the fold, and continues to receive additions to its thickness from the flat part of the matrix as long as it

is adherent thereto. Hence it happens that the nail is stronger the farther from the root, and that its outer surface is harder than the deep part where the recent and soft additions to the thickness are placed.

The substance of a nail is an instance of the texture called horn. But it is always to be kept in mind that the word horn has a double meaning, which has descended to it from the Latin. This has obviously arisen from the structure of the horns of the sheep and cxen, which consist of an outer coating of the texture called horn investing a core of bone. But on the horn of the stag there is no horny covering, the structure being a growth of bone, which, when young, is covered with integument, but afterwards becomes denuded. Instances of morbid growth of solid horny texture occur occasionally in man, but rarely grow to any considerable size. In bedridden persons, whose nails have been neglected, it sometimes happens that some of them project like claws, curving over beyond the digit, and become nearly as thick as they are broad.

47. *A Hair* consists of a bulb or root imbedded in a follicle, and a shaft or stem ascending therefrom. The follicle is an invagination of the integument lined with a thin prolongation of the cuticle, divisible into two layers, sometimes called the inner and outer root-sheath, and so adherent to the root of the hair that it is liable to be removed with it when a hair is pulled out. At the base of the follicle is an enlarged papilla; and the hair itself may be considered as the exaggerated cuticular investment of this papilla. The root of the hair forms a bulbous enlargement round the papilla, and consists in greater part of polygonal cells, which in dark hairs are loaded with pigment; but towards the upper part, round about, the cellular substance is changed to fibrous, and on the surface there is an imbricated epithelium continuous, below, with the innermost layer of the cuticular lining of the follicle. All these three elements may be represented in the stem. The epithelium on the surface of the root, traced upwards, is seen to form on the stem an extremely thin coat, of which the most easily discernible part is a network formed by the thickened edges of the scales. In many of the larger hairs, the cells which constitute the main

oulk of the root are continued in a column up the centre of the stem, and are termed the *medulla*. But in the smaller hairs of the body, and even often in the hairs of the head, the medulla is absent, or only present in small patches; and in all instances the bulk of the stem is of fibrous substance, which, in contradistinction to the medulla, is termed the *cortical* part. This cortical substance appears in the natural state nearly homogeneous; but when boiled with potash it is seen to consist of flat fibres, which are derived from the cells of the root by elongation and alteration of consistence.

The three elements of the stem of the hair are very differently represented in different animals. In wool the edges of the epithelial cells are prominent, and by their tendency to catch cause the hairs to be easily felted. In some small animals the epithelium is like a series of hollow cones embracing the hairs. In some, as in the mouse, the medulla is thrown into a series of air

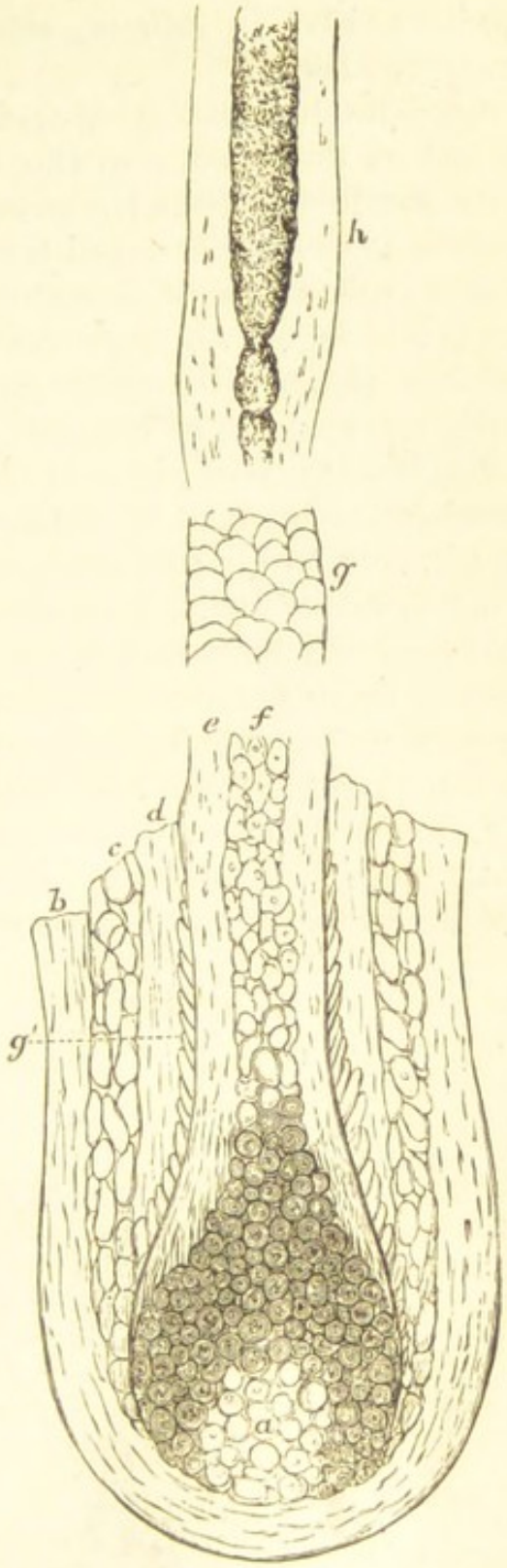


Fig. 40.—HAIR. *a*, Papilla in the centre of the bulb; *b*, dermic coat of the hair-follicle; *c*, *d*, outer and inner cuticular lining; *e*, cortex of the shaft; *f*, medulla; *g*, epithelium; *g'*, the same seen in profile, imbricated on the root; *h*, portion of shaft become white, showing the medulla enlarged by presence of minute air-bells, reflecting the light, and making the hair thicker.

cavities, and in others, such as the pig, the medulla is entirely absent.

48. The shaft of the hair is in some instances cylindrical, and in others flattened, and the tendency to curling is connected with the form. Thus the straight hair of the North American Indian is cylindrical, and the negro's woolly hair is quite flat. The pigment, on which the colour depends, is diffused in variable degree through cortex and medulla; but the most curious point with regard to the medulla is its connection with the turning of the hair white. In that change there is a disappearance of pigment; but there is likewise the development in the medulla of numbers of closely set minute globules of air. Such air globules are also constantly present in the white hairs of other animals, and reflect the light from their surfaces. A hair may begin to turn white in any part of its course, or in patches at different points; and sometimes one may see in one hair some parts unchanged, some with the pigment gone, but without air globules, others with air globules, but with the pigment remaining, and parts with both changes complete. It will be observed, therefore, that the hair undergoes changes of nutrition in its whole length.

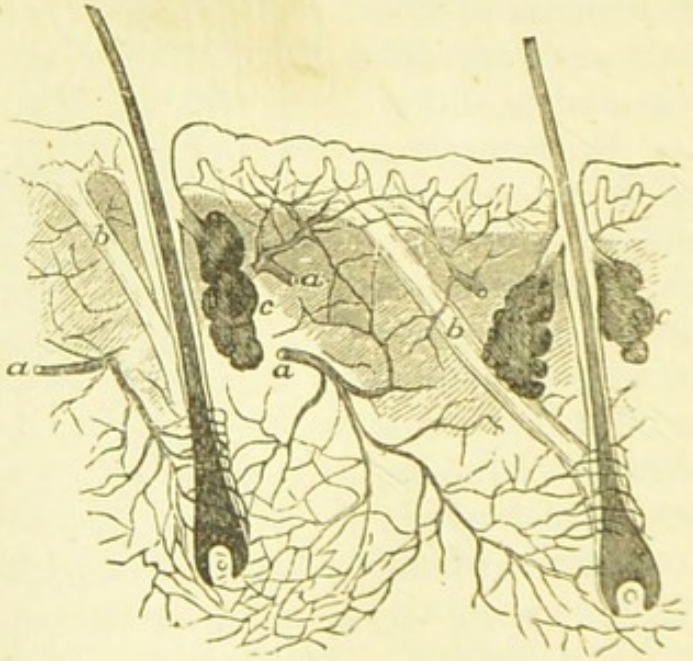


Fig. 41.—Section of Scalp, showing two roots of hairs. *a*, *a*, Blood-vessels; *b*,*b*, erector muscles of the hair; *c*,*c*, sebaceous glands.

These may take place with great rapidity; for at least one case has occurred in hospital, under medical supervision, in which the hair has grown white in a single night from anxiety, and there is, therefore, no reason to doubt the historical traditions of similar occurrences. The appearance in one night also of single white hairs without any special disturbance of the system, has been noted by competent observers, and is probably a very common occurrence.

The sensation of the hair standing erect from emotional or other causes is accounted for by the fact that a band of unstriped muscle descends from the corium, and is attached to the lower part of the hair follicle on the side towards which the hair is sloped, so that by its contraction it pulls the root of the hair into the vertical position.

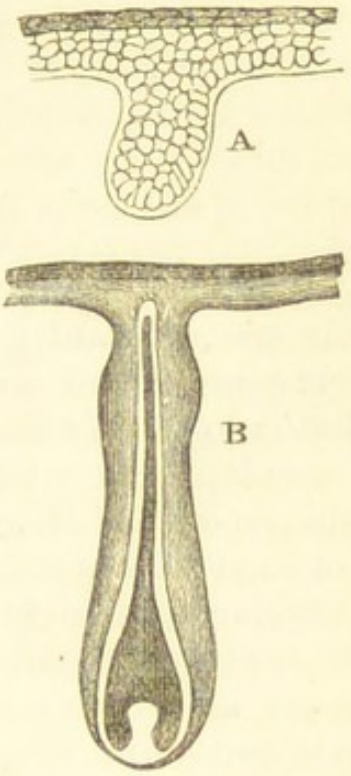


Fig. 42.—Development of a Hair. A, Downward growth of epidermis. B, Form of the hair completed before appearing on the surface. After Kölliker.

The first commencement of a hair in the embryo consists of a thickening of the cuticle by growth downwards into the corium; and within the mass of cells so deposited the form of the hair makes its appearance with a slender shaft and a large bulb, into which a papilla from the corium projects. Then, in the process of growth, the young hair bursts through the cuticular sheath in which it has been enveloped, and projects on the surface.

CHAPTER VI.

ALIMENTATION.

49. It has been already mentioned that the tissues of the body are constantly parting with particles which enter into their composition, and are receiving new materials to replace what is lost. We have seen that increased muscular exertion is accompanied with increased loss of substance; and the same is true of increased mental exertion, and of increased evolution of animal heat, as in exposure to extreme cold. Muscular and mental effort, and the maintenance of the temperature of the body, as well as regeneration of the tissues, all involve losses of substance which require to be made good; and thus, as has been said at the outset, the body may be regarded as a vortex whose component particles are ever changing while its form remains.

The processes by which materials are altered and thrown off are all processes of oxidation, by which complex chemical combinations are reduced to others of simpler descriptions; and this is sometimes expressed, though not very accurately, by using the word combustion in speaking of such changes. The ultimate products of combustion of organic matter are, as will be recollected, carbonic acid, water, and ammonia; that is to say, that, keeping sulphur, phosphorus, and mineral matters out of account, and confining our attention to the carbon, hydrogen, oxygen, and nitrogen of organic matters, the most complete oxidation of such substances which can be effected is into carbonic acid, water, and ammonia. The oxidation within the body falls short of this; by far the greater part of the matters which escape from it, after having circulated in the system, being eliminated as carbonic acid, water, and *urea*. No doubt, as has already been pointed out, there is a continual casting off of horny

matters and of oil from the integument; and there is discharge of undecomposed matter in the form of mucus from intestinal and other passages, as well as certain substances derived from the bile; but the total amount of loss from such sources is comparatively small. Also, it is to be noticed, that ammonia escapes from the body in minute quantities, and that there is usually in the urine a distinct though small quantity of uric acid, a product of less complete oxidation of nitrogenous substance than urea. But urea, the principal organic constituent of the urine, a material of the same composition as cyanate of ammonia, and therefore one stage removed from that perfect oxidation which results in carbonic acid and ammonia, is the substance in the form of which by far the greater part of the nitrogenous debris escapes from the body.

Keeping out of consideration the debris of food which has never entered the system, but is discharged in the fæces, the amount of nitrogen given off daily may be estimated at 250 grains,* and the amount of carbon which escapes in the form of carbonic acid may be reckoned at 4000 grains; these substances must therefore be daily introduced into the system in those quantities in the shape of food, if the weight of the body and its constitution are to be maintained. Supposing the 250 grains of nitrogen to enter the system in the form of albumen, then in consequence of urea containing a much larger percentage of nitrogen and smaller percentage of carbon in its composition than albumen, there will be liberated in the conversion of the albumen into urea 755 grains of carbon, or seven-eighths of the total amount which the albumen contains, to escape in the form of carbonic acid, while the rest of the 4000 grains daily lost must be furnished by additional supplies of food, which need not contain any nitrogen. The amount of solid food necessary for the preservation of health is thus regulated by the loss of substance from the body; but as a certain quantity of the food always escapes digestion, and is discharged, after traversing the alimentary canal, without having entered the system, the supply taken has to be in excess of what is required to make up for systemic loss. It has been calculated that there are daily

* One ounce avoirdupois contains 437½ grains.

required for an adult man about 40 ounces of so-called solid food, yielding 22 or 23 ounces when evaporated to dryness, and from 50 to 80 ounces of water.

50. The aliment required by the body consists of organic food, salts, and water. The reason why water is required in larger proportion in our aliment than that in which it exists in the tissues, is that, by processes of filtration and evaporation, the body is constantly losing water by the skin, the kidneys, and the lungs, additional to what is produced by waste of tissue. Common salt or chloride of sodium, on account of its great solubility and the ease with which it passes through membranes, is also particularly liable to escape both by the skin and the kidneys, and is found in all the secretions; it requires therefore to be supplied in quantity greater than that in which it exists in the requisite amount of solid aliment. The results of experiment, as well as general experience, show that the addition of this substance to the food is advantageous to nutrition; and it is well known to farmers that it is relished by cattle, and improves their condition. Other mineral matters useful in the economy, as, for example, salts of lime, occur in solution in the water which we drink, as well as in our solid food.

The organic matters used as food, like those which are met with in the composition of the body, are divisible into nitrogenous and carbonaceous. *Nitrogenous* foods are of two kinds, namely, albuminoid or proteid substances, and gelatinoids. Albuminoids are obtainable from both vegetable and animal sources, though much more abundantly from the latter; in flesh diet they are supplied in the forms of muscle-fibrin and albumen; in eggs albumen is furnished, mingled with oil in the yolk, and in the white altogether pure; and in milk the albuminoid constituent is casein, distinguished from albumen by not coagulating when heated. Under the title of gelatinoids may be conveniently grouped a set of substances obtained from animal sources, and including not only gelatin and chondrin, but the tissues which yield them. Also, nearly allied to those substances in nutritive value are kreatin and other flavouring ingredients in the juice of meat.

Carbonaceous foods are likewise of two principal kinds—

the oils and the carbohydrates. Both consist of carbon, hydrogen, and oxygen, but the oils have a much greater number of equivalents in their chemical formulæ than the carbohydrates; that is to say, they consist of more complex arrangements of atoms; they have likewise a larger amount of carbon and a smaller proportion of oxygen in their composition. The carbohydrates are so called from consisting of carbon in conjunction with hydrogen and oxygen, in the proportion in which they are combined in water; they include starch, together with the allied substance cellulose, which forms a large part of growing vegetables, and sugar. Starch is a highly important constituent of vegetable diet, forming the larger part of the weight of flour, and a much greater proportion of the substance of potatoes. It occurs in small granules which are insoluble in cold water, but which burst when boiled, the contents of the starch granule being dissolved, while the outer envelope remains unacted on. It is a property of starch that in the presence of certain substances, sometimes termed amylolytic ferments, it becomes converted into grape sugar; and no starch is capable of being absorbed into the system until it has undergone that change. The sugars used in food are of three principal descriptions—cane sugar, grape sugar, and sugar of milk. It may be here remarked that milk, the sole food provided by nature for the infant, consists of a mixture of a solution of proteid substance in the form of casein, oil in the form of butter, sugar of milk, and various salts, and therefore contains all the varieties of aliment necessary for health.

51. Properly to nourish the body, the daily waste must be balanced by daily repair, and the food must contain a sufficiency of every substance required by the tissues. It follows from this, and has been proved by experiment, that no amount of carbonaceous food will make up for want of nitrogenous ingredients. On this account, animals which feed on vegetables have to consume large quantities of food that they may extract the requisite amount of nitrogenous substance; and persons who feed entirely on potatoes, require to use much greater quantities than they would require of other diet, because potatoes consist principally of starch, and have remarkably little nitrogenous substance in their composition.

In fact, it may be said, that in a diet sufficient in quantity, if the nitrogenous constituents be too plentiful, unnecessary work is thrown on the kidneys, while, if they be too scanty, an unnecessary load is thrown on the intestines. Moreover, it has been found by experiment that no amount of gelatinoid substance will suit instead of the albuminoids; animals can be supported on lean meat, but they die when fed on jelly alone, even when it is pleasantly flavoured, and at first relished. It appears, therefore, that animals have no power of building up albuminoid matter from simpler chemical substances. They have no power of manufacturing organic matter from the materials found in inorganic nature, but feed either directly on the vegetable world, or on other animals which have fed on vegetables; and there is no proof that in any instance they have the power of acting on the simpler organic substances, so as to produce from them the more complex. Further, it appears from the researches of botanists, that even in plants the power of building organic matter is confined to the green parts. The statement may therefore be ventured on, that *so far as observation has yet proceeded, it would appear that the presence of chlorophyll is as necessary for the production of organic matter in organisms, as the presence of protoplasm is necessary for growth.*

With regard to gelatin, the question is often asked how it happens, if it be incapable of sustaining life, that in conjunction with other things, it is useful as an article of diet, and a favourite in the sick room. Perhaps that question is sufficiently answered by pointing out that carbonaceous substances are likewise insufficient by themselves to support life, and that in the formation of urea from gelatin, five-sixths of the carbon is unused, and therefore combines with oxygen to form carbonic acid, as does the carbon of carbonaceous food; also, that gelatin requires little digestion, and is at once decomposed on entering the circulation.

All carbonaceous food serves the economy sooner or later by undergoing oxidation into carbonic acid and water, and thereby supporting the temperature of the body, or assisting its vital processes, as we have seen that it does in muscular action. Oil may be temporarily stored up in the shape of adipose tissue: and the carbohydrates may be stored as

glycogen in the liver, a viscus which likewise serves as a reservoir for oil, healthily in fishes, and more or less pathologically in man; but there is no proof that grape sugar can be converted into oil, nor that either oil or sugar is changed into any more complex substance. It is quite possible that the fattening effects which the carbohydrates often have, may be produced by their saving from oxidation oil which would otherwise be consumed in their stead. Certain it is that, in dieting the sick, the use of the carbohydrates is not found to be equivalent to the use of oils.

CHAPTER VII.

DIGESTION.

52. The food is received into the digestive or alimentary tube; there it is subjected to a series of agencies by which it is in greater or less part digested or reduced to a condition in which it can be sucked up by appropriate vessels; and, while this portion is absorbed into the circulation, the effete remainder passes on and is discharged. The digestive tube, beginning at the mouth, is continued to the stomach by the throat and gullet, while the stomach is succeeded by the small and great intestine. In its passage along this tract, the food is subjected to both mechanical and chemical processes; and it is proposed to follow its course, and mark the mechanical actions to which it is subjected, before directing attention to the chemical changes. But, among the first of these mechanical actions is that of the teeth; and the whole structure and history of these may be conveniently considered at the outset, previous to noticing their action in mastication.

53. **The Teeth.**—Under this term, in its widest signification, may be included all hard structures for the trituration of the food; and these are of many different kinds, and found in different positions. In certain molluscs, *e.g.*, the genus *Bulla*, and in crustacea, *e.g.*, the lobster and crab, teeth of shell are developed in the walls of the stomach; and both in crustacea and insects, modified limbs, called jaws, are used for the seizure of food: in the cuttle fishes, the same function is performed by a horny beak in two parts like that of a bird; and in other molluscs by the rasping action of minute plates set on a long muscular tongue. In the vertebrata, the same variety of structures for breaking down the food exists. Birds and turtles have beaks which are horny developments of the integument covering the jaws, and graminiverous

birds have not only muscular gizzards, but by swallowing stones, furnish themselves with temporary stomachic teeth of a most efficient description.

Even among teeth, properly so called, namely, structures impregnated with mineral matter, there is great variety. In fishes and reptiles, they may be jointed to bones by means of ligament, or welded to them immovably, and may be attached to numerous bones abutting on the oral cavity; indeed, true teeth occur (*Synodontis*) lying in the integument unconnected with any bone. In crocodiles, the teeth are in large sockets. In mammals, they are confined to the inferior, superior, and inter-maxillary bones, and are fastened in closely fitting sockets, so that, when full grown, they cannot drop out, even when the bones have been macerated.

A tooth, such as may be obtained from the human subject, consists of a crown projecting above the gum, and a root imbedded in a socket of the jaw, and the place where these meet is called the neck. The root may consist of one fang or several; and at the extremity of each fang is a little opening leading into a cavity in the interior of the tooth, which is filled with a soft and sensitive substance called the pulp, while the blood-vessels and nerve of the pulp pass through the little opening. The main mass of the hard substance of the tooth is com-

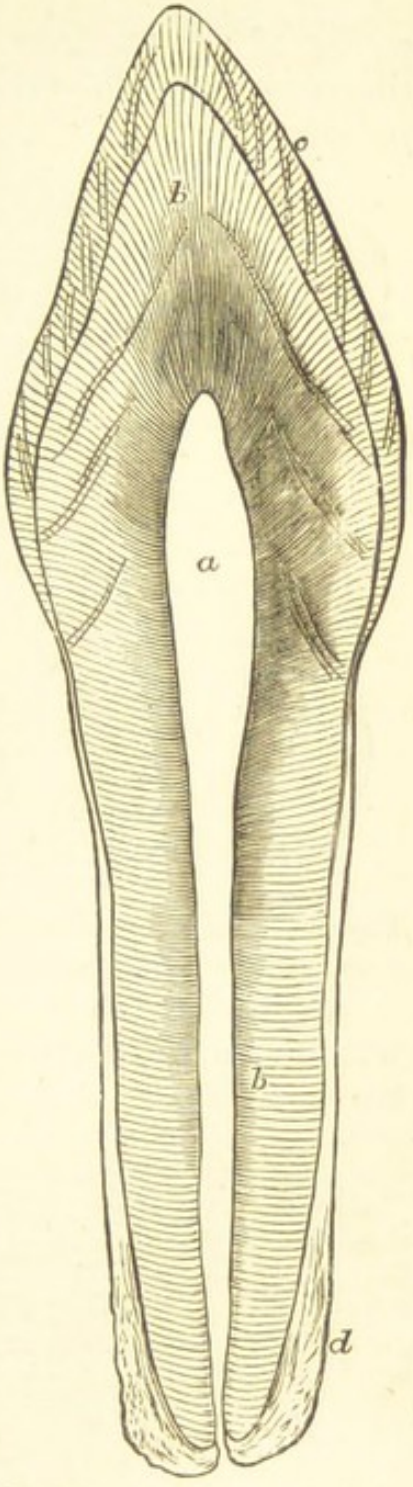


Fig. 43.—Incisor Tooth, vertical section. *a*, pulp cavity; *b*, *b*, dentine showing the general curves of the tubes and three contour lines crossing them; *c*, enamel, with coloured bands crossing its prisms; *d*, crusta petrosa.

posed of a structure called dentine, and this is covered in the crown with a cap of enamel, and in the root with *crusta petrosa*.

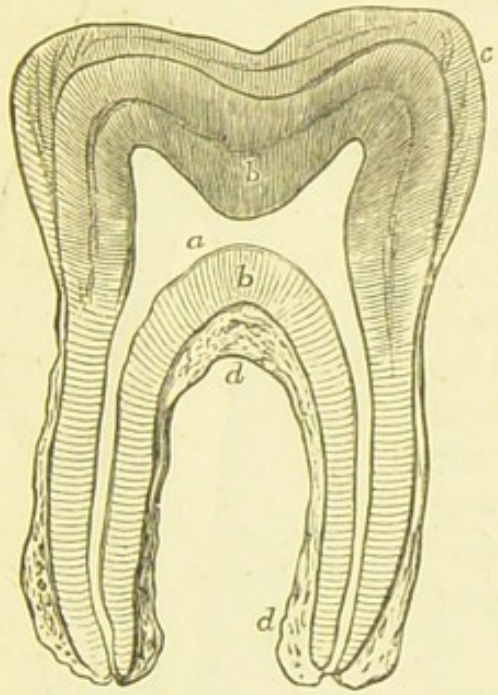


Fig. 44.—Molar Tooth, vertical section; letters same as in fig. 43.

54. *Dentine* has a matrix yielding gelatin, and impregnated with mineral matter in slightly greater proportion than bone; but, instead of lacunæ, it contains a multitude of closely set tubes, which radiate from the pulp-cavity in an undulating nearly parallel course, getting smaller as they approach the surface, and giving off branches. Each tube contains an albuminoid fibre, which, at least in the young state, would appear to be an offshoot from a corpuscle at its inner or pulp-extremity, comparable with a bone-corpuscle; and as the dentine grows from without inwards, invading the pulp-cavity, these corpuscles travel inwards also. Crossing the substance of the dentine,

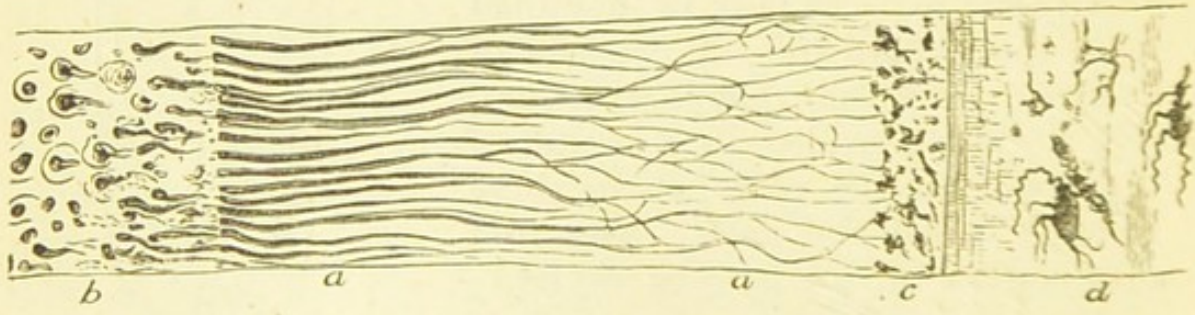


Fig. 45.—Dentine. At *a*, the section is parallel to the tubes; at *b*, it cuts them across; *c*, granular layer (of Purkinje) resulting from the presence of small spaces connected with the extremities of the dentine tubes; *d*, crusta petrosa.

faint lines may be often seen, called *contour lines* (Owen), which consist of chains of irregular spaces in the matrix, filled with less refractive material, and possibly caused by the influence of the irregular pressure to which the teeth are subjected.

Enamel is an exceeding hard substance, containing only 3½ per cent. of animal matter, while the rest of it consists of phosphate of lime and other earthy salts. It is composed of solid vertical columns or prisms, the sides of which closely fit to one another, like pillars of basalt, but are by no means strictly parallel, for they interlace to a certain extent. They are about $\frac{1}{5000}$ inch diameter, and have a transverse striation which is particularly distinct in the young state. The enamel prisms are crossed by bands of a brownish tinge called *coloured lines*, which have probably a similar origin to the contour lines of the dentine, both being most frequent in old teeth.

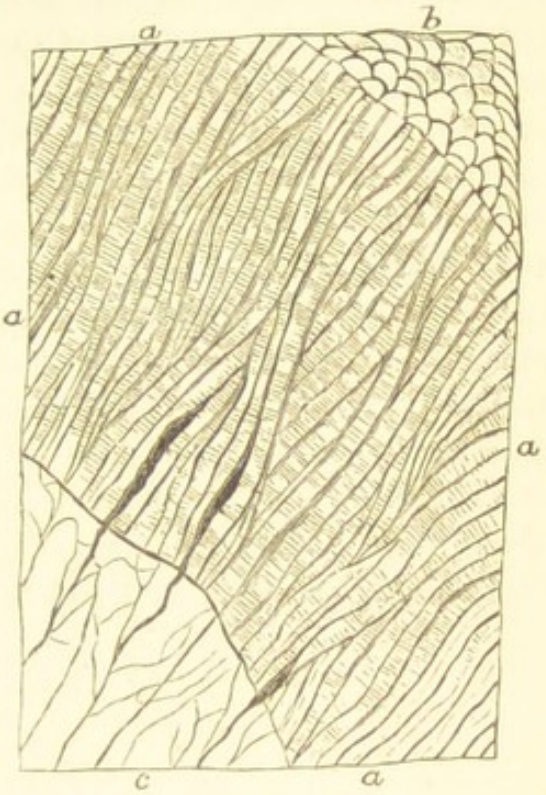


Fig. 46.—ENAMEL. *a*, *a*, longitudinal section; *b*, free outer extremities of the prisms, seen in perspective; *c*, dentine.

The *crusta petrosa* or *cement* (fig. 45, *d*,) is softer than dentine, and consists of a deposit of layers of solid bone-matrix, in which are sparsely scattered lacunæ, with very irregular canaliculi coming off from them. In the human teeth it is confined to the root, but in the complex crowned teeth of some animals, for example, the molars of the ox, it fills up depressions which dip deeply down into the crown, and is there situated superficial to the enamel. When such a tooth is worn, as it soon is after coming into use, the dark coloured crusta petrosa, filling up the complicated depressions, is seen surrounded by lines of pure white enamel, on the other side of which is the yellow dentine, somewhat hollowed out, as is also the crusta petrosa, from being softer than enamel.

55. Teeth, in their first development, have a considerable resemblance to hairs; for both make their first appearance. in the embryo, from tegumentary depressions

filled with epithelium, and with a papilla at the bottom; and in both the depression becomes temporarily converted into a closed sac, which afterwards is burst open by the protrusion of the contained organ. The layer of epithelium immediately in contact with the tooth-papilla is converted into enamel, the enamel-columns corresponding with the elongated cells of the deepset layer of the cuticle. The dentine is formed from the superficial part of the papilla itself, while the remainder of that structure constitutes the pulp. The development of the tooth proceeds from the summit of the crown downwards, the pulp thus becoming gradually enclosed. The sacs of the permanent teeth make their first appearance from the necks of the sacs of the milk set at a very early period, while the latter are still open, and subsequently descend to positions beneath the milk teeth, which they are destined to replace.

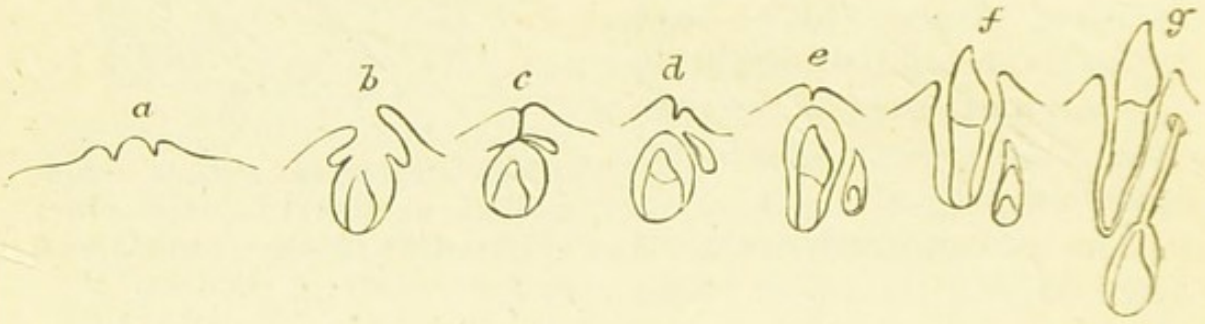


Fig. 47.—DEVELOPMENT of a temporary and a permanent tooth (Goodsir). *a*, papilla on the floor of the primitive dental groove; *b*, papilla enclosed in a follicle in the bottom of the secondary groove, and opercula above the follicle; *c*, papilla become a pulp, and the follicle a sac, by adhesion of the opercular lips, and the secondary groove adherent, except behind the inner operculum, where it has left a shut *cavity of reserve* for the permanent tooth; *d*, *e*, temporary tooth increasing by growth downwards of the fang, and the permanent tooth-sac receding from the surface; *f*, temporary tooth appearing on the surface; *g*, permanent tooth-sac much removed from the gum, but connected with it by a cord which passes through a foramen behind the temporary socket.

56. The milk teeth are twenty in number, namely, two incisors, a canine or eye tooth, and two molars, on each side in the upper and the lower jaw. The permanent teeth are thirty-two in number, namely:—incisors and canines, replac-

ing the corresponding milk teeth; premolars or bicuspids, replacing the milk-molars; and three true molar teeth on each side in each jaw, which are not preceded by any deciduous or milk teeth.

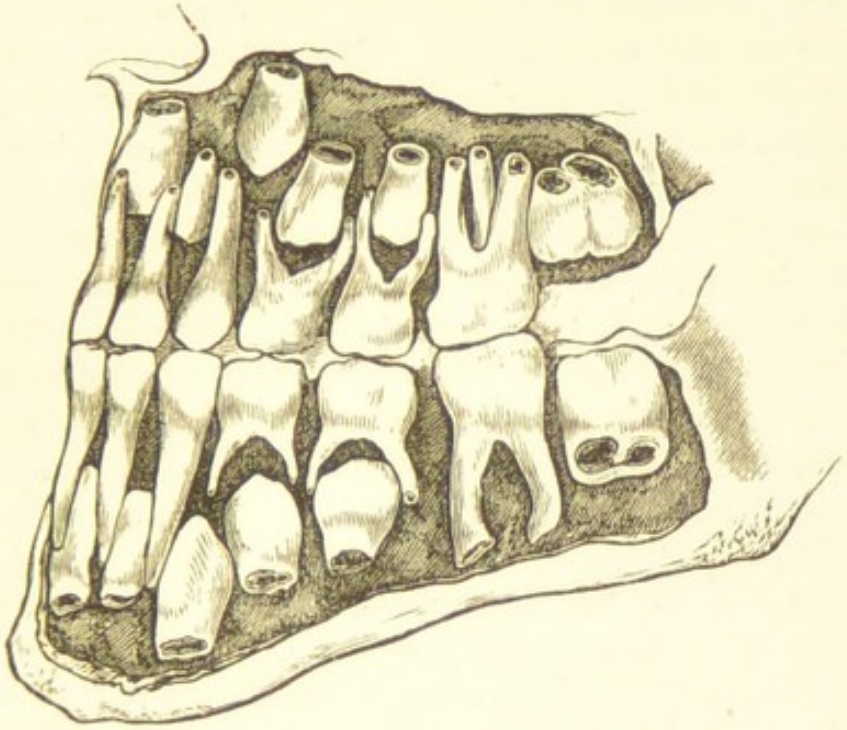


Fig. 48. — TEMPORARY AND PERMANENT TEETH in the jaws of a child six years old. The temporary teeth are all still present, and the crowns of the corresponding permanent teeth are formed; the first molars have appeared, and behind them are the second molars with the divisions between the fangs in process of formation.

The incisor and canine teeth are simple, each having only one fang and one prominence of the crown; the crowns of the incisors being chisel-shaped, while those of the canines come to a point or *cusp*. The premolar teeth get the name of bicuspid because the crown of each has two cusps, an inner and an outer; their fangs likewise, especially those of the anterior premolars, have a tendency to divide towards the extremity. The molar teeth, both milk-molars and true, have the extremity of the crown thrown into several elevations, and are said to be multicuspid. Those of the upper jaw have three fangs, two on the outside, and one directed inwards. Those of the lower jaw have only two fangs, one in front of the other, but they are double fangs, that is to say, they are

flattened as if composed of two combined, and have each two openings at the extremity.

57. In infancy the teeth begin to cut the gums about the seventh month, the central incisors appearing first, and the others in order backwards, with the exception that the first milk-molar precedes the eye-tooth in front of it. The last of this series, the second milk-molars, appear about the end of the second year. The next teeth to appear are the first true molars, sometimes called the five-year old teeth; then, about the seventh year, the milk teeth begin to drop by absorption of the fangs, and the permanent teeth to come up above the gums in their place. The changing of the teeth begins in front, and goes regularly backwards, with the exception that, as in the first dentition, the canines are delayed, both bicuspids making their appearance before the permanent canines come up, about the twelfth year. Soon afterwards, the second molars cut the gums, and lastly, at very variable periods, often a number of years later, the third molars, or wisdom teeth, come to the surface.

58. **Course of the Ingesta.**—The mouth, or *buccal cavity*, as it is technically called to distinguish it from the opening of the lips, is walled in by voluntary muscles of the face; within the arches of teeth it has the tongue in its floor, and its roof formed by the palate, which separates it from the nasal cavity, while it communicates behind with the throat, by a constricted part called the *fauces*. The arch of the fauces is limited above by a prolongation backwards of the palate, consisting of soft parts unsupported by bone, and termed the soft palate or *velum palati*. This has a free edge directed backwards, and prolonged into a pendulous structure in the middle, called the *uvula*, while on each side descend from it two prominences, the anterior and posterior pillars of the fauces. Between these are placed the glandular-looking bodies known as the *tonsils*, structures of obscure function, but sometimes troublesome by enlargement, or by inflammation and ulceration in sore throat.

The cavity behind the fauces is called the *pharynx*. It is surrounded behind and on the sides with constrictor muscles, while in front it communicates with a number of openings. It extends above the soft palate to the base of

the skull, and there it has in front of it the posterior nares, or apertures of the nasal cavities, which are continued back from the nostrils, separated one from the other by a septum. At the sides of the posterior nares are the Eustachian tubes leading back to the ears. Below the soft palate, in series from above downwards, are the arch of the fauces, the *glottis*, or opening into the windpipe, and the *œsophagus*, which is the continuation downwards of the pharynx, but, unlike it, is a complete tube with strong circular and longitudinal muscular fibres round it.

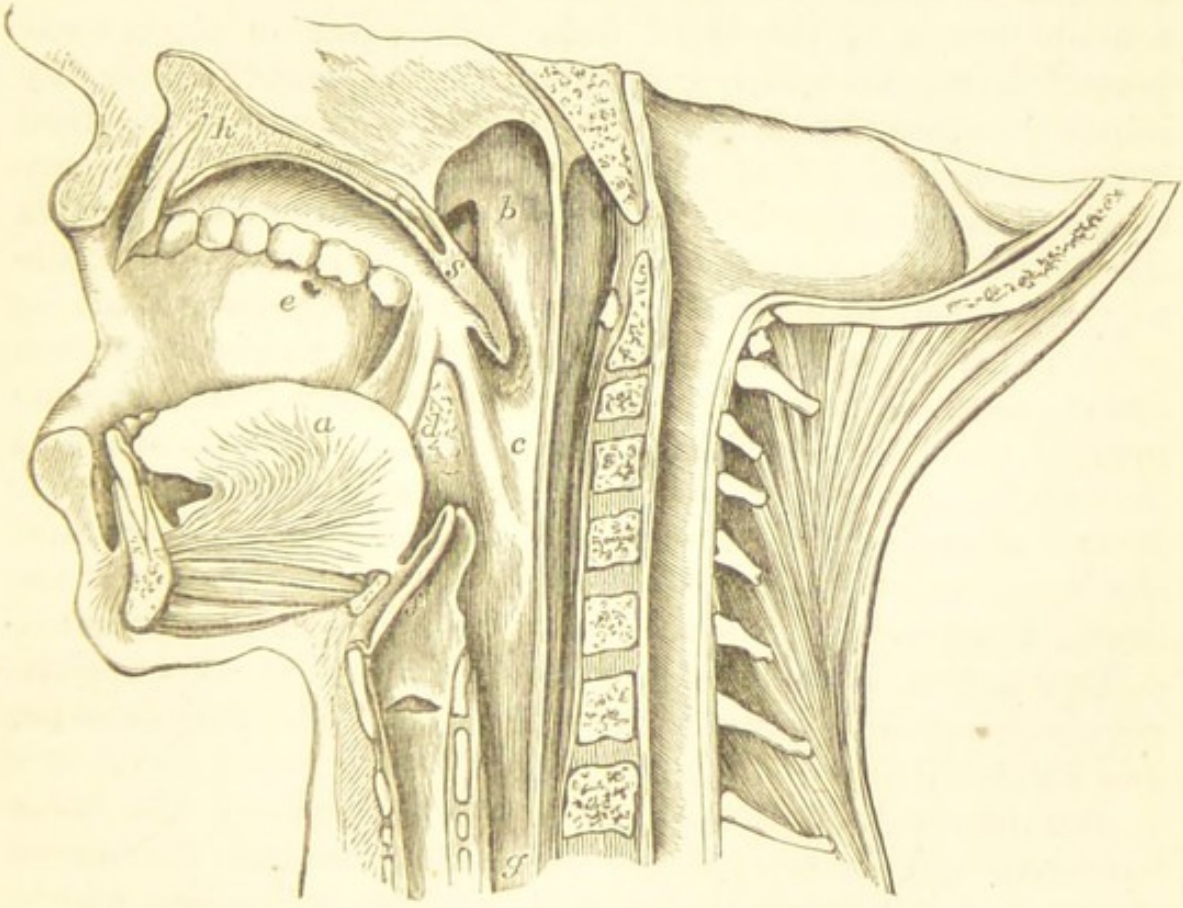


Fig. 49.—Buccal Cavity and Pharynx, vertical section. *a*, tongue, *b*, nasal or upper division of pharynx, and to the front of it the orifice of the Eustachian tube; *c*, inferior division of pharynx; *d*, tonsil with the anterior and posterior pillars of the fauces in front and behind it; *e*, orifice of duct of parotid gland; *f*, the top of the larynx, with the epiglottis in front of it; *g*, œsophagus; *h*, section of hard palate; *s*, of soft palate and uvula.

Loosely connected with the skull by ligament and muscle, is a slender U-shaped bone, the *hyoid*, which can be felt with the finger at the fold between the neck and the chin. Sus-

pended from this is the larynx, or the upper part of the windpipe, modified as the organ of voice, while to its upper surface is attached the root of the tongue; and behind it is the *epiglottis*, a plate of reticular cartilage covered with mucous membrane, which in the state of rest stands straight up in front of the glottis, but in swallowing is folded down over that opening, so as to prevent anything entering into the air passages.

59. When solid food is taken into the mouth, the teeth, the tongue, the palate, and the muscles of the jaws and cheeks, combine to break it down by *mastication*. The jaws act as a double lever of the third order, like a pair of tongs; the powerful muscles which shut them being placed nearer the joints than are the ranges of teeth between which the food is crushed. In biting with the incisor teeth, the jaws are simply brought together; but in breaking the food up with the molar ranges, the lower jaw is slightly rotated from side to side, at the same time that it is withdrawn from and approached to the upper, and thus the food is rubbed between the opposed cusps as well as bruised by them. The tongue presses the food out from between it and the palate, and throws it on to the teeth on one side or other, thus mixing it up and aiding the thorough permeation of the saliva; and the muscles of the cheeks catch the portions which are crushed outwards by the teeth, and return them inwards.

The act of swallowing, or *deglutition*, consists of three parts, of which the first is voluntary, the second spasmodic, and the third involuntary.

The purely voluntary part consists in pushing the bolus back between the tongue and palate till it reaches the fauces. As soon as it gets there, the will initiates a process, which, when started, proceeds with great rapidity and is finished in a moment, without the will being able to delay it. This spasmodic stage involves a number of structures. If the finger be placed on the hyoid bone, it will be found to be jerked suddenly upwards and forwards; at the same time the back of the tongue, on which the food has been placed, is jerked upwards and backwards; and any one who can succeed in swallowing with the mouth open in front of a looking-glass, will see that the soft palate is made tense, and

that the two posterior pillars of the fauces * for a moment approach the middle line, so as with the aid of the uvula to shut off the nasal part of the pharynx from the lower portion. By this means the food is thrown back into the lower part of the pharynx, and thereupon, by the contraction of the pharyngeal constrictors, it is propelled into the œsophagus, and so into the stomach. At the same time that provision is made to prevent the food passing up into the nose, the windpipe is also effectually protected from the entrance of the smallest particle. This is accomplished by the upward and forward movement of the hyoid bone, by which the larynx is brought under cover of the root of the tongue, and that part of the tongue, being also pulled backwards, pushes with it the epiglottis, pressing it down over the aperture of the air passage, while the contraction of a few muscular fibres at the sides of that structure shut it down completely like a lid.

The propulsion of the food down the œsophagus is of the same description as along the intestine. The œsophagus, as has been mentioned, is surrounded with circular and longitudinal fibres; the latter are outermost, as is the typical intestinal arrangement; and in both intestine and œsophagus what happens is this:—the longitudinal fibres contract in the part of the tube in which the food is, the circular fibres contract immediately behind and over it, and thus the food is forced on, and, as it travels, the wave of contraction travels with it. In the intestine, this method of contraction is called *vermicular* or *peristaltic* movement.

60. The lower end of the œsophagus, a little to the left of the middle line, pierces the diaphragm, as the arched muscular partition is called which separates the thoracic from the abdominal cavity, and it immediately terminates in the stomach.

The *Stomach* is a large expansion of the alimentary tube, which lies in great part under cover of the lower ribs of the left side, but extends across the middle line. It is of curved form, its upper surface being short and concave, its lower long and convex. At its left end, called also the cardiac extremity, it is expanded, and it gradually becomes narrower

* They are the prominences corresponding to the edges of two muscles, the palato-pharyngei.

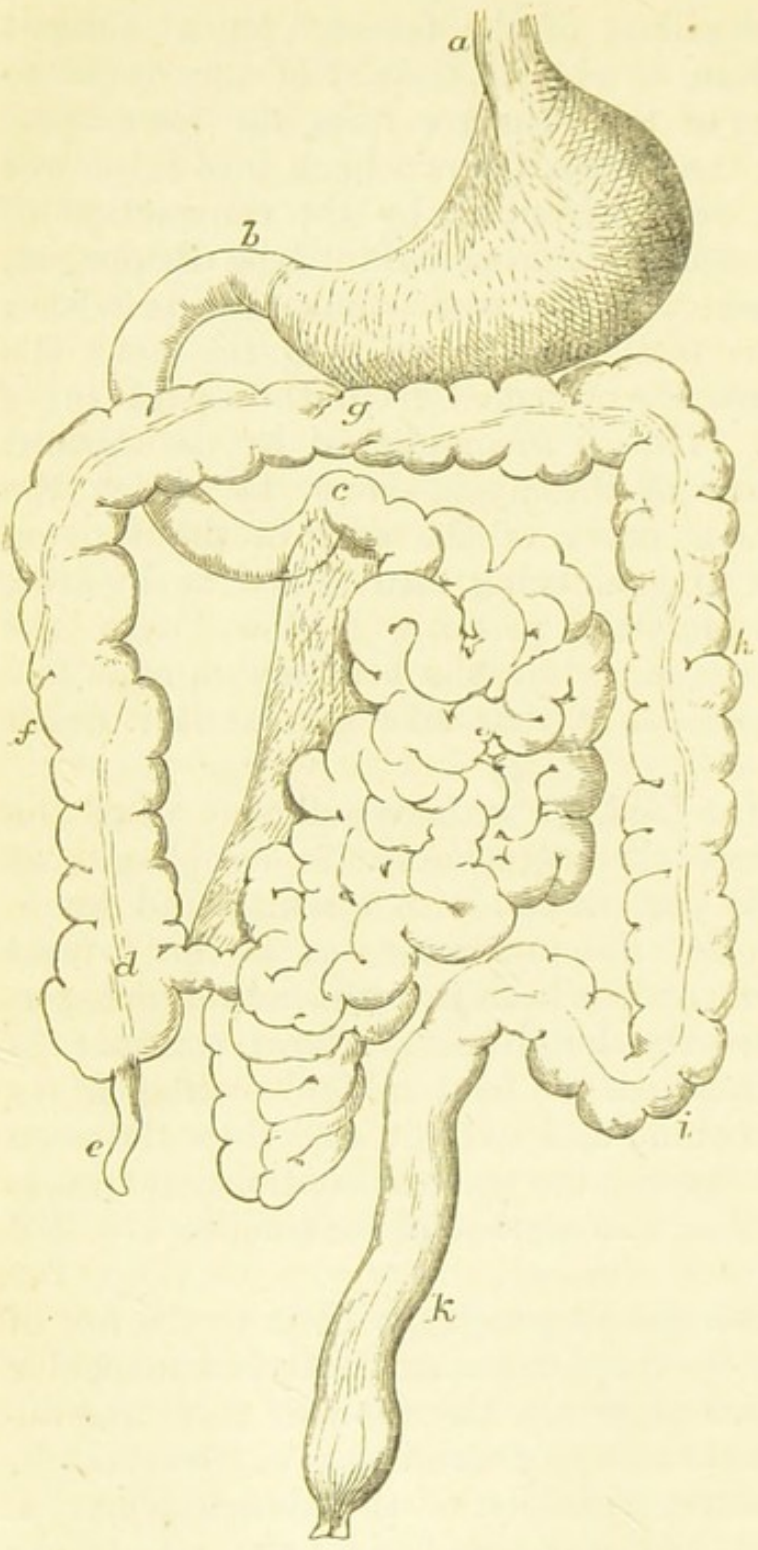


Fig. 50. — Digestive Tube. *a*, Œsophagus ending in the stomach; *b*, pylorus; from *b* to *c*, duodenum; from *c* to *d*, jejunum and ileum with the line of attachment of the mesentery; *d*, cœcum; *e*, vermiform appendix; *f*, *g*, *h*, ascending, transverse, and descending colon; *i*, sigmoid flexure; *k*, rectum.

as the intestinal extremity is approached, a little to the right of the middle line. The entrance into the intestine is called the *pylorus*, and is guarded by a strong band of circular fibres, which keeps the opening usually closed, and gives to it the title of pyloric valve. Observations were made by watching the movements of the stem of a thermometer, the bulb of which was introduced into the stomach of a man, through a fistulous opening which had been left in the healing of a wound made by the accidental explosion of a gun; and it appears from them that when the stomach is acting, the contraction of its walls causes its contents to be moved about in a stream passing from left to right along the great curvature

of the stomach, and back along the small curvature. While the stomach thus keeps its contents in motion, its walls rapidly absorb superfluous fluid, and at the same time pour out the gastric juice. By united mechanical and chemical action the food is gradually converted into pulp; and the pyloric valve, which, at the commencement of digestion, is kept quite closed, relaxes sufficiently to allow the pulp to pass as rapidly as formed, thus allowing the whole action of the stomach to be concentrated on the parts of its contents which are not yet broken down. Gradually, however, in the later stages of digestion, the irritability of the pyloric valve becomes exhausted, and at last even the most indigestible solids are allowed to pass.

61. The stomach is succeeded by the *small intestine*, a tube about twenty feet long, and having a breadth of about an inch and a half at the commencement, and an inch at its termination. For about the first ten inches it is bound down in a crescentic form to the back of the abdomen; and this part is termed the *duodenum*, and has the bile duct, and the duct of a large gland, called the pancreas, opening into it close together about its middle. The remainder of the small intestine is not connected with the abdominal wall, except through the medium of the mesentery—a fold of the peritoneum or lining membrane of the abdomen, containing within it vessels and nerves. The upper third of this part of the intestine gets the name of *jejunum* (empty), from usually containing little but the pulp sent down from the stomach, and here termed *chyme*. But the more fluid portions of the chyme get absorbed as it descends, and in the lower two-thirds of the small intestine, the *ileum*, the contents are consequently usually more solid. The ileum opens into the large intestine in the region of the right groin.

62. The large intestine is about five or six feet long. It begins in a short *cul-de-sac*, the *cæcum* (caput cœcum coli), below the entrance of the ileum; and into the extremity of this there opens a small glandular structure, the *vermiform appendage*, which represents the enormously large intestinum cæcum found in various animals, such as sheep and rabbits. At first the large intestine passes directly upwards to a point beneath the liver, and in this part of its course it is

called the *ascending colon;* it then passes across beneath the stomach to the left side as the *transverse colon*, and runs down to the region of the left groin under the name of *descending colon;* there it makes a loose bend, termed the *sigmoid flexure*, and passes into the pelvis, where it is called the *rectum*, or lower bowel.

At the entrance of the small intestine into the great, there is an arrangement, called the *ileo-colic valve*, to prevent matters which have once passed into the great intestine regurgitating into the ileum. It consists of two redundant folds of the mucous membrane at the opening projecting like an upper and a lower lip into the colon, while from the angles of their junction prominences of mucous membrane, the frænа, pass round so as partially to encircle the great intestine. When the great intestine is distended, the frænа are pulled tight, and the lips of the valve brought into firm contact, the distending matters pressing their surfaces together. Thus, while there is no obstacle to the passage of matters from the ileum into the cæcum, regurgitation backwards is effectually prevented, and the more distended the cæcum the firmer is the closure of the valve. The efficiency of the valve is independent of muscular action, and can be exhibited perfectly on the dead subject.

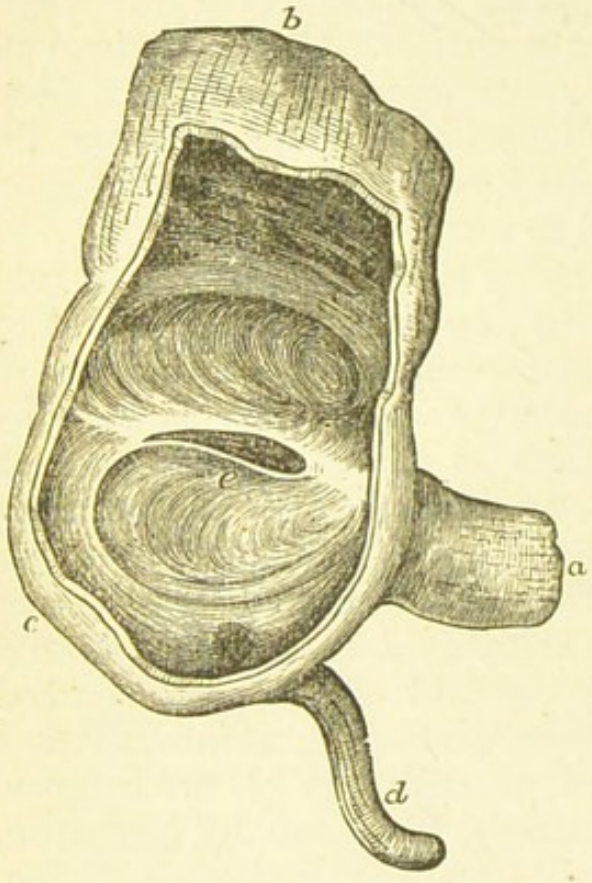


Fig. 51.—Ileo-colic Valve. *a*, cut end of the ileum; *b*, cut end of the colon; *c*, caput cæcum coli; *d*, vermiform appendage; *e*, lower lip of the valve.

63. As might be expected from the existence of the ileo-colic valve, the contents of the intestine on entering the colon undergo considerable change: here they begin to acquire a

fœcal odour; yet additional matters continue to be absorbed from them in their passage onwards. In the colon both the longitudinal and circular muscular fibres of the walls are collected into bundles; the longitudinal fibres forming three bands, and the circular dividing the intermediate spaces into shallow recesses; and thus, although the total diameter of this part of the intestine may exceed two inches, its contents are brought well into contact with its walls as they lie in these recesses; and as they are pressed onwards from one recess to another, different portions are brought to the surface. The rectum, or lower bowel, has the muscular fibres regularly disposed around, except near the outlet, where the circular fibres form a strong *sphincter*, or habitually contracted ring of muscle, on which the power of retention is principally dependent, although it is assisted by striped muscles when the pressure on it is great.

64. The form of digestive tube, which has been briefly described, is that which is found in the human subject, but there is great variety in different animals. In certain fishes, the pipe fishes and others, the tube is straight, but in most of them it is convoluted; and in all it is wide from the throat to the pylorus, then constricted, and again widened towards the termination; this latter enlargement being evidently the representative of the large intestine. A valve even exists at the entrance into the large intestine in many fishes. Thus it will be seen that already in the lowest division of vertebrate animals, the digestive tube is divisible into three great parts. In mammals neither the part above the pylorus nor that below the ileo-colic valve has a uniform breadth; the stomach is separated from the pharynx by a narrow œsophagus; and the cæcum is in some instances greatly larger than the rest of the great intestine. The stomach and cæcum are the parts which undergo the most remarkable complications. The human stomach is an instance of the simplest and typical form of the organ in mammals; but in various animals belonging to widely separate orders, remarkable complications exist, *e.g.*, in the camel, the kangaroo, the cetacea, the peccary, and certain monkeys.

Probably the arrangement most interesting to the general reader is the ordinary ruminant stomach, which is divided

into four compartments. When the ruminant is feeding, the food passes into a large compartment, the *paunch*, which is the cardiac extremity of the stomach, elongated and folded on itself in fœtal life, and subsequently much expanded. When the animal lies down to ruminate, the contents of the paunch are propelled in successive portions into a small compartment called the *reticulum*, from the honey-combed appearance of its walls, and placed to the front below the œsophagus, and by it are returned to the mouth in separate pellets. After being a second time masticated, the food is again swallowed, and being prevented by the closure of a ring of muscular fibres from re-entering the first two compartments, it falls into the third, the *omasum*, which lies behind the second, and is of similar size, but has its mucous membrane thrown into numerous broad folds which separate up the bolus, and allow it to pass in portions gradually into the fourth compartment or *abomasum*, which is the pyloric end of the stomach, and the only part furnished with a highly vascular and glandular mucous membrane.

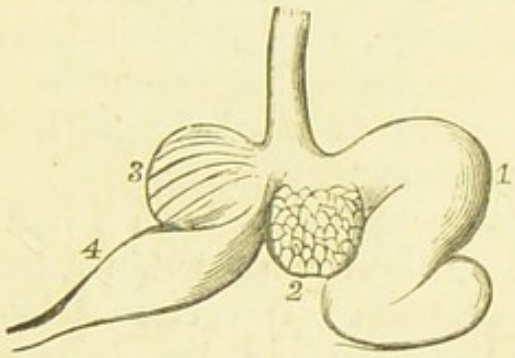


Fig. 52.—Ruminant Stomach, diagrammatic view.

The cœcum may acquire a great development even in animals in which the stomach is simple. This is the case in the rabbit and in the horse, in both which it has great width and length. Generally, the alimentary tube is much more elongated and complex in vegetable-feeders than in carnivora.

65. Digestive Fluids.—The first substance added to the food is the *saliva*, which is furnished by three pairs of compound sacculated or lobulated glands—the parotid, the submaxillary, and the sublingual. The parotid gland is the largest, and is named from its nearness to the ear, lying as it does in the hollow between the ear and the lower jaw. It turns over the hinder border of the jaw; and from this part of it issues a duct—the duct of Stenson—large enough to admit a crow-quill, and opening into the mouth through the cheek, opposite the second molar tooth of the

upper jaw. The submaxillary gland, about the size of a large prune, lies beneath the lower jaw, and its duct—the duct of Wharton—opens under the tongue. The termination of this duct, along with its fellow, may be seen in a looking-glass, making a little swelling on the lower part of the frænum or bridle of the tongue. At the same time will be seen on each side of the frænum, between the tongue and the jaw, an elevation about the size of an almond, with the outlines of the sublingual gland seen through the mucous membrane. It has several ducts, some of which open separately, while others fall into Wharton's duct. Besides these large glands, there are numerous others of small size which open into the mouth, particularly the buccal glands, a series of structures the size of lentils, scattered under the mucous membrane of the lips and cheeks, and a smaller set of glands near the tip of the tongue; but they are engaged in the secretion of a mucus which has little or nothing to do with digestion. The saliva has a slightly alkaline reaction, and its most important ingredient, besides water, is a nitrogenous substance called *ptyalin* which has in a very high degree the property of converting starch into grape-sugar, provided that the solution be alkaline. So powerful is this action, that a notable amount of the starch taken into the mouth as food is converted into dextrin or sugar before being swallowed; and when the food is of a tenacious consistence, masticated and taken in quantity, a large part of it may escape for a

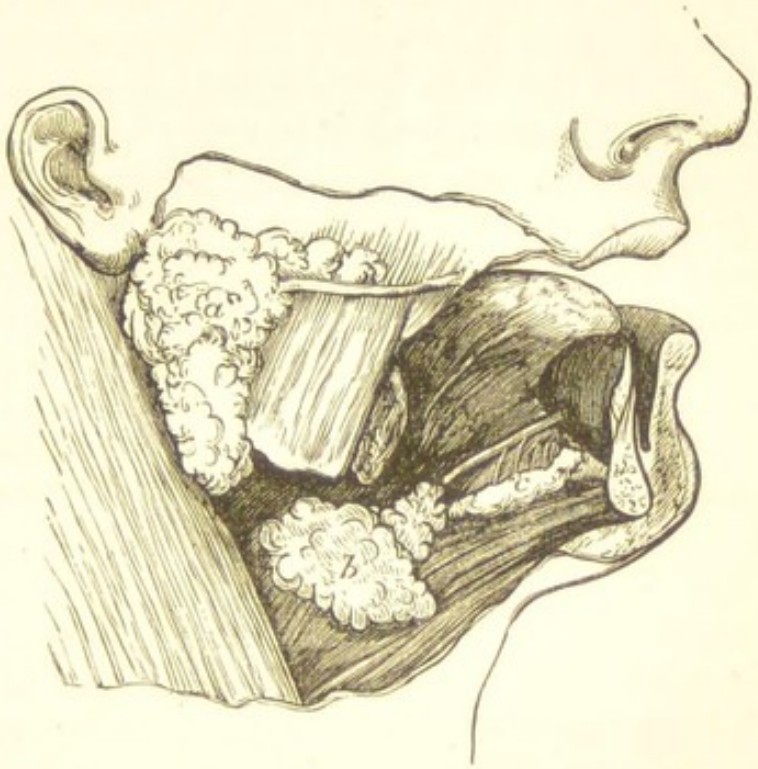


Fig. 53.—Salivary Glands. *a*, parotid; *b*, submaxillary; *c*, sublingual.

time the contact of the acid gastric juice, and have a much larger quantity of its starch acted on in the stomach. The conversion of starch into sugar, however, is neither the only nor even the principal use of the saliva, as is proved, first, from the salivary glands being well developed in carnivorous animals, which, in the natural state, use no starch in their food; and, secondly, from the amount of saliva mixed with the food bearing a direct proportion to its dryness—a circumstance which shows that it is important as a moistener.

66. In the stomach the food causes a flow of *gastric juice*, an acid secretion with a peculiar nitrogenous principle, called *pepsin*. Various acids may be developed among the contents of the stomach, the most important of which are lactic, acetic, and butyric; but these are generated accidentally in the processes of change, and it has been shown by investigations, both on the lower animals and on man, that free hydrochloric acid is that which is secreted by the glands of the stomach. The use of the acid, however, appears to be to aid the pepsin; the peculiar properties of that substance being exhibited in none but acid solutions: and for this purpose any acid suffices. Pepsin is obtainable from the mucous membrane of the stomach of animals by the action of water. It is the active principle in the rennet used in manufacturing cheese; rennet being a preparation of the mucous membrane of a calf's stomach, used on account of the property, which pepsin possesses, of curdling casein. In an acid solution, at a temperature of about 100° F., pepsin dissolves coagulated albumen, and renders it incapable of being coagulated again by heat. It acts in like manner on nearly all albuminoids, and the substances into which it converts them are called *peptones;* but the chemical nature of these is not thoroughly understood. It likewise dissolves gelatin and gelatiniferous tissue, converting them into a solution which does not jelly on cooling; but it has no action on either oil or starch. The gastric juice therefore digests none but nitrogenous substances.

67. The mucous membrane of the stomach, by which the gastric juice is secreted, is thick, soft, and smooth. Looked at under the microscope, the surface is seen to be thrown into shallow pits, into each of which open several small

glands; and in sections vertical to the surface the mucous membrane is shown to consist in greater part of tubular glands, sometimes branched, called the *gastric follicles*, which may reach $\frac{1}{20}$ inch in length, and are crowded together. They are all lined with columnar epithelium down to the bottom, and the epithelial cells have been seen to undergo a change of appearance in digestion, when the gastric juice is secreted; but the majority of the follicles likewise contain numbers of large oval and more easily discovered cells underneath the columnar epithelium, structures of uncertain function, which, from having been supposed to be the agents in secreting pepsin, have been named peptic cells.

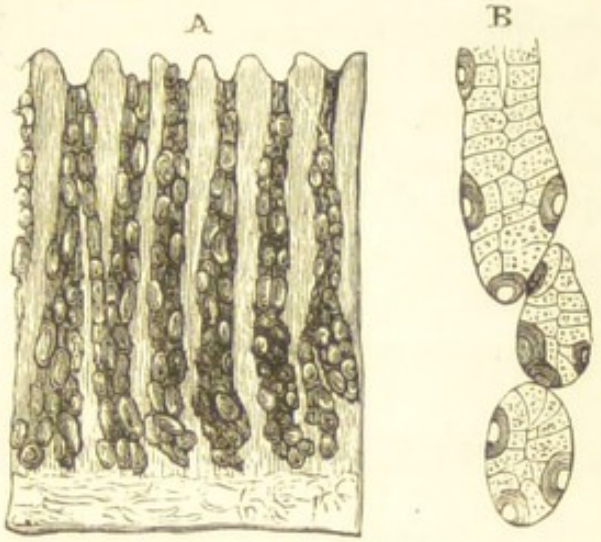


Fig. 54.—Gastric Follicles. A, Vertical section of mucous membrane from the middle of the human stomach. B, A more highly magnified view of portion of a gastric follicle of a dog, showing both peptic and columnar cells. From Heidenhain.

The glands in which these cells occur are called peptic glands, while the others are termed mucous. In some animals, for example the dog, certain regions of the stomach contain none but peptic glands, while the pyloric region has none but mucous glands; and this circumstance has been taken advantage of to determine the character of the secretion furnished by the two kinds of glands. But while one observer (Ebstein) gives a most careful and convincing account of experiments to prove that both kinds secrete pepsin, numerous others come to a different conclusion; and it may be considered as still undecided whether the peptic or the columnar cells are the agents by which pepsin is really secreted.

68. Immediately beyond the pyloric valve, on entering the intestine, the mucous membrane changes its character. Not only is it firmer and thinner, but it is covered over with minute thread-like projections like velvet pile, named *villi*,

best brought into view by laying the opened intestine in water, so as to make them float. They are as much as half a line long in the duodenum, and extremely crowded, but gradually get shorter and fewer in the lower parts of the small intestine, until, near the termination of the ileum, they degenerate into scattered wart-like eminences. The villi are confined entirely to the small intestine, and are a means of increasing the extent of mucous membrane for the purpose of absorption; each villus being dipped like a finger in the chyme, and sucking up the digested parts of it by every portion of its surface. The absorbent surface of the small intestine is further increased by crescentic folds of the mucous membrane passing more than half round it, and dipping into the interior. They are called *valvulæ conniventes*, and, like the villi, are most numerous and well developed in the duodenum and jejunum.

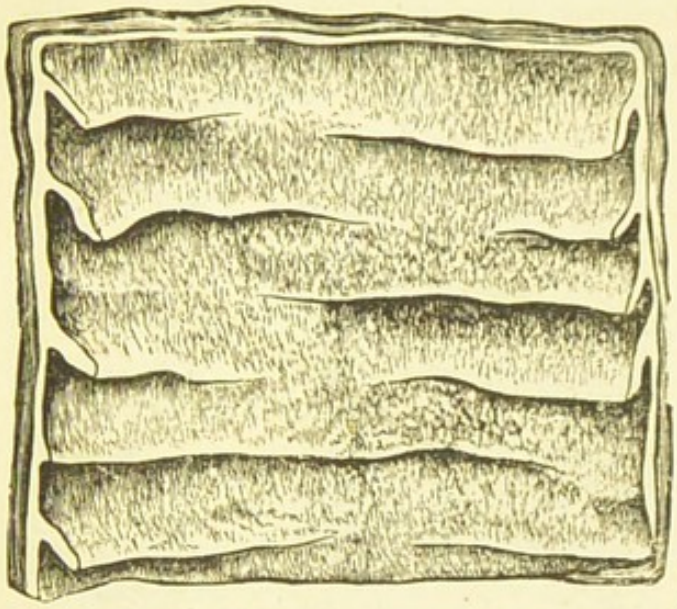


Fig. 55. — VALVULÆ CONNIVENTES, exhibited in a portion of jejunum cut open. Two-thirds natural size.

The thickness of the mucous membrane of the small intestine is occupied, like that of the stomach, with closely set tubules, only they are much smaller than those of the stomach, contain no other than columnar epithelium, and are quite simple; these are called the *follicles* or *crypts of Lieberkühn*. The duodenum has likewise three other secretions poured into it, namely, the *bile*, the *pancreatic juice*, and the secretion of a number of minute glands of a lobulated description, scattered beneath its mucous membrane, and called *Brünner's glands*.

69. The pancreas is a large lobulated gland, about eight inches long and one inch and a half broad, not unlike the salivary glands in appearance, and sometimes called by

the Germans the abdominal salivary gland; its secretion, however, is much more important. The pancreatic juice, which is a viscid alkaline fluid containing an albuminoid principle, has a most powerful action in converting starch into sugar, and has the advantage over saliva, that this action is not prevented by the presence of acid. It has also the property, at the temperature of the body, of making a very complete emulsion, or milky fluid, with oils; that is to say, it resolves them into exceedingly minute globules, which remain separate from one another; and these find their way through the walls of the villi into the absorbent vessels. In rabbits the duct of the pancreas opens into the intestine considerably lower than the bile duct; and in them, as Bernard has observed, there are no oil globules in the absorbent vessels above the level of the pancreatic duct; which shows that the bile is incapable of digesting fats without the pancreatic juice. This fluid has likewise been shown to have a solvent action on albuminoids outside the body; and it is possible, as has been suggested by one observer (Flint) that muscular fibre, disintegrated by the gastric juice, is afterwards completely dissolved by means of the pancreatic. It appears, then, that the pancreatic juice is the principal means of digesting starch and oil, and that it is likewise useful in digesting albuminoids.

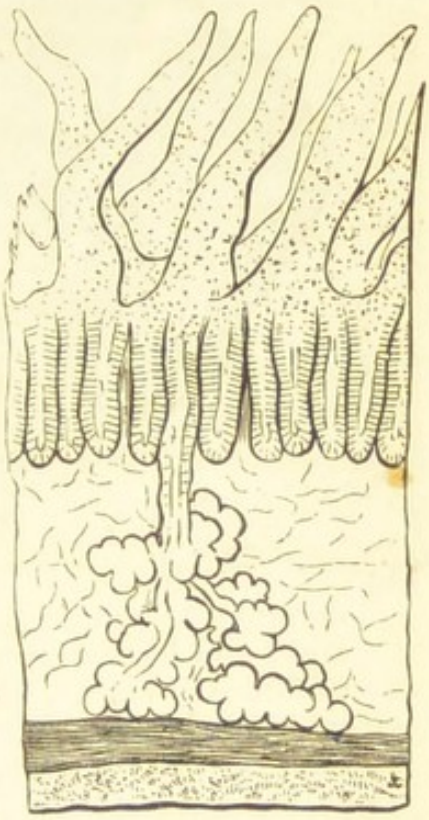


Fig. 56. — DUODENUM, vertical section magnified. *a*, Villi; *b*, Lieberkühnian follicles; *c*, Brünner's gland in the submucous tissue; *d*, muscular walls.

70. The action of the fluid secreted by the Lieberkühnian follicles (*succus intestinalis*), has been examined by gathering it from the intestines of animals experimented on, and by other means. Like the pancreatic juice, it is an alkaline fluid which acts on starch, oil, and albuminoid matters; but

its action is weak compared with that of the gastric and pancreatic juices.

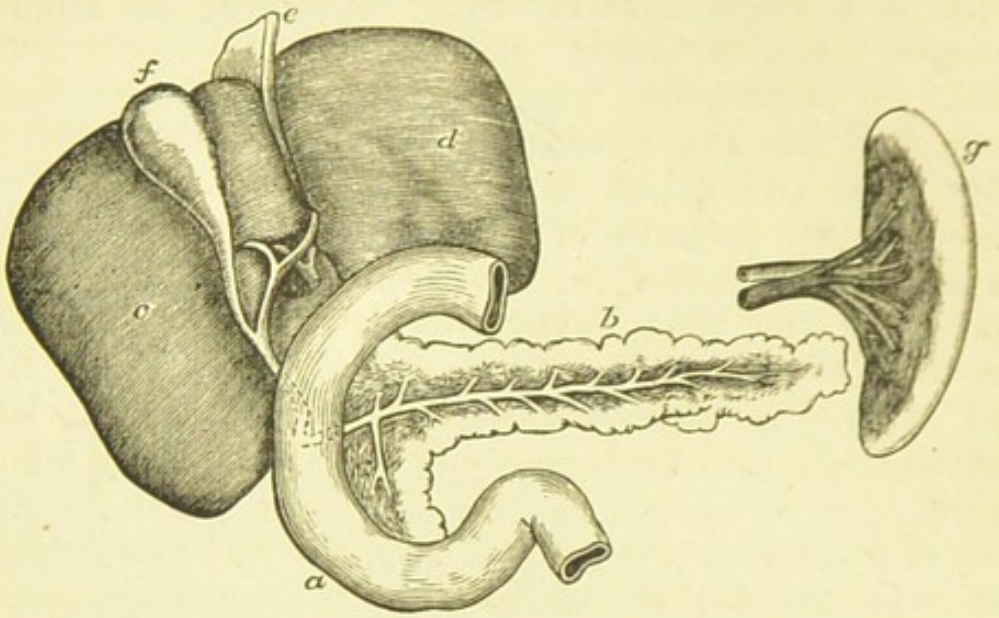


Fig. 57.—Duodenum, Pancreas, Liver, and Spleen. *a*, Duodenum; *b*, pancreas, with the pancreatic duct laid bare; *c*, *d*, right and left lobes of the liver, seen from below; *e*, obliterated umbilical vein; *f*, gall bladder, opening into the cystic duct which joins with the hepatic duct, to form the ductus communis choledochus; *g*, spleen.

71. In considering the use of the bile in the intestine, it is necessary to note that the liver, as will be shown in another place, is not a mere preparer of a digestive fluid, and that bile seems rather to be formed in connection with a blood-purifying process in the liver, than as an aid to digestion. The bile is, however, undoubtedly of great service in the absorption of oils. In dogs in which the gall ducts have been shut off from the intestine, and the bile allowed to escape by an external opening, the operation is followed by greatly impaired power of absorbing oils. Indeed, bile is the strongest soap known, ox-gall being on that account used by painters to wash away oil paint; and it seems probable that, by lubricating the villi, the bile assists the minute globules in the emulsion formed by the pancreatic juice to permeate the mucous membrane. Bile is likewise an antiseptic, and prevents the putrefaction in the contents of the intestine, which always takes place when its flow is prevented. But, in addition to all this, it is to be observed

that, in health, the essential constituents of the bile are not to be found in the fæces, only the colouring matter is left; also, dogs from which the bile is abstracted by a fistulous opening, are remarkably ravenous. These facts seem to point out that the bile, which acts as a narcotic poison when introduced unchanged into the blood, is decomposed in the intestine, and gives rise to innocuous products, which are re-absorbed to nourish the body. The seat of this decomposition appears to be the great intestine; for there the bile disappears, and various substances are found which are obviously derived from its constituents. Of these, two are crystalline, viz., *excretin*, a carbonaceous substance containing sulphur (Marcet), and *stercorin*, a body derived from cholesterin (Flint).

72. The great intestine has a smooth mucous membrane, with tubular follicles like those of the small intestine, but apparently having a different secretion. The details of the processes which take place in this part of the alimentary tube are but little understood. The bulk of the fæces consists of matters which have resisted all digestive processes, and always contains starch grains, muscular fibre, and vegetable tissues, when these substances have formed part of the diet.

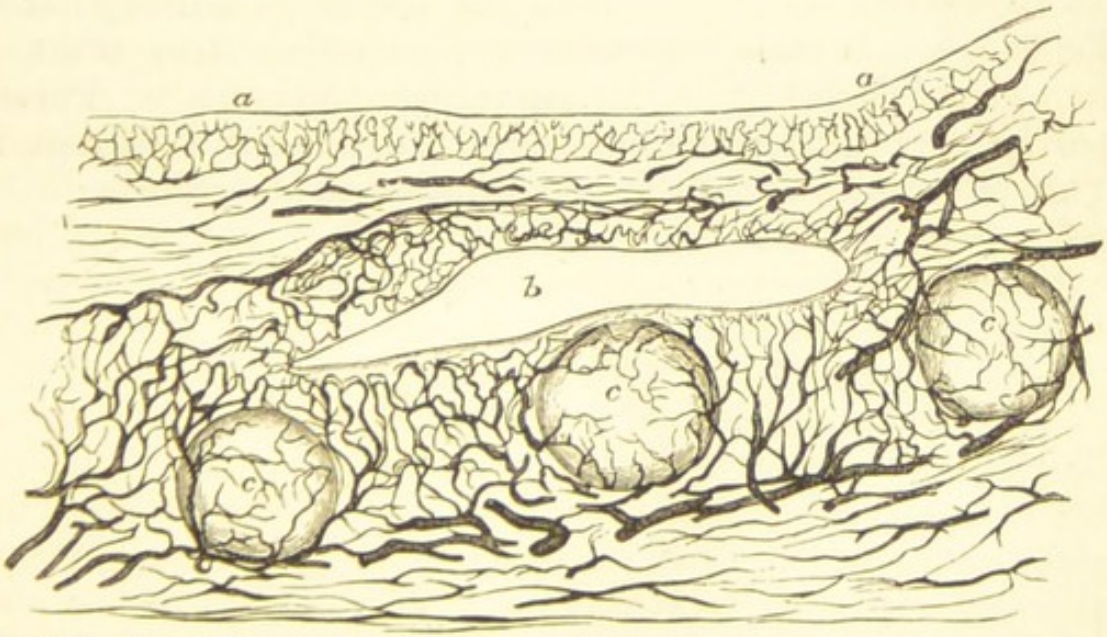


Fig. 58.—Section of an Injected Tonsil. *a*, *a*, Mucous membrane of fauces; *b*, a recess; *c*, *c*, *c*, closed follicles.

73. Before leaving the consideration of the alimentary tube,

a set of structures of obscure function, found in every part of it, may be mentioned, namely, the *closed follicles.* These are bodies the size of small millet grains, imbedded in the mucous membrane, and containing corpuscular matter and loops of capillary blood-vessels. A number of such structures, grouped round recesses of the mucous membrane of the fauces, constitute the *tonsils* (p. 88); they are also numerously scattered in the pharynx, and are called *lenticular* glands in the stomach. In the ileum they are gathered in elongated and rounded groups about half an inch broad, called *Peyer's patches,* or *agminated glands;* and in the great intestine they are very plentifully scattered all over, and called *solitary glands.* In recent years they have been very generally supposed to be connected with the absorbent system; but there is no sufficient proof that their function is not secretory, although their structure differs from that of secreting glands. Peyer's patches are interesting as being the seat of a deposit in typhoid fever, and subject to ulceration in that disease.

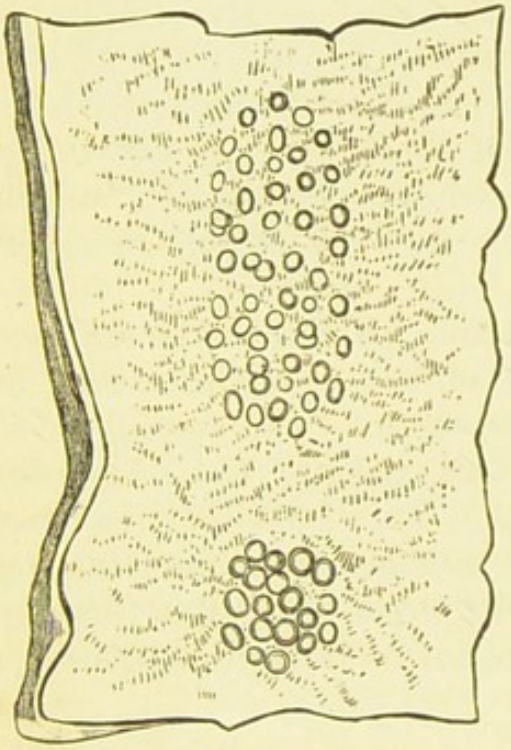


Fig. 59.—Two Peyer's Patches, natural size.

CHAPTER VIII.

THE BLOOD.

74. HAVING traced the process of digestion, it would be natural to pursue the history of the new supplies of nourishment after their entrance into the economy from the alimentary tube. It will be found, however, to be more convenient, if, instead of adhering strictly to the course taken by these supplies, we first consider the blood, and afterwards the streams which fall into it, and its mode of elaboration.

On account of the extreme facility with which substances pass outwards and inwards between the minutest vessels and the tissues, and the impossibility of completely emptying the vascular system, even in the bodies of animals, it is exceedingly difficult to estimate the amount of the blood. In one observation, in which the blood was carefully washed from the bodies of two executed criminals, and the calculation based on the amount of solid matter obtained, the weight of blood was estimated as one-eighth of that of the body (Weber and Lehmann). According to other calculations founded on observations on animals, and made by mixing a portion of blood with a known amount of water, then washing out the vessels, and reducing the washings to the same tint as the standard solution, it was computed at about one-thirteenth of the weight of the body, or twelve pounds in a person eleven stones weight (Welcker).

75. When blood flows from a wound it speedily coagulates or runs into a clot. This depends on the presence of a spontaneously coagulable albuminoid substance, called *fibrin*, which, being diffused through the blood, entangles the other constituents in its meshes. But if the blood be allowed to remain in a vessel, the coagulum contracts, and expels from it the *serum*, a straw-coloured fluid which may be more or

less tinged with red. If, while the blood is flowing, in bleeding from the arm, the physician whips or rapidly stirs it with a bunch of small rods, as sometimes used to be done, the fibrin will adhere in tough coagulated masses to the rods, and the remainder of the blood will remain fluid. This defibrinated blood, after a while, will separate into clear serum above, and a dark dense portion below. An examination of blood under the microscope shows it to consist of a clear fluid with a multitude of coloured corpuscles floating in it; and the separation of the defibrinated blood into two parts, is the result of these corpuscles falling to the bottom of the liquid serum. If blood be taken from a person in certain exceptional conditions, or if it be taken from a horse, instead of the whole mass becoming converted into one uniform clot, the blood-corpuscles will subside considerably before coagulation sets in, and then there will be in the upper part of the vessel a straw-coloured coagulum forming a transparent jelly. That is a state of matters which formerly medical practitioners considered as a certain sign of inflammation, and described by saying that the blood was *buffed*. The clear coagulum in contracting becomes loosened from the edge of the vessel, and hollowed on its upper surface, while a pure serum is pressed out at the sides and into the concavity above; and this the old practitioners expressed by saying that the blood was *cupped*.

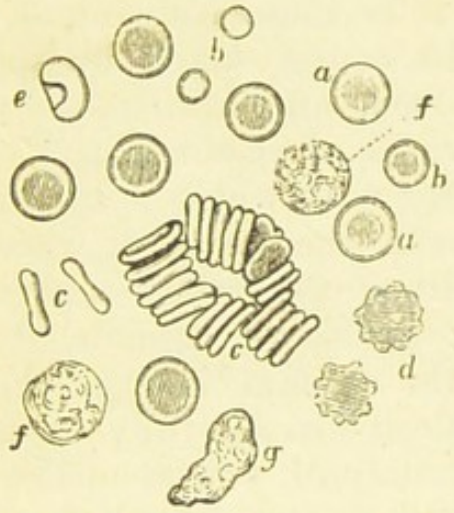


Fig. 60.—Human Blood Corpuscles. *a*, *a*, Red corpuscles of the ordinary appearance; *b*, *b*, red corpuscles of smaller size, such as are now and then seen exceptionally; *c*, *c*, red corpuscles seen in profile, single and in rows; *d*, two red corpuscles shrivelled by partial evaporation of the serum; *e*, a red corpuscle swollen by slight addition of water; *f*, *f*, white corpuscles; *g*, one which has undergone amœboid change of form.

These observations furnish a rough but instructive analysis of blood. Three constituents are exhibited, the corpuscles, the serum, and the fibrin. The serum and fibrin together constitute the *liquor sanguinis*, or *blood plasma*. The blood may thus be separ-

ated into liquor sanguinis and corpuscles, or into defibrinated blood and fibrin, or, lastly, into serum and a coloured clot consisting of the fibrin with the corpuscles entangled in it.

76. When blood is examined microscopically it is seen to contain two kinds of corpuscles, the coloured kind already alluded to, and a less numerous set of white corpuscles.

The coloured or red corpuscles are, properly speaking, deep orange, as may be seen by streaking blood on a white surface. They are disc-shaped bodies, about $\frac{1}{3200}$ inch diameter in man, circular, and flat or somewhat concave on each side. They are clear, and in mammals are destitute of nucleus; but this is a mammalian peculiarity, for in all other vertebrate animals they have a nucleus and are oval. In the camel tribe they are likewise oval, but are destitute of nucleus as in other mammals. In different vertebrate animals the red corpuscles differ greatly in size, as indeed do other textural elements. Their size is dependent more on the affinities of the animal than on its bulk. In ruminants generally they are small; and in the smallest ruminant, the musk deer, their diameter is only $\frac{1}{12325}$ of an inch. In birds they are smaller than in reptiles; and those of greatest size are found in the amphibia, the largest known being those of the *proteus*, which are $\frac{1}{400}$ of an inch in length.

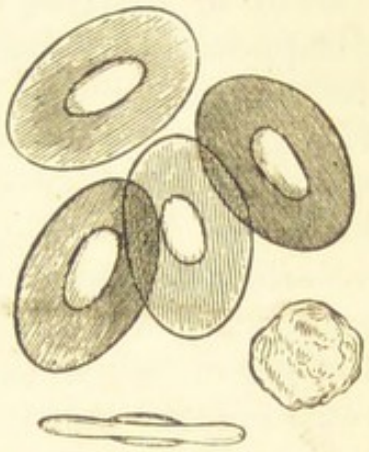


Fig. 61.—Blood Corpuscles of Frog, viz., four red corpuscles seen in full view, one in profile, and one white corpuscle.

Red corpuscles contain a firm framework or stroma, besides their coloured contents; but it is difficult to believe that they have any envelope, when one sees the great power of elongation which they have in threading their way through narrow passages, and the changes of shape which they undergo in various circumstances outside the body, without exposure of a membrane. They may often be seen to become indented round the edges; and the processes between the indentations may grow to a length which seems inconsistent with the supposition that they are firmer toward the surface than within.

In blood which has a tendency to "buff," the red corpuscles are seen under the microscope to arrange themselves in columns like rows of coin, their cohesive attraction one to another being increased. or that between them and the liquor sanguinis being diminished. The main function of the red corpuscles is, as we shall find, to carry oxygen.

77. The white or colourless corpuscles, also termed *leucocytes*, are spherical in form, larger than the red, being, in man, about $\frac{1}{3000}$ inch in diameter, or more than that. They have a turbid or mottled appearance, which, on addition of water, disappears and discovers a nucleus. When coagulation is retarded, and the red corpuscles sink, the white corpuscles rise gradually to the top, showing that they are lighter than the fluid part of the blood, while the red corpuscles are heavier. Watching them as they circulate in the capillary vessels of the web of a frog's foot, one may see that the white corpuscles often show a tendency to adhere to the wall of the vessel, while the red corpuscles keep in a stream in the centre of it; and it has been proved by repeated observation that white corpuscles are capable of making their way through the capillary wall, which comes together again behind them without apparent breach of continuity, while they pass on into the tissue. It would appear that red corpuscles sometimes pass out in the same way; but the white have a much greater tendency to escape, and after they have done so, no line can be drawn between them and the other amœboid bodies, that is to say, the connective-tissue-corpuscles, for the white corpuscles have amœboid properties. Moreover, *pus*, the matter thrown out in suppuration, consists of a fluid rich in corpuscles, which cannot be separated by any line of distinction from white corpuscles; and it is not yet settled to what extent these consist of transuded white corpuscles, or how far they are derived from processes of multiplication among the connective-tissue-corpuscles. But whatever may be the occasional functions of the white corpuscles exercised by escaping into the tissues, they seem to have a much more important purpose within the circulation, for it is probable that the red corpuscles are formed from them by disappearance of the nucleus and alteration of their contents.

We shall find that the white corpuscles take origin in the

spleen and in the lymphatic glands; they appear in great numbers immediately after eating, and quickly disappear again. Thus, a German observer (Hirt) computed the proportion of white to red corpuscles in his own blood, and found that before breakfast it was 1 in 1800, an hour afterwards 1 in 700, and between eleven and twelve o'clock 1 in 1500. He took dinner at one o'clock, after which the proportion was 1 in 400, while two hours afterwards it sunk to 1 in 1475. After an eight o'clock supper it was 1 in 550, and at eleven o'clock 1 in 1200.

78. Turning now to the chemical composition of the blood, we find that the liquor sanguinis is essentially an albuminoid solution. It is slightly alkaline, and contains about 97 parts of solid matter in every thousand. Of these only four parts consist of fibrin; while the albumen, which is the principal constituent of the serum, forms nearly 79 parts; the mineral matters constitute more than 8 parts; urea, kreatin, and other matters soluble in water, usually grouped together under the name of extractive, make up about 4, and the fats less than 2 parts in the thousand.

The blood is, in health, very uniform in its composition, and it will naturally occur to ask how the uniformity is maintained, seeing that the additions made to it must vary much with the character of the diet. It may also be asked how it happens that the blood, which nourishes the whole body, has so little resemblance to the total composition of the body. Both these questions admit of one answer, namely, that the amount of any substance in the blood at one time depends not only on the quantity which enters the circulation, but on the length of time that it remains there. Thus, there is very little fatty matter in the blood, although quantities enter with the supplies of nourishment from the food, and at least one substance, roughly classed under this head, cholesterine, is returned from the brain; and there is only a very minute quantity of urea in the blood, although there is reason to believe that a considerable amount of what is eliminated by the kidneys pre-exists in it: but the explanation is simply that none of these substances are allowed to accumulate in the blood, that they are removed from it as speedily as they enter it.

79. The small amount of fibrin in the liquor sanguinis, compared with the quantity of albumen, will attract the student's attention. The proportion of fibrin present varies in different parts of the circulation, and it is not easy to determine the measure of its variation; but there is one circumstance which makes it seem probable that the fibrin is not used for the manufacture of tissue, but is a product resulting from the changes effected in the blood by circulating among the tissues; and that is, that the blood emerging from the liver, after being subjected to the action of that organ, is no longer spontaneously coagulable, and only yields a small amount of fibrin after violent whipping with rods (Béclard).

The fibrin remains fluid while the blood circulates in the body, yet it coagulates almost immediately when withdrawn from its vessels, and still more speedily when stirred than when kept at rest, unless it be kept fluid by reducing the temperature to the freezing point, or by addition of certain foreign matters. This fluidity of the blood within the vessels, and coagulation when removed from them, has long been a puzzle to physiologists, and is not even yet fully explained. But there is one point which is certain, namely, that coagulation is the result of the mixing together of two different substances, both of them albuminoids, and only one of them present in the liquor sanguinis, while the other, which is required in comparatively very small quantity, is contained in the red corpuscles. The fibrinous element of the liquor sanguinis is, on this account, sometimes termed *fibrinogen*, while the element furnished by the corpuscles, known as *paraglobulin*, gets also the title of *fibrinoplastin*, or is said to exercise a fibrinoplastic action. The necessity for the mixing of two elements before coagulation can take place may be illustrated by tying a large vein of an ox at two places, and removing the included portion filled with blood. If this portion of vein be hung up, the contained blood will remain fluid, but the corpuscles will fall to the bottom. If, after that, the vein be opened, so as to allow the pure liquor sanguinis to run out, it will be found that the liquid so obtained will continue fluid for any length of time in any vessel, and however much it may be stirred; but when a few red blood corpuscles are mixed with it, it coagulates at once.

This experiment also illustrates another point, namely, that while contact with foreign bodies causes the red corpuscles to part with their paraglobulin, the wall of a blood-vessel has no such effect. The blood will remain fluid for days in the veins of a sheep's trotter got from the butcher, and yet will coagulate immediately when the veins are ripped open with scissors (Lister). We do not know the explanation of this, and we do not know to what the formation of fibrinogen from albumen in the liquor sanguinis is due; but what has been said is sufficient to show that coagulation is not a vital process, as was once supposed, but is a change of a chemical description.

80. The red corpuscles consist of a firm stroma with a substance in solution, which is partly composed of the paraglobulin already mentioned, but principally of a coloured substance, *hæmoglobin*, which is an albuminoid with the property of being crystallizable, the form of crystal varying in different animals. The colouring matter can be entirely separated from the albuminoid, but not without chemical change, the product obtained being termed insoluble *hæmatin*, a substance remarkably distinguished by yielding more than 12 per cent. pure oxide of iron when burned. Iron is known in medicine as a most powerful tonic in debility caused by impoverishment or loss of blood, and this is in some measure explained by the consideration that for the production of blood, it is an essential ingredient.

Hæmoglobin is principally remarkable as the substance which gives to the blood its power of absorbing oxygen.

81. Blood contains in its composition an amount of gas, which, when liberated, is nearly equal to half the volume of liquid from which it has been set free. This gas can be extracted by means of the air pump, part of it easily, and the rest with the aid of warmth. It contains a small quantity of nitrogen, probably introduced in the lungs from the external air, in accordance with ordinary physical laws, and not of any physiological importance. But the great bulk of the gas consists of carbonic acid and oxygen, which vary in their proportion in different parts of the circulation; the carbonic acid being, however, always in much larger volume than the oxygen.

It has already been pointed out that throughout the body chemical changes are constantly taking place, in which oxygen combines with organic matters, and that carbonic acid is among the products. This oxygen is introduced in respiration, and is carried by the blood in the arteries to the textures; while the blood which returns thence by the veins carries with it, back to the lungs, the carbonic acid resulting from the processes of oxidation which have taken place throughout the body. The blood going to the textures, or what is ordinarily known as arterial blood, has therefore more oxygen in it than that which returns by the veins, and the venous blood has more carbonic acid than the arterial. There is, however, a considerable amount of oxygen left in venous blood, except when the animal is killed by asphyxia, that is to say, stoppage of respiration; and the amount of carbonic acid given off by the lungs, is only a small proportion of the total amount contained in the blood.

82. The difference in the gaseous contents of the blood going to the textures, and that which returns from them, is accompanied with a great difference of colour. When blood is allowed to flow from a vein, it comes in a stream as dark as claret, while the blood which comes from a superficial cut is much lighter, and what spouts from a wounded artery is of a bright scarlet. The dark blood from a vein, when spilt on the ground, becomes bright in a few minutes, exposure to the oxygen of the air sufficing to enable it to part with carbonic acid, and take up oxygen; and scarlet blood exposed to carbonic acid becomes dark. If a test tube be filled to about a fourth from the top with defibrinated blood, such as can be obtained by breaking down clot, and be shaken up a few times so as to enable the air to mix with it, it will become bright scarlet, and when allowed to stand for some time it will get dark again; when shaken a second time, it will again grow bright; and this experiment may be repeated on the same specimen of blood day after day. The same changes may be exhibited with a solution of the colouring matter of the red corpuscles; for the corpuscles are destroyed by addition of water, and their fluid contents are set loose, and this solution alters its colour on exposure to oxygen and carbonic acid alternately.

It appears, therefore, in the first place, that the difference in colour of dark and scarlet blood depends, at least partly, on a chemical change in the coloured contents of the corpuscles; and this agrees with the results of spectral analysis, by which it is proved that the colouring matter, or *cruorin* as it is sometimes called, if arterial blood, is a different chemical substance from that of venous blood (Stokes). In the second place, it appears that the hæmoglobin is the oxygen-carrier in the blood. Indeed, it is proved by direct experiment that serum has little more power of absorbing oxygen than water has. With regard to the carbonic acid of the blood, although no doubt a large portion of it is known to be contained in the serum, it seems probable, from the effect of that gas on the colouring matter, that the portion which is removed in respiration belongs to the corpuscles.

83. Before leaving this subject, it may be well to notice an exception to the general rule, that blood returning from the textures is dark—not only is that sent to the heart from the lungs scarlet, but the blood returning from certain glands in action is of the same tint. Thus, in experiments on dogs it has been found, that while the blood in the veins coming from the sub-maxillary gland is dark when the gland is at rest, if the nerve (*chorda tympani*) which supplies the secreting structure be excited, and the gland thus irritated to secrete saliva, a much larger quantity of blood passes through the gland, and it escapes from it scarlet. The blood returning from the kidneys is also scarlet as long as urine is secreted, but is dark when, from any cause, the secretion ceases. In both these instances, it will be observed, that an enormously larger amount of blood passes through the organ than is required for the nourishment of its textures. In the same way, if the blood-vessels of a rabbit's head are paralysed by dividing the sympathetic nerve in the neck, in consequence of the great increase of blood allowed into the part, a portion returns unaltered, and the blood is found red in the jugular vein.

CHAPTER IX.

CIRCULATION.

84. We have already had occasion to mention that the blood circulates through the body in a system of close vessels. It is propelled by the heart through the arteries to a fine capillary network, whence it returns to the heart again by the veins.

The blood which has circulated in the tissues requires to be aerated to reconvert it from the dark to the scarlet condition, before it can be allowed to go to the tissues again; and this is managed in different ways in different animals. In fishes, the blood returning from the system is propelled by the heart into the gills, and from them right on into the system again; passing through two sets of capillaries, one in the gills and the other in the system, before it returns to the heart. In amphibians, for example in the frog, and in reptiles, with the exception of the crocodiles, the blood is propelled from the heart partly into the respiratory organs, and partly into the system, and returns from both these destinations to be mixed in the heart; and this mixture of scarlet and dark blood is what circulates again both in the system and respiratory organs. In crocodiles, none but dark blood is sent to the lungs; but there is a communication by which part of the dark blood may be carried back into the system along with the scarlet stream. In warm-blooded animals, namely, birds and mammals, the whole of the blood returning from the system is sent from the heart to the lungs, and the whole of the blood returned from the lungs is sent into the system.

In fishes, the heart consists of one receiving chamber or auricle, and one propulsive chamber or ventricle. In the frog and the turtle, it has two auricles, one receiving dark blood from the body, and the other red blood from the lungs,

and these discharge their contents into one common ventricle, which propels the mixture partly into the lungs, and partly through the body. In warm-blooded animals, the heart is a completely double organ, consisting of two auricles and two ventricles: the right auricle receives the dark blood brought back from the tissues, and sends it into the right ventricle, which propels it through the lungs; the left auricle

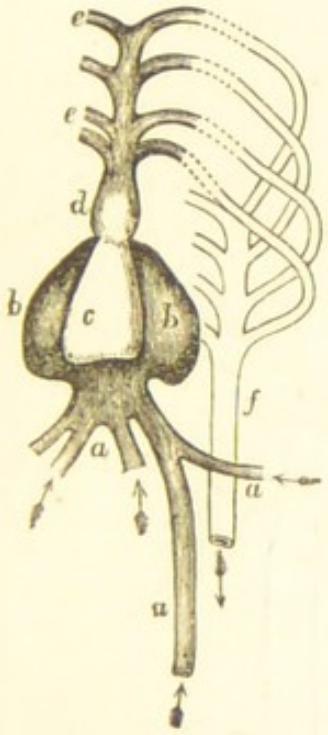


Fig. 62.—Heart and Great Vessels of Fish. *a*, *a*, *a*, Veins; *b*, *b*, right and left extremities of the single auricle of the heart; *c*, ventricle of heart; *d*, bulbus arteriosus; *e*, *e*, branchial arteries which convey the dark blood from the heart into the gills, to be purified before passing on into the branchial veins, and thence into *f*, the aorta.

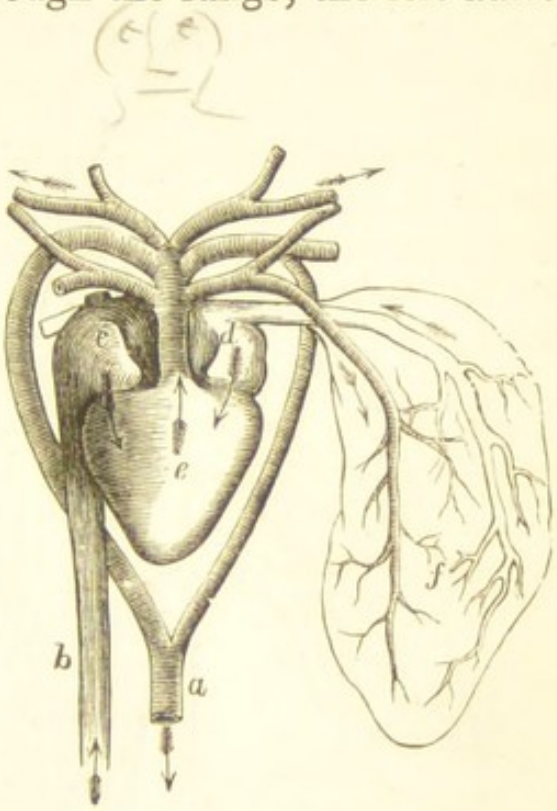


Fig. 63.—Heart and Great Vessels of Frog. *a*, Aorta; *b*, venous trunk carrying dark blood to *c*, the right auricle of the heart; *d*, left auricle receiving aerated blood from the lungs; *e*, ventricle receiving blood from both auricles, and propelling the mixed fluid up the truncus arteriosus, both into the lungs and the system; *f*, left lung.

receives the red blood returning from the lungs, and passes the pure stream on into the left ventricle to be propelled into the tissues of the body. In fishes, as well as in warm-blooded animals, only red blood circulates through the body; but in

amphibians and reptiles, while the heart is more complex, the circulation is less perfect, there being a double waste of power in sending part of the dark blood into the body, and part of the red blood back to the lungs, which, though in a manner accounted for as being a stage of progression toward the more perfect organ found in higher animals, might have been difficult to explain, if it could have been noted by an observer before birds and mammals appeared on the earth.

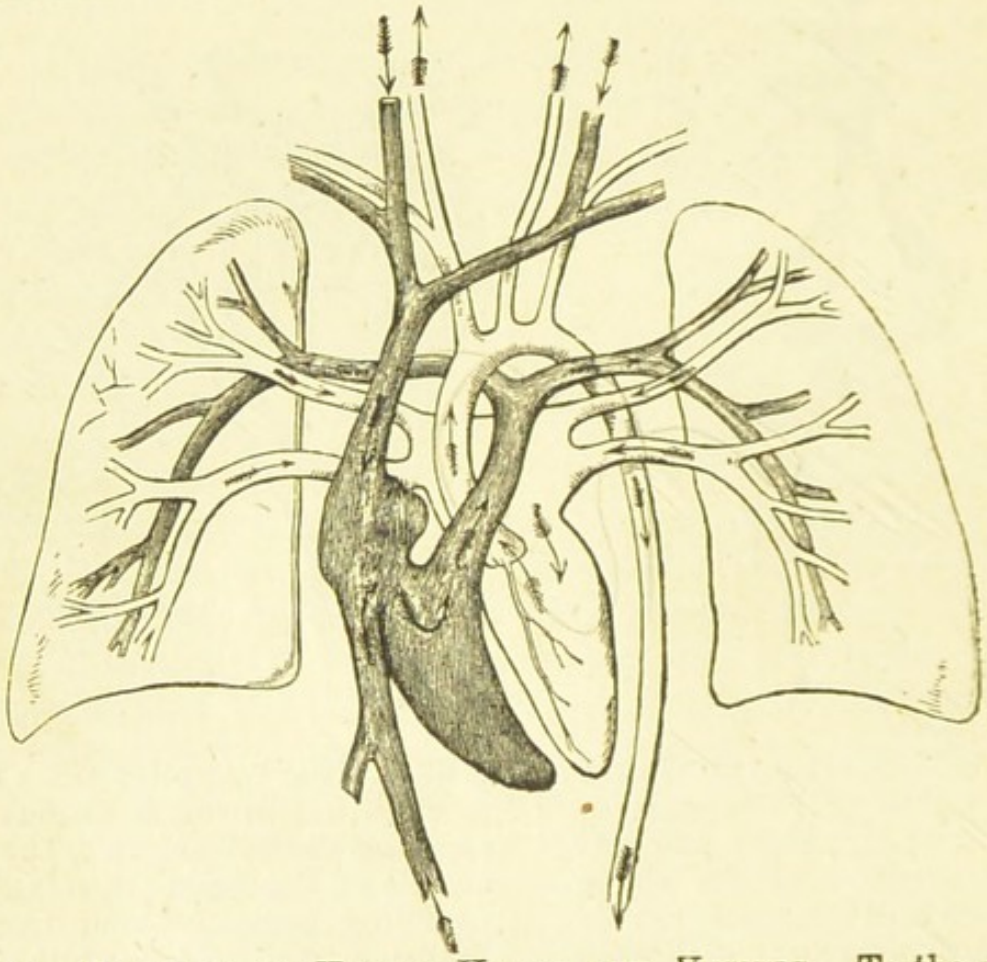


Fig. 64.—Diagram of Human Heart and Vessels. To the sides are the lungs represented in outline; and above and below are the cut ends of the systemic vessels. The arrows indicate the course of the blood. In the vessels left pale, pure blood circulates; and in the darkened vessels, impure blood.

85. The **Heart** in mammals, as will be seen from what has been said, is divisible into a right and a left part, each of which is comparable with a fish heart, consisting, as it does, of an auricle and a ventricle; these parts are completely separate, one from the other, from the time of birth, so far as the blood contained in them is concerned; but they act syn-

chronously, and are structurally one heart. Anatomically considered, the natural division of the heart is into an auricular and ventricular part, separated by a deep sulcus, the auriculo-ventricular groove. The ventricular part is a strong muscular structure invested completely with the serous covering of the pericardium, and unconnected with other viscera. It is directed downwards, forwards, and to the left side, resting on the diaphragm in man, and narrowing to the *apex*, which is felt beating opposite the interval between the sixth and seventh costal cartilages of the left side. The apex is formed entirely by the walls of the left ventricle, which are three times as thick as those of the right ventricle, the blood requiring much greater force to propel it through the system than to send it through the lungs; and if the ventricles be cut across, the section of the left ventricle will be seen to be circular, while the right is curved crescentically round it.

Above the auriculo-ventricular groove, ascending from the *base* of the ventricles, the two arterial trunks issuing from those two cavities lie close together behind the breast-bone, each twisted somewhat round the other. That which rises from the right ventricle is the *pulmonary artery*, and divides into a right and left branch, one going to each lung; while the systemic artery, arising from the left ventricle, and concealed at its origin by the pulmonary artery, is called the *aorta*.

The auricles have exceedingly thin muscular walls, their whole function being to receive the blood, which continues pouring in during the contraction of the ventricles, and to pass it into them through the large auriculo-ventricular apertures as soon as they relax. They lie behind and to the sides of the arterial trunks, and each is prolonged into a pointed *cul-de-sac* in front, which, from a fancied resemblance to a dog's ear, is called the auricular appendage; and these appendages have given their name of auricles to the cavities to which they belong. The cavities are separated one from the other by a thin septum, which, as seen from the right auricle, presents a depression and, in front of it, a crescentic border, the *fossa* and *annulus ovalis*, marking the position of an opening which exists, and is made use of, in fœtal life,

but is shut up after birth. In the rare instances in which it continues after birth to allow blood to pass through it, the circulation of dark blood in the system is the result, constituting the disease called cyanosis, and destroying life.

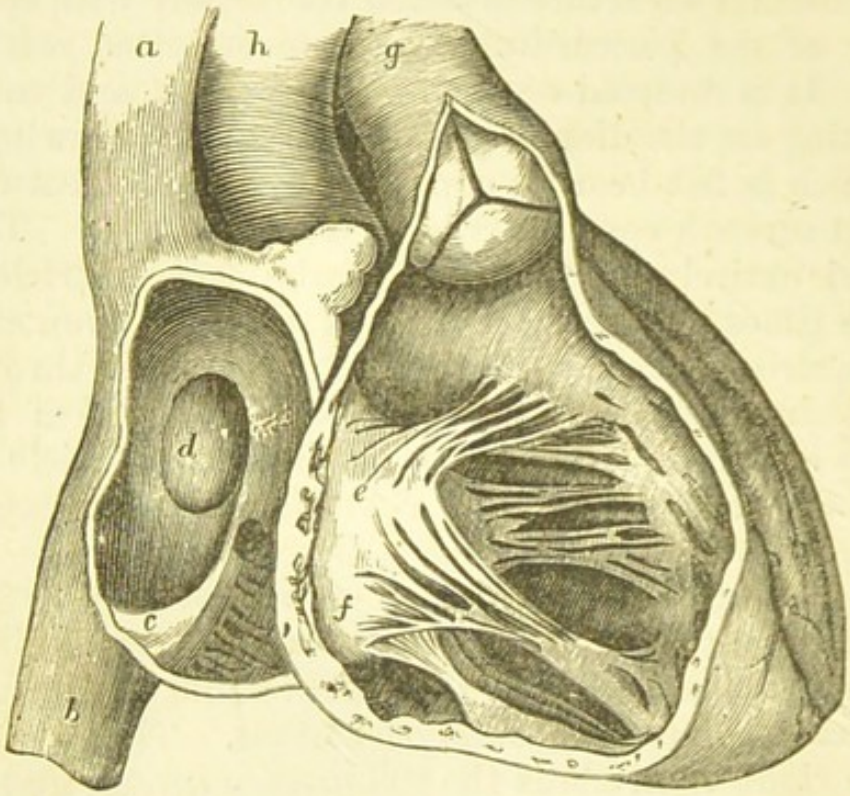


Fig. 65.—Right Side of the Heart. *a*, *b*, Superior and inferior vena cava entering the right auricle; *c*, Eustachian valve; *d*, annulus ovalis; *e*, *f*, anterior and posterior cusps of the tricuspid valve descending from the margin of the auriculo-ventricular opening; *g*, pulmonary artery with its orifice shut by distension of the three pouches of its semilunar valve; *h*, aorta.

The right auricle receives blood in two streams nearly vertically opposite one another, one from the vena cava superior, bringing the blood from the head and upper limbs, the other from the vena cava inferior, bringing the blood from the lower limbs and greater part of the trunk; while, in addition, the blood from the walls of the heart enters by one considerable and several smaller orifices. The left auricle receives its blood by streams transversely opposite one another, entering by the pulmonary veins from the right and left lungs.

86. The heart can be seen in action by laying open a frog, but still more satisfactorily in the chest of a mammal. The

auricles are seen to contract first, and to distend the ventricles with blood; the ventricles contract immediately afterwards, and then there is a pause before the auricles become quite distended and contract again. The contraction of the auricles is completed in about a third of the time taken by the ventricles to contract; but it is not thorough, for it proceeds in a wave forwards from the venous trunks to the tips of the appendages, so that the appendages are at first distended, and when in turn they contract, the rest of the auricular walls are already relaxed. On account of this mode of contraction of the auricles, there is in health little tendency of the blood to regurgitate into the venous trunks; and the mouths of these vessels are unguarded in mammals, although protected by competent valves in other animals. There is in man a fold of membrane, the Eustachian valve, in front of the vena cava inferior; but it can have little action as a valve after birth, for it is frequently nearly absent in the adult. The ventricles contract in a different way from the auricles. The muscular fibres in the middle depth of their walls embrace them circularly, while the successively deeper and more superficial layers have successively steeper degrees of obliquity, and are continuous one with another both at base and apex; and in consequence of this arrangement, these cavities are contracted throughout their whole extent by both shortening and narrowing at the same time, till they are completely emptied. But no matter how completely or forcibly the ventricles might contract, they would make but an inefficient engine of propulsion were there not some means of preventing the blood being pushed, during their contraction, back into the auricles, and recoiling, after their contraction, back into them from the arteries. Such waste of power is prevented by the presence of *valves*, which guard the arterial and auriculo-ventricular orifices.

87. The arterial valves guarding the entrances into the pulmonary artery and aorta are named *semilunar*, because they consist each of three delicate pouches, with semilunar attachments to the wall of the artery. The pouches are placed in a circle, with their mouths turned away from the heart, and are pushed flat against the arterial walls when the blood is

rushing out of the ventricles; but as soon as the ventricular contraction ceases, and the elasticity of the arteries tends to make the blood recoil, they are filled with the blood in the arteries, the sides of each are pressed against the adjacent sides of the two others, and all three reach in to the centre of the orifice, so as effectually to block it up. The action of these valves can be studied in a sheep's heart, by pouring water into the cut arteries, when it will be seen that not a drop passes back into the ventricles.

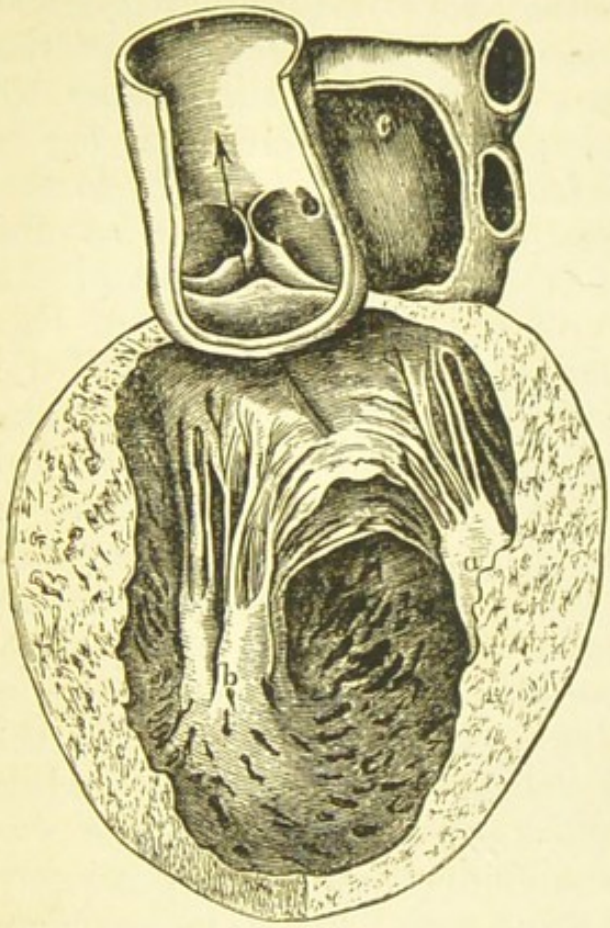


Fig. 66.—Left Side of the Heart. The pulmonary artery has been removed. An arrow is passed through the aortic orifice between the semilunar pouches of its valve; and the lower end of the arrow rests on the anterior cusp of the mitral valve. *a*, *b*, Anterior and posterior musculi papillares, with chordæ tendineæ passing up from each to both cusps; *c*, auricular cavity.

The auriculo-ventricular valves of the right and left sides of the heart are named respectively the *tricuspid* and the *bicuspid* or *mitral*, the one consisting of three pointed membranous flaps or cusps, and the other of two. The cusps are attached at the base to the margins of the auriculo-ventricular orifices, and are kept in the interior of the ventricles by a number of threads, *chordæ tendineæ*, attached to their edges and backs, and fastened at the other end to muscular prominences, the *musculi papillares*. The arrangements are on the same principle in both valves, but may be studied best on the mitral, which is the more perfect of the two. The chordæ tendineæ of each cusp are divided into two sets; those from each half joining with those of the adjacent half of the other cusp to be inserted into one mus-

culus papillaris. Thus the contraction of the musculi papillares not only prevents the cusps from being flung into the auricle, but keeps their edges in apposition. These muscles contract at the same time as the ventricular wall with which their fibres are continuous, and the contraction of the ventricle pushes the blood against the backs of the valves, so as to bring them quite together, block up completely the passage into the auricle, and leave the blood no other aperture of exit save into the artery.

88. If we apply our ear to any one's chest, we find that the heart makes some noise in its action, that there is a perpetual "pit-pat, pit-pat," or recurrence of two successive sounds; first a slightly prolonged sound, then, a moment afterwards, another short and clear, and after that a longer interval before the first sound is repeated. The first sound will be found to occur at the same moment as the beat against the chest, and nearly at the same moment as the pulse at the wrist; it is synchronous also with the systole or contraction of the ventricles, and is caused by the vibration of the auriculo-ventricular valves when suddenly closed by the pressure of the blood on them. It continues audible in an animal when the chest has been laid open, so does the second. The second sound is caused by the closure of the arterial valves, as has been experimentally proved by introducing a pair of needles, one into the pulmonary artery, and the other into the aorta, so as to prevent the valves shutting, and observing that at once the sound ceases.

The beating of the heart against the chest is called the *impulse*, and is caused by the apex, which is at all times in contact with the wall of the chest, being pressed against it in the ventricular contraction by jerking upwards, forwards, and to the left. This movement is probably caused by the arch of the aorta being thrown into a rigid and more expanded curve when filled with blood, while it is fixed in its position behind; but it has been suggested that it results from the disposition of the muscular fibres of the ventricles.

89. The frequency of the heart's pulsations varies in health with different circumstances, but principally according to age. In infancy the beats are 120 or more per minute; in early life they quickly diminish in frequency; in the adult they

are about 75 in the male, and 85 in the female; and in old age the average is lower.

The heart's action is easily influenced in its regularity, strength, and rapidity by the amount of blood in the body, and by the nervous impressions conveyed from other parts. Thus, it may be weak from want of blood, or, when the deficiency is sudden or great, it may be fluttering or irregular; and, on the other hand, the rarer phenomenon is occasionally observed of interference with the heart's action dependent on a superabundance of blood. Emotions also, and conditions of the viscera, send impressions through the nerves which readily disturb the heart. But it is important to observe that the rhythmic action may continue when all connection with other parts has been cut off. A turtle's or a frog's heart will continue to beat when removed from the body, and the successive contractions of its parts will continue to take place in regular sequence, even though there is no longer any blood to stimulate it. When it is divided vertically the portions continue to beat, and when divided transversely the rhythm continues in the basal part, but is lost in the apex. There are not only numerous nerves, but likewise minute nerve-centres, the *ganglia of Remak*, scattered over the heart; and by these, kept in communication with one another by the copious nerves in the auriculo-ventricular groove, the action is immediately governed (p. 216). No doubt it is difficult to understand how the nerves are stimulated to produce rhythmic contraction; but it must not be forgotten that the pulsation of the heart is only one of a great number of instances of periodicity in nervous action, and that any nervous action frequently repeated has a tendency to go on recurring.

90. The **Arteries**, into which the blood is sent by the heart, are a series of branching, elastic, and contractile tubes. They have a smooth internal lining, and externally have a tough felted coat of areolar tissue; but the main thickness of their walls consists of a middle coat of elastic and muscular fibres intermixed and arranged circularly, lying among meshes of elastic membrane. In the larger arteries the muscular fibres are exceedingly small, and the elastic fibres abundant; but as the vessels get smaller there is a

greater development of muscular tissue, and less of the elastic, until in the minute arterioles the elastic tissue dis-

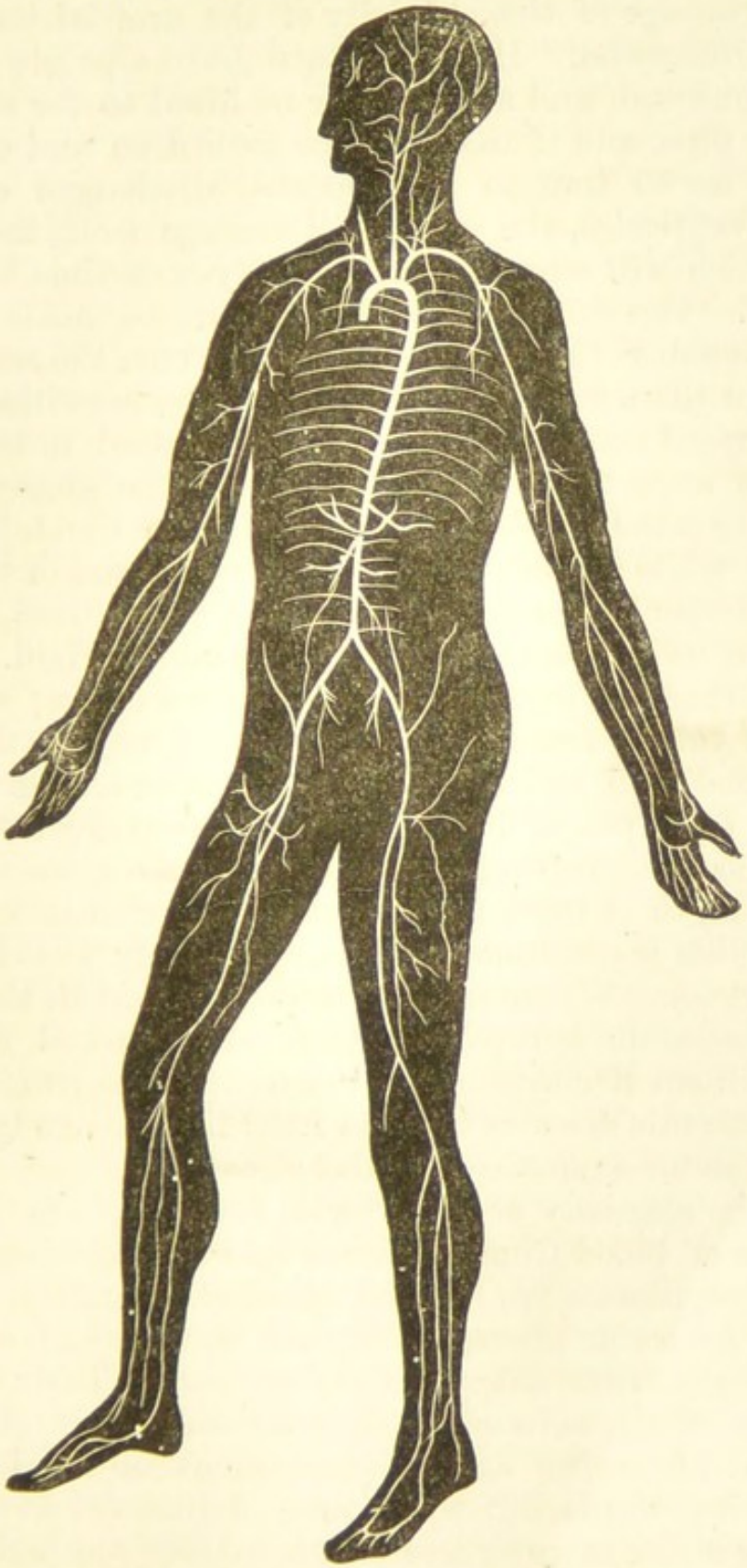


Fig. 67.—Arterial System.

appears altogether, and the middle coat consists of muscle only.

The advantage of the elasticity of the arterial walls may be easily illustrated. If a glass tube have a nozzle fastened into it at one end, and at the other be fitted to the stop-cock of a water pipe, and if the water be turned on and off alternately so as to imitate the repeated discharges of blood from the ventricles, the water will emerge from the nozzle in jets, which will cease instantaneously each time that it is turned off. But if the same experiment be made with a long india-rubber tube instead of a glass one, the water will spring from the nozzle in a continuous flow, notwithstanding the interrupted manner in which it is admitted to the tube; and if the experiment be varied so that the glass and the india-rubber tube shall both be filled from the top at the same time, while the nozzles on the two tubes are of the same size, the elastic one will discharge in a given time a much larger quantity of water than the one which is rigid. In the rigid tube there is great loss of force by friction; while in the elastic tube, as each fresh jet of fluid enters, the walls are distended, and as it ceases they recover, and give their contents a fresh propulsion onwards in a second wave, which distends the tube further on; and thus, after traversing a sufficient length of tube, the interrupted stream is converted into one which is continuous. This is precisely what happens in the arteries. When a large artery is divided, the blood comes in separate abrupt jets with well marked intervals between; in smaller arteries the duration of the jets is longer and the intervals are shorter, and from little twigs the blood spouts out in an almost continuous stream.

While the elasticity of the arteries thus converts the separate gushes of blood from the heart into one continuous flow before the capillaries are reached, their contractility, derived from their muscular fibres, determines the amount of blood which is sent at different times to each part. Their contraction is not of the vermicular description, but purely tonic: they do not assist the forward movement of the blood by propelling it onwards, but, by varying in diameter at different times, they allow more or less blood to pass through them. The muscular fibres are governed by nerves, termed *vaso-*

motor: these are found in the sympathetic trunks (p. 215), and their action may be illustrated by dividing the sympathetic nerve of a rabbit in the neck, when immediately the ear of the side experimented on gets red, and the whole of that side of the head becomes warmer than the other; the reason being that the paralysed arterioles no longer resist the entrance of the red and warm blood, but allow it to distend them. This condition is the same as takes place in *blushing*, only in blushing the withdrawal of the nervous stimulus is temporary, caused by the communication of a disturbing influence from the brain, the result of emotion.

91. The *pulse* in the arteries is caused by their distension and elongation under the pressure exerted by the rush of blood with each beat of the heart, but can only be felt in those positions in which an artery lies near some firm structure against which it can be pressed. With the aid of instruments it can be shown that it is communicated with great rapidity to the whole arterial system, the smallest arteries pulsating within a sixth of a second after the largest. The blood already in the arteries is pushed on by each new quantity thrown in from the heart; the velocity with which the blood travels being far less than that with which the pulse is communicated. The actual rate of movement of the blood can be observed in the arteries of animals by the insertion of an instrument for the purpose between the ends of a divided vessel, and it is calculated from such experiments, that in man the mean velocity is about ten inches per second in the carotid, and about two and a quarter in the foot, the rate of flow being much slower in small arteries than in large. The reason why it is slower is to be found in a peculiarity in the branching of arteries; for in almost all instances in which an artery divides, the united areas of the divisions are greater than the area of the parent trunk; and, consequently, the total area of the combined arterial channels increases rapidly the farther the distance from the heart.

While the frequency of the pulse corresponds with that of the heart's contractions, its character depends on a variety of circumstances, of which the chief are the amount of blood in the body, the vigour and regularity of the heart's action, and the degree to which the muscular fibres of the arterial

wall are contracted, and so offer resistance to the heart. Some of the peculiarities of the pulse, which cannot be appreciated by pressure of the finger on the wrist, are exhibited with the aid of the *sphygmograph* (Marey), an instrument which is fastened to the wrist, and in which a spring, pressed against the radial artery, causes a light lever, carrying a pen, to move up and down. The pen is in contact with a slip of paper or smoked glass set in motion by clock-work, and produces a tracing which indicates the pulsations by elevations, and the element of time by horizontal distance. Such a tracing shows, that in health the distension of the vessel takes place with almost instantaneous suddenness, commencing and finishing abruptly;

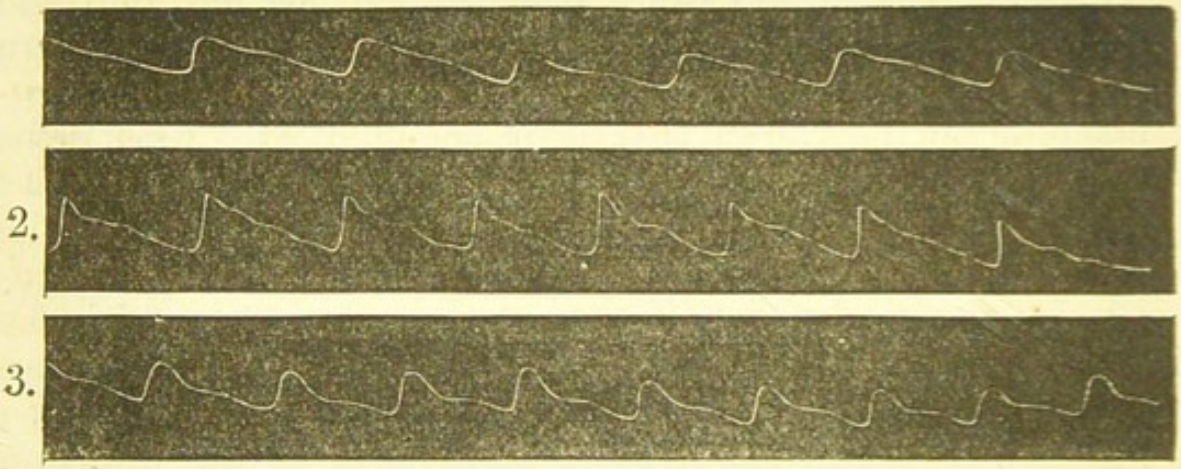


Fig. 68.—Sphygmographic Tracings of the pulses of three persons all healthy. In 1, the arterial resistance is greatest; in 2, the dilatation of the vessel has taken place with such force as to jerk the lever of the instrument from its rest, and hence the sharp points at the tops of the waves; 3, is a distinctly dicrotous pulse.

while the gradual character of the recoil is shown by its making a long sloping line. When the arterial resistance is great, as it is in the most robust health, it counteracts the distending impulse given by the heart, so that the rise of the tracing is not so considerable as it would otherwise be; and in these circumstances there is a moment's continuance of the distension, then a gradual and but slightly undulating descent. But when the arterial resistance is slight, the secondary distending impulses given by the elastic recoil of the larger vessels produce more effect on the tracing, and one particular rise becomes prominent, which appears to be caused by the walls of the commencement of the aorta, redistended by the

blood thrown back on the aortic valves, again recoiling. Such a pulse is said to be *dicrotous*.

92. The Capillaries are the smallest blood-vessels, those through the walls of which materials pass to and from the tissues, and so delicate that, as has already been pointed out, even blood corpuscles are able, without injury to the walls, to escape from them into the parts around. They vary from $\frac{1}{2000}$ to $\frac{1}{3500}$ inch in diameter, and are arranged like the meshes of a net. The meshes vary in size and form in different localities: for the most part they are polygonal; in the papillæ of the skin they are in loops; in muscle they are oblong; and in the lung they are circular, with the diameters of the circles little greater than the breadth of the capillaries between which they lie. In some tissues they can be seen under the microscope without previous preparation; and they exhibit the appearance of a homogeneous membranous wall with oval nuclei imbedded in it, and projecting to the outside. With the aid of a weak solution of nitrate of silver, a delicate lining of epithelium, or *endothelium* as it is sometimes called, is brought into view; but it must not be supposed that the nuclei mentioned belong to that lining.

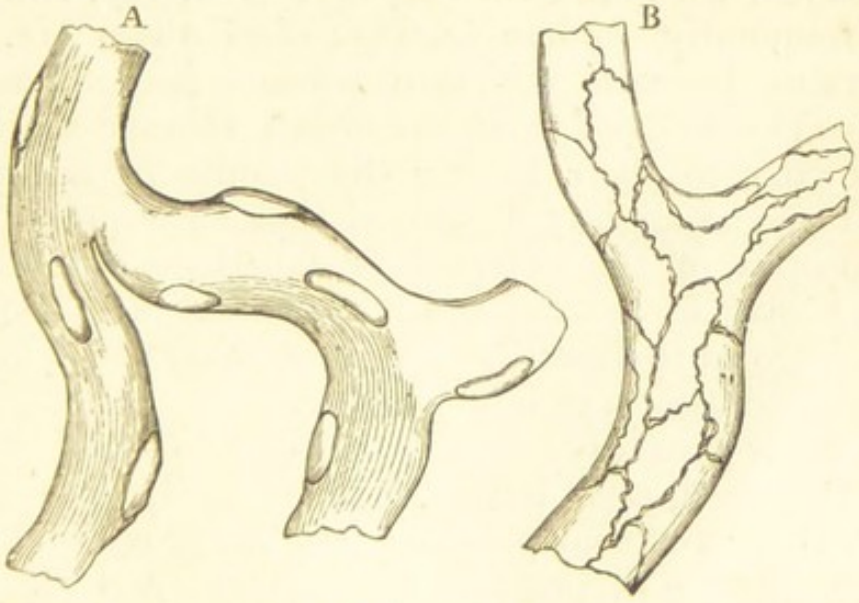


Fig. 69.—CAPILLARIES, highly magnified. A, exhibits the nuclei; B, the endothelium as displayed by means of nitrate of silver.

The blood can be seen circulating in the capillaries of the web of a frog's foot, a tadpole's tail, or a bat's wing, without

injury to the animal; and may be still better studied in some internal parts of small animals operated on for the purpose. Furthermore, by gazing steadily at a bright field, and moving a finger rapidly in front of the eye, some persons are able to bring into view the blood corpuscles coursing in the capillaries of the retina in their own eyes (p. 251). From such data as these, the calculation is made that the blood moves in the capillaries in the human subject at the rate of one or two inches per minute. The movement looks much more rapid when seen under the microscope in a frog's foot; but the reason of that is, that the distance which the corpuscles travel being magnified, the apparent rate of motion is proportionately increased; because the rate of movement is the distance travelled in a given time.

93. The Veins begin by radicles from the capillaries, in like manner as the arteries end in these vessels. The blood moves in them from the capillaries towards the heart, and their course on that account is described from twig to trunk like the course of a river. They are larger than the corresponding branches of arteries, and in the limbs they are more numerous. Thus, in the lower limb below the knee, and in the upper limb below the armpit, the main arteries are accompanied with *venæ comites*, that is to say, two or more veins frequently communicating; and there are, besides, large veins beneath the skin without any corresponding artery. The walls of veins are much thinner than arterial walls, owing to their having the middle or muscular and elastic tunic so slightly developed that their principal thickness consists of the external or felted coat; and thus it happens that in a wound, an artery cut across forthwith contracts so as to lessen its apparent diameter, while a vein gapes and continues as large as ever.

The veins give little or no assistance to the flow of blood by elastic recoil, and, indeed, become easily distended to an undue extent; but they present a peculiar provision to prevent the accumulation of pressure within them, and regurgitation backwards, for they are provided here and there with valves. These valves are on the same principle as the arterial valves of the heart, consisting of semilunar pouches; but the pouches look towards the heart, and instead of there being three of

them together, there are only two. They are very delicate, consisting of folds of the lining membrane of the vessel, and are quite transparent; but when liquid is injected from the direction of the heart, it is effectually prevented by them from passing back to the twigs. They are nearly absent from the head and neck, and are most abundant in the lower limbs. By preventing regurgitation, they convert the accidental pressure of surrounding parts into an auxiliary of the circulation, pushing the blood onwards, but incapable of pushing it backwards. Such pressure may, however, easily be sufficiently great to prevent the entrance of blood into a vein; thus in letting blood from the arm it is customary to make the patient exercise the fingers sufficiently to keep up pressure by contraction of the flexor muscles in the forearm on the deep veins, and so compel the return of the blood by the superficial set.

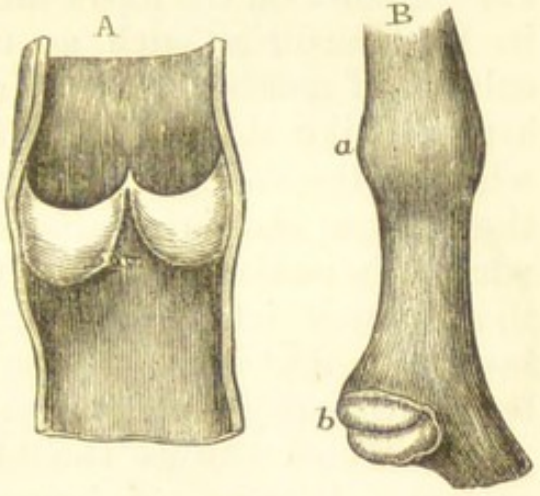


Fig. 70.—Venous Valves. A, a vein laid open to show the two pouches of a valve. B, an unopened vein, exhibits at *a*, the dilatation opposite a valve; and at *b*, a closed valve seen from below.

It will be perceived from what has been said, that the rate of flow of the blood in individual veins is very variable. Looking, however, at the venous system as a whole, it will be easily understood that it pours into the heart, in a given time, exactly the same amount of blood as is discharged into the arteries; and as the sectional area of the veins is everywhere greater than that of the corresponding arteries, the flow of blood within them is in the same proportion slower, probably nowhere more than half as fast; but as, in the arteries, the velocity of the blood is less the nearer it approaches the capillaries, on account of the larger sectional area of the total number of vessels in which it is distributed, so it again increases in the passage from the small to the large veins.

94. The *pressure* or force with which the blood is urged on its

course by the heart must not be confused with its velocity. The velocity is at its minimum in the capillaries; the pressure diminishes from quitting the heart till the return to it, being dissipated by the friction of the tissues which resist it. From experiments on the lower animals, it is calculated to be equal in large arteries, such as the carotid, to the support of a column of mercury more than six inches high, and in small arteries, like those of the foot, to be about a fourth less; while in the veins, after having experienced the resistance of the tissues in the capillaries, it is only about a twelfth of what it is in the arteries. These observations, together with the fact that defibrinated blood has been injected through the body of a dog with less pressure than that exerted by the heart (Sharpey), point out that the heart is the motive power which causes the blood to flow through the whole system. It must not, however, on that account be supposed that the tissues have no influence whatever on the circulation, for we have proof to the contrary in the fact that in interference with respiration, the unaërated blood fails to pass the capillaries, and that in inflammations, examined microscopically in the web of the frog's foot, blood corpuscles are seen arrested in their course without any obstruction existing in the channel beyond.

95. The *time* required for a portion of the blood to be carried through the *whole circulation*, has been made the subject of most interesting experiments. An easily detected substance, such as ferrocyanide of potassium, is introduced into a vein on one side of the neck of an animal, and the time noted which elapses before it is present in the blood allowed to flow from the corresponding vein on the other side. The substance introduced has to pass through the heart and lungs, and some part of the head or neck, before it can reach the aperture where it is sought for, and thus makes a circuit through both pulmonary and systemic circulation. In the horse, such a circulation is completed in little more than half a minute, and in smaller animals in a much shorter time. Small animals have the pulse rapid; and the rule may be laid down that a complete circulation takes place in from 20 to 30 beats of the heart. This may well appear incredible at first, when it is considered how slowly the blood moves in

the capillaries, but the explanation is found by taking intc account the exceedingly short distance of capillary circulation traversed by each portion of blood, probably in no case exceeding the tenth of an inch.

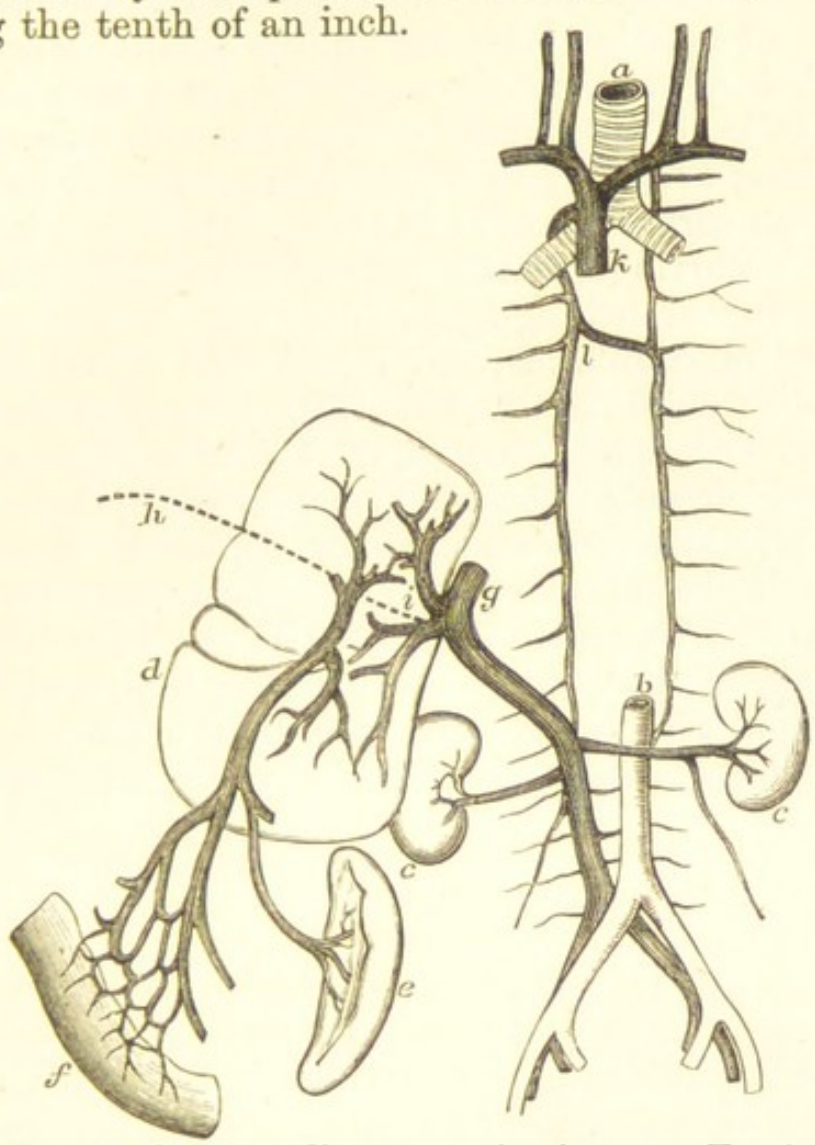


Fig. 71.—Venous System, diagrammatic view. *a*, Trachea dividing into the two bronchi; *b*, aorta dividing into the two common iliac arteries, which again divide into the external and internal iliacs; *c*, *c*, kidneys, with the renal veins emerging from them; *d*, liver; *e*, spleen; *f*, portion of intestine, with mesenteric vein proceeding from it to join the splenic and form the portal vein, which branches in the liver; *g*, inferior vena cava receiving the hepatic veins emerging from the liver; *h*, obliterated umbilical vein; *i*, obliterated ductus venosus; *k*, superior vena cava formed by union of the two innominate or brachio-cephalic veins; *l*, the right vena azygos joined by the left.

96. Portal System.—Before leaving the subject of the circulation, it remains to be pointed out that there are exceptions to the rule that the arteries continually divide

till they reach the capillaries, and that the veins emerging from these bring the blood directly back to the heart. Looking at vertebrate animals generally, one finds many instances of arteries breaking up into small branches which reunite before reaching the capillaries, and such an arrangement is called a *rete mirabile*. There is only one instance of such a thing occurring in the human subject, namely, in the Malpighian corpuscles of the kidney. But there is a notable instance, occurring in man and all vertebrate animals, of a venous trunk branching again into twigs, which open into a second set of capillaries; and that is the portal vein. The portal vein receives all the blood returning from the stomach, intestines, and spleen, and divides into a right and a left branch, which enter the liver, and break up into branches which pour their contents into the capillaries of that organ, and then discharge their blood into the hepatic veins, which open into the vena cava inferior. Thus all the blood which goes to the stomach and intestines has to pass through two sets of capillaries before returning to the heart, and this is the blood on which the liver exercises its purifying power.

CHAPTER X.

RESPIRATION AND TEMPERATURE.

97. The object of respiration is to liberate the carbonic acid accumulated in the blood returning from the tissues, and to take in a fresh supply of oxygen, which, passing to the tissues, is used in chemical decompositions, by which more carbonic acid is produced. Respiration, therefore, is not a process of combustion, but it affords an index of the amount of combustion taking place in the tissues. It consists essentially of an interchange of gases between the blood and the medium in which the animal lives, and requires that these two should be brought into as close contact as possible.

This contact is achieved in some animals by introducing the medium into the body, and conveying it to the tissues. Thus, in star fishes there is a water-vascular system, and in insects there are air tubes or *tracheæ* kept open by a spiral thread coiled round them, which, opening by *stigmata* on the sides, ramify throughout the whole body, and are emptied and refilled with air by pulsatile movements of the abdomen. But in the majority of animals, including all vertebrates, the blood is brought into contact with the surrounding medium in a special organ devoted to the purpose; and this in water-breathing animals consists of *gills* or projecting organs with blood-vessels on the surface, while in air-breathing animals it consists of *lungs* or bags into which the air is introduced.

In frogs and serpents, the lungs are simple pouches with shallow recesses round about, the partitions of which project into the interior; and these pouches are each opened abruptly into by a main air tube or *bronchus*. In turtles and crocodiles the air tubes are branched, and each branch opens into a cavity in the heart of a sponge of ramifying recesses;

while in birds there are no longer any dilated cavities, but every air tube is surrounded with a system of air cells, completely separated by septa of connective tissue from those which surround others. In the lungs of man and other mammals, the air tubes go on dividing and subdividing till they terminate in minute tubules, which open into irregular passages, surrounded with air cells: and in the manner of their development they exhibit both the modes of increase in complexity observed in the zoological series; for they take origin in the embryo as a pair of simple pouches coming off from the throat, and these branch out into smaller pouches budding in like manner till lobules are formed, which, instead of branching outwards, have septa growing inwards into their cavities.

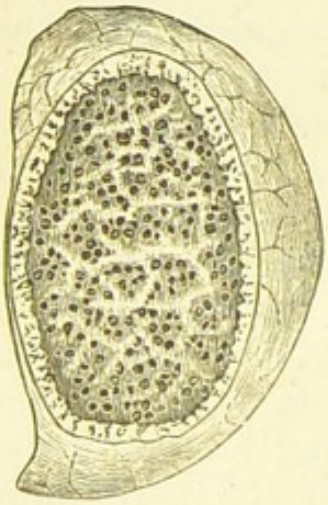


Fig. 72.—Frog's Lung, opened from behind, enlarged.

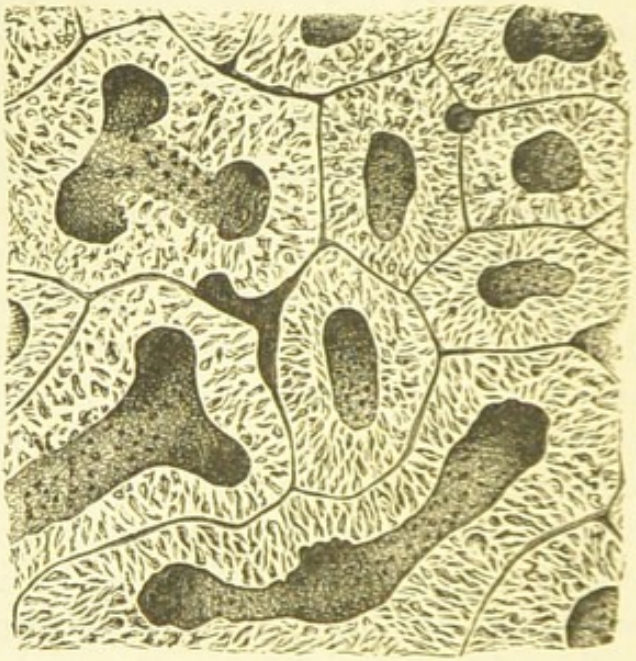


Fig. 73.—Duck's Lung; section, magnified twenty diameters.

98. The main air tube, the *trachea* or windpipe, is about four and a half inches long, and is surmounted by the *larynx*, the part in which the glottis is placed, and which constitutes the organ of voice. The constant patency of the trachea is insured by a series of cartilaginous hoops, which in some animals form complete rings, but in the human subject are deficient behind. This tube divides below into a right and left *bronchus* of similar structure; and each of these divides

and subdivides into smaller and smaller *bronchial tubes*, the larger of which have crescentic cartilages arranged in their walls, not, as in the trachea, one directly over another, but in such a way as to maintain the cylindrical form of the tube on every aspect, while in the smaller these cartilages degenerate to irregular nodules, and disappear.

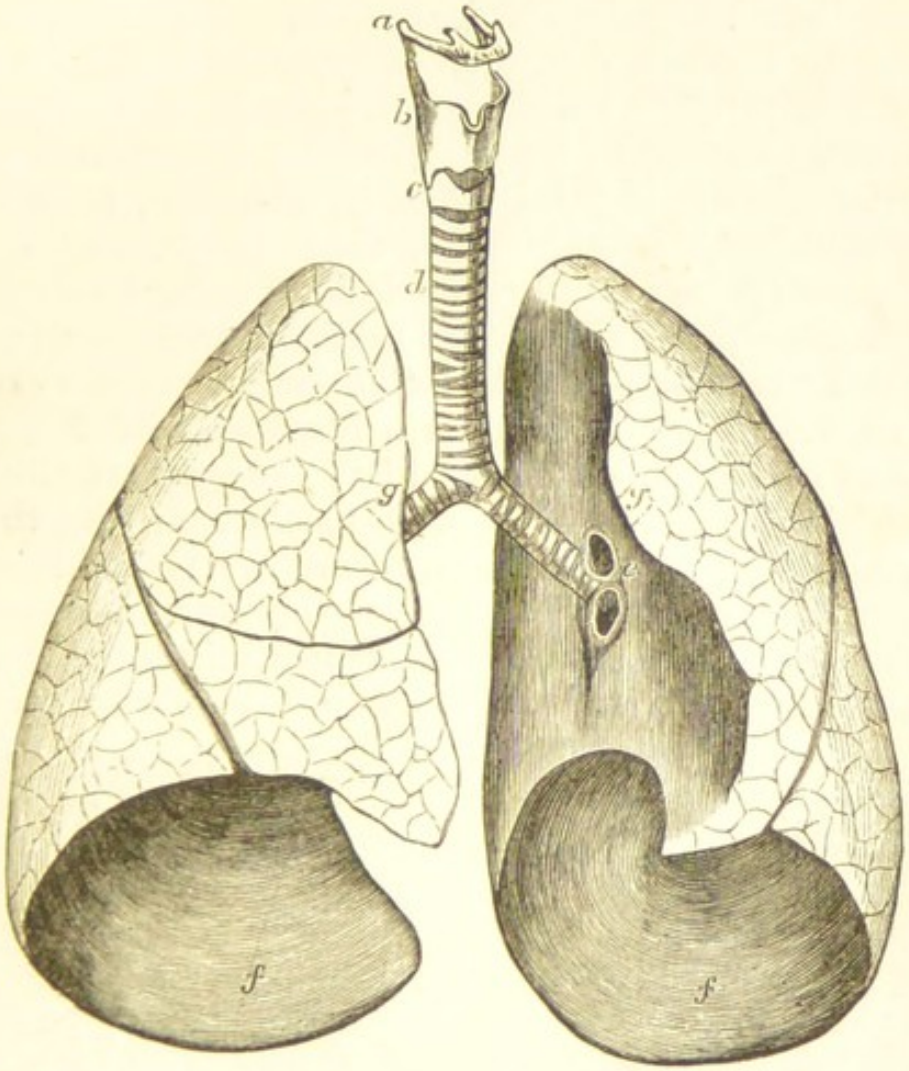


Fig. 74.—HUMAN WINDPIPE AND LUNGS. *a*, Hyoid bone; *b*, *c*, thyroid and cricoid cartilages of larynx; *d*, trachea dividing inferiorly into right and left bronchus; *e*, root of left lung, the pulmonary artery and vein cut across; *f*, *f*, the bases of the lungs, which rest on the diaphragm; *g*, *g*, portions of the anterior margins, which in the body reach to the middle line, and have only folds of pleura between them. The right lung is seen to have three lobes, the left two; the right is shorter than the left, and the anterior part of the left is hollowed out opposite the position of the apex of the heart.

In all these tubes, except the smallest, there is a longi-

tudinal arrangement of elastic fibrous tissue, enabling them to elongate when required by the stretching of the neck or the expansion of the lungs; also transverse muscular fibres, confined, in the trachea and bronchi, to the back part where the cartilages are deficient, but circular in the other tubes, and capable by their contraction of modifying the freedom of entrance of air into the lungs, as is strikingly exemplified in asthma, which consists of spasms of these muscles to such extent as to produce difficulty of breathing. The mucous membrane is furnished with mucous glands, and lined with ciliated columnar epithelium. But the bronchial tubes of smallest size, reduced to $\frac{1}{50}$ inch in diameter, have homogeneous walls with a simple squamous lining, and each of these terminates in an *ultimate lobule* or *infundibulum*, consisting, as has been already said, of an irregular passage, surrounded with air cells. These air cells or *locules* are cup-shaped depressions, consisting of a framework of fine elastic tissue, and one of the closest capillary networks in the body, in which circulates the blood sent to the lungs by the pulmonary artery; and in order to secure the greatest possible contact of the blood with the air, the septa between the locules present only one layer of capillaries exposed on both sides, and protected only by a very delicate epithelium.



Fig. 75.—Cast of Infundibula $\frac{15}{1}$; from Henle.

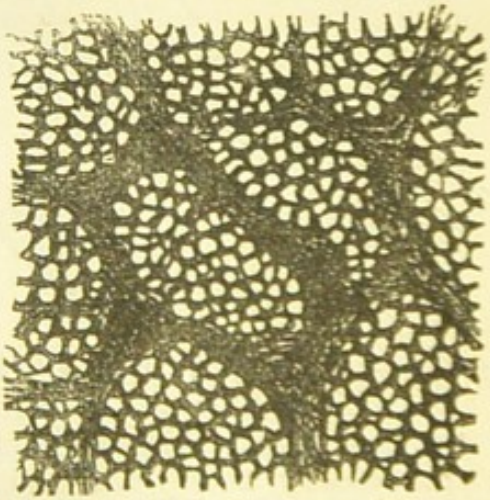


Fig. 76.—Air Cells, with capillary blood-vessels injected, $\frac{50}{1}$.

The ultimate lobules are united in groups to form larger lobules, from a quarter to half an inch in diameter, very closely united one to another, but with outlines which, in those of the surface of the lung, can be easily distinguished,

particularly in the human subject, where they are usually more or less marked by the deposit of black pigment. The tissue between the lobules and that of the bronchial tubes require, like all other tissue, oxygenated blood for their nourishment; and as that which arrives by the pulmonary artery is unfit for use, they receive their supply from small systemic branches called the bronchial arteries.

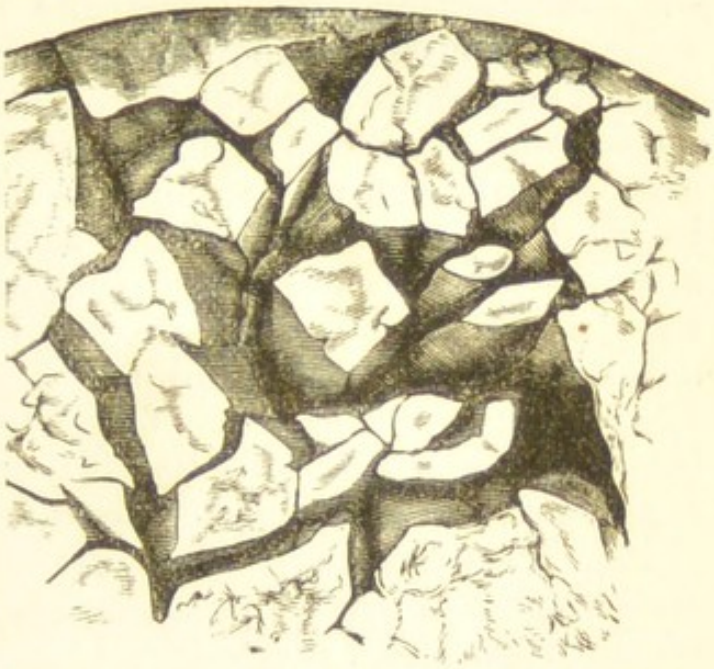


Fig. 77.—Lobules of Human Lung, partially separated; natural size.

Each lung is completely invested with a serous membrane, the *pleura*, the visceral layer of which is adherent to its surface, while the parietal layer is reflected from what is called the *root* of the lung, where the bronchus and blood-vessels enter, to the walls of the chest, the outer surface of the pericardium, and the upper surface of the diaphragm.

99. The means by which the air is introduced into the lungs and expelled therefrom, is similar to that by which it is drawn into and forced out from a concertina. The interior of the lungs communicates freely with the air outside by means of the windpipe, and when the capacity of the cavity containing them is enlarged, the air passes in, while, when the capacity is diminished, a quantity of air is expelled. This is the principle of the mechanism of respiration in the majority of animals; but in frogs the want of osseous thoracic walls, and in turtles their rigidity, renders it impracticable; and therefore both these animals pump the air down into their lungs by a motion of a swallowing description, which may be seen constantly going on in their throats.

100. The expansion and diminution of the chest in respiration affects the whole thoracic cavity, containing the heart and great blood-vessels as well as the lungs. It may, therefore,

be expected to exercise a certain influence on the arteries and veins, drawing in and pressing out the blood in them, in the same way as the air is drawn in and pressed out through the windpipe; and this is actually the case, so far as the veins are concerned, the flow of blood into the chest being greater in inspiration; but the blood in the arteries is protected from the effects of inspiration by the strength of the arterial coats, and thus inspiration assists the circulation by its effect on the veins, without retarding the blood in the arteries. The respiratory rhythm consists of three parts—the inspiration, the expiration (which has only half the duration of the inspiration), and a period of rest after the expiration; and it has been found that the arterial pressure begins to rise when inspiration is begun, and increases during expiration, then falls in the period of rest (Sanderson).

101. The enlargement of the thoracic cavity in inspiration is accomplished partly by the diaphragm, partly by movement of the ribs. The diaphragm is the floor of the thoracic cavity, separating it from the abdomen. It is a muscle, tendinous in the centre, and with muscular fibres radiating all round, and inserted into lumbar vertebræ, into the cartilages of the lower six ribs, and into the lower end of the breast bone. When at rest it is arched upwards, in a dome over the liver and stomach, and lies against the costal walls of the thorax for some distance behind and at the sides; but when it is contracted, its arched fibres are straightened and drawn asunder from the thoracic walls, pressing downwards the viscera beneath it, and producing a compensatory heaving of the abdomen. Diaphragmatic or abdominal breathing occurs in a very marked degree in children, the floor of the thorax bearing a much larger proportion to its height in children than in the adult.

The breathing of women is sometimes called *superior costal*, and that of men *inferior costal*, because the most obvious movements of the ribs are above the breasts in women, and in men on the sides of the chest. The elevation of the ribs will be best observed by placing the hands on the sides and front of the chest of another person while he inhales deeply. The hands will then be felt to be raised and separated one from the other. If the breast bone be watched, it will be seen that its

rise and fall are comparatively slight, that only in deep inspirations is the upper end of the bone raised at all, and that while in the best formed chests its lower end moves somewhat upwards and forwards in ordinary breathing, there are many chests in which there is little or no movement of the

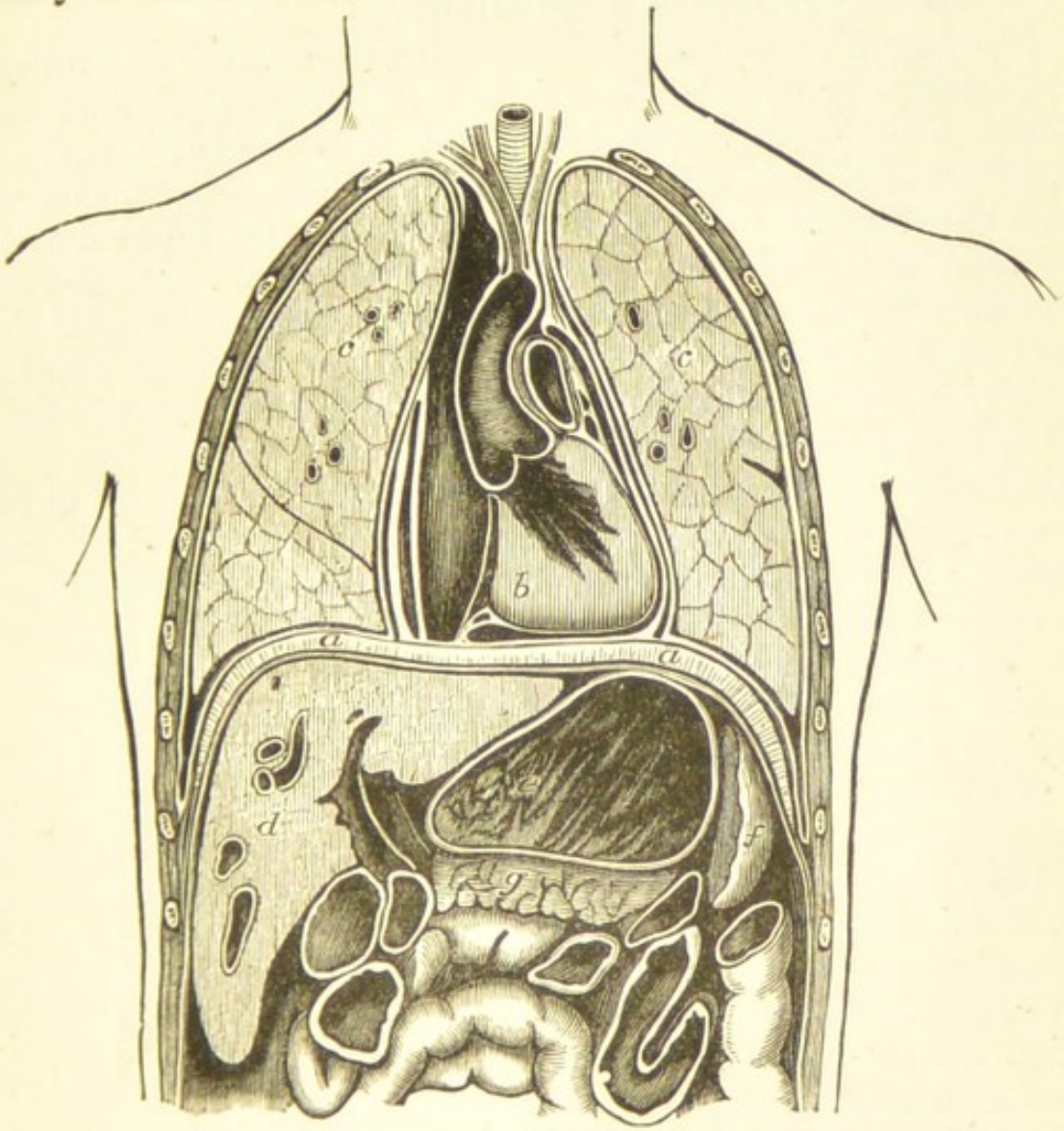


Fig. 78.—Vertical Transverse Section of Chest and Stomach, to show the arched form of *a*, *a*, the diaphragm; *b*, the heart; *c*, *c*, lungs; *d*, liver; *e*, stomach; *f*, spleen; *g*, pancreas. The reflexions of the pericardium and pleuræ round the heart and lungs are represented. Altered from Luschke.

breast bone at all. The enlargement of the chest, by movement of the ribs, in quiet breathing, is therefore principally effected by raising the lateral arches or hoops formed by large ribs, so as to bring them into the positions previously occupied by smaller ribs above them; and in deep inspira-

tion these are further elevated by the first pair of ribs being themselves raised by muscles descending from the neck. The elevation of the first pair of ribs increases the capacity of the thorax considerably; for although those ribs are short, and embrace but a small portion of lung, their elevation involves the additional raising of those below.

If a finger be placed on the twelfth rib during the fullest inspiration, it will be found that it is scarcely, if at all, raised, that its principal movement is backwards; and the importance of this will be appreciated when it is considered that the thoracic cavity is increased in size by depression of its floor, and would be diminished rather than enlarged by elevation of the attachments of the diaphragm. In fact, the the four lowest pairs of ribs are specially acted on in inspiration by a pair of muscles (serrati postici inferiores), whose office is to pull them backwards and resist their elevation. The backward enlargement of the thorax, particularly in its lower part, is further provided for by the downward and backward direction taken by the ribs as they extend out from the back bone, and is exceedingly important, as it is at the lower and back part of the thorax that the greatest mass of the lungs is situated. That is a fact which ought to be generally borne in mind, not only as pointing out one source of evil from the vicious habit of tight-lacing, but because it is a popular error that in protecting the chest from cold, it is sufficient to accumulate warmth on the fore part. Bronchitis, no doubt, is liable to have its source in exposure to cold by the mouth or in front of the chest, but pneumonia or inflammation of the texture of the lung is more frequently traceable to exposure of the waist: for example, by the evaporation of a shirt damp from perspiration.

102. The muscles by which the ribs are moved are placed between them, forming two layers, sloped in opposite directions, and named the external and internal intercostal muscles.* In full inspiration muscles of the neck are also

* On the Continent it seems to be now generally admitted that both these sets of fibres are of service in inspiration; but in English text-books another theory continues to hold its ground, which is only thus referred to that the student may be warned against it as an error. The merits of the question cannot be here discussed.

called into action to elevate the breast bone and first pair of ribs; and when breathing is difficult, particularly from asthma, additional force is obtained by fixing the arms, as, for example, by laying hold of an arm-chair; and these muscles extending between the chest and shoulders, being fixed at the latter attachment, exercise their action on the former. It is principally in inspiration that muscular force is called into requisition, expiration being largely aided by the elasticity of both ribs and lungs; for the ribs in inspiration are pulled forcibly out of their natural curve, and the elasticity of the pulmonary texture may be easily demonstrated by noting the rapidity with which the lungs of dead animals collapse after artificial inflation. In certain circumstances, however, a considerable exertion may be required in expiration, as, for instance, in playing a wind instrument or in glass-blowing; and then the abdominal muscles may be brought strongly into action both to push up the diaphragm and to depress the ribs.

103. The acts of inspiration take place at a rate usually varying from fifteen to twenty per minute; but, like the pulsations of the heart, they are much more frequent in childhood, being above forty per minute in the infant. Only a small portion of the air in the lungs is changed in each ordinary respiration; the quantity so changed, or the *breathing air*, as it is termed, being on an average twenty or twenty-five cubic inches, while the *vital capacity*, or amount of air which can be expelled after a full inspiration, and which therefore includes a *complemental* supply not usually taken in, and a *reserve* quantity not usually parted with, is estimated on an average at 225 cubic inches. Even after the most forcible expiration, a large amount of *residual* air remains in the chest; and indeed it is impossible, even by direct pressure, completely to expel the air from the healthy lung of an animal which has breathed, so that it shall sink in water, like the lung of an animal born dead, into which the air has never entered.

104. The vital capacity indicates the mobility of the walls of the chest, but by no means varies according to the dimensions of the cavity; for differences in the dimensions occur, irrespective of height, age, or weight, whereas the vital

capacity increases according to the weight in persons of less than 11½ stones, and in persons above that weight is said to diminish at the rate of a cubic inch per pound; it increases also with age up to the period from the thirtieth to the thirty-fifth year, then diminishes 1½ inches every year; and it increases regularly with the height of the individual. This increase of vital capacity according to height is all the more interesting, as it was contrary to the expectation of the observer who first noted it (Hutchinson); because, as he justly observed, height depends principally on length of limb, and he could not see how that could affect respiration. The student, however, will observe that length of limb gives increase of surface exposed to contact with the atmosphere, and liable to be cooled thereby, and that the person who has the greatest amount of surface requires the greatest amount of combustion in his tissues to keep up the temperature of the body, and consequently requires more oxygen, and gives off more carbonic acid than others.

It has been recently shown that a distinct influence is exerted by climate on the vital capacity; it being found that in the course of a voyage, the capacity, being measured in the north and south temperate zones, and in crossing the equator, rises in the tropics and falls again on reaching temperate latitudes. This curious phenomenon apparently depends on the lungs containing less blood and a greater volume of air in hot climates, so that they are more compressible in expiration. It is an accompaniment not of increased but of diminished respiration (Rattray).

The advantage of a large chest may be easily understood; for the activity of respiration corresponds with the vital capacity, and not with the thoracic dimensions; it is regulated by conditions throughout the body, and not by the size of the organ; therefore the smaller the lungs the greater the work thrown on each portion of them, and the greatest work of all is thrown on each portion when small lungs are combined with great height. Drill masters are right in teaching that an erect figure is good for the lungs; for the ribs are so attached to the vertebral column, that when the column is bent forwards their elevation is prevented; and that the full expansion of the chest requires a straight back may be easily

demonstrated by taking in as full a breath as possible in the stooping posture, and then rising and throwing the shoulders back, when it will be found that an additional quantity of air can be inhaled. The stooping posture renders part of the lung useless, throws the work on the rest, and leaves a smaller amount of residual air with which to dilute that which is inhaled.

105. The atmosphere which we breathe consists of 79 volumes of nitrogen with 21 of oxygen, containing in every 10,000 volumes four or five of carbonic acid. It further contains minute quantities of accidental gaseous impurities, and has constantly numbers of exceedingly small particles of organic matter floating about in it, including germs of different kinds of mould. The degree of moisture varies at different times, but the amount which it is capable of dissolving increases rapidly with rise of temperature.

The air exhaled in expiration differs from what has been breathed, in temperature, moisture, and the quantity of carbonic acid and oxygen which it contains.

The temperature of the exhaled air is approached to that of the blood, varying usually from 97° to above 99°F., according to the rapidity of the respiration and the temperature of the surrounding air. When respiration is slow, the air has longer time to become assimilated in temperature to the interior of the body; and when the surrounding temperature is low, a longer contact is required to approach it to blood heat.

The air exhaled is always nearly saturated with moisture, however dry it may have been when taken in; and therefore the maximum of water is removed from the body by this channel during exercise in air which is cold and dry; for then the respiration is active, and the air admitted and warmed within the chest requires most moisture for its saturation. The average amount of water thus removed has been calculated to be from nine ounces to more than a pound in twenty-four hours.

106. The volume of carbonic acid contained in the expired air forms usually about $4\frac{1}{2}$ per cent. of its bulk. The proportion is, however, variable. When respiration is rapid, the percentage of carbonic acid in each breath is diminished, while the total amount exhaled in a given time is increased. When

the same air is breathed several times, as happens in crowded rooms, and with deficient ventilation, the percentage of carbonic acid in the expired air is increased. But this accumulation of carbonic acid in the air furnishes an impediment to breathing, independent of the exhaustion of the oxygen; for however often the same air be passed through the lungs, it never contains more than 10 per cent. carbonic acid. In an artificial atmosphere, animals have lived till the percentage of carbonic acid reached 12 and even 18; but when they are placed at once in an atmosphere containing that amount, they are immediately suffocated, no matter how great the amount of oxygen present. It is plain, therefore, that carbonic acid inhaled is actively deleterious, and differs altogether from the nitrogen contained in the atmosphere; nitrogen being simply negative, acting as a diluent of the oxygen, incapable of taking the place of that substance, but in no way interfering with its action. Animals live without discomfort in an atmosphere in which hydrogen is substituted for nitrogen.

The amount of carbonic acid exhaled in a given time goes on increasing in males till thirty years of age, while from forty, or sooner, it diminishes as age advances.

In females the amount ceases to increase at puberty, and remains stationary till the cessation of reproductive activity, when it again increases for a time. The amount of carbonic acid exhaled from the lungs of an adult man may be estimated as sufficient to yield about nine ounces avoirdupois of carbon in twenty-four hours.* But it varies according to a great variety of circumstances, being increased by cold, by food, and most of all by exercise; while warmth, fasting, rest, and sleep diminish it.

107. The amount of oxygen taken into the blood in respiration does not bear any constant proportion to the amount of carbonic acid given off; but it is generally somewhat greater, and is always so when the period of observation is extended over twenty-four hours. Carbonic acid contains exactly its own volume of oxygen; and therefore if the oxygen taken in corresponded with the carbonic acid given off in each respira-

* Eight ounces is the amount generally mentioned in text-books; but that means troy ounces formerly in use in matters medical.

tion, there would be just sufficient oxygen to account for the formation of the carbonic acid. But there is an additional amount of oxygen inhaled, rendering the volume of air expired smaller than that which is inspired; and this additional amount must be used for some other purpose than the formation of the carbonic acid escaping by the lungs. A small portion may be used in the formation of the carbonic acid which escapes by the skin, estimated at one-fiftieth of what is exhaled by the lungs; but experiments on the total respiration, both pulmonary and cutaneous, made by placing a man in an air-tight chamber and estimating the carbonic acid evolved, agree with those confined to the pulmonary in showing that the oxygen given off in twenty-four hours, in form of carbonic acid, is less than what is taken up; and we must therefore suppose that the excess of the oxygen is used in other processes of oxidation, converting the hydrogen of organic matters into water, and their sulphur and phosphorus into sulphuric and phosphoric acids. This is in keeping with the observation that the proportion of oxygen absorbed is greater in feeding on animal than on vegetable food; for the carbohydrates, it will be recollected, already contain as much oxygen as would combine with their hydrogen to form water, whereas oils and nitrogenous substances are comparatively deficient in oxygen.

108. Gases brought into contact one with another tend to diffuse till they form a uniform mixture; and when two gases are separated by a membrane, they pass in opposite directions through it in definite proportions. The first of these laws is, in all probability, of the utmost importance in diffusing the inspired air through the residual and reserve air left in the lungs after the last expiration. But the variability which has been mentioned in the proportion of the inspired oxygen to the expired carbonic acid, affords sufficient proof that it is not by diffusion, as has sometimes been supposed, that the interchange of these gases takes place between the air and the blood. Another objection to the supposition is that the gases appear to be, at least in part, in chemical combination with the blood.

109. When respiration is obstructed, either mechanically or by deficiency or impurity of air, *asphyxia* or suffocation

takes place. The face becomes livid with unaërated blood, the veins of the neck swollen, the circulation in the lungs stopped, and the heart gorged with dark blood, especially on the right side: there is evidence that the systemic as well as the pulmonary capillaries refuse to allow the blood to pass through them (Dalton), and death quickly supervenes.

Even a slight interference with respiration retards the circulation, and this interference may be caused by impeded expiration, as in blowing a trumpet, or violent spasmodic expiration, as in coughing, in both which cases the veins of the neck are seen to swell; or, by impeded inspiration, as in asthma, or by inhalation of a poisoned atmosphere, in which cases the hindrance to circulation is the vitiated condition of the blood.

The cessation of circulation, however, is not the cause of death by asphyxia; that is rather to be imputed to the poisonous influence of vitiated blood on the brain. Arrest of the heart's action, constituting the condition known as *syncope* or fainting, may be recovered from after a period of time to which it is difficult to name a limit; but asphyxia causes death in less than five minutes, and even more speedily in drowning, which is complicated by entrance of water into the lungs. The few recorded instances of recovery after submergence for longer periods are to be accounted for by supposing that the patient fainted at the moment of falling into the water, or before falling in, and so had lain without effort at inspiration.

110. It is of importance to observe that air may be vitiated by many impurities besides carbonic acid. Principal among these are minute particles of living and dead organic matters floating in the air, and products of decomposition of organic debris. The precise nature and properties of the different substances with which the air may be filled are difficult to determine. It must not be supposed that things which are offensive to the senses are necessarily deleterious to the health. There is no proved relationship between the intensity of bad smells and insalubrity of the air, and many invectives about poisoned atmospheres, sufficiently excellent in their general tendency, are based on very slender scientific foundation. But while it is admitted that un-

pleasant odours are not always injurious, there can be no doubt that constant exposure to the emanations of putrefaction, especially such as is fed with meagre supplies of oxygen, engendering products of unstable equilibrium, is thoroughly baneful, and may exert its noxious influence with but little warning given to the nostrils.

All disinfectants in use act in one or other of two ways: they either decompose organic matter, or they preserve or pickle it; permanganate of potash, chlorine, and fumes of burning sulphur being examples of the destructive kind, while creosote and carbolic acid are instances of the preservative or antiseptic description.

111. Ventilation has for its object the preservation, within buildings, of an atmosphere as free as possible from accumulation of carbonic acid, or any other impurity, by affording ingress to fresh air and egress to the vitiated. Practically, the great problem is how to attain this end with as little admission of cold as possible, and without draughts. Draughts are not only highly dangerous, on account of the well known, but ill understood, sympathy between the secretion of different parts of the integument and various internal organs, but are deservedly regarded with much dislike, a dislike which may be so great that impure air will be endured in preference. To avoid draughts, the communication of a heated room with the external air should be constant, free, and directed away from the position of the inmates, or the air should be heated by some special contrivance before it gains admission. The dense air from without rushes into an apartment with the greater force the narrower the aperture of entrance; and no arrangement can well be imagined more likely to produce exposure to draughts than a room with a warm fire on one side, and insufficient ventilation taking place through the key-holes and chinks of windows and doors on the other. The heated air passes up the chimney, and cold air rushes in streams with great velocity through the narrow apertures opposite. The density of cold air gives it such force, in rushing into a heated enclosure, that it travels inwards or falls down through an opening in the ceiling very compactly; and, therefore, in good ventilation, means should be taken to diffuse the entering streams of cold air, and direct them away

from the occupants; and in large halls the ventilation should be placed at a variety of levels.

112. Internal Temperature.—The temperature of the interior of the body is very constant, its healthy variation being limited to a range of probably two degrees. In this respect warm blooded animals differ from the cold blooded; for the evolution of heat in cold blooded animals being only sufficient to warm them a very few degrees above the surrounding medium, the temperature varies with that of the medium. In all instances the heat evolved is the result of chemical action; and the processes in warm blooded animals being more active, a greater amount of heat is evolved, while, reciprocally, a certain temperature is required for the carrying on of these processes by the more delicately constituted elements of texture.

The highest temperature is found in birds, in some of which it reaches 110° F. or more. The temperature of the human blood varies from 100° to 102°; and it has been already mentioned (p. 125) that the blood is the source of warmth to the tissues. It has not exactly the same temperature throughout the circulation, but exhibits definite, though slight, differences in different parts. It was many years ago observed that the blood in the jugular vein of an animal was slightly cooler than that in the corresponding artery (John Davy), and it was judged, naturally, that the blood was warmed as it became arterialized in the lungs. The observation was correct, and yet, curiously enough, the conclusion was wrong; for in later observations thermometers have been introduced by Bernard, not merely into the jugular vein, but into the heart itself, and into the renal and hepatic veins, with an interesting result which explains the matter differently. The warmest blood in the body is that which has been subjected to processes of change in the kidneys and liver; the coldest blood is that which returns from the surface of the body, where heat is constantly lost by radiation; the blood entering the heart from the inferior *vena cava*, containing what comes from the liver and kidneys, is warmer than that which returns by the jugular vein from the head; the mingled contents of the right side of the heart have an intermediate temperature; this blood then passes into the lungs,

where it is exposed to the inhaled air, and when it reaches the arteries it is slightly colder than it was when in the right side of the heart, although it is not quite so cold as the blood in the jugular vein. That the blood should be cooled in passing through the lungs is contrary to all old beliefs, but it will not strike the student as strange when he considers how much heat is abstracted by the inhaled air before it quits the lungs. The absorption of oxygen by venous blood is proved experimentally to be accompanied with a certain evolution of heat; but the quantity is not sufficient to balance the loss by exposure to air inhaled at ordinary temperatures.

In disease, the temperature of the body may vary greatly from the healthy standard; in febrile affections it may rise to 106° or more, and in conditions of great feebleness, such as the collapse in cholera, it has been known to descend below 70°.

It will be understood, however, that the extremes of external temperature, which can be borne with impunity, are not accompanied with any such changes within the body, but illustrate the power which the body has of maintaining its own proper temperature. Thus, in extreme cold, the greater combustion necessary in the tissues is testified by the more active respiration; while in exposure to heat, the body is kept cool by evaporation. Temperatures far above what would be sufficient to boil the juices of the body, were they exposed directly to the heat, can be borne for a short time with impunity, provided always that the air be dry, so as to aid free evaporation from the surface; but moist air cannot be endured above a very moderate heat.

CHAPTER XI.

ABSORPTION.

113. We have now to take into consideration the means by which the substance of the blood is replenished. This is effected by absorption, or the sucking up of material into vessels, partly from the alimentary canal, and partly from the tissues. Matter from both these sources is absorbed by the capillary blood-vessels, and so carried into the veins; but there is another set of vessels, the *lymphatics*, more especially referred to when absorbents are spoken of, whose whole office is one of absorption.

The lymphatics or absorbents are a system of vessels with delicate walls, and having the appearance of long and slender threads when they are empty. The trunk into which the majority of them pour their contents, the *thoracic duct*, is no greater in diameter than a small crow quill, and sometimes not so large. The thoracic duct begins in the upper part of the back of the abdomen, where it forms a dilatation four or five times its width in the rest of its course, named the *receptaculum chyli*, and runs up through the thorax in front of the vertebral column, to open, at the root of the neck, into the angle of junction of the left jugular and left subclavian veins. It receives the absorbents from the whole body, with the exception of the right half of the thorax, right arm, and right side of the head and neck. The absorbents from these parts unite to form a short trunk, which opens into the angle of junction of the right jugular and subclavian veins, and is called the *right lymphatic duct*.

The lymphatic vessels are difficult to study on account of their slenderness, and because they are thickly beset with valves like those of veins, which, in most instances, effectually

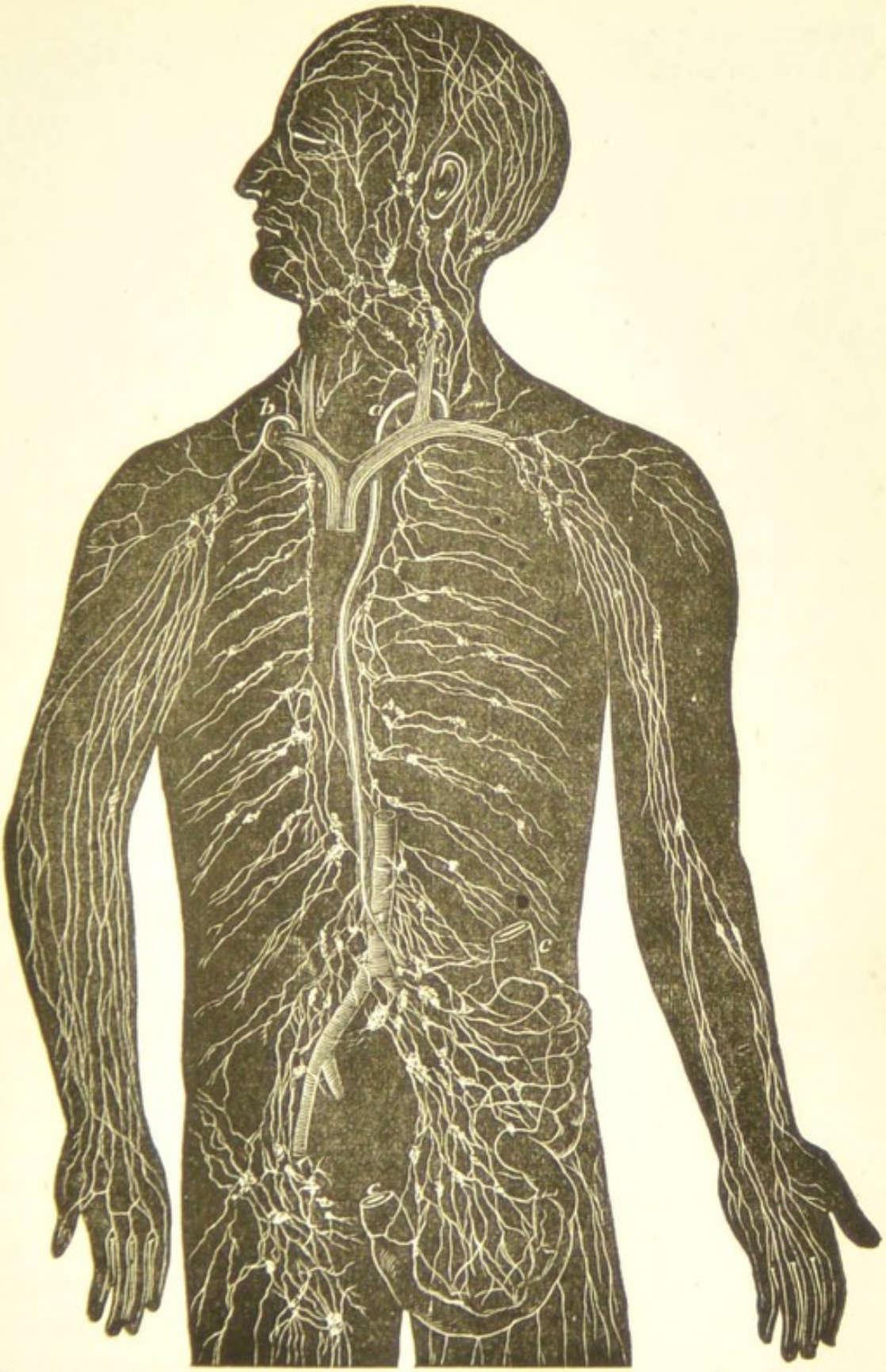


Fig. 79.—Absorbent System: Diagrammatic view of Lacteals and Lymphatics. *a*, Thoracic duct opening into the angle of junction of left subclavian and internal jugular veins; *b*, right lymphatic duct; *c*, *c*, portion of small intestine, with lacteals proceeding from it to the receptaculum chyli. On the right arm the superficial lymphatics are exhibited; on the left the deep lymphatics.

prevent the injection of fluid backwards from the larger trunks into the radicles. These valves are set so thickly as to give to the vessels, when filled, a beaded appearance, there being a dilatation opposite each valvular pouch. In the limbs and in the walls of the trunk, they are arranged in a deep and superficial set; and in the viscera there is usually, in like manner, a set on the surface of an organ, and a deep set accompanying its blood-vessels.



Fig. 80. — LYMPHATIC GLAND of the groin. *a*, An afferent duct, with the concavities of the valves turned toward the gland; *b*, *b*, efferent ducts with the convexities of their valves toward the gland (Mascagni).

At different points in their course the lymphatics are interrupted by *lymphatic glands*, tough structures, often about the size of an almond, and mostly arranged in groups. Each of these receives a number of lymphatics distinguished as *afferent* vessels, which pour their contents into it, and gives off a number of *efferent* vessels which carry the contents onwards. They are liable to be swollen or inflamed by the irritation of fluids brought to them from inflamed parts, and in that state are often felt through the skin as hard knots, popularly known as kernels. Thus, hardened kernels are often felt in the neck after eruptions on the head, and below and behind the jaw after toothache; in the upper part of the thigh, from blisters of the foot; and in the armpit from irritations on the arm, back, or breast.

114. The lymphatics commence in very fine networks, and in interstitial spaces in the tissues; in some instances lined with exceedingly delicate epithelium, like the capillary blood-vessels, and in others not. The fluid which they contain is termed *lymph*. The

lymph is a clear, transparent fluid, slightly alkaline in reaction, as is the blood, and containing albumen, salts, and a variable amount of extractive. As it comes from the tissues it is perfectly structureless; but, after passing through lymphatic glands, it contains *lymph corpuscles* identical in all respects with the white corpuscles of the blood, and also becomes spontaneously coagulable, forming a weak clot. The function of the lymphatic glands appears, therefore, to be to form white corpuscles; and this view is corroborated by their structure: for the lymphatics, on entering them, lose their proper walls, and are continued into irregular spaces, winding between masses of stroma loaded with corpuscles which, as they develop, are loosened, and float away in the lymph. The addition of the corpuscles to the lymph is sufficient to account for its acquiring the property of coagulability; the reason for the lymph, as it comes from the tissues, not being spotaneously coagulable, being simply that, like liquor sanguinis drawn pure from the vein (p. 110), it contains no fibrinoplastin.

115. The absorbents which come from the small intestine, although they in no way differ from the lymphatics of the rest of the body, are distinguished as *lacteals*. The distinction is unscientific, inasmuch as the lacteals are simply the lymphatics of the small intestine, carrying lymph and nothing else when the intestine is empty; but the name arose naturally enough from the milky appearance of their contents during digestion, and must be submitted to. The lacteals pass from the intestine back between the folds of the mesentery to reach the receptaculum chyli, and in their course traverse a plentiful group of lymphatic glands, named, from their position, *mesenteric*, and subject, like other lymphatic glands, to be irritated into inflammation and disease, when the fluids reaching them by their afferent vessels are altered by inflammation of the tissues from which they are derived. Moreover, such disease, unfortunately common in weak children, is of much graver importance in the instance of these than of other lymphatic glands, since it interferes with the passage of nourishment from the intestine into the blood. This constitutes the essence of the disease called tabes mesenterica.

116. The fluid taken up by the lacteals from the contents of the intestine is termed *chyle*. The chyle resembles lymph in containing albumen and salts, and in not containing nucleated corpuscles, nor being spontaneously coagulable, until it has passed through lymphatic glands; but it is distinguished by its milky appearance. This milkiness varies according to the nature of the diet, the greatest opacity and whiteness occurring when the food is rich in oleaginous constituents; and on microscopic examination it is seen to depend on the presence of multitudes of exceedingly minute molecules of oil, which, floating, as they do, in an albuminous fluid, have no tendency to run together into larger globules. The term chyle is sometimes applied not only to the milky contents of the lacteals, but also to the emulsion contained in the intestine below the entrance of the pancreatic duct, which is the source from which the lacteals are filled; and a sharp distinction is thus drawn between the *chyme* or pulp formed by the action of the stomach, and the material lower in the intestine. This extended use of the term chyle is, however, objectionable, as the two fluids to which it is applied are not identical; that which is found in the intestine containing not merely what is fitted to be taken into the lacteals, but large quantities of other matters, partly destined to be absorbed by the capillary blood-vessels, and partly to pass onwards and undergo further change, or be ejected.

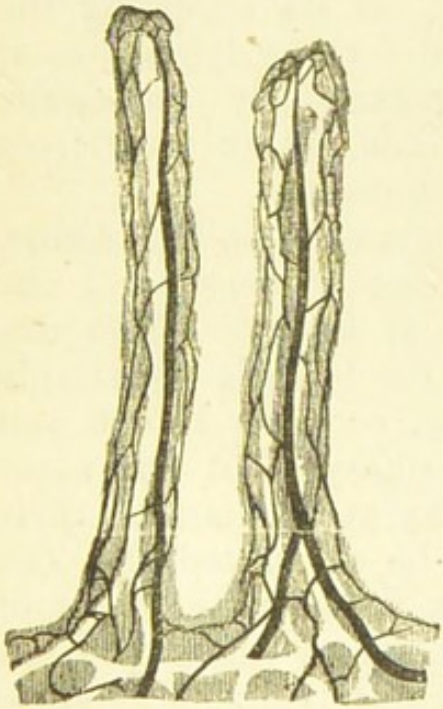


Fig. 81.—Two Villi of human intestine deprived of their epithelium, and with the lacteals and blood-vessels injected. The lacteals are white, the blood-vessels black (Teichmann).

117. The nourishment prepared in the alimentary canal is taken up, partly into the blood-vessels, and partly into the absorbents; and although this process undoubtedly may go on to some extent in the stomach and whole length of the intestinal tract, it is carried on most actively by the villi of the small intestine (p. 99).

Every villus presents on its surface a coat of columnar epithelium continuous with that of the rest of the mucous membrane, and beneath this a network of capillary blood-vessels, while in the centre there is a lacteal. In the lower animals there are sometimes several lacteals forming loops in one villus; but in the human subject there is usually only one in each. This lacteal is somewhat dilated at its extremity, and it does not appear at that part to have any special wall.



Fig. 82.—Columnar Epithelial Cells of Intestine, highly magnified, showing the striated substance on their free extremities.

When absorption is going on, the epithelial cells of the villi become turbid with molecules of oil, the tissue beneath becomes turbid likewise, and from the tissue the lacteals are filled. The free extremity of each columnar epithelial cell presents a thick layer of substance less consistent than the rest of the cell wall, but more consistent than its contents, and sometimes having a vertically streaked appearance. Through this substance the molecules of emulsified oil find their way; and afterwards they pass onwards through fine prolongations of the deep ends of the epithelial cells: these appear to communicate with branches of connective-tissue-corpuscles, by which in like manner the molecules are carried to the lacteal.

Only a small quantity of oil is taken into the capillary blood-vessels, by far the greater amount being absorbed by the lacteals; and this, indeed, is the most notable difference between lacteal and capillary absorption, so far as nutritive matters are concerned, for it is very certain that saccharine and albuminoid substances are taken up freely by both sets



Fig. 83.—Blood-vessels of Mucous Membrane of Stomach: vertical section magnified. *a*, Venous radicles descending from the free surface; *b*, veins; *c*, arteries.

of vessels. The arrangement by which the blood-vessels are enabled to furnish material for the nourishment of texture, and formation of secretions, while they also absorb matters presented to them in both stomach and intestine, is a very beautiful one. It is plain that blood, to which variable amounts of chance ingredients had been added, would be unfit for purposes of nutrition; but the difficulty is got over in this way, that the arterioles break up into capillaries in the deep part of the mucous membrane, which first supply the glandular structure, and then open into venous radicles which take origin close to the surface; so that the blood, in its purity, nourishes the glands, and does not take up foreign matters until about to enter the veins.

118. The passage of liquids through membranes is regulated by physical laws of diffusion, which are closely connected with capillary attraction. Just as gases diffuse according to definite laws, so also do liquids. Their diffusion through membranes or porous septa is called *osmosis;* or, inasmuch as there are two currents in opposite directions wherever a membrane separates two different fluids, the words *endosmosis* and *exosmosis* may be used to indicate the inward and outward flow. If a piece of moist bladder be stretched across a tube, and any saline solution introduced into the vessel thus made, and the end of the tube be then dipped in water, it will be found that in a short time a portion of the solution has passed through into the water, while a larger amount of water has passed into the tube, and raised the height of the liquid within it. The same experiment may be made with solutions of different sorts on the two sides of the membrane. But the important points to note are, that different solutions pass through in definite proportion to the amount of any particular substance passing in the opposite direction, and that while some substances diffuse with facility, others do so with difficulty. The substances which diffuse easily are called *crystalloids*, while those which diffuse with difficulty are called *colloids* (Graham). Thus albumen in its ordinary condition is a colloid, but when converted into peptone it becomes crystalloid. It is in consequence of endosmosis that, when water is added to blood, the red corpuscles become swollen and spherical. The substance in which the

fluid parts of the corpuscle are entangled acts as a membrane would, and while a certain amount of fluid passes out, a larger amount of water passes in and gorges the corpuscle. So also nucleated cells, when water is added to them, become rapidly swollen, till they burst and are destroyed.

Now, there seems no reason to doubt that the absorption into the capillary blood-vessels is an instance of endosmosis without intervention of any vital force. All sorts of salts and other diffusible substances, whether simply useless or positively injurious, find their way into them; while it is proved by experiment that such substances do not pass into the lacteals, at least so rapidly. And this is not altogether inexplicable; for we have seen that the capillaries are near the surface of the villus, while the lacteal is in the centre, and receives its supplies through the action of nucleated corpuscles. In fact, a little reflection will show that the action of the epithelium in lacteal absorption differs from that of secreting cells in separating substances from the blood in nothing, save that in secretion the current is from vessels to a free surface, while in lacteal absorption the current is from a free surface to the interior of a vessel.

119. The difference in the absorbing power of the lacteals and the blood-vessels has probably a considerable importance, dependent on the different courses taken by the two sets of vessels. The lacteals, which are deeply placed in the villi, and fed by other means than mere endosmosis, send their contents, by the thoracic duct, into the circulation at a point where the blood is returning to the heart and has only to be subjected to the influence of respiration before being diffused throughout the body. The blood-vessels, on the other hand, take up everything according to its diffusibility; but they carry their stream into the portal vein, whence it is conveyed through the capillaries of the liver; and not until it has been subjected to the influence of that organ—which has, besides other functions, an arrestive power—is it allowed to reach the heart.

As in the case of intestinal absorption, so also throughout the body, fluids appear to pass into the blood-vessels easily by endosmosis; and the circumstances are not well known which call for the necessity of lymphatics as well as blood-

vessels. Yet, when it is considered that lymphatics at their origin are less distinctly bounded than the capillary blood-vessels, and much more closely communicate with the fluids of the tissues, it seems not improbable that, as has been suggested, the crystalloids are principally taken into the blood, while the colloids left behind are carried away by the lymphatics.

CHAPTER XII.

THE DUCTLESS GLANDS, THE LIVER, AND THE KIDNEYS.

In the preceding chapters we have so far traced the history of the blood, that we have seen how it is vitiated in the tissues and oxygenated in the lungs, and how it is replenished with material both from the waste of the tissues and from the digested food; we have noted one source of origin of the corpuscles, and studied the purification from carbonic acid. But there still remain for consideration various processes of elaboration and depuration carried on by the spleen and other ductless glands, by the liver, and by the kidneys.

120. **The Ductless Glands.**—Under this head are grouped the spleen, the thyroid and thymus glands, the suprarenal capsules, and also the lymphatic glands and the closed follicles of the digestive tube, both of which have been already considered (pp. 103 and 153).

The *thyroid body* is a limited structure, consisting, in the human subject, of two lobes joined together by an isthmus, and situated on the windpipe in the neck, and is larger in the female than the male. It is exceedingly vascular, and consists of numbers of minute vesicles, with glairy contents, and each invested with a rich network of capillaries. It is sometimes subject to enormous enlargement, constituting the disease called goître, a tumour remarkable not merely for the great size which it sometimes acquires, but for being associated frequently with a form of idiocy and general deficiency of development, to which the name of cretinism is given. But nothing precise is known of the function of the thyroid body.

The *thymus gland* is a structure situated lower down on the windpipe than the thyroid, being placed in the upper

part of the chest. In its early history it is closely associated with the thyroid, but its structure is different in detail.

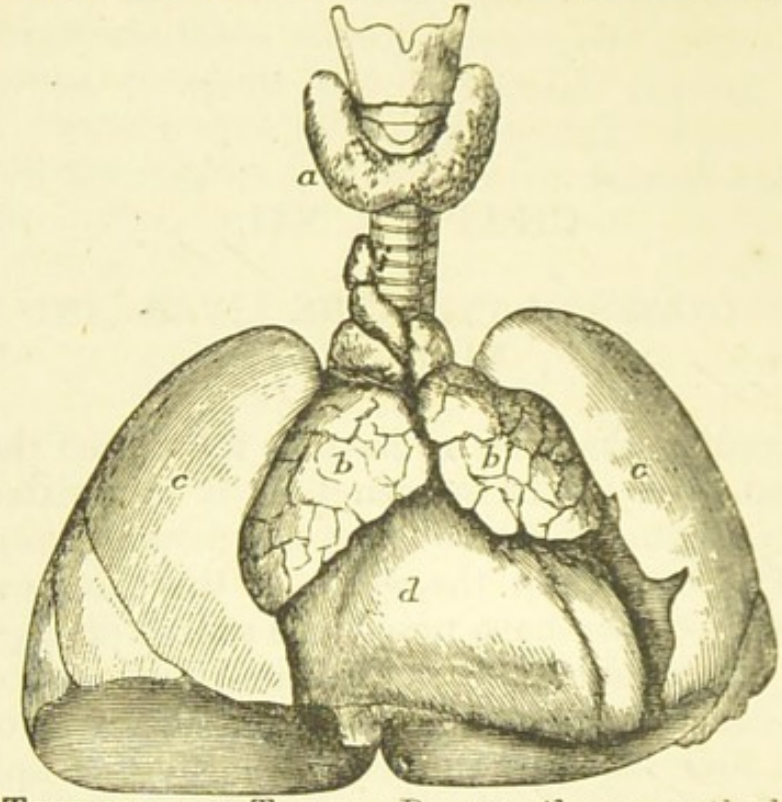


Fig. 84.—THYROID AND THYMUS BODIES, three months before birth. *a*, Thyroid body resting on trachea and larynx; *b*, *b*, thymus; *c*, *c*, lungs, as yet unexpanded; *d*, heart.

It reaches its greatest development in infancy, and disappears usually with childhood. Its function, supposed to be connected with blood-elaboration, is unknown.

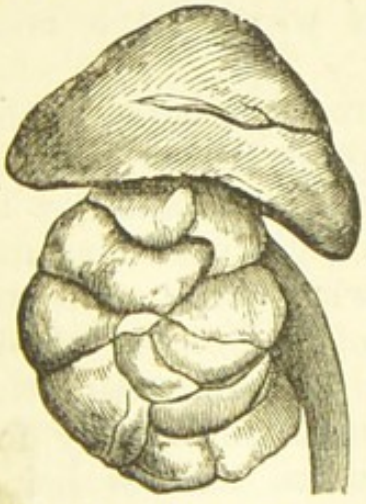


Fig. 85.—SUPRARENAL CAPSULE AND KIDNEY, three months before birth; the kidney presenting at this period a lobulated surface.

The *suprarenal capsules*, are a pair of bodies surmounting the kidneys, and fitting on to their upper ends. Like the thymus, they are exceedingly large before birth. They are highly vascular in the interior, but are likewise remarkable for their copious supply of sympathetic nerves, and it is scarcely safe to say that they are blood-elaborating glands at all. All that is known about them is, that there is a peculiar form of wasting disease accompanied with deep bronzing of the skin, in which there is fre-

quently found, after death, an extensive alteration of these structures.

121. The *spleen* (figs. 57 and 78) is an organ engaged beyond all question in the elaboration of the blood, and however obscure the particulars of its function may be, there is at least more known about it than about the other organs which have been briefly described. It is the largest of the ductless glands, very variable in size, but usually from 5 to 7 oz. in weight. It increases largely some hours after eating, then gradually diminishes while fasting is continued. It is a flattened oval body about 4 or 5 inches long, and 3 inches or more in breadth, and lies against the left end of the stomach. It has a tough capsule, and consists of a deep purple pulp imbedded in the meshes of a network of fibrous trabeculæ, which is highly elastic, and probably also contains some muscular tissue. The pulp consists of granular bodies of deep colour and about the size of blood corpuscles, and nucleated corpuscles of very variable size, the larger of which have several nuclei. In sections of spleens of the domestic animals, and in spleens of young subjects, but not so easily detected in the healthy adult human spleen, are less deeply coloured spots like sago grains, called *Malpighian corpuscles* of the spleen. They are collections of small nucleated corpuscles in the sheaths of the arterioles. The splenic artery and vein are very large for the size of the organ. The venous blood is conveyed into the portal vein to be sent through the liver.

The very fact that the large supply of arterial blood sent to the spleen is, after passing through that organ, transmitted to the liver, seems to point to its having undergone, meanwhile, some great change which renders necessary the action of the liver, as well as of respiration, before it is fit again to traverse the tissues, and this idea is supported by examination of the blood. The blood in the splenic vein has the serum of a reddish colour unlike that of any other blood, and it contains less solid matter than other venous blood, a circumstance easily explained on the supposition that there is in the spleen a greater amount of chemical action, involving the formation of carbonic acid and water at the expense of solid matter, than occurs in the tissues throughout the

body. It contains also a smaller proportion of red corpuscles than other blood, which perhaps results from a portion of their contents having transuded into the serum, as shown by its colour, and by the corpuscles being firmer, smaller, and more nearly spherical. Lastly, the colourless corpuscles are exceedingly plentiful; and it is to be noted that in a diseased condition called leucocythæmia, in which the colourless corpuscles of the blood are remarkably increased in number, there is likewise great enlargement of the spleen. These are the principal facts on which rest the two theories generally held as to the function of the spleen, namely, that it is a manufacturer of white corpuscles, and a destroyer of the red.

That the spleen is a source of white corpuscles can scarcely be doubted; but that it is its special function to destroy red corpuscles, is not so clear. No doubt heaps of withered red corpuscles have been seen in the spleen as an exceptional occurrence; but it is plain that there is an action exercised on all the red corpuscles, and it seems very possible that the object of that action is restoration rather than destruction. A very curious circumstance, which by no means makes the function of the spleen more comprehensible, is that the whole organ may be extirpated, not only without death ensuing, but without any inconvenience resulting. It is obvious, however, that this is more explicable on the supposition that the spleen is one of many structures which produce blood corpuscles, than if we consider it as the sole agent of their destruction.

122. The Liver (figs. 57 and 78).—The liver is much the largest gland in the body, between 3 and 4 lbs. in weight, and of remarkable complexity, both of structure and function. Its most obvious function is to secrete bile; but the bile is secreted less for the sake of its utility in digestion, than as a product resulting from certain complicated processes of blood-purification.

The liver lies beneath the diaphragm, with the greater part of its bulk on the right side, under cover of the ribs, and from its position is the organ most liable to compression and injury by tight-lacing. It has a right and left lobe, and is, in fact, a bilateral organ in all vertebrate animals. It even

happens in a few fishes that these lobes are quite disconnected, forming symmetrically placed right and left livers. Before birth the liver bears a much larger proportion to the body than it does afterwards; and the bile which is at that time secreted by it accumulates in the intestine, to be expelled when the child is born, and is called *meconium*. Originally the liver occupies the whole of the upper part of the abdomen, and the left lobe is as large as the right; but this does not continue long; and in the adult, the left lobe is comparatively small, and falls considerably short of reaching the left side of the body.

The greater part of the blood sent to the liver enters it by the portal vein, and comes from the stomach, intestine, and spleen; but there is likewise a hepatic artery which nourishes the textures of the viscus; and the blood entering by this channel is afterwards conveyed to the capillaries of the portal system. The hepatic substance is arranged in minute lobules, each of which has ramifications of the portal vein in its circumference, and in its centre a radicle of the hepatic vein, by which the blood is carried from the liver into the vena cava. A rich network of small-meshed capillaries not only unites the branches of the portal and hepatic veins, but pervades the whole organ, passing continuously from one lobule to another. Only a few animals, such as the pig, furnish an exception to this rule, and have the hepatic lobules distinct.



Fig. 86. — HEPATIC LOBULE, capillary network: radicle of hepatic vein in the centre, and branches of portal vein at the circumference, together with two small twigs of hepatic artery.

When the blood-vessels are empty, a section of liver under the microscope exhibits little else than a mass of nucleated corpuscles. These corpuscles, termed the *hepatic cells*, are somewhat flattened polyhedral bodies of an average diameter of $\frac{1}{1000}$ of an inch, of a yellowish tinge, containing numerous

granules, and in the human subject distinct oil globules. They have a radiating columnar arrangement in the lobules, and pour their secretion into a network of minute intercellular channels, definitely walled, and capable of being injected; which, however, are not to be considered as proper secreting ducts, but correspond with similar channels between the cells contained within the saccules of the salivary glands and pancreas.

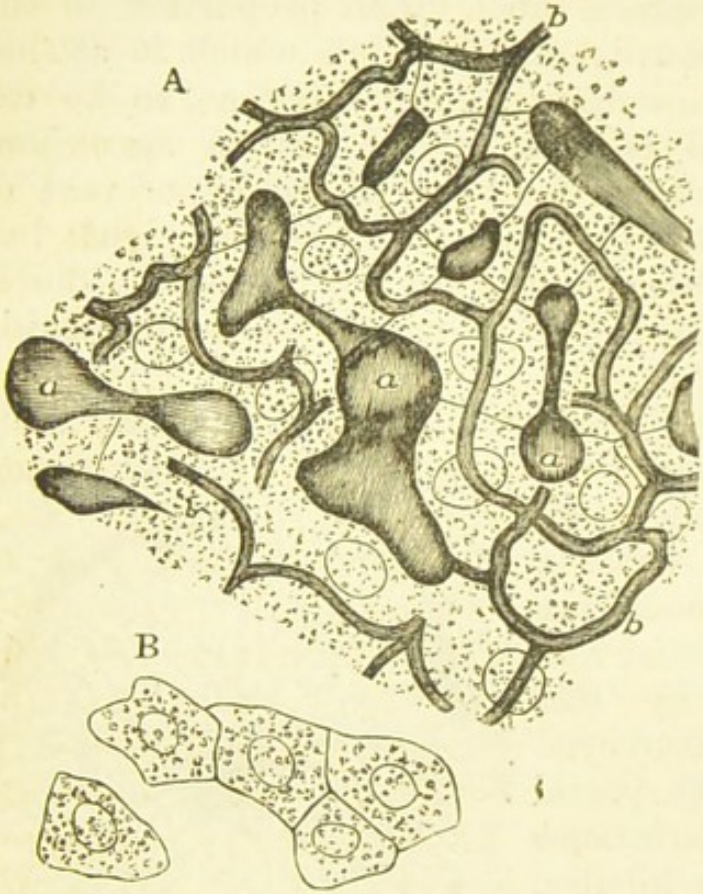


Fig. 87.—A, HEPATIC STRUCTURE highly magnified; *a*, *a*, section of capillaries; *b*, *b*, intercellular channels (Hering). B, Individual hepatic cells.

In the livers of many invertebrate animals, the secreting cells are obviously arranged in the form of an epithelial lining of a lobulated gland (fig. 34), and there can be no doubt that the hepatic cells of vertebrata are morphologically comparable with these. An appearance of a limiting membrane has even been demonstrated by one observer (Beale), surrounding the columns within the lobules, and it is legitimate to look on these columns as consisting of intercommunicating tubules filled with secreting epithelium; but they are not so distinct as the blind extremities of any other gland.

Minute bile ducts, with independent walls, are seen between the lobules; and these fall into ducts of larger size, copiously beset with mucous glands. A right and left trunk emerge from the corresponding lobes, and unite to form the *hepatic* duct with which the gall bladder communicates by a duct of its own, the *cystic*, to form with it the *common bile duct*.

The gall bladder is a reservoir in which the bile is stored till required in the intestine; but although very generally found in all classes of vertebrata, there are some animals in which it is absent.

123. The Bile contains a large amount of mucus derived from the glands of the ducts, no doubt of some important use; but what that use is, unless it be to protect the mucous membrane of the ducts and gall bladder from the action of bile long left in their interior, is unknown. It contains also a special colouring matter, rich in iron, and no doubt derived from the colouring matter of the blood, so much of which is found in the serum of the splenic vein. But the most characteristic substances are those which give it the properties of a soap, as stated in a previous page (p. 102). These substances are termed the *glycocholate* and *taurocholate of soda*. Their acids are of very complex composition, and easily resolved, the one into cholic acid and glycin, the other into cholic acid and taurin. Cholic acid is a substance very similar in composition to the ordinary fatty acids, having, like them, a large number of equivalents of carbon and hydrogen in combination with a much smaller quantity of oxygen; glycin and taurin are bases of comparatively simple chemical formula, and containing nitrogen, while taurin contains sulphur in addition. It will be noted, therefore, that the biliary acids must be formed, at least in part, from the nitrogenous constituents of the blood. They do not pre-exist in the blood, but are manufactured by the liver; for they are never found even in the smallest quantity in analyses of healthy blood. Bile likewise contains phosphates in quantity; also a certain amount of cholesterin, a non-nitrogenous crystalline substance, allied to the fats, and crystallizing in large quadrilateral plates, a constituent of the brain, and very possibly brought to the liver from that source.

From experiments on animals, in which the bile is gathered by means of a fistulous opening, the flow would appear to be very great, and is calculated at two or three pounds per diem in the human subject. It is increased a few hours after eating, and reaches its maximum about the eighth hour, then gradually diminishes while fasting is continued. The

flow is augmented by flesh diet, but not by a diet consisting exclusively of fat.

124. Within the substance of the liver another product besides bile is found, namely, *glycogen* (Bernard). This, which is likewise called the *amyloid substance* of the liver, is a material similar to starch or dextrin, of the same chemical composition, and easily converted into sugar. It is obtained as a white powder by precipitation in alcohol from a filtered extract of boiled and pounded liver. It is stored in the hepatic tissue, probably within the cells, and after death is speedily converted in considerable quantities into sugar, which is found in the blood-vessels of the organ. For, if a liver newly excised from an animal have the vessels washed out with water injected through the portal vein till it is quite free from sugar, in a few hours afterwards, if they are again washed out, abundance of sugar will be obtained. What becomes of the glycogen during life, however, is a point on which some difference of opinion exists; but it may be mentioned that even those who are most sceptical of its passage during life into the blood, have themselves found sugar in at least minute quantities in blood drawn from the right side of the heart of living animals by means of a pipette introduced by the jugular vein (Pavy and M'Donnell): and the student will recollect that it has been already pointed out (p. 109) that the smallness of the quantity of any substance in the blood is no proof that a large amount of it does not pass through the circulation, but only shows that it does not accumulate there. The sugar which enters the circulation from the liver is, in health, destroyed or altered in the lungs.

Analyses of the livers of animals which had been fed for several days on one particular diet, show that glycogen accumulates most rapidly when the diet consists of starch and sugar, but that it is also formed from purely nitrogenous food; while, when fat and gelatin alone are consumed, the liver is free from glycogen (M'Donnell).

125. The blood, in passing through the liver, undergoes a marked amount of change. This is known by analysis of the blood entering by the portal vein, and that which leaves by the hepatic. The blood of the hepatic vein is of very dark colour, and its corpuscles resemble those of the splenic

vein in resisting the action of water, and collecting in heaps instead of nummular rows. It forms no spontaneous coagulum, and only a small quantity of fibrin can be obtained from it, even when whipped with rods. It has both a larger proportion of corpuscles, and a larger amount of solid matter in its serum than the portal blood; that is to say, it has less water, as one might expect from the fact that the bile has a much lower specific gravity than blood. The solid residue obtained by evaporation of its serum, contains a very decidedly smaller amount of albumen than the solid substance of the portal serum, a smaller amount of fat, and a large increase in the amount both of salts and extractive matters. We must conclude, therefore, that albuminoids are decomposed in the liver, and that their decomposition gives rise to the nitrogenous part of the additional extractive matters in the hepatic vein.

126. The student has now been put in possession of the principal known facts which bear on the question of the use of the liver in the economy, and it remains to consider what its uses are. To do so, is to pass from the region of fact to that of hypothesis, and it is well that the student should understand how widely different these are, one from the other. It is the deficiency in our knowledge of facts which necessitates conjecture; were the chain of facts complete, the need for conjecture would cease.

Some points are beyond all doubt: the liver certainly arrests fats and sugar, storing the latter up in the form of glycogen. Whether it arrests other substances is not so certain; but it cannot be denied that after death from arsenic and other metals, the poison is found in particular abundance in this viscus. It rids the blood of the colouring matter which stains the serum coming from the spleen, and it decomposes albuminoids, either on account of their being in a condition unfit for circulation, or in overabundance. The products of this decomposition are, it may be supposed, nitrogenous extractive matters remaining in the blood, and the bile removed from it; and it is quite possible that glycogen, when present in the hepatic cells, may assist the decomposition, though it is certain that bile is formed when glycogen is absent from the liver. It has been pre-

viously pointed out (p. 103) that the biliary acids are decomposed in the intestine, and that the products are probably in part absorbed. The kind of nourishment resulting from decomposition of the biliary acids, and taken up again from the intestine, is not known, but it may be pretty safely conjectured to be fatty; in which case, the action of the liver, so far as that material is concerned, would be the preparation of fat from nitrogenous matters. But it is not to be forgotten that an excessive secretion of bile is a cause of purging, and may thus be altogether got rid of by the bowel. The functions of the liver may therefore be grouped under the three heads of arrest, decomposition, and elimination.

On the whole, especially when the large size of the liver before birth is considered, and the work thrown on that viscus in the case of Europeans in hot climates, it may be hazarded as a conjecture that, besides being a storehouse for non-nitrogenous material not immediately required, the liver aids the elimination of albuminoids with less complete decomposition, and therefore less evolution of heat, than is required to decompose them in the tissues.

127. The Kidneys.—The kidneys are the principal eliminators of nitrogenous debris and of salts from the blood. In the human subject they are about four inches long, two and a half broad, and flattened from before backwards. On the inner side of each is a depression called the *hilus*, where the renal artery enters, and the vein and duct emerge. The duct is called the *ureter;* it is dilated at its commencement, but diminishes rapidly to the size of a goose quill, and after a course of fourteen inches or more, opens into the lower part of the urinary bladder.

The kidney is a tubular gland, and in all classes of vertebrata its tubules present, at or near their origin, small grape-like bodies, called Malpighian corpuscles. In many fishes the two kidneys extend the whole length of the abdomen, from the head backwards, and in many they are blended in one mass behind. In the other vertebrata, the permanent kidneys are preceded, in the embryo, by a pair of *primordial kidneys* or *Wolffian bodies*, originally extending along the sides of the vertebral column, but afterwards confined to the hinder part of the abdominal cavity. These consist, like the per-

manent kidneys, of *tubuli uriniferi* commencing in dilatations; they exercise their functions for a limited period, and then disappear nearly altogether; but their ducts, and other tissue connected with them, are closely associated with the development of the ducts of the essential reproductive organs in both sexes. In reptiles and birds the kidneys have a frilled or convoluted appearance; in mammals they are more compact than in any other vertebrata.

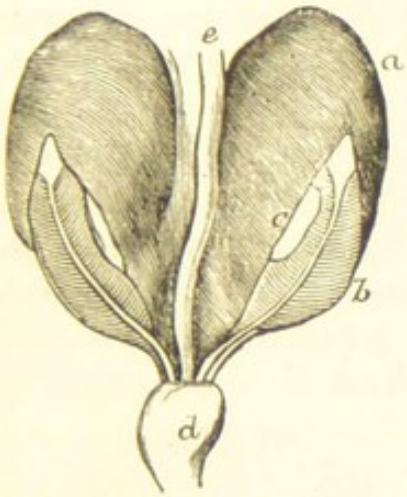


Fig. 88.—Wolffian Bodies of Embryo Pig. *a*, kidney; *b*, Wolffian body, and, on its surface, the Müllerian duct, afterwards the Fallopian tube; *c*, ovary; *d*, urinary bladder turned down; *e*, rectum. Double size.

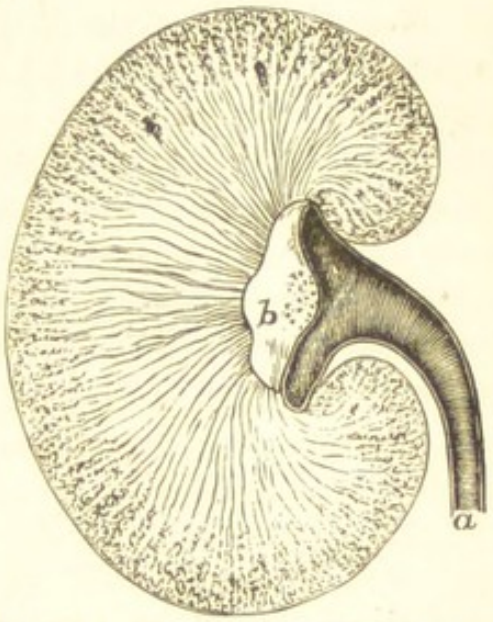


Fig. 89.—Kidney of Kangaroo, vertical section. *a*, Ureter; *b*, cone, to the summit of which all the tubules are gathered.

In the part of their course nearest the circumference of the organ, the tubules of the mammalian kidney are convoluted, giving a granular appearance to the texture; while in the inner part of their course they are straight, and give to the texture a striated appearance. The granular outer part is called the *cortical* portion of the kidney, and the striated inner part is called the *medullary* portion.

128. If a sheep's or a rabbit's kidney be examined, the cortical substance will be seen to form a uniform layer, while the straight tubules of the medullary part are gathered together in one group, having the form of a ridge in the sheep, and of a cone in the rabbit and the kangaroo, projecting into the dilatation from which the ureter springs.

In the porpoise each kidney consists of a large number of

distinct renules, completely separable one from another, and every one possessed of a cortical covering and a medullary part gathered into a cone like that of a rabbit's kidney. In the seal these renules are distinct, but cannot be dissected separate; while in the ox they are fused more closely together, but form separate lobules on the surface.

The human kidney has the smooth surface of that of the sheep, but in construction more nearly approaches to that of the ox. Before birth, it presents a lobulated appearance of the surface (fig. 85) like the ox kidney; but the lobules become so fused together that their outlines are soon obliterated, and the general surface made smooth like the kidney of the sheep. The construction, however, is at once manifest on laying the organ open by a vertical section from the hilus to the outer border. Then it is seen that the medullary substance consists of a number of cones distinct each from the rest, being separated by extensions of the cortical part.

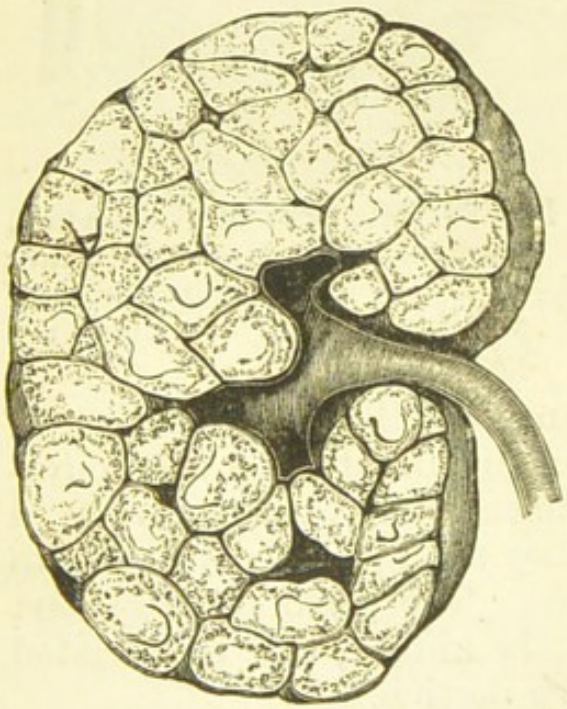


Fig. 90.—KIDNEY OF SEAL, vertical section.

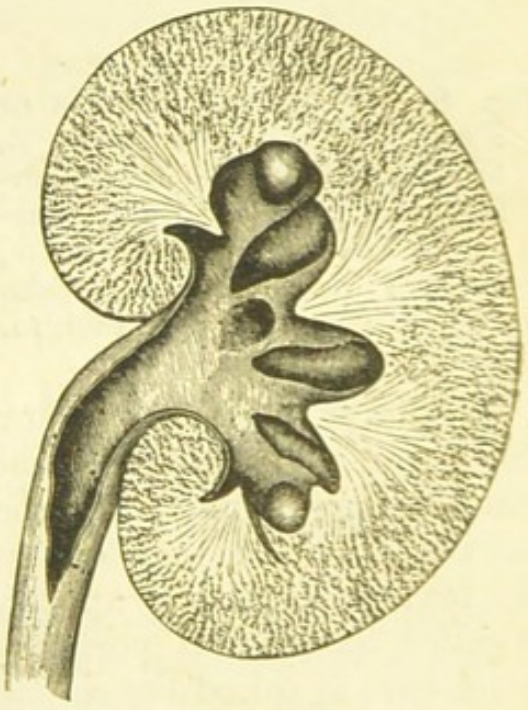


Fig. 91.—HUMAN KIDNEY, vertical section.

These are called *pyramids of Malpighi;* and while their bases are imbedded in the cortex, the apex of each projects into a cup or *calyx* which embraces it; and the calyces open, each by a constricted orifice opposite the apex of the pyramid which it embraces, into the *pelvis* of the kidney,

a common cavity in the hilus, from which the ureter takes origin.

129. The straight tubes of which each pyramid is composed, open by a group of orifices at the summit, and divide several times as they pass backwards. They are the continuations of the convoluted tubes which form the cortex. And if the texture be carefully examined in the deep part of the cortex, it will be seen, even with the naked eye, particularly in a minutely injected kidney, that the striated appearance produced by the straight tubes of the pyramid is prolonged outwards in a series of streaks, each of which is imbedded in the granular-looking convoluted portions of the tubes. Such a streak, with the convoluted tubes belonging to it, is distinguished as a pyramid of Ferrein. Thus, a group of tubules forms a pyramid of Ferrein; a number of these have their straight parts prolonged, and unite to form a simple kidney,

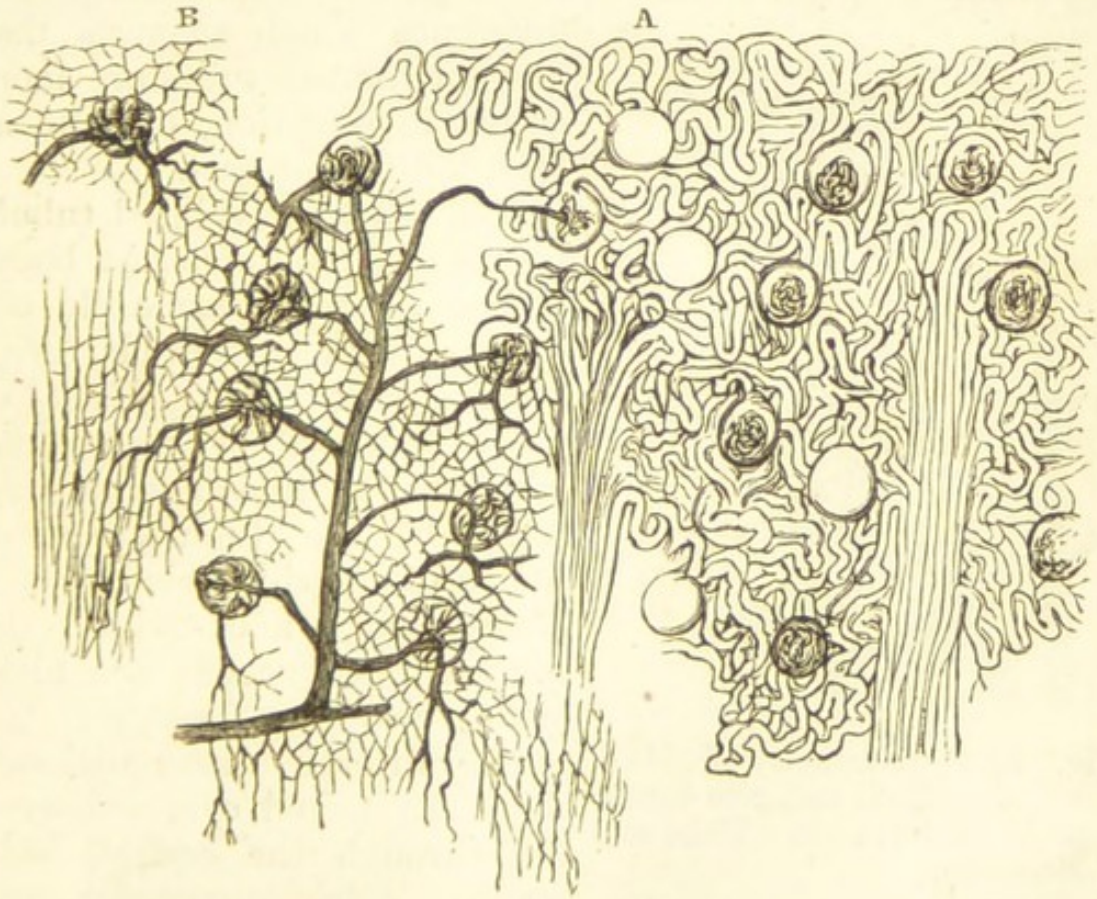


Fig. 92.—TEXTURE OF KIDNEY, semi-diagrammatic view. A, Tubules and Malpighian corpuscles of two pyramids of Ferrein; B, afferent and efferent blood-vessels of Malpighian corpuscles, and capillary networks.

or a lobule with one Malpighian pyramid; several lobules may become blended in one Malpighian pyramid and larger lobule; and, lastly, in such a kidney as the human, the lobules are completely fused in a higher unity.

The great majority of the uriniferous tubules are about $\frac{1}{600}$ inch in diameter; near the summit of the Malpighian pyramids, however, trunks of twice or thrice that size are formed by the union of others; and there are also loops of much smaller diameter, each of which is intercalated in the course of a convoluted tubule, and descends into the medullary substance.

Where the change of arrangement from the convoluted to the straight condition takes place, there is likewise a change of structure; for the columnar or rather cubical epithelial corpuscles of the convoluted tubes are turbid masses without distinct outline, while those of the straight tubes have the appearance of cell walls round them, and clear contents; a difference which suggests that the convoluted tubes are more active in secretion, or take at least a different part.

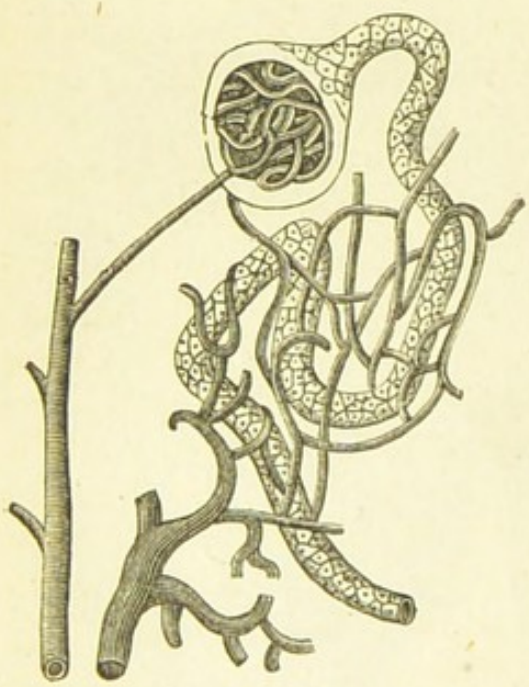


Fig. 93. — Relations of MALPIGHIAN CORPUSCLE to tubule and blood-vessels. Todd and Bowman.

130. Each convoluted tubule begins in a little spherical body, named after the same old observer as the pyramids, *Malpighian corpuscles.* Each of these consists of a *capsule*, which is the dilated commencement of the tubule, and a bunch of blood-vessels called a *glomerulus ;* and, when the minute blood-vessels are filled with colouring matter, the glomeruli are distinguishable with the naked eye, scattered all through the cortical substance. Each glomerulus consists of a bunch of loops of blood-vessels taking origin from a single little *afferent* artery which enters the capsule at the part opposite to that which is continued into the tubule,

and pouring their contents into an *efferent* vessel smaller than the afferent one, and emerging close to it. These efferent vessels are likewise to be considered as arteries, for, on their emergence, they break up into capillaries, which supply the whole capillary network of the tubules with blood which has previously passed through the Malpighian corpuscles. The glomerulus, when distended, completely fills the capsule into which it dips, and in which it may be said to hang loose, being covered with only a delicate layer of squamous epithelium.

The structure of the Malpighian corpuscles leaves little reasonable doubt as to their function; they are fitted to allow water to drain off from the blood: and it is in keeping with this hypothesis that they are very rudimentary in birds, as in birds the urine is of semi-solid consistence, forming the white part of their mutings. The drain of water from the blood in the glomerulus accounts for the efferent vessel being smaller than the afferent; and the blood, being freed from superfluous water first, is brought in a more concentrated state into contact with the tubules, whose epithelia remove from it the solid constituents of the urine.

131. The **Urinary Bladder** is a hollow viscus, with its outlet at its lower part, and when empty it lies altogether within the pelvis, but when distended it is enlarged in an upward direction, rising considerably above the pelvis, and resting against the abdominal wall, to which it is bound down by peritoneum. In that state it is comparatively unprotected; and when overdistended, it has been known to be ruptured by very slight accidental violence. The ureters open into the bladder behind its orifice or neck, their points of entrance forming with that orifice the angles of an equilateral triangle, with sides about $1\frac{1}{2}$ inches long, and called the *trigone*. The mucous membrane of the bladder has a stratified squamous epithelium, while that of the ureters is intermediate between the squamous and columnar varieties. At the orifices of the ureters, which enter the bladder obliquely, the mucous membrane is somewhat redundant, so as to form on each orifice a valve which effectually prevents regurgitation.

The muscular walls of the bladder have the fibres extending round it in every variety of direction, yet not without

definite arrangement; for they can be shown to consist of multitudes of figures of eight, with the crossings of the figures in front and behind, and their loops round the summit and outlet (Pettigrew). The fibres are of the unstriped description; but round the *urethra* or canal of exit, where it emerges from the pelvis, there are muscles of the striped kind, by whose action the contents of the bladder are voluntarily retained, when its walls are irritated to contract by the stimulus of distension.

132. The Urine.—The average amount secreted by the kidneys is about fifty fluid ounces, or two pints and a half, in the day; the reaction is usually acid, and the average specific gravity is 1·020; but the amount of water secreted by this channel is affected not only by the amount imbibed, but by various circumstances, particularly temperature and exercise, which influence the quantity carried away by the skin and lungs. Whatever diminishes the amount of water secreted by the kidneys, or increases the quantity of waste substance, heightens the specific gravity of the urine.

The solid contents of the urine consist of nitrogenous matters and salts. The salts are chlorides, sulphates, and phosphates. Chlorides occur in all the fluids of the body; the sulphates take origin, no doubt, by the oxidation of the sulphur contained in albuminoid matters; and the phosphates are derived from the oxidation of the phosphorus in albuminoids, and in the protagon of the nervous system, and from the phosphates pre-existing in the bones and various fluids.

The principal nitrogenous matter in the urine is urea, which, as already stated, is the substance in the form of which by far the greater part of the nitrogen escapes from the body. It is exceedingly soluble, and contains exactly one half its weight of nitrogen. About 500 grains of urea may be said to escape by the kidneys in twenty-four hours. There is contained in the urine of man a small quantity of hippuric acid, a substance which gets its name from being found abundantly in the urine of the horse; and there is likewise ordinarily a small quantity of uric acid, which is important; because, from slight derangements of nutrition, its amount is liable to increase, and when it accumulates in the blood it produces gout, while, in the urine, on

account of its sparing solubility, it may lead to stone in the bladder.

It may be further remarked, that in animals which void the urine solid, uric acid takes the place of urea; thus from serpents uric acid is obtained in masses of pure crystals. Other matters are contained in the urine in small quantity, such as a peculiar pigment, various extractive matters, among which may be mentioned kreatin, and mucus from the bladder.

The kidney is both a separator of urea from the blood, and a manufacturer of more. That some of the urea is formed elsewhere, and carried to the kidneys in the circulating stream, is shown from that substance being always present in the blood, although in small quantity, and from its accumulating in animals from which the kidneys have been extracted. But that it is in large part manufactured by the kidneys, is proved by its accumulating far more rapidly in animals whose ureters have been tied, than in those that have had the kidneys removed.

CHAPTER XIII.

THE NERVOUS SYSTEM.

133. In the working of a nervous system in any animal, there are three sets of parts involved; namely, the nervous centre, the terminal organ, and the link of communication between the two, namely, the nerve. The distinctive part of every nervous centre consists of nucleated corpuscles, and any nervous mass containing nerve-corpuscles is called a *ganglion*. The nerve consists of uninterrupted fibres in structural continuity with the corpuscles, and without any branching until close to their termination; and the terminal organs are likewise in structural continuity with the nerves.

These terminal organs are, however, of very various descriptions, and with as much claim, in many instances, to be separately grouped as to be considered along with the nervous system to which they are so intimately united. For example, it would be difficult to raise a valid objection to considering muscular fibres in their entirety as terminal organs of nerves; yet they have a development and function of their own, and it would be inconvenient, as well as erroneous, to look on them as mere parts of the nervous system which governs them. It will be recollected that in treating of the skin, several terminal nervous organs have already been described (p. 68), to which the integuments owe their sensibility; and more complex organs are devoted to the special senses, which will hereafter be described. But at present we shall consider only the nervous centres and the nerves.

The nervous system, as developed in the invertebrate animals, consists of a series of ganglia connected in chains or other groups, and giving off nerves; but in the vertebrata it is divisible into two parts. One of these is the *cerebro-spinal* system, consisting of the brain and spinal cord, together

termed the *cerebro-spinal axis*, and of the nerves issuing therefrom, which supply the voluntary muscles, the integuments and organs of special sense, and various other structures; the other is called the *sympathetic* system, and consists

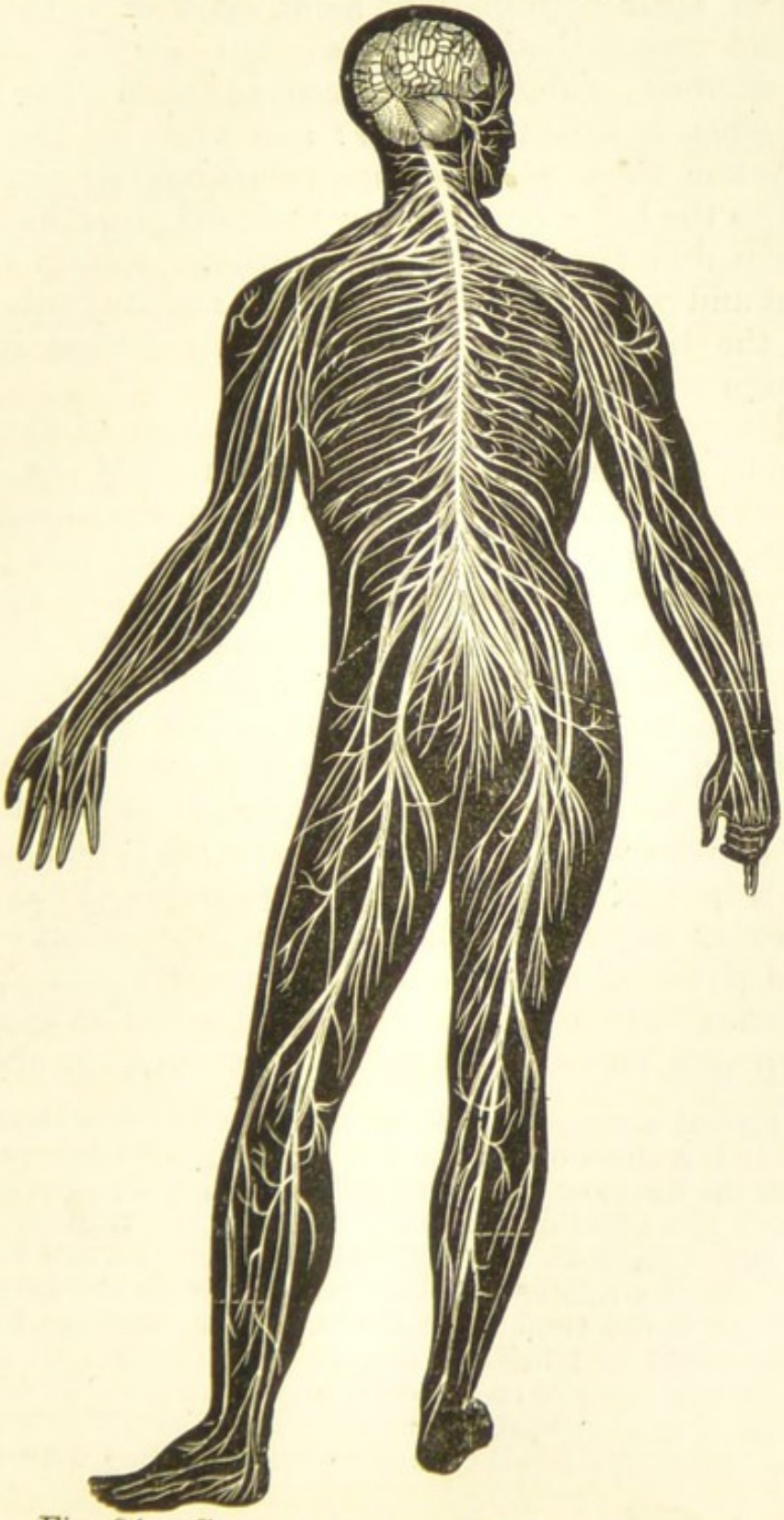


Fig. 94.—Cerebro-spinal Nervous System.

of chains and irregular collections of ganglia, and of nerves supplied principally to viscera and blood-vessels.*

The rule that the nerve-fibres remain distinct, each from every other, and never branch until within a microscopic distance of their termination, holds good of both cerebro-spinal and sympathetic systems; but nerves consist of bundles of fibres, which may be re-arranged in other bundles, forming what is called a *plexus;* and while in the cerebro-spinal system these plexuses are comparatively simple, and confined to the large trunks near their origin and a few fine twigs here and there, in the sympathetic system they are abundant and complex, giving a meshed and intricate appearance to the bundles, which are seldom collected in moderately large trunks.

134. Nervous Action.—The simplest idea of the use of the nervous system is got from what is termed *reflex action*, because that is uncomplicated with consciousness. In a reflex action an irritation is applied to a part, and produces in a nerve a change of condition, which is called an *impression;* this impression is termed *sensory* or *centripetal*, and travels to the nerve-centre with which the nerve is connected, and thence it is reflected along some other nerve-fibre, and takes a *centrifugal* course to a muscle or other organ, which it stimulates to action. If the organ so stimulated be a muscle, the nervous action is *excito-motor;* if it be a secreting cell, the action is *excito-secretory;* if it be an electric organ, such as exists in various fishes, the nervous action excites it to give a shock of electricity. But in every case it is one description of change which, under the name of an *impression*, passes up one nerve, through the nerve-centre, and down

* The typical arrangement of nervous system found in segmented invertebrata is a chain of ganglia running along the lower part of the body, with the foremost placed in front or above the opening of the mouth; and the question naturally arises, what relation has this chain to the vertebrate nervous system? Now, certain researches seem to point out a relationship between vertebrate and invertebrate animals through the tunicate molluscs. These molluscs have only one ganglion, which, I believe, may be fairly considered as homologous with the anterior or pre-œsophageal ganglion of articulata; and it appears most probable that the cerebro-spinal axis of vertebrata is a highly developed structure corresponding with that one ganglion.

another nerve to reach the terminal organ; while the effect produced depends on the intrinsic properties of that organ. It is also interesting to notice that in such an action there is no generation of new force; but the irritant, or *stimulus*, gives rise to or is converted into a nervous impression, and the impression, after travelling through a circuit, is followed by the action of the terminal organ.

It is by such reflex action that a flow of saliva follows the introduction of sapid substances into the mouth. The sapid substance irritates the nerves of the mouth, and the impressions travel along them to a nervous centre, whence they are reflected along the nerves terminating in the secreting corpuscles of the gland. So, also, the muscles of the stomach and intestines are excited to regular movements, not by the direct influence of the food, but by impressions originated in nerve extremities, conducted to centres, and thence reflected. Direct irritation of muscle produces mere spasmodic contraction of the muscular fibres irritated; but the impressions sent from nervous centres produce a co-ordinated action of numbers of fibres, suited to the accomplishment of some definite end. That, no doubt, is a result not thoroughly understood; but it is connected with the circumstance that a nerve-centre always consists of numbers of corpuscles, and gives off a number of fibres.

Impressions sent to nervous centres are not, however, always reflected to the region whence they came. They may pass to other nervous centres, and lead to changes in all parts of the body; and, when they reach the brain, they produce sensation.

Here we are brought into contact with an apparent complication in the functions of the nervous system, its relations to consciousness. These relations are exhibited in two ways, one is the production of sensation by nervous action reaching the brain; the other is the production of nervous action initiated in the brain by volition. It is, however, to be clearly understood that the brain is only a complex arrangement of nerves and nerve-corpuscles, comparable with the simpler nervous centres; and although it both affects and is affected by the mind, there is no reason to believe that its active condition is dissimilar from that of nerves and nerve-

corpuscles throughout the rest of the nervous system. Its peculiarity lies in a sympathy between it and the mind, whereby centripetal action which has reached it affects the mind, and the mind in turn excites nervous action in it, which may extend centrifugally to the voluntary muscles.

The sum of the function of the nervous system is, that it conveys and distributes nervous impression. The waves of impressed condition, or nervous impulses, may originate either from external irritation applied to terminal organs, or from an unknown description of irritation exerted by the mind; and in some instances they influence the mind, while in others they act on muscles and glands. Further, it must be admitted that no mental action can take place without nervous action; but it is distinctly to be understood that nervous impression, or the active state of the nervous system, is not the same thing as mental action, but is a definite physical change, which, there is no reason to doubt, is always of one description.

135. Living nerve resembles living muscle in being in a peculiar state of electric tension when at rest, and in changing its electric condition when in action. Detached portions of nerve examined by means of the galvanometer give results similar to those obtained from blocks of muscle (p. 57); but the currents being much weaker, a finer instrument is required for their detection. Nerve has further the remarkable property, that if a portion be placed within the circuit of a galvanic current, a current in the same direction is produced in the whole length of the nerve: the nerve is then said to be in a state of *electrotonus*. A galvanic current applied to a trunk of nerve supplying a muscle does not maintain the muscle in contraction; but there is a contraction every time that the circuit is completed, and every time that it is broken, so that the muscle can only be kept contracted by a constantly interrupted current. In electrotonus the nerve still performs its functions, but its degree of irritability is altered in different parts of its course. These facts show that nervous influence is not a current of electricity. By applying the stimulus to different points on the nerve trunk, and measuring, with an instrument called a *myographion*, the difference in time between application of the stimulus and contraction

of the muscle, the rate can be demonstrated at which the nervous influence or impression travels. The rate is estimated at more than 100 feet per second in the human subject; but it is known to vary at different times in the same nerve.

136. Nervous Tissues.—*Nerve-fibres* present considerable variety of microscopic appearance. But those which are largest, and found most abundantly in nerve trunks taking origin from the brain and spinal cord, are the *medullated* fibres. These may have a diameter as great as $\frac{1}{1500}$ of an inch. They present a *limiting membrane*, with nuclei

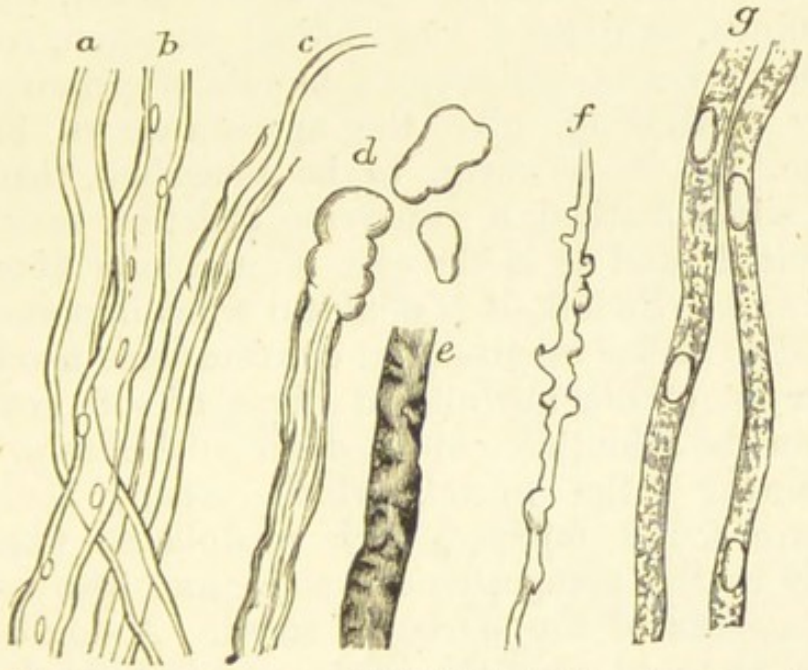


Fig. 95.—NERVE-FIBRES. *a*, Medullated fibre in the fresh state; *b*, similar fibre showing the nuclei of the limiting membrane; *c*, axis-cylinder projecting beyond the torn limiting membrane of a fibre, from which the medullary sheath has been partially removed; *d*, substance of medullary sheath escaping in irregular drops; *e*, fibre treated with acetic acid; *f*, fine medullated fibre from brain, the medullary sheath running into drops, being unsupported by any limiting membrane; *g*, grey fibres.

scattered on it, like the sarcolemma of muscle, and inside of this, in the fresh state, a clear and seemingly homogeneous substance, which oozes out in a semifluid fashion from places where the limiting membrane is ruptured. But after a short time, or on addition of reagents, such as a drop of acetic acid, a coagulation takes place, and there are then exhibited a thin central thread, the *axis-cylinder*, in the middle, and around this a substance which is called from its opacity when

coagulated, *white substance of Schwann*, and from its marrow-like consistency, the *medullary sheath*. The limiting membrane is absent from the fibres within the brain and spinal cord. The axis-cylinder is of albuminoid composition, while the white substance is rich in *protagon*, a material containing phosphorus, soluble in warm alcohol, but not in ether, and readily yielding fatty compounds by decomposition. Within its nervous centre a medullated fibre often becomes much reduced in diameter, and at its peripheral termination it may consist of axis-cylinder without any white substance, and may break up into branches. The axis-cylinder, when carefully examined, exhibits a longitudinal striation, considered by some observers as indicating a bundle of primitive fibrils which, by separating, give the appearance of branching referred to. It is, however, to be remarked that by the nitrate of silver method, a transverse striation may be likewise exhibited; and as in the case of muscular fibre, so also in that of axis-cylinders, it is doubtful what importance is to be attached to either longitudinal or transverse markings.

Another set of non-medullated fibres of soft consistence, darker than the medullated fibres, distinguished as *grey fibres*, and presenting large nuclei, which occupy their whole breadth, are found mingled with medullated fibres most abundantly in the sympathetic system, and also constitute all the filaments of the nerve of smell. A doubt may be entertained as to whether the nuclei are imbedded in their protoplasmic substance, or belong to a sheath. But what is most important for the student to understand is, that every nerve in the body has an albuminoid thread, while only some are enveloped in the substance yielding protagon.

137. Nerve-corpuscles, improperly called nerve-cells, are sometimes surrounded with a nucleated sheath, but they have no cell wall. They consist of a clear nucleus, and one or more nucleoli imbedded in a mass of protoplasm loaded with granules. They send out, in probably every instance, processes termed *poles*. Some of these poles are continuous with nerves, others communicate with other corpuscles; while, in the case of multipolar corpuscles, many of them would appear to ramify till the branches reach an extreme tenuity.

The firmness of the different parts of the nervous system

depends much more upon the connective tissue present, than on the nervous elements. The nerves in their course through the tissues are tough strong cords, which bear a strong pull in dissection, because the fibres are bound together by means of firm sheaths of connective tissue; and for a similar reason the ganglia of the sympathetic system are exceedingly tough.

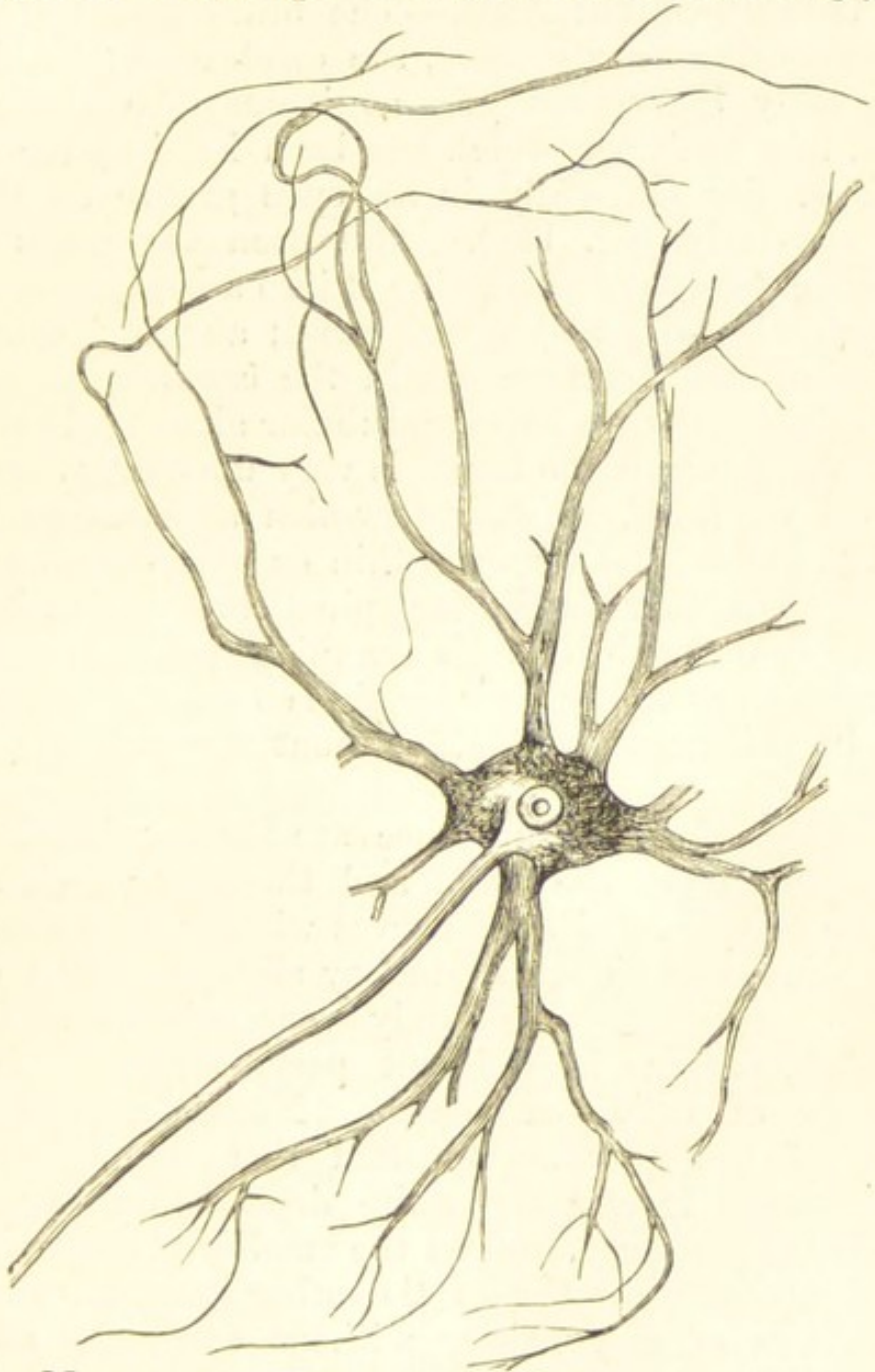


Fig. 96.—MULTIPOLAR NERVE-CORPUSCLE from anterior cornu of spinal cord of ox. Schultze after Deiters.

But the brain and spinal cord are of a soft consistence, easily destroyed by handling, and reduced to viscid pulp by a little

pressure, because the substance which binds their nervous elements is nearly as delicate as those elements themselves. The nerves emerging from the brain and spinal cord are likewise delicate before piercing the fibrous membrane (dura mater) which surrounds those structures and mingles its fibres with the nerve trunks as they issue from it.

138. Cerebro-Spinal Axis.—The brain and spinal cord form one continuous structure, the cerebro-spinal axis; and this, in early embryonic life, as it may be studied, for example, in a hen's egg which has been hatched for two or three days, lies originally in an open groove on the surface of the body (fig. 149). But soon the edges of the groove come together, converting it into a tube, which is the future cranial cavity and spinal canal; and in like manner the edges of the structure within the canal unite, and the cerebro-spinal axis thus becomes tubular also (fig. 153). But the part which forms the brain is very unequally developed, being bent on itself, its cavity swollen at some parts, constricted at others, and its walls thin or absent at one place and thick at another; while the spinal cord retains its cylindrical shape, although its walls are thickened, and its hollow, which remains as the *central canal*, is so small that it cannot be seen in the human subject without the aid of a microscope.

Two descriptions of substance are distinguished in the cerebro-spinal axis, the *white* and the *grey* or *cineritious*. The white matter consists of nerves without corpuscles, and owes its whiteness to the medullary sheaths of the nerves; while the grey matter has only very minute medullated fibres, and contains in different parts a great variety of dispositions of nerve-corpuscles. Notwithstanding these varieties of the grey matter, and that the difference in colour between it and the white depends on the greater vascularity of the grey, and on the smaller proportion borne by the medullary sheaths to the other textural elements; yet, as tracts of grey matter without corpuscles are very small, and the white matter has no corpuscles anywhere, the grey matter may be considered as ganglionic, and the white as merely conducting. Along the whole length of the original cerebro-spinal cylinder, grey matter lies next the

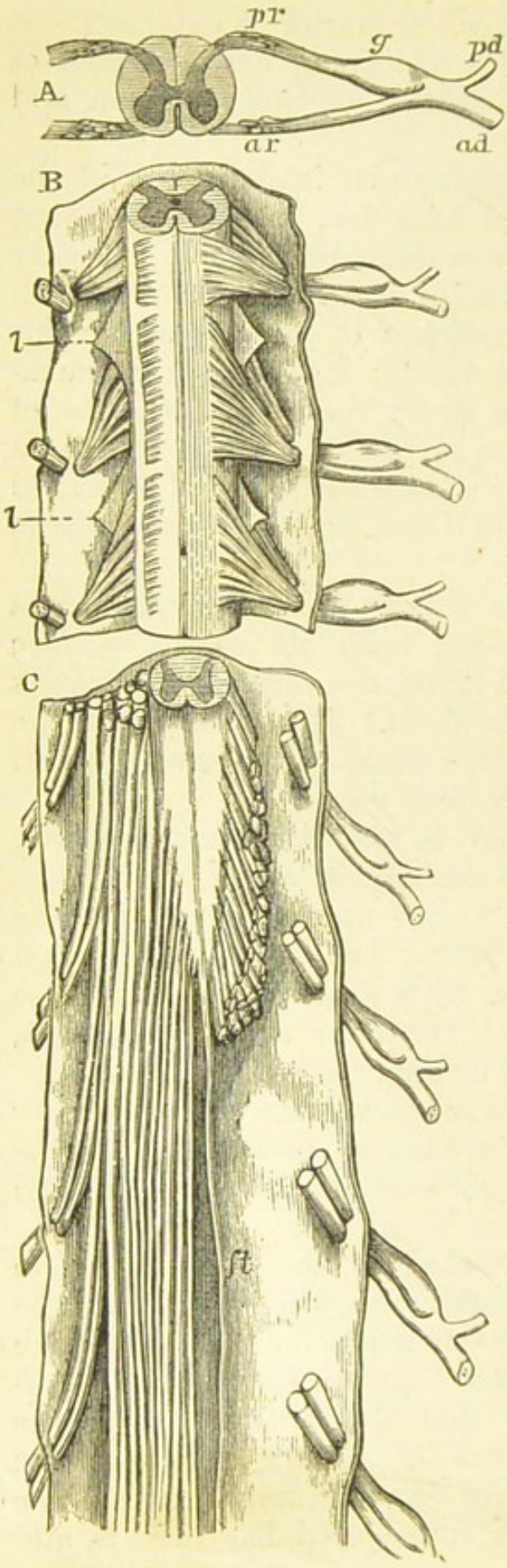
interior of the tube, while the white matter is exterior; but in the brain there are extensive additional developments of grey matter on the convoluted surface of the cerebrum and cerebellum.

139. Large blood-vessels appear to be inadmissible in the substance of the cerebro-spinal axis, for, instead of having vessels ramifying through it as in other textures, it is closely invested with a vascular membrane called *pia mater*, which consists of thickly meshed branches of arteries and veins united with a little connective tissue; and from this membrane, which dips down into every fissure, multitudes of small arteries enter all over the surface, so minute that, in a section of the brain, the only vessels visible to the naked eye appear as scattered spots of blood no larger than marks made with the point of a pin.

Over the pia mater there is a delicate transparent serous membrane, called the *arachnoid*, with its serous surface turned outwards, and stretched across the various inequalities of surface, without dipping into them. It is adherent to the pia mater over great part of the surface of the brain, but on the spinal cord is disposed as a loose bag.

Superficial to the arachnoid is placed the *dura mater*, an exceedingly tough fibrous membrane, which, within the cranium, serves as periosteum to the interior of the skull, as well as for an envelope to the brain; but in the spinal canal is separated from the vertebræ by a space containing loose adipose tissue and large veins. Its outer surface is rough, but the inner is polished and clothed with epithelium, completing with the opposed arachnoid membrane the boundaries of a serous cavity, called the *arachnoid space*, in contradistinction to the *subarachnoid space* between the arachnoid and pia mater.

The spinal arachnoid is attached to the dura mater on each side, not only by the sheaths with which it clothes the nerves, but by a series of attachments, one between each pair of successive nerves, constituting the *ligamentum denticulatum*. When it is added that the subarachnoid space contains a considerable amount of watery secretion, the *cerebro-spinal fluid*, principally in the spinal canal, the student will perceive that the spinal cord has in this, and



in its loose coverings, in the middle of which it is retained by the ligamenta denticulata and the passage outwards of its nerves, an efficient protection which accounts for its immunity from damage in movements of the vertebral column. The brain, on the other hand, fits exactly within the cavity of the unyielding cranium.

140. The Spinal Cord extends from the skull to the level of the first lumbar vertebra, and is from fifteen to eighteen inches long. It is about the thickness of the little finger, but is broader from side to side at the part of the neck where the great nerves pass off to supply the arms, and presents another thickening at its lower end,

Fig. 97. — Spinal Cord. A, Transverse section in cervical region; *a r*, anterior root of spinal nerve; *p r*, posterior root: *g*, spinal ganglion; *a d*, anterior division of nerve; *p d*, posterior division. B, Front view of a portion in the dorsal region, with the dura mater laid open, and the anterior roots of nerve on the right side divided; *l l*, ligamentum denticulatum. C, Front view of the extremity of the cord and part of the cauda equina. The roots of the nerves are divided on the left side; *f t*, filum terminale. The arachnoid is omitted in these figures.

where the trunks to the lower limbs take origin. It is divided into two symmetrical parts by a deep *anterior median fissure*, and by what is called the *posterior median fissure*, which is deeper than the anterior, but is not a true fissure, being only a septum of the proper connective tissue of the cord with larger vessels in it than are found in the nervous substance. Between these two fissures is the microscopically small *central canal*, situated in grey matter constituting what is called the *grey commissure*, in contradistinction to a little white matter in front of it, called the *white commissure*. On each side, the grey commissure spreads out into an extended mass of grey matter,

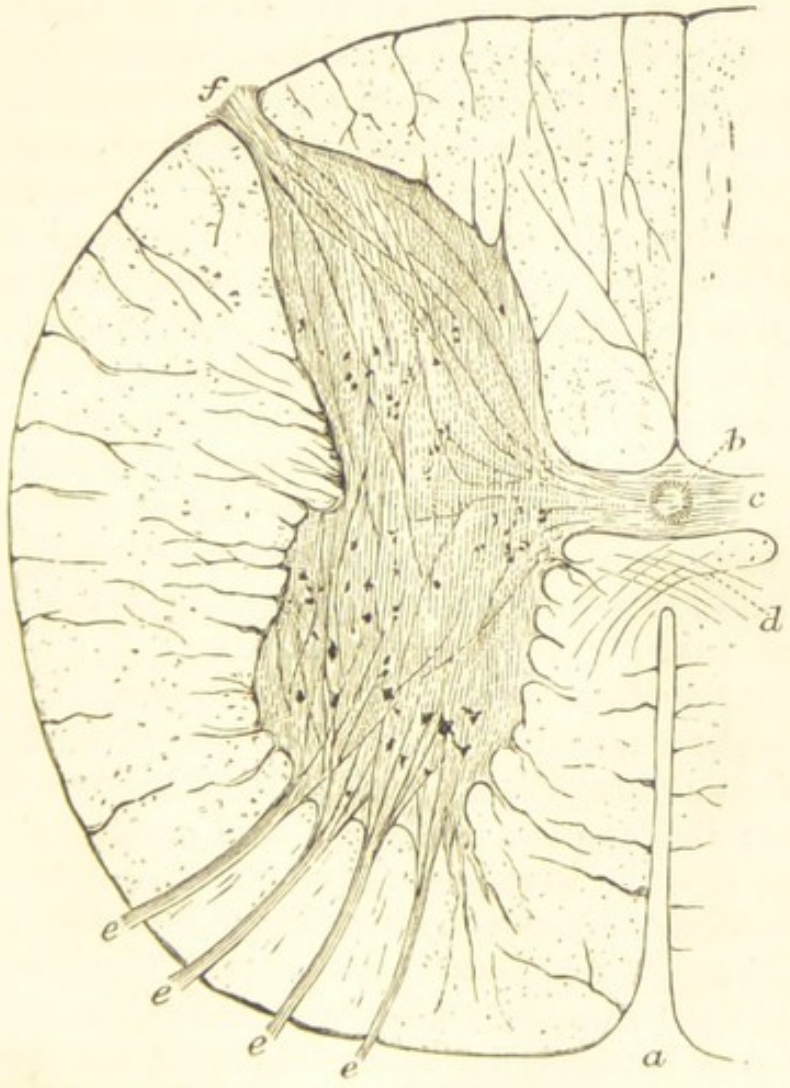


Fig. 98.—SPINAL CORD, transverse section; *a*, anterior fissure; *b*, central canal; *c*, grey commissure; *d*, white commissure; *e*, *e*, bundles of anterior root of nerve coming from the anterior cornu of the grey matter; *f*, posterior root passing in to the posterior cornu.

which, in transverse section, is seen to project forwards and backwards, constituting the *anterior* and *posterior cornua.*

The *spinal nerves* are attached to the cord symmetrically, and emerge from the spinal canal by the intervertebral foramina, one on each side, between each pair of successive vertebræ. There are thirty-one pairs of them, the uppermost emerging between the atlas and skull, and the lowermost behind the coccyx; and while the upper pairs pass directly outwards to pierce the dura mater, the lower pairs, including the large nerves for the lower limbs, come off, crowded together, from the lower end of the cord, and descend to their apertures of exit in a bundle, called *cauda equina*, invested with a common bag of arachnoid. The first eight spinal nerves are termed cervical, then follow twelve dorsal, five lumbar, and five sacral, each one of which is named after the vertebra above it; and lastly, there is a small coccygeal pair.

Each spinal nerve arises by an anterior and a posterior root, which emerge from the cord in two vertical series of fibres; and when the cord is cut across, the fibres of the posterior roots, which enter at the level of the section, are seen to pass in to the posterior cornu so compactly as to divide a *posterior column* of the white matter of the cord completely from the rest; while the fibres of the anterior root pass to the anterior cornu in scattered bundles, which make by no means so definite a separation between what are termed the *anterior* and *lateral columns.*

The posterior roots are larger than the anterior, and have each a ganglion situated in the invertebral foramen, immediately internal to the point where the anterior and posterior roots unite; but the use of these *spinal ganglia* is unknown. No sooner are the fibres of the roots united in one trunk than they divide into an anterior and posterior division, each containing fibres from both roots. The posterior divisions supply the muscles which erect the back and head, and also a tract of integument extending from the crown of the head the whole length of the back. The anterior divisions supply the whole of the rest of the body: those between the ribs are termed *intercostal*, and pass separately round the visceral cavity, between the intercostal muscles, giving off

cutaneous branches in front and at the sides; but most of the rest are united in plexuses—the first four cervical forming the *cervical* plexus; the last four cervical, and greater part of the first dorsal, joining to make the *brachial* plexus for the supply of the upper limb; and the lumbar and four upper sacral nerves making the *lumbar* and *sacral* plexuses, principally distributed to the lower limb.

141. The functions of the anterior and posterior roots can be exhibited by vivisection only. If the spinal canal of an animal be laid open, and the posterior roots of the nerves going to one of its limbs be divided, while the anterior roots are left uninjured, the animal will continue to move the limb and walk on it as if nothing had happened; but the limb may be pinched, burned, or cut, without any sign of suffering being produced. The distal end of the divided posterior roots may be irritated freely without any effect of any sort being apparent; but if irritation be applied to the end in connection with the cord, the animal will give unmistakable signs of acute pain. If, however, instead of the posterior roots, the anterior roots be divided, the limb which the nerves supply will become immediately powerless; the animal will be no longer able to move it, and it will hang flaccid; but, though paralysed in respect of motion, it will exhibit no paralysis of sensation, for the animal will show as much sign of pain when that limb is pinched as if the nerves had not been touched. When the ends of the divided anterior roots in connection with the cord are irritated, no effect is produced; but when the other ends are irritated, the muscles of the limb are contracted and spasmodic movements take place. From such experiments as these, it is concluded that *the anterior roots of the spinal nerves are motor, and the posterior roots sensory.*

142. Experiment, which reveals thus much with regard to the spinal nerves, throws light also on the functions of the spinal cord. If the cord be cut right across, the animal ceases to have any feeling in the regions supplied with nerves given off from the part of the cord severed from communication with the brain, and has no longer any power to move them; the cord is, therefore, the sole conductor of impressions to and from the spinal nerves. But it is also a

nervous centre taking part in reflex actions; for, if the paralysed limbs be pinched or otherwise irritated, their muscles are contracted so as to draw them up, as if under the influence of the will, but without the animal evincing any knowledge of either the irritation or the movement; the explanation being that the irritation causes an impression to be transmitted by the sensory nerves to the cord, and this is thence reflected in such manner down the motor nerves as to produce a co-ordinated contraction of the muscles.

The same points are still better illustrated in those instances in which the spinal cord has been injured by violence in man, so as practically to divide it. If, in such a case, the soles of the feet are tickled, the limbs are drawn up, but the patient is able to tell you that he is quite unconscious of the whole matter. And here it is to be noticed that reflex movements are occasioned much more easily in such a case than in healthy circumstances, when the communication with the brain is uninjured. It is as if the consciousness exercised a control over the tendency to reflex action; or as if the force were carried on to the brain, instead of being reflected back by the motor nerves. So also, reflex action takes place more easily during sleep than when one is awake; and to this is to be attributed the ease with which, during sleep, deep parts are affected by irritations applied to the surface over them, so that exposure of the chest to cold during sleep is more dangerous than at other times.

When one side of the spinal cord of an animal is divided in the dorsal region, sensation is lost in the hind limb on the opposite side, and movement on the same side as the operation. When a longitudinal division is made down the middle, separating one lateral half of the cord from the other, in the region from which spring the nerves to either fore or hinder limb, sensation is destroyed on both sides, while motion is unaffected. It is plain, therefore, that the tracts through which sensory impressions are conducted cross the middle line soon after the entrance of the posterior roots of nerves into the cord, while motor impressions pass directly down. But immediately above the spinal cord, in the fore part of the portion of the brain termed the medulla oblongata, which

is continuous with the cord, a number of bundles of white fibres are seen crossing the middle line, forming what is called the *decussation of the anterior pyramids.* If a section be made in the middle line, longitudinally through that decussation, it is followed by loss of all voluntary movement on both sides; and all sections on one side of the brain above that point, which injure the power of movement, do so on the opposite side from that on which they are made. Therefore the tracts by which motor impulses pass from the brain to the muscles cross the middle line, just as sensory impressions cross, and each side of the brain is connected with the opposite side of the body, as regards both sensation and motion; but the sensory decussation takes place throughout the spinal cord, and the motor decussation in the medulla oblongata.

It further appears that the conduction of sensory impressions upwards takes place by means of the grey matter of the cord. If a cut be so made as to divide the white substance of the posterior half of the cord, while at a somewhat different level the white substance of the anterior half be divided, care being taken to leave the grey matter as much as possible uninjured, sensation remains unimpaired. On the other hand, if an instrument be introduced with as little damage as possible to the white matter, and be moved so as to divide the whole of the grey, sensation is completely destroyed below the site of the injury. Voluntary movement, as well as sensation, continues when the white columns have been all divided and the grey matter has been left intact; but if the grey matter be completely divided, together with the posterior columns, a certain amount of stimulus to voluntary movement is still conveyed through the anterior and lateral columns. It therefore appears that, while sensory impressions are conveyed entirely through the grey matter, motor impressions are conveyed through both grey and white.

143. Another point in the physiology of the spinal cord is worthy of mention. When the posterior columns are divided in the dorsal region, not only is the operation in itself painful, but sensibility becomes inexplicably exalted in the parts supplied from beyond the lesion, and irritation of either lip of the wound gives great pain. But if the division be made in

the neck, where the origins of the nerves are further separated; and if it be made at a point midway between the origins of successive nerves, not only is it painless, but irritation of the lips of the wound produces no pain. From this it is concluded that the proper fibres of the cord, those not directly continuous with the nerves, are insensible to irritation, and that the pain in the dorsal region is occasioned by irritation to the fibres of the sensory nerve-roots as they pass in to the grey matter, some of them passing upwards and others downwards in their course to the posterior cornu, so that there are divided fibres in connection with the grey matter in both the lips of the wound. And not only are the fibres proper to the cord insensible to direct irritation, but so also is the brain. Slicing the brain away in experiments on animals is painless, and disease of the substance of the brain is painless, although inflammation of the membranes covering it is acutely painful, the membranes having nerves distributed in them. There is thus a very marked difference in the irritability of the fibres of the central nervous system and the peripheral nerves; it does not, however, follow that the active or impressed condition is not of the same description in both.

CHAPTER XIV.

THE NERVOUS SYSTEM—*Continued.*

144. Structure of the Encephalon.—*The brain* or *encephalon*, the portion of the cerebro-spinal axis contained within the cranium, consists of various parts to which different names are given. The part in continuity with the spinal cord, as has already been mentioned, is called the *medulla oblongata.* It is about an inch and a quarter long, and broadened above, and in it both the white and grey matter have a different arrangement from that existing in the cord. In front are the columns called *anterior pyramids*, whose decussation has already been mentioned; outside these are the *olivary bodies*, each containing a grey centre of unknown function; while outside these are two stout pillars called *restiform bodies*, including the posterior half of the lateral columns of the cord, and all the fibres of the posterior columns with the exception of two small bands behind, distinguished as *posterior pyramids.* These and the restiform bodies slope outwards as they ascend, and limit at the back of the medulla oblongata a groove lined with grey matter, continued up from the central canal of the spinal cord. This groove forms the floor of what is called the *fourth ventricle* of the brain, a space between the medulla oblongata and the cerebellum.

Above, the medulla oblongata is crossed in front by a thick transverse band, called the *pons Varolii*, which conceals the continuation of the fibres of the medulla upwards to the cerebrum, and sends its fibres into the cerebellum on each side. Below them the restiform bodies enter the cerebellum, and thus are formed what are called the middle and inferior *crura cerebelli;* while the superior crura are a pair of bands which pass from the cerebellum to the cerebrum. All the

fibres of the medulla oblongata, with the exception of the restiform bodies, pass up to the cerebrum.

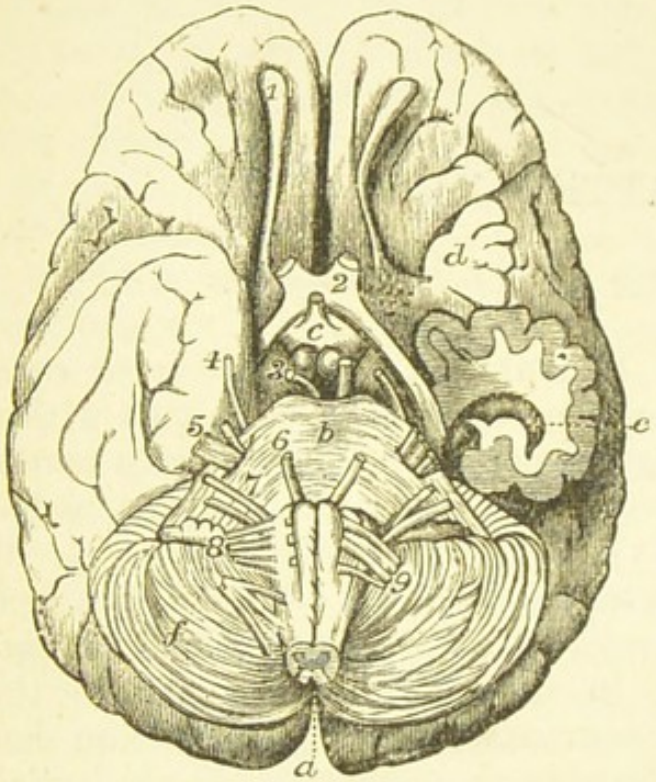


Fig. 99.—Under Surface of Brain. *a*, Spinal cord cut across below the medulla oblongata: on the latter are seen, from the middle line outwards, anterior pyramids, olivary bodies, and restiform bodies. *b*, Pons Varolii; *c*, infundibulum (the pituitary body having been removed); *d*, *gyri operti*, or island of Reil; *e*, section of descending cornu of the left lateral ventricle, displayed by removal of part of the middle lobe of the hemisphere, exhibiting sections of the tænia hippocampi and hippocampus major; *f*, cerebellum. 1, Olfactory bulb; 2–9, successive cranial nerves, marked each with its proper number.

The cerebellum is a large mass of brain substance covered on the surface with grey matter arranged in complex transverse laminæ, with folds of pia mater between them. Its main bulk in the human subject consists of two large lateral lobes; but between these, in a depression or *vallecula* below, there is another portion, the *inferior vermiform process;* while above there is an elevation where the lateral lobes meet in the middle, the *superior vermiform process;* and what gives a special significance to these processes is, that they correspond with a *middle lobe of the cerebellum* in other mammals, which in the lower orders forms the greater part of the structure. In birds there are no lateral lobes, and in osseous fishes the cerebellum is reduced to a mesial pouch, without lamination, whose hollow is an expansion upwards of the continuation of the original central canal. In the human subject this hollow is seen in the roof of the fourth ventricle, in front of the inferior vermiform process.

The medulla oblongata, pons Varolii, and cerebellum, which

may be termed collectively the epencephalon (Owen), occupy an inferior compartment in the back part of the cranium; the cerebellum being roofed in and separated from the rest of the brain above it by a septum of dura mater called the *tentorium cerebelli*, which in some animals, as the cat, even contains a lamina of bone.



Fig. 100.—Mesial Section of Brain. *a*, Medulla oblongata; *b*, pons Varolii; *c*, fourth ventricle, and, behind it, valve of Vieussens; *d*, iter, and, behind it, corpora quadrigemina; *e*, pineal body; *f*, optic thalamus looking into the third ventricle, and, in front of it, an open passage from the third to the lateral ventricle, called *foramen of Monro*; *g*, left layer of septum lucidum bounding the fifth ventricle, and, beneath it, the fornix; *h*, posterior extremity of corpus callosum above the transverse fissure; *i*, optic nerve; *k*, pituitary body; *l*, one of the corpora albicantia.

145. The whole of the brain above the level of the tentorium is included under the name of *cerebrum*, and is connected with the parts below by a neck or *isthmus*, in thickness about the size of a florin, which traverses a space left between the free edge of the tentorium and the body of the sphenoid bone. This isthmus, as seen from below, consists of two thick pillars, the *crura cerebri*, emerging above the pons Varolii, diverging as they ascend, and almost immediately concealed by the two cerebral hemispheres.

The *cerebral hemispheres* in man form by far the most bulky part of the brain. They are covered with a thick coating of grey matter of stratified structure, exhibiting an arrangement of corpuscles and fibres connecting one part of it with another, and the whole with the parts of the brain from which the hemispheres arise, as illustrated in fig. 101. This grey matter is thrown into a number of *convolutions* arranged on a definite plan, though varying in their finer

details in different individuals, and even on the two sides of the brain. They are absent in the lower orders of mammals, become more abundant the higher we ascend in the series, and reach their greatest complexity in man. The only plausible explanation of the use of these convolutions is this, that grey matter requiring a rich vascular supply, and only minute vessels being admissible within it, increase of surface is a necessary condition of increase of bulk, so as to bring its parts sufficiently near the pia mater, in which the arteries for its nourishment divide. Nor is this supposition contradicted by the presence of convolutions in the brains of small animals; for in them the length of capillary travelled by the blood in each circulation is likewise small, and, therefore, the distance to which the blood can penetrate from the pia mater may be supposed to be in proportion to the size of the animal.



Fig. 101.—Grey Matter of the Convolutions: ideal vertical section.

The hemispheres are in contact with very nearly the whole extent of the cranial wall above the tentorium. They are separated one from the other above, behind, and in front by a deep *longitudinal fissure*, into which dips a process of dura mater, called the *falx cerebri*, attached behind along the middle line of the tentorium, and in front to the mesial part of the ethmoid bone. At the bottom of the longitudinal fissure they are united by a thick transverse commissure or bond of junction, the *corpus callosum*, which

presents a thick posterior border in front of the tentorial attachment of the falx, and at its fore part curves downwards behind the ethmoidal attachment of that structure, to become continuous with a thin lamina which completes the floor of the cavity of the brain in the middle line.

The parts of the hemispheres, which project forwards, resting on the anterior fossa of the skull, over the orbits, are called *anterior lobes;* the parts above the cerebellum are the *posterior lobes*, and the parts turning down over the crura cerebri, and resting in the middle fossæ, on the sphenoid and temporal bones, are distinguished as the *middle lobes.*

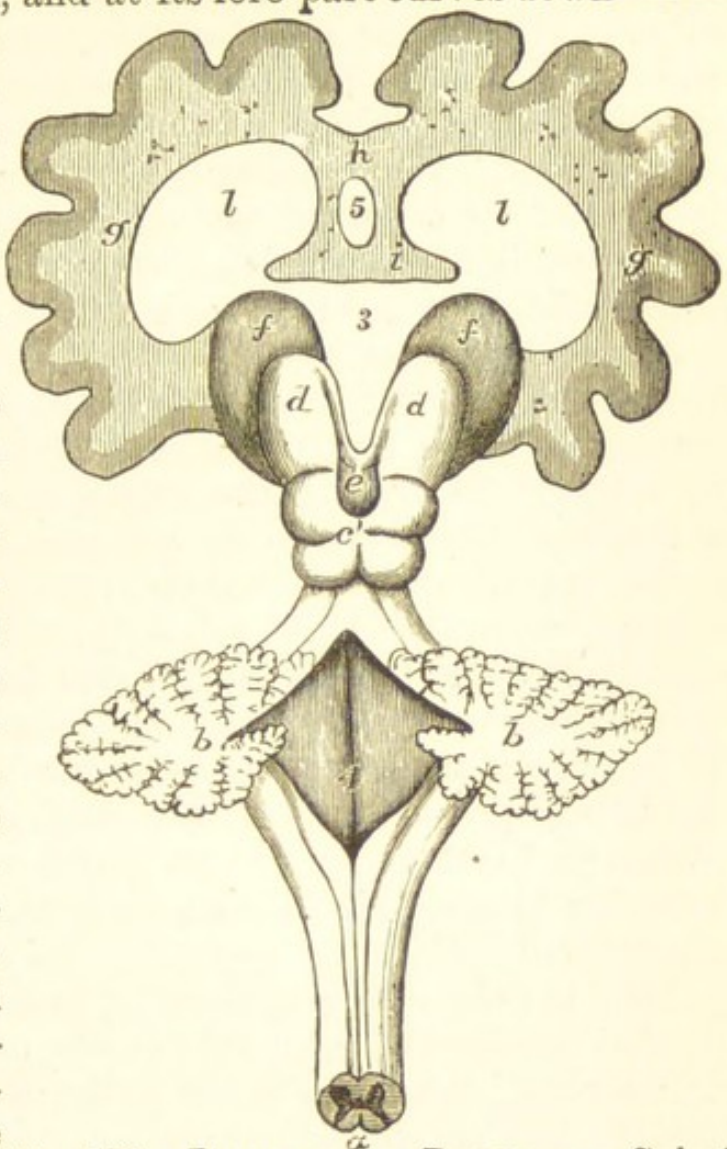


Fig. 102.—Diagram of Brain. *a*, Spinal cord; *b*, *b*, cerebellum divided, and, above it, the valve of Vieussens partially divided; *c*, corpora quadrigemina; *d*, *d*, optic thalami; *e*, pineal body; *f*, *f*, corpora striata; *g*, *g*, cerebral hemispheres in section; *h*, corpus callosum; *i*, fornix; *l*, *l*, lateral ventricles; 3, third ventricle; 4, fourth ventricle; 5, fifth ventricle, bounded on each side by septum lucidum.

146. If a human brain, or still better, the brain of any of the domestic quadrupeds, be examined, and the cerebellum be turned aside from the hemispheres, the isthmus will be brought into complete view, and there will be displayed above it an elevation divided by a crucial depression into four parts, and called on that account *corpora quadrigemina.* Two tracts will also be seen, about half an inch separate, adherent to

the crura cerebri, and proceeding to the corpora quadrigemina from the cerebellum; these are the superior crura cerebelli already alluded to; and, between these, a thin lamina, called *valve of Vieussens*, limited by the cerebellum behind and the corpora quadrigemina in front, forms the roof of the fore part of the fourth ventricle, as that hollow is continued forwards into a narrow canal or *iter* which passes beneath the corpora quadrigemina, and opens in front of them.

By reflecting the hemispheres well forwards off the crura, a pair of large elevations, the *optic thalami*, will be exposed in front of the corpora quadrigemina; and, by dividing the corpus callosum and other structures, so as to permit more complete reflection of the hemispheres, still another pair of elevations, the *corpora striata*, will be seen in front of the optic thalami, and external to them. A soft body, about the size of a pea, the *pineal body*, will be likewise noticed attached by a slender connection in front of the corpora quadrigemina, and overhanging them, imbedded in pia mater. It may be mentioned of this structure that it is remarkable in being present in all the divisions of the vertebrata, although in the lower forms represented by little else than vascular tissue, and in man consisting of degenerated brain structure.

147. On the under surface, or *base* of the brain, the crura cerebri are crossed by two bands of fibres, which can be traced round the crura to the back parts of the optic thalami, and to the corpora quadrigemina. These bands, the *optic tracts*, meet in the middle line, and enclose a lozenge-shaped interval between the crura; at their place of junction, the *optic commissure*, they exchange fibres, and in front of this they diverge as the *optic nerves*, or nerves of sight, to the eyeballs. In the lozenge-shaped interval, between the crura, are seen a pair of white bodies like small peas, the *corpora albicantia*, which are closely connected with the optic thalami, and in front of them a funnel of membranous grey brain matter, the *infundibulum*, leading to a firm body which lies in the sella turcica of the sphenoid bone, and is called the *pituitary body*—a structure certainly not nervous, of function quite unknown, but well developed in all divisions of the vertebrata. Outside the fore part of the lozenge-shaped

interval, on each side lies a deep fissure, *fissure of Sylvius*, separating the middle from the anterior lobe of the hemisphere, and in this is concealed a group of convolutions, the *island of Reil*, corresponding exactly in position with the corpora striata seen from the interior of the brain. On the under surface of the anterior lobes are the *olfactory bulbs*, from which the nerves of smell take origin.

148. There are many other complications in the structure of the brain which have not been alluded to; but probably the best general conception of the whole organ will be obtained by looking now at some of the simpler forms seen in the lower animals, and in development.

If we examine the brain of a codfish, we see at the back part the "posterior" columns of the cord separate one from the other, so as to leave a hollow between them, with a mesial groove, which is continuous with the central canal of the cord, and is the fourth ventricle. Overlying this is a mesial pouch, the cerebellum; in front of the cerebellum are two bodies, the *optic lobes*, likewise hollow; and in front of the optic lobes is another pair of small bodies, which may be called

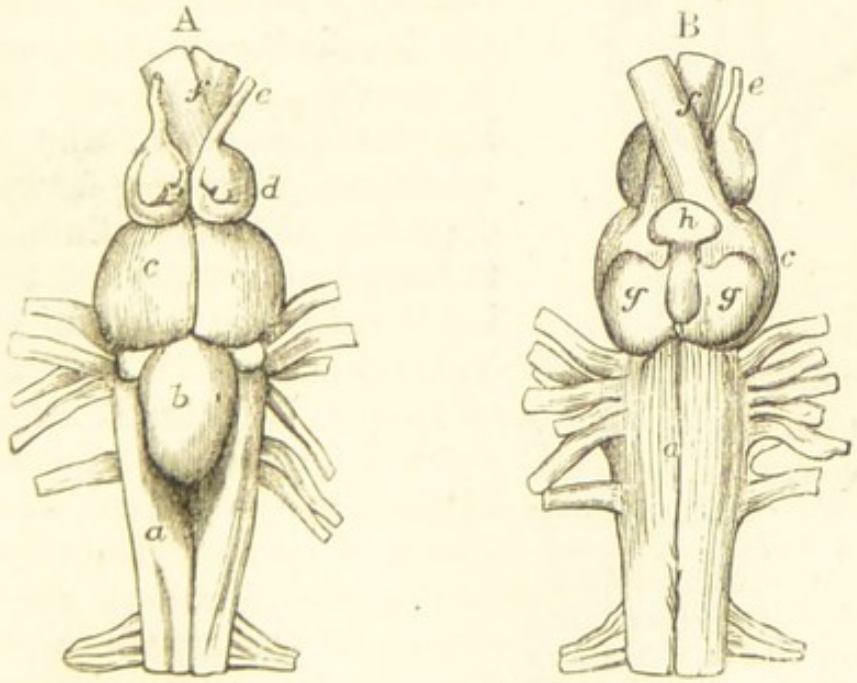


Fig. 103. — Brain of a Cod. A, From above. B, From below. *a*, Medulla oblongata; *b*, cerebellum; *c*, optic lobe; *d*, hemisphere-vesicle; *e*, olfactory bulb; *f*, *f*, optic nerves; *g*, *g*, hypoaria; *h*, pituitary body.

hemisphere-vesicles; while foremost of all are two olfactory lobes or bulbs. In front of the medulla oblongata, on the under surface, are two masses placed close together with a slight elevation between them, the *hypoaria* or inferior lobes, and immediately in front of them the pituitary body. The hypoaria lie beneath the optic lobes; and, in front of them, apparently arising from the optic lobes, are the optic nerves, which, as they pass forwards, cross one over the other, so that each supplies the eye of the side opposite to that from which it arises.

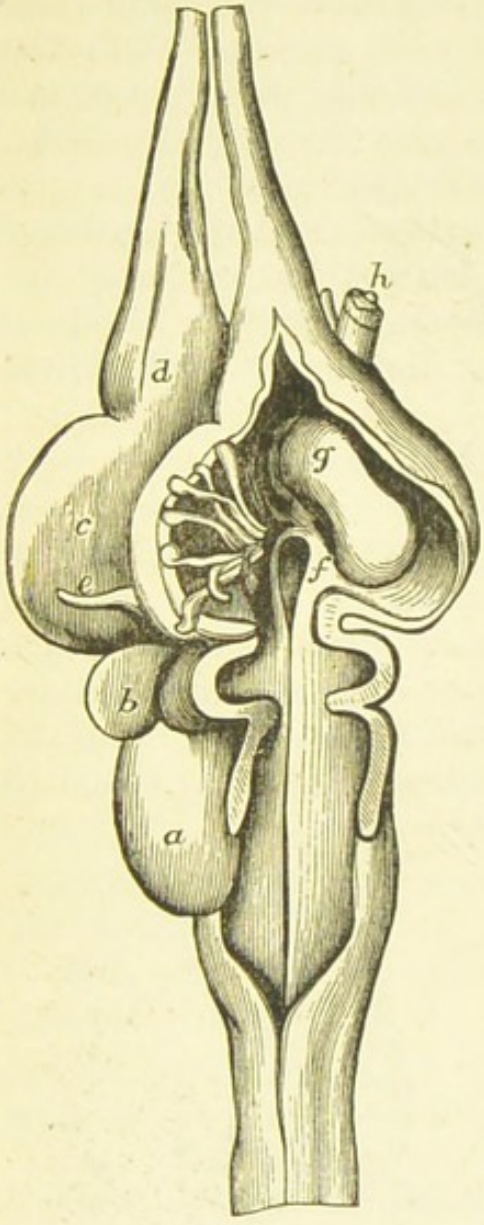


Fig. 104. — BRAIN OF A TURTLE, opened along the right side. *a*, Cerebellum; *b*, optic lobe; *c*, hemisphere; *d*, olfactory bulb; *e*, pineal body; *f*, opening into infundibulum, and, to the left of that, the choroid plexus; *g*, corpus striatum; *h*, optic nerve.

In a turtle's brain there is no difficulty in recognising the medulla oblongata, cerebellum, optic lobes, and olfactory bulbs, and the olfactory and optic nerves; but the hemisphere-vesicles are much larger than in the cod. On opening up the brain, the common ventricle, prolonged forwards underneath the cerebellum, is seen to turn downwards, and terminate in a *cul-de-sac* at the pituitary body; and, above this point, it bifurcates to extend through the hemisphere-vesicles and olfactory bulbs. In the floor of each hemisphere-vesicle is a thickened part, the corpus striatum; and in the cavity of the vesicle there is a digitate vascular expansion of the pia mater, the *choroid plexus*, which enters from the exterior at a spot on the mesial side of the vesicle, at its back part, where there is a breach of continuity in the brain

matter of the vesicular wall. There is also another vascular development inwards of the pia mater, between the cerebellum and the medulla oblongata, the choroid plexus of the fourth ventricle. In this brain we miss the hypoaria of the brain of fishes; but it may be noted that, close to the position where they might be expected, there is seen in the interior a thickening at the sides of the mesial canal, where it dips down at its termination. The optic nerves at their decussation are partially blended in an optic commissure, and behind that point are inseparable from the brain, and named optic tracts.

In the brain of a bird, for example the turkey, the cerebellum is no longer a mere hollow vesicle; its cavity is minute, its surface covered with grey matter, and thrown into deep transverse laminæ. The optic lobes project laterally, and even downwards, instead of upwards. There is a thorough decussation of the optic tracts. The hemisphere-vesicles when opened are seen to be covered with a very thin lamina, and filled up by the projection upwards of the corpora striata, so that what are usually called the hemispheres of birds, may be said to consist principally of corpora striata. Between the hemisphere-vesicles and the optic lobes there is a thick neck of substance, but no very important mass deserving a name.

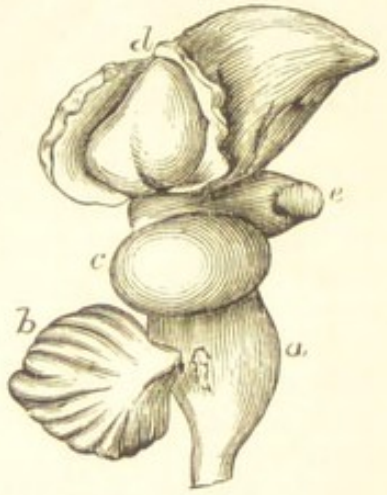


Fig. 105. — Brain of a Turkey. *a*, Medulla oblongata; *b*, cerebellum; *c*, optic lobe; *d*, roof of hemisphere reflected to show corpus striatum; *e*, optic nerve.

149. If we pass now to a mammalian brain in a fœtal stage, such as the lamb's brain in fig. 106, we have little difficulty in recognising corresponding or homologous structures. The medulla oblongata and cerebellum are obvious. In front of the cerebellum are the optic lobes, placed superiorly as in reptiles and fishes, and constituting the structures divided in mammals by a crucial depression into four parts, and called the corpora quadrigemina. In front of these are the hemisphere-vesicles containing the corpora striata; but a little

care suffices to turn the hemisphere-vesicles outwards, and then come into view between them the *optic thalami*, in this early stage united, like the corpora quadrigemina, one with the other, over the mesial canal, and covered with pia mater. Along by the anterior and outer margin of each of the optic thalami, a fissure is seen between it and the hemisphere-vesicle, at which, as in the turtle, a large choroid plexus enters; and the ruptured margin of the vesicle has its edge turned away from the middle line into the interior of the cavity. At a later period this everted part adheres, across the middle line, with its fellow of the opposite side; and thus is formed a structure peculiar to mammals, the *fornix*, separated from the corpora quadrigemina and optic thalami by a *transverse fissure*, containing the invaginated part of the pia mater supporting the choroid plexus, and called the *velum interpositum*. At a still more advanced period of embryonic growth, the adjacent surfaces of the hemisphere-vesicles become joined together by development of the corpus callosum, which is united posteriorly to the back part of the fornix, then arches forwards at a higher level, and turns downwards in front so as to enclose a mesial space above that body. The parts of the walls of the vesicles limiting this mesial space continue very slender, and constitute the *septum lucidum;* and the space itself is termed the *fifth ventricle*. The cavities of the hemisphere-vesicles are called the *lateral ventricles;* the space between the velum interpositum and optic thalami, as well as between these bodies, is the *third ventricle;* the *fourth ventricle*, as has already been stated, is the space between the cerebellum and medulla oblongata; and the canal continued forwards from this, beneath the corpora quadrigemina, is called the *iter* (*a tertio ad quartum ventriculum*) or *aqueduct of Sylvius*.

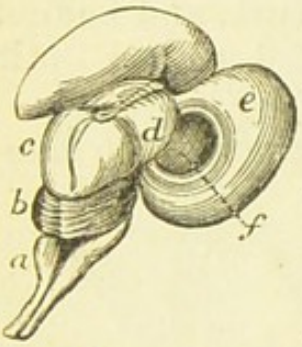


Fig. 106.—Brain of Embryo Lamb, from above and the right side. *a*, Medulla oblongata; *b*, cerebellum; *c*, corpora quadrigemina; *d*, optic thalami; *e*, right hemisphere-vesicle reflected; *f*, corpus striatum. Round the opening into the lateral ventricle is the rudimentary fornix. The choroid plexus, which, at this period, is exceedingly large, has been removed.

In the developed brain, the fissures into the lateral ventricles, converted by the adhesion of the lateral halves of the fornix into one transverse fissure as pointed out, extend round the crura cerebri to the extremity of the middle lobe of the brain at the inner end of the fissure of Sylvius; and the extensions of the lateral ventricles, into which they open, are called the *descending cornua;* the margin of the fissure in each descending cornu is bounded by a slender prolongation of the fornix, called *tænia hippocampi*, because it lies beside a convexity of the floor of the cornu, the *hippocampus major:* the *posterior* and *anterior cornua* being blind pouches in the corresponding lobes. In front, the fornix dips down in the form of a couple of pillars in front of the optic thalami; and these pillars, after dipping to the base of the brain, and forming the corpora albicantia, twist upwards, and enter, each one, the optic thalamus of its own side. The fornix is thus a band of junction between the back parts of each hemisphere and the corresponding optic thalamus.

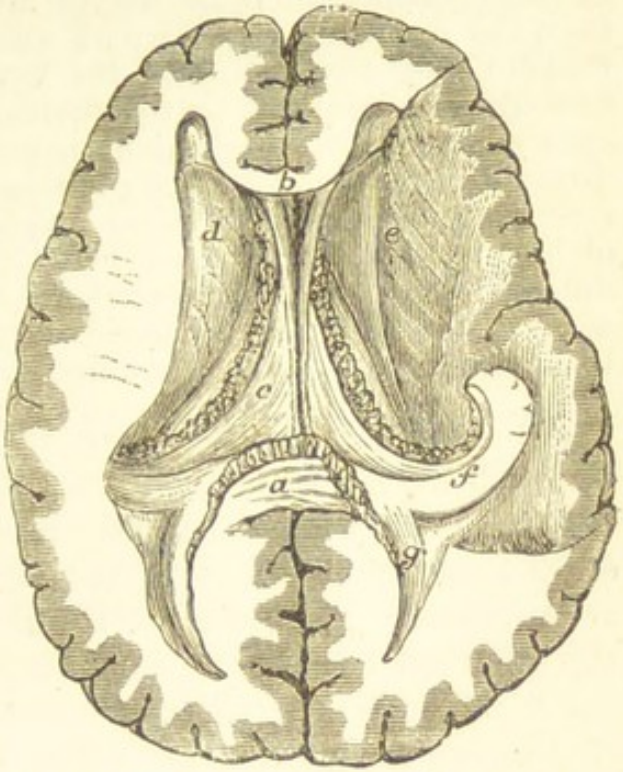


Fig. 107.—The Lateral Ventricles. *a*, Posterior border of corpus callosum; *b*, front of corpus callosum, and below it fifth ventricle, bounded by the layers of the septum lucidum; *c*, fornix, and, beyond it, the choroid plexus; *d*, corpus striatum, and, between it and the fornix, a portion of the optic thalamus; *e*, section of corpus striatum; *f*, descending cornu of lateral ventricle, with hippocampus major in its floor, and tænia hippocampi in front; *g*, hippocampus minor in the floor of the posterior cornu.

In leaving this difficult subject, it is necessary to point the student's attention to one point which appears to have escaped the attention of anatomists, but which, to me at least, is pretty obvious from considerations alluded to in the preceding description, namely,

that the hypoaria of fishes correspond with the optic thalami of mammals. In corroboration of this view, it may be mentioned that in various fishes the optic nerves arise from the hypoaria as well as from the optic lobes or corpora quadrigemina. No doubt the optic thalami look upwards, and the hypoaria downwards; but in their first development the optic thalami are directed downwards, the embryonic vesicle from which they are derived (p. 287) being turned directly down; and in the position of the optic lobes of birds, as compared with those of other animals, we have a parallel instance of homologous brain-masses being developed in the adult state in different directions. My excuse for mentioning this in an elementary work is, that without recognition of this hitherto unappreciated point the simplicity of the brain cannot be recognised.

150. Cranial Nerves (fig 99).—From the under surface of the brain, a number of nerves emerge which are termed cranial. They differ greatly among themselves, both in size and function, and are variously numbered by different anatomists. But none of the methods of enumeration have the smallest title to be considered scientifically accurate; for they all agree in attempting to reduce to a linear series structures which do not serially correspond; therefore it is well to be guided by motives of convenience, and follow the plan generally adopted by English writers.

The *first* pair, the *olfactory* nerves, devoted to the sense of smell, are brushes of exceedingly soft and delicate filaments, given off from the under surface of the olfactory bulbs already alluded to as lying beneath the anterior lobes of the cerebral hemispheres. These olfactory bulbs are much more largely developed in the majority of mammals than in man, and in some of them have cavities communicating with the interior of the brain. They are, in fact, vesicular outgrowths from the brain.

The *second* pair, the *optic* nerves or nerves of sight, come off, as has been already explained, from the optic commissure. Development shows that they also are vesicular outgrowths from the brain.

The *third*, *fourth*, and *sixth* pairs are all of them small motor nerves, which supply muscles of the eyeball, the third and fourth appearing above the pons Varolii, and the sixth below it.

The *fifth* pair, the *trifacial* nerves, are large trunks, whose fibres take origin in the medulla oblongata, and pierce the

pons Varolii. They resemble the spinal nerves, in consisting each of a motor and sensory root; and in the sensory, which is much the larger, having a ganglion on it. The sensory part separates into three divisions, and supplies the scalp in front of the ear, and all the face, as well as the teeth and a large part of the tongue, with sensation; the motor part mixes with the third division of the sensory, and is distributed to the muscles of mastication.

The *seventh* pair consists of two portions, which emerge on the surface of the brain, in the angle between the crus cerebri, the cerebellum, and the medulla oblongata, and enter the temporal bone together. One portion, the *portio mollis* or *auditory* nerve, is the nerve of hearing, and is distributed within the bone; the other, the *portio dura* or *facial* nerve, is conducted through the temporal bone, and proceeds to the face to supply the muscles of expression. Within the temporal bone, the portio dura gives off the *chorda tympani*, which traverses the tympanic cavity, and joining with the lingual branch of the fifth nerve passes to a small ganglion, the submaxillary ganglion, and is the nerve alluded to at p. 64 as governing the secretion of the submaxillary gland.

The *eighth* pair comprises three pairs of trunks, which arise from the medulla oblongata, and leave the skull by one pair of apertures. (1.) The *glossopharyngeal* nerves supply sensory branches, devoted to the sense of taste, to the back of the tongue, and motor and sensory branches to the pharynx. (2.) The *pneumogastric* or *vagus* nerve is both sensory and motor; it descends on the œsophagus to the stomach, and filaments may be traced from it even to the viscera. It supplies, in its course, branches to the pharynx, larynx and lungs, and the heart, and is intimately associated with the sympathetic, in connection with which it will be again referred to. (3.) The *spinal accessory* is entirely motor, and consists of two parts, of which one, the accessory, joins the pneumogastric, while the other is distributed to two large muscles, the sterno-mastoid and trapezius.

The *ninth* pair, or *hypoglossal* nerves, are the motor nerves of the tongue. They emerge from the medulla oblongata behind the olivary eminences, which separate them from the eighth pair in front of these eminences.

151. Functions of the Encephalon. — The medulla oblongata is principally remarkable for its connection with respiration. Respiration is a reflex act in which a stimulus is apparently furnished by the unaërated blood, an impression is conveyed to a nervous centre, and an impulse proceeds thence, producing a co-ordinated movement of the muscles of the chest. No doubt these movements are capable of considerable control by the will, but they are continued in conditions of unconsciousness; and, although by an effort they may be delayed for a moment, the impulse soon becomes imperative, and breaks through all restraint. The centre engaged in this reflex action is the medulla oblongata; and that part of the brain is, therefore, of the utmost importance for the continuance of life. The whole of the rest of the brain may be gradually removed without any interference with respiration; also the spinal cord may be divided at different levels; and only when the section is made high up in the neck, above the origin of the (phrenic) nerves which supply the diaphragm, is respiration materially affected; but when that portion of the medulla oblongata is removed from which the vagus nerves take origin, respiration ceases at once, and the animal dies. This does not arise from mere interference with the functions of the vagus; for that pair of nerves may be divided, and respiration continues, although, no doubt, the entrance of air into the windpipe is interfered with by paralysis of the larynx, and even when that inconvenience is remedied by an artificial opening into the trachea, death results after a time from the irritation of foreign bodies entering the lungs. The sudden death which follows removal of the upper part of the medulla oblongata is, therefore, only to be accounted for by that part being the centre from which the respiratory movements receive their impulse. It is likewise the centre engaged in the act of swallowing, which, like respiration, continues to be performed after removal of the rest of the brain.

Being the centre which governs respiration, the medulla oblongata is likewise to be regarded as the centre engaged in various spasmodic actions of an occasional kind. In *coughing*, an irritation of the pneumogastric nerve excites first a spasmodic closure of the glottis, and afterwards a convulsive

expiration, by which the air forces its way out at the contracted opening. In *sneezing*, an irritation of the fifth nerve leads to a convulsive expiration with the glottis open, but the tongue raised so as to divert the expelled air from escaping by the mouth, and send it through the nostrils. In *hiccough*, the glottis is shut, and a momentary spasmodic contraction of the diaphragm and abdominal walls takes place; while in *vomiting*, a similar action is more prolonged. The walls of the stomach appear to take no part, or only a secondary part in vomiting; for a dog, in which the stomach was replaced by a bladder, was made to vomit perfectly, by injection of tartar emetic into its veins (Magendie). The excitation of the reflex action in vomiting is not always the same, for it may be the result of irritation of the fauces, or may be induced by nausea, an ill-understood sensation depending on disturbance of the cerebral circulation.

It may be furthur mentioned that irritation of the medulla oblongata in the floor of the fourth ventricle, produces artificial diabetes, that is to say, sugar in the urine. This it does by paralysing the blood-vessels of the liver, and so leading to an abnormal amount of sugar being thrown into the blood.

152. When one of the crura cerebri or optic thalami is divided or destroyed, total paralysis of both sensation and voluntary movement is the result. When the cerebellum is removed, the power of standing, and of all steady and definite movement is lost, although the animal continues to move its limbs in its attempts to stand and walk. It seems as if the impulse to voluntary movement descended from the optic thalami, while the power of co-ordination of movements resided in the cerebellum.

When the corpora quadrigemina are destroyed, total blindness results; and when only one side is destroyed, there is blindness in the opposite eye, a result to be accounted for by the crossing of fibres in the optic commissure. It is curious that injury to the optic thalami appears to have no effect on vision, although the optic tracts arise in part from those bodies, as well as from the corpora quadrigemina.

With regard to the corpora striata, experiment gives none but negative evidence, while the study of development and

comparative anatomy show them to be properly considered as part and parcel of the cerebral hemispheres.

It has already been pointed out that in early development the corpora striata make their appearance in the floor of the hemisphere-vesicles; they are covered with grey matter on the surface, continuous with that which lines the whole cylinder of the cerebro-spinal axis; and they have other patches of grey matter within them, which, when cut across, present the striated appearance from which the bodies are named; and the lowest of these is in communication with the island of Reil, so that a communication is here established between the grey matter lining the cerebro-spinal canal, and that of the cerebral convolutions. We have seen also that in different animals, while the corpora striata and cerebral hemispheres are intimately connected, they are very variously proportioned one to the other; for, in fishes, one pair of structures represents both; in the turtle a small corpus striatum lies at the bottom of each hemisphere, looking into the interior of its vesicle; and in birds, the islands of Reil and corpora striata form the greater part of the hemispheres: indeed, in the common fowl, the hemispheres consist of scarcely anything else; and when a physiologist, in vivisection, slices what he terms the hemispheres from a fowl, he in reality, removes in the upper slices the corpora striata covered with a thin membrane representing the roof of the hemispheres.

153. The cerebral hemispheres are the parts of the brain connected with the higher operations of intelligence. The experiment just alluded to, as performed on fowls, can be performed less easily on mammals; but the result in both cases is the same, namely, that the larger the part of the hemispheres taken away, the less intelligence remains. The effect of removal of the hemispheres from a pigeon is graphically described by Dalton, the American physiologist. "The bird remains sitting motionless on his perch, or standing upon the ground, with the eyes closed, and the head sunk between the shoulders. Occasionally, the bird opens his eyes with a vacant stare, stretches his neck, perhaps shakes his bill once or twice, or smooths down the feathers upon his shoulders, and then relapses into his former apathetic con-

dition. This state of immobility, however, is not accompanied by the loss of sight, of hearing, or of ordinary sensibility. All these functions remain, as well as that of voluntary motion. If a pistol be discharged behind the back of the animal, he at once opens his eyes, moves his head half round, and gives evident signs of having heard the report; but he immediately becomes quiet again, and pays no further attention to it. . . . Longet has found that by moving a lighted candle before the animal's eyes in a dark place, the head of the bird will often follow the movements of the candle from side to side, or in a circle. . . . . The limbs and muscles are still under the control of the will; but the will itself is inactive, because, apparently, it lacks its usual mental stimulus and direction."

It is difficult, however, to say how far that part of the nervous system extends on which the existence of consciousness is dependent. Possibly it reaches over a greater area in the lower than the higher animals. A decapitated frog can be made to leap, and will thrust objects aside when irritated; and although these movements are sometimes said to be reflex, it is not easy to understand how they can be so. But, undoubtedly, all the higher manifestations of consciousness which constitute intelligence, depend on the cerebral hemispheres. On comparing different kinds of mammals, it is found that increased development of the hemisperes and complexity of the convolutions into which their surface is thrown are associated with increased intelligence. In rodent animals, such as rabbits, the hemispheres are small and smooth, while in apes, they are proportionally larger, and are more highly convoluted than in any animal but man. Even in the higher races of men, the convolutions are more complex than in the lowest. The circumstance that disease of the grey matter of the hemispheres is liable to be accompanied with intellectual derangement, likewise points to a connection between the hemispheres and intelligence.

But if the *sensorium*, or seat of consciousness, be confined to the encephalon, the question arises: How do we become aware of impressions made at the surface of the body? The old physiologists believed in the diffusion of consciousness

through a *sensorium commune* extending throughout the nervous system; but the loss of all sensation in parts whose nervous communication with the brain has been severed puts an end to that theory. At the present day, it is customary to say that the mind refers impressions received at the brain to the extremities of the nerves by which they have been conducted. But it is perfectly certain that there is no separate nervous communication between the brain and each point of the surface of the body in which sensations can be distinguished. The question is of the utmost interest psychologically, but is still unsettled. Personally, I believe that the only tenable theory yet put forward is that which I have elsewhere broached, viz., that while consciousness is dependent on the encephalon, the sensorium extends thence, so far as there is, at any moment, unbroken continuity of nerves in the active or impressed condition.

154. It is frequently supposed that different parts of the hemispheres are connected with different faculties of the mind; and the opinion that the frontal, parietal, and occipital regions are devoted respectively to the intellectual powers, moral faculties and appetites, or in some other way differ in function, is not confined to the believers in the system founded by Gall, and commonly known as *phrenology*. But there is no foundation for any such supposition. On the contrary, the evidence points to an opposite conclusion. Serious damage to the hemispheres, of a limited description, often occurs without loss of life, and such cases may occur without any apparent interference with intellectual functions. A tumour may press on some particular part of a hemisphere without producing any disturbance, and bodies have penetrated the brain, and portions of brain protruding from wounds have been removed by surgeons, without any obvious impairment of the mental faculties. Not only so, but the kind of disturbance which is liable to occur from such injuries does not vary according to the site of lesion, so as to affect, in one instance, the faculties of perception, in another the disposition, and in a third the powers of volition, as might be expected, were phrenological theories true.

In recent years a little colour has seemed to be given to the theory of separate organs in the cerebral hemispheres, by

the discovery that imperfections of speech, constituting a condition called *aphasia*, arise from disease of a limited portion of the brain, immediately outside the island of Reil, particularly on the left side. In these cases the affections of speech are very various, but always depend on mental deficiency and not on paralysis of the tongue. In some instances there is total dumbness, in others, incapability of clearly uttering any word; and in a larger number of cases, certain words and phrases are pronounced perfectly, but they are not the words which convey the idea which the patient wishes to express. Perhaps some word is repeated on all occasions; and even when the right expression is suggested to the patient, he is unable to employ any other than that which he keeps repeating, although quite conscious of his blunder. The very variety, however, of these cases of aphasia, shows that they do not arise from damage to the organ of a specific faculty. It is more rational to recognise in them the result of a lesion which interferes with the consentaneous action of the different parts of the hemisphere, by attacking the fibres where they emerge from the corpus striatum to proceed to every part. And we may well believe that consentaneous action of the hemispheres is especially required in so complex a process as conversation, which requires a number of distinct mental operations to be carried on at one time.

155. A consideration of the different mental operations required in talking, is exceedingly instructive. The attention of the speaker is directed principally to the idea which he wishes to express. And, if engaged in a continuous discourse, he must at the same time think of the sequence of his utterances, and especially what is immediately to succeed the sentence with which he is engaged. The choice of words will also occupy his mind to a recognisable degree; but apart from this intentional choice, there is the choice of the simpler grammar and names of objects, which are so habitual that we fail to separate them in our thoughts from the ideas which they express. Still less attention is devoted to the complex movements of the organs of voice and speech; although they are all performed in the service of the mind, and it was with mental effort in infancy that we learned, by

means of observation and imitation, to accomplish them. Gesture also accompanies speech without attention being directed to it; and, except in exceedingly rare cases of mental absorption, the speaker during all these mental actions is able to note what is going on around him.

The exactitude of the tongue in speech furnishes but one of many instances of complex movements performed under mental stimulus, without perceptible attention being given to them; the movements of the limbs in walking afford another example; and these are the kinds of acts which are sometimes, although erroneously, called *unconscious cerebration.* They are precisely like other voluntary movements, only the effect of habit on the mind is such that the mind gives the stimulus to the nervous system to accomplish them, without expenditure of attention. But the mind not only may initiate commands without devoting attention to them; it may receive impressions in like manner; and it often happens that an impression received without perceptible attention will lead to a customary act. Thus, a rider, without conscious effort, accommodates himself to the movements of his horse, and a sailor balances himself on board a ship. An act so performed may well be called *automatic;* but the term *acquired reflex action* sometimes given to it is of more doubtful propriety; for in true reflex action there is an unbroken sequence of physical changes, while, in such actions as these, a physical cause produces a psychical effect, and psychical change is the stimulus to the movement.

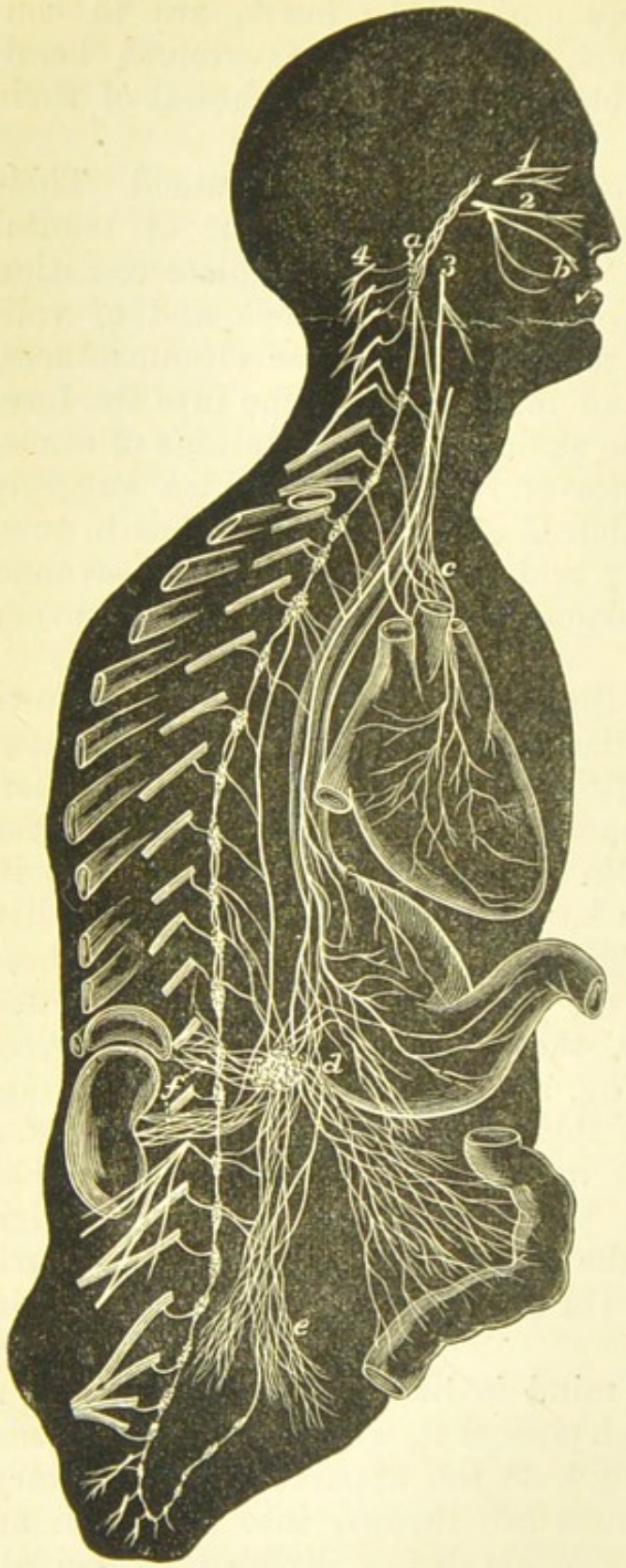
156. The most moderate exercise of the mental faculties, the mere continuance of consciousness, appears to involve exhaustion of the brain, and necessitates restoration of its vigour by *sleep.* Of the physical relations of sleep very little is known. It has been pointed out that the circulation in the brain is less active during sleep than at other times, but this is not proved to be constant; nor, supposing it to be so, does it sufficiently explain the state of unconsciousness. It may, however, be fairly assumed that the passage of the brain into a condition of inactivity, is the cause of the cessation of mental action. Just as some muscles, for example the fibres of the heart, move ceaselessly, while others require rest, so some of the nervous centres, including the

ganglia which immediately govern the heart, are in continual action, while others, including the cerebral hemispheres, require considerable pauses for the renewal of their activity.

Dreams, like sleep, are only imperfectly understood. Their main peculiarity consists in a certain amount of mental activity existing, with complete or almost complete cessation both of impressions from the organs of sense, and of volitionary impulses to the muscles. In these circumstances, the pictures of memory and imagination come into the foreground, unrepressed by the stronger representations of sense, and assume the appearance of reality. One idea suggests another, and each one which is sufficiently vivid has in turn the semblance of reality; and from this arise the strange shifting of scenes and curious confusions with which every one is familiar.

Apparitions, and other illusions from mental causes, are to be accounted for in a similar way. Many well authenticated instances are on record of figures appearing to persons otherwise perfectly sane. Among them may be mentioned the case of Nicolai, the Berlin bookseller, who saw persons in the room with him, when he knew that there was in reality no one present; but so far from being disturbed by these apparitions, made them the subject of study and recorded the details. In his case, they were traced to the neglect of a customary bloodletting, and disappeared after leeching. In such rare occurrences there is the same prominence of a mental picture as occurs in dreams; but, in dreams, that prominence results from the absence of sensations originated by contact with the outer world; while, in apparitions, it is the consequence of some pathological action within the brain.

In *somnambulism*, the mind is likewise occupied as in a dream; but the ideas which possess it, while others have been excluded, become so strong that the apparatus of voluntary movement and of the senses are thrown into action in an automatic fashion, the attention being directed to the all absorbing imagination. The *mesmeric* trance is a very similar condition, in which the will is altogether governed by the ideas impressed by another person.



157. The Sympathetic System. — This is the portion of the nervous system by which the viscera are principally supplied. The primary part consists of two chains of ganglia, one on each side, in front of the vertebral column, called the *prevertebral chains*, or the *great sympathetic*.

In the dorsal, lumbar, and sacral regions, these chains present a ganglion for almost every spinal nerve, and each spinal nerve has a twig of communication with its corresponding ganglion. Inferiorly the two chains meet together in a *ganglion impar* in front of the coccyx. In the neck

Fig. 108. — SYMPATHETIC SYSTEM OF NERVES. *a*, Superior cervical ganglion, from which the sympathetic chain is continued regularly downwards as far as the coccyx, where it communicates with its fellow. It is likewise continued irregularly in the cranium. At *b*, the chains of opposite sides communicate behind the upper incisors; *c*, cardiac plexus; *d*, solar plexus; *e*, hypogastric plexus; *f*, renal and supra-renal plexus. 1 and 2, First and second divisions of fifth cranial nerve; 3, vagus nerve; 4, first spinal nerve.

there are only three ganglia, but they communicate with all the cervical nerves; and the uppermost ganglion, which is the largest, sends branches upwards into the skull, round the internal carotid artery. Within the skull the chain can be traced, in somewhat irregular fashion, communicating with the fifth and other nerves; and two cords pass forwards, one on each side of the septum of the nose, to unite on the palate behind the incisor teeth, and form the superior termination of the chain, at the spot which I once demonstrated, and still hold, to be the arch of the foremost segment of the skull.

In the neck, the sympathetic chains give off branches to the heart; and in the chest they send twigs to the lungs. From the thoracic ganglia there likewise descend three pairs of splanchnic nerves, which form a very large plexus in the upper part of the abdomen, the *solar plexus*. This plexus contains two large *semilunar ganglia*, and sends branches along the blood-vessels to the stomach, liver, intestines, and other abdominal viscera, and communicates by large branches on the aorta with the hypogastric plexus, which is placed within the pelvis and supplies the viscera there.

The sympathetic system is especially devoted to the supply of the viscera and blood-vessels, but it is by no means independent of the cerebro-spinal system; as is proved anatomically by its close connection with the pneumogastric nerves and its communications with the spinal cord, and physiologically by the conveyance of influences through it from the cerebro-spinal axis. That nervous influence is so conveyed is illustrated by many familiar effects of mental conditions on different visceral actions, but still more explicitly by the effects of experiments on the nerves to the blood-vessels.

158. The *vaso-motor nerves*, or *nerves to the arterioles*, form an important part of the sympathetic system. When in action, they contract the muscular coats of the vessels, and limit the amount of blood to the part supplied by them; and it has been already pointed out (p. 125), that division of the sympathetic in the neck causes paralysis, and consequent distension, of the arteries of the head. But division of the spinal

cord in the cervical region produces paralysis of the blood-vessels of the whole body; and other experiments show that the great vaso-motor centre of all the vessels is situated in the neighbourhood of the medulla oblongata; and that while the vaso-motor nerves of the head and neck leave the cord at the base of the neck to reascend in the sympathetic, those to the rest of the body issue by the anterior roots of the spinal nerves.

The *heart* receives its nervous supply partly from the sympathetic, and partly from the pneumogastric nerve. Irritation of the sympathetic accelerates its action, as also does irritation of the branch of communication between the spinal cord and the inferior cervical ganglion of the sympathetic. Thus the heart may be said to receive its motor supply similarly to the arteries. But what is much more remarkable is, that irritation of the pneumogastric diminishes the frequency of the heart's action, and if carried sufficiently far arrests it. This it does by preventing in some way the normal impulse to contraction; for the arrested heart has its walls relaxed, and contracts on application of direct stimulus, and therefore the *inhibitory* action, as it is called, cannot be explained either by spasm or exhaustion.

There are other instances of similar inhibitory actions. Thus, if one of the sensory nerves of a rabbit's ear be divided, and its central end stimulated, the vessels of the ear dilate; and in the case of the submaxillary salivary gland of a rabbit, while irritation of the sympathetic contracts the blood-vessels, irritation of another nerve dilates them and increases the secretion. Such phenomena have led to the use of the expression *inhibitory nerves;* but the use of that phrase must not lead it to be supposed that the inhibitory action is in any case direct. The dilatation of the vessels of the submaxillary gland is explained by the consideration that nerves end in the secreting cells, and that increased action of the cells may well attract more blood; and cases which cannot be explained in a similar fashion may possibly be all of them the result of action on nervous centres, and not on terminal organs. It is not conceivable that nervous impression could have two antagonistic effects on a muscle,

according as it came by one nerve fibre or another; but the heart has ganglia within it, and it can be understood that a nervous current from one source might divert another current out of its usual channel, or possibly oppose its passage through a ganglion.

CHAPTER XV.

THE SENSES.

The senses are five in number, namely, common sensation and the four special senses; and the special senses are naturally arranged in two pairs, taste and smell giving sensations of a simple kind, while the sensations of sight and hearing are of a far more complex description, and produced by the action of exceedingly complex organs.

159. Common Sensation includes *feeling* and *touch*. In feeling, the mind has simply the idea of a condition of the body; while from touch it receives an idea of properties of external objects. Pain, tickling, and a sense of warmth or cold are instances of feeling which are not necessarily accompanied with touch.

Although the variety of common sensation constituting touch is confined to the surface of the body and to the mouth, and the skin, with its nerve terminations, already described (p. 68), is the principal organ of this sense, feeling is not confined to the surface. Pain, as we all know, may be felt in the deep parts; and there is another form of feeling in deep tissues which has excited a good deal of attention, namely, *muscular sense*. Although the mind is unconscious of the particular muscles which exist in any part, it is yet able to regulate their contraction, so as to produce and direct every movement with precision, which it could not do without a knowledge of the position of the parts. No doubt this knowledge is only partly due to a sense of the state of the muscles, as may be illustrated by the consideration that in moving one's fingers there is little sense of action save in the fingers themselves, although we know that the muscles which flex and extend the fingers are really in the forearm; but we can make the muscles of a limb rigid by an effort of the will

without changing the position of the limb, and this rigidity is accompanied with a peculiar sensation. Also, the sense of muscular exhaustion or weariness is derived, in part at least, from the muscles themselves; and the *sense of resistance* consists partly in a feeling of the expenditure of a certain amount of muscular exertion which meets with opposition. That, however, is only one element in the sense of resistance, and one which comes into play only when there is muscular action; but suppose that the head is reclined, and that something comes in contact with it, the force of the contact and the hardness or softness of the object are both appreciated, although no muscles are brought into play, and although there are none in the part which has been touched. Obviously, in such circumstances, what is appreciated is the character and degree of the pressure exercised against the skin.

And now, if the student, having considered these different varieties of feeling, will attempt to analyse what touch consists in, he will find that it is not a different sense from feeling, but only an application of it, accompanied with a judgment of the mind. The hardness or softness, roughness or smoothness, of the object touched, exercise different kinds of pressure on the skin, and can be examined by means of more or less muscular exertion; while the sense of the position of the touching organ enables us to determine the form and extent of the object.

The sense of *temperature* has some claim to be considered as distinct from all others; for rare instances are on record of the loss of this sense in a limb, leading to the exposure to severe injury from burning, while the other varieties of common sensation remained.

160. An important element in delicacy of touch consists in the localization of the feeling excited by contact; and an attempt has been made to measure the degree of sensitiveness of different parts of the surface, by ascertaining how nearly two points, say the points of a pair of compasses, may be approached one to the other, and yet be distinguished as separate when simultaneously laid against the skin. Judged in this way, the tongue is more sensitive than the fingers, and the back has very little sensation. But if the student try the experi-

ment for himself, he will find that this is a test simply of the power of localization of sensation, and that of the three parts mentioned, the back is the most acutely affected by a given amount of pressure; it is the part on which the pressure of a fine point most quickly causes pain. The reason of this is not very far to seek. The epidermis of the back is much thinner than that of either the tongue or the fingers, and therefore when an object touches it, the nerve-extremities are less protected. On the other hand, the nerve-extremities are far more numerous in the tongue and fingers, and a given irritation produces a slighter impression on a greater number of them. When the impressed condition of a nerve is carried to a certain pitch of intensity, pain is the result; but when a number of nerves are impressed in a slighter degree, increased information is obtained. Thus it happens that the back, with few nerves and comparatively thin skin, is highly sensitive, but a very poor tactile organ; while the fingers, with many nerves and thick cuticle, bear rougher usage without pain, at the same time that they are useful for touch.

A very common experiment illustrates that a distinction must be drawn between the localization of impressions on the surface of a touching organ, and the sense of the position of the organ, spoken of in a previous paragraph. If the middle finger be crossed over the back of the forefinger, and a pencil or a pea be placed between the tips of the two fingers, the sensation produced is not that of a single round object, but of two distinct objects; and if the eyes be shut, the illusion will be complete. The reason is, that while each finger conveys a correct tactile sensation, the mind fails to recognise the exact relative positions of the unusually placed tactile surfaces.

161. All the finer differences of touch disappear in pain. Heat, cold, chemical and mechanical irritation, all produce pain when applied in excess; and although the character of the pain varies with the nature of the damage done to texture, in no case is there any resemblance between the pain and the sensation caused by a minor degree of the stimulus.

Pain, then, may be considered as a sensation distinct from others, and resulting from an excess of the impressed condition in a sensory nerve; indeed, it may be felt in parts which

are not otherwise endowed with feeling, as, for example, the stomach and intestines. Allied to it there are various other sensations, not belonging to any of the five senses, but which may be here alluded to. Among them are some which are pathological, such as *numbness*, arising from derangement of the conditions necessary for the normal activity of the nerves of any part, and *giddiness* and *nausea*, which owe their origin to deranged conditions within the brain. *Hunger* and *thirst* are more healthy sensations, which are of an exceedingly curious kind; for while the one is felt in the stomach, and the other in the throat, both are greatly dependent on the general state of nutrition of the body. Indigestible substances give only a very temporary relief from hunger, while, on the other hand, the stomach may be quite empty without the sensation existing; and thirst is only partially relieved by the mere contact of fluid with the fauces.

162. Smell, the sense by which we distinguish odours, is located within the nasal cavities, and depends on a simpler mechanism than any other of the special senses.

The nasal cavities or fossæ extend from the nostrils back to the pharynx, into which they open behind; the communication being termed the *posterior nares* (fig. 49). Superiorly, they are separated from the cranial cavity by a thin plate of bone, the cribriform plate of the ethmoid, which is perforated by the filaments of the olfactory nerve; and inferiorly their floor is made by the hard and soft palate; while between them is placed a vertical septum dividing one fossa or cavity from the other.

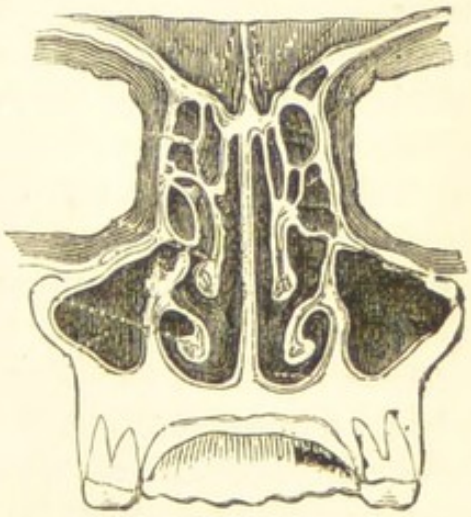


Fig. 109.—Nasal Fossæ, transverse vertical section.

The outer wall, in the human subject, presents three ledges of bone, one above another, projecting inwards with a downward curve, and termed *turbinated* bones. The inferior is a distinct bone; while the others are portions of the ethmoid, and project little lower than the floor of the orbit.

The ethmoid bone consists of a central plate, the cribriform

plate, and two lateral masses. The central plate descends in the middle line from the cribriform plate, and forms the upper part of the nasal septum; while the lower part of the septum is formed behind by another bone, the vomer, and in front is cartilaginous. The lateral masses of the ethmoid form, by two smooth surfaces, part of the inner walls of the orbit, and are hollowed out into air cells, with thin papery walls lined with mucous membrane, and communicating with the nasal fossæ. The ethmoidal turbinated bones form part of these lateral masses. The superior one exists only in the hinder half of each mass, and overhangs a space between it and the middle turbinated bone called the *superior meatus* of the nose, which communicates in front with ethmoidal cells, and has the opening of a space hollowed out of the sphenoid bone, the *sphenoidal sinus*, opposite it behind (fig. 17). The other turbinated bone of the ethmoid, called the middle turbinated bone, is at the lower part of the lateral mass, and overhangs a gallery between it and the inferior turbinated bone, the *middle meatus* of the nose. This communicates with a hollow in the upper jaw, the *maxillary sinus* or *antrum*, and also, by a passage through the fore part of the lateral mass of the ethmoid, with the *frontal sinus*, a large hollow in the frontal bone, in the lower part of the forehead. A third gallery or passage, the *inferior meatus*, lies between the inferior turbinated bone and the floor of the nose; and into it there opens near the front the *nasal duct*, a canal by which the tears are conveyed from the eye; while, opposite its extremity behind, is the orifice of a communication leading from the ear, the *Eustachian tube.*

163. I have thought it better to give the student at once a connected account of the whole interior of the nose, but it must not be supposed that all the structures now described are connected with smell. What is called the nose, in the more extended sense of the word, has a number of different functions. The nose proper, or feature so called, is simply an organ of expression. The nostrils are of use as the openings into the nasal cavities, but the prominence above them is merely ornamental. The nasal cavities are connected with three functions—breathing, voice, and smell. Only the ethmoidal part has the filaments of the olfactory nerve

distributed in its mucous membrane; the lower part is furnished with ciliated epithelium like the rest of the respiratory tract, as is also the part of the pharynx into which it opens; and in quiet breathing the upper edge of the epiglottis comes almost in contact with the edge of the soft palate which forms its floor behind. When the mouth is shut, the air passes to and from the larynx through the nasal fossæ; and, even when the mouth is open, a considerable quantity of air passes through them; and the current is broken by the various turbinated projections, so that part of it is directed upwards to the olfactory region, and the whole of it is assimilated to the temperature of the body before entering the larynx. In "sniffing," or drawing air into the nose to assist smell, the inspirations are short, abrupt, and repeated, so as to put small quantities of air into rapid motion; and in each inspiration there is a slight but quick contraction of the nostrils, both increasing the rapidity of the air and directing it upwards.

Both the nasal fossæ and the various sinuses opening off from them act as reverberating cavities to improve the timbre of the voice; and it is in connection with the voice, not with smell, that the nasal fossæ in the human subject are extensive. They differ from those of quadrupeds in their greater vertical height and diminished extent from before backwards, and in communicating with larger and more numerous sinuses. But, in addition, it will be seen on comparison with any common mammal, such as the dog or the sheep, that in the human subject there is a very small amount of surface provided for the distribution of the olfactory nerves. In those animals the turbinated bones are far more complex, and finer secondary turbinations come off from the main laminæ, while all are directed with their ends towards the nostrils, so that the inhaled air is exposed to a most extensive sensitive surface. This corresponds with what one would expect, both from the very small comparative size in man of the olfactory bulbs of the brain, and from the obviously acute sense of smell in the lower animals, exceeding in some of them, such as the dog, anything which our own senses enable us to conceive.

164. The olfactory nerves consist each of a brush of fila-

ments of the soft and nucleated variety, and ramify beneath the mucous membrane of the upper and middle turbinated bones and the ethmoidal part of the nasal septum; and in this, which is termed the olfactory region, the mucous membrane of the nose, called also the *Schneiderian* or *pituitary membrane*, is softer and smoother, and has the mucous glands smaller than they are in the lower part of the nasal fossæ. The olfactory mucous membrane is likewise distinguished by being clothed with a non-ciliated columnar epithelium. But between the ordinary columnar cells are scattered slender nucleated bodies, each of which is in continuity with a filament of olfactory nerve, and in birds and amphibia is furnished with a single hair or a bundle of fine cilia. These are called *olfactory cells;* and we are led to believe that the wonderfully and imponderably minute odorous particles drawn into the nasal fossæ in inspiration affect their extremities, and, through them, the olfactory nerves.

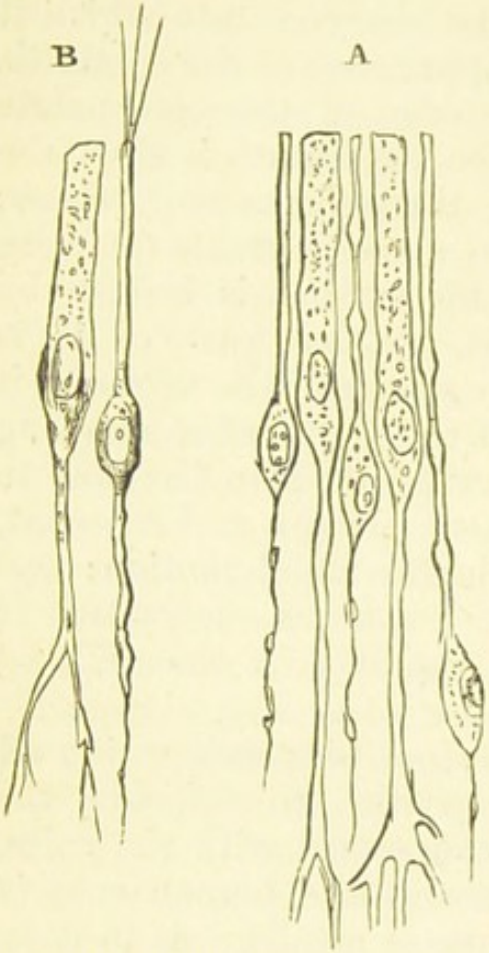


Fig. 110.—Olfactory Cells, with the epithelial cells between which they lie; both with deep connections. A, Human. B, From frog. After Schultze and Frey.

165. Taste is a sense which is closely allied to both common sensation and smell, and as it is less definite in its nature than the other special senses, so also it is dependent on a less definitely distinguished nervous supply; for while smell, sight, and hearing, have each a special nerve devoted to them, the organ of taste has its sensory supply from two mixed nerves, the glosso-pharyngeal and the gustatory or lingual branch of the fifth.

The organ of taste is the upper surface of the tongue. This is covered with *papillæ*, which differ from those on the general surface of the skin, not only in being larger, but also

in being compound. The papillæ are of three kinds. Thickly disposed over the whole surface are those of smallest size, the *filiform* kind, which are long and slender prominences, as their name indicates, and have a few simple papillæ at their extremities. Scattered sparsely among the filiform are the *fungiform* papillæ, which have a rounded shape, and sometimes remain red when the rest of the tongue is furred, giving a spotted appearance to the surface. The papillæ of the third description are called *circumvallate*, and are several times larger than the fungiform. They are usually less than a dozen in number, and are arranged near the back of the tongue in two lines diverging from the mesial groove in a curved fashion. They, as well as the fungiform kind, have simple papillæ on their broad tops, and they get their name from each being sunk into a hollow, whose outer wall rises up like a rampart to a level with it.

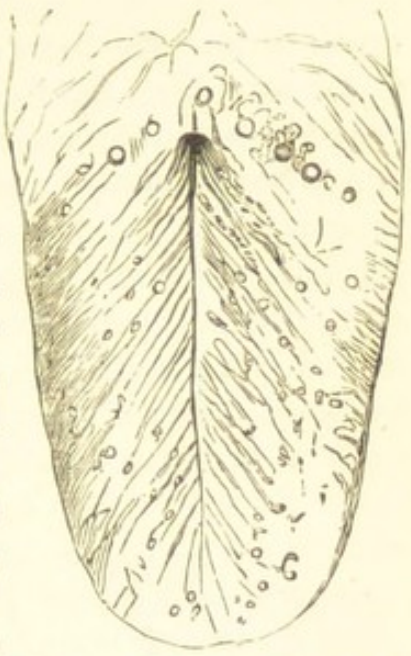


Fig. 111. — TONGUE, showing the circumvallate papillæ near the root, and the fungiform scattered over the surface.

The epithelium which covers the tongue is of a thick stratified squamous description; and the variations in the distinctness of the papillæ, in different states of health, depend more on the condition of the epithelium than on differences in the prominences which they clothe.

166. The sensory nerves of the tongue end in a variety of ways. End-bulbs (p. 68) are found in the papillæ close to their extremities. Also, on the frog's tongue, nerves have been traced into elongated cells with forked extremities, situated in the epithelium; and although the mammalian tongue is very different from that of the frog, yet it is likely that some similar mode of nerve-termination is scattered over the tongue of the mammal also; for forked cells, continuous with nerve-fibres, have been described in the epidermis of general integument. But the most remarkable mode of nerve-termination found in the tongue is in the *taste-cones* of

Schwalbe and Lovén. These are structures which are found nowhere else but on the protected sides of the circumvallate papillæ. Each cone occupies the whole thickness of the epithelium; its base is on the papilla, its apex at the surface, and its sides are convex. It consists of vertically placed nucleated cells running the whole length of the cone, the outer of which are flattened like the staves of a barrel, and form coats like those of an onion, while the inner are rod-shaped, and some of them with hair-like extremities, like the olfactory cells; and the group of these extremities at the top of each cone projects into the fossa round the papilla, through a small opening left between the flattened superficial cells of the surrounding epithelium.

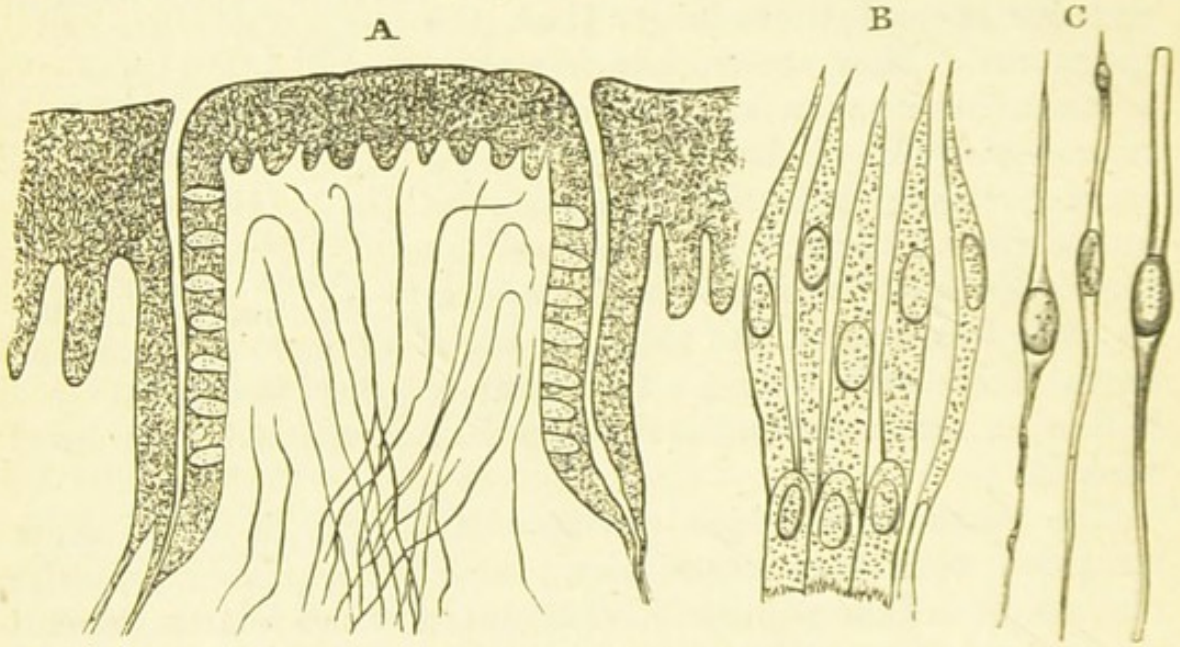


Fig. 112.—Taste-Cones of Sheep. A, Vertical section of circumvallate papilla, exhibiting seven taste-cones on each side. B, Outer cells of taste-cone. C, Inner cells. Schwalbe.

167. All tastes are not perceived by the same means. Astringents are perceived when applied to the fore part of the tongue, but not when applied to the back part. Bitters are perceived when applied to the back part, but do not affect the fore part. Sweet and saline tastes are perceived by means of both the fore and back part, but most acutely by the fore part. If sugar be laid on the tip of the tongue, the sweetness is at once perceived, though not so acutely as after pressing the tongue to the palate; but it may be rubbed into the back of the tongue, as also into the palate, without any

taste being detected till the palate and that part of the tongue are pressed together in swallowing. Perhaps the accurate pressure of the palate is necessary to bring the dissolved sugar into contact with the taste-cones.

In what is termed flavour, there is something more than mere taste. The texture of the substance tasted is an element which enters into flavour; for example, the smoothness, roughness, hardness, or softness; and these are appreciated by the acute common sensation in the tongue and palate. Smell is another element in flavour; and, besides that, many tastes and smells are so associated, that the smell brings the taste to mind, and certain aromatic tastes even suggest what seem in some way correspondent odours to the imagination. It is a matter of common observation, that interference with smell, as during an attack of catarrh, interferes with the power of distinguishing flavours.

There is another curious circumstance which points to a connection between taste and smell. In a number of mammals there is a sensory organ on each side of the septum of the nose, close to the floor, called the *organ of Jacobson*. It is a pouch lined with mucous membrane, receiving a twig from the olfactory nerve, and another from the source which supplies common sensation to the nose and palate; and its orifice is pointed downwards, so that in many animals it is most easily entered through a canal in the fore part of the palate. The use of this organ is hard to conceive; but it brings the distribution of the olfactory nerve very close to the organ of taste.

The back part of the tongue is supplied by the glossopharyngeal nerve, but the anterior three-fourths almost entirely by the gustatory branch of the fifth; and it is difficult to avoid the conclusion that both nerves are really nerves of taste.

168. Vision.—If by means of the eye we merely had a sensation varying in intensity according to the amount, and in character according to the colours of the light before us, vision would be a sense completely comparable with taste or smell. But to produce the effect of the landscape, there is required, in addition, an exceedingly fine power of localization of the impressions made by different rays, not indeed a

power which enables us to perceive, as in touch, the spot where the stimulus is applied, but one by which the relative positions of all the rays entering the eye at one time may be recognised.

It is further necessary that every nerve-termination or sensitive point in the eye shall receive only one ray at a time, and that it shall be the proper ray. In the case of insects, this is managed by every nerve-termination being placed at the bottom of a long dark-walled tube, so that it is affected by none but the ray which falls vertically on it. But in all vertebrata, as well as in the cephalopodous molluscs, of which the cuttle fishes are a familiar example, the object is achieved in much greater perfection by an optical apparatus which throws the inverted image of the landscape on a sensitive surface at the bottom of a dark chamber.

The whole optical apparatus, as well as the sensitive surface, is contained within the eyeball; the range of vision is increased, and the two eyes are enabled to act in concert, by means of muscles which turn the eyeballs; and inasmuch as the fore part of the eye must be preserved from opacity, whether from dryness, scratching, or the nutritive changes consequent on irritation, it is protected by the eyebrows, eyelids, eyelashes, and a lachrymal apparatus.

169. The eyeball is a nearly spherical structure, about an inch in diameter, pierced at the back, at a point about a tenth of an inch internal to the centre, by the optic nerve, which, being in its sheath a stout cylinder a sixth of an inch thick, looks like the stalk of a berry. The outer investment of the eyeball is protective, and, in the greater part of its extent, is an exceedingly tough felted fibrous coat, called the *sclerotic*, thickest behind; but in front it becomes abruptly transparent, so as to form a clear window, the *cornea*, through which one can look into the interior. At the edge of junction, the fibres of the sclerotic are continuous with those of the cornea, the same bundle being opaque in the outer part of its extent, and transparent in the inner; but in the cornea the fibres are arranged in numerous parallel laminæ, with intercommunicating branched spaces between them. The cornea is altogether destitute of blood-vessels, though supplied with a network of nerves near its surface; and it is

limited behind by an elastic lamina, and covered in front with epithelium. The lining membrane of the eyelids and front of the eye is called the *conjunctiva;* it is continuous with the skin at the margin of the lids; inside the lids it is pink with blood-vessels; where reflected on the sclerotic or white of the eye, it becomes more delicate and transparent, although still a distinct membrane easily detached; but when it reaches the cornea, every structure corresponding with the cutis vera is lost, and there remains only a stratified epithelium closely adherent to the proper corneal structure. No blood-vessels lie beneath this epithelium to interfere with vision; but when inflammation is excited, vessels push their way inwards with a rapidity which is exceedingly interesting, as showing how speedily capillaries can be developed.*

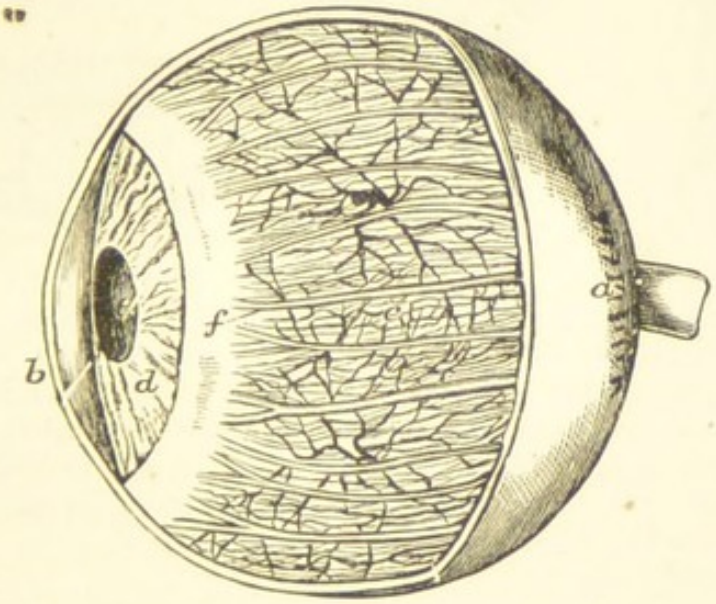


Fig. 113.—HUMAN EYE enlarged, with part of the cornea and sclerotic removed. *a*, Sclerotic; *b*, cornea; *c*, choroid coat, showing arteries and veins, and the ciliary nerves on the surface; *d*, iris; *e*, pupil; *f*, ciliary muscle.

170. Looking at the living eye, one sees, through the transparent cornea, the part which is coloured. This is a muscular curtain, the *iris*, with a circular perforation in the centre, the

* An injection by Stirling, in my possession, beautifully demonstrates that the conjunctival network of capillaries, on reaching the edge of the cornea, is reflected and continuous with a deeper network belonging to the sclerotic. A similarly reflected sheet of capillaries is described by Hyrtl at the attachment of the round ligament of the hip-joint to the femur.

pupil, which appears black, because few of the rays of light which enter it are reflected from the camera behind. The iris is attached round about to the margin of the sclerotic, where it meets the cornea; and it has two sets of muscular fibres; a circular set round its pupilary margin, which contracts the pupil; and a radiating set towards its circumference, by which the pupil is dilated. The circular fibres are governed by the third cranial nerve, the radiating fibres by the sympathetic. Division of the sympathetic in the neck causes the pupil to contract, while stimulation of the divided trunk causes it to dilate.

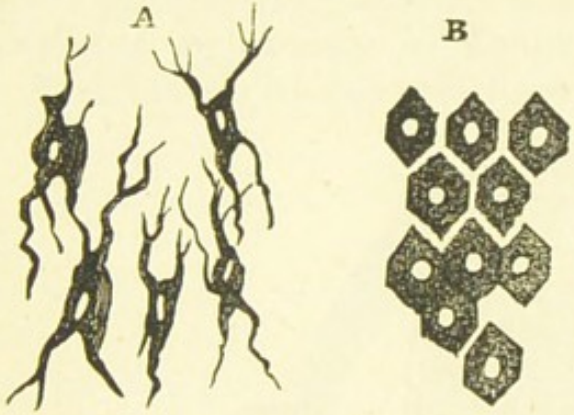


Fig. 114.—Pigment Corpuscles of the Choroid Coat. A, Branched corpuscles from the connective tissue of the choroid coat: the white spot in each is the nucleus. B, Pigmentary epithelium on the inner surface of the choroid coat.



Fig. 115.—Section of Choroid of the Ox, diagrammatic view. *a*, Arteries and veins; *b*, arterioles and venous radicles piercing the tapetum; *c*, membrane of Ruysch.

In making a dissection of the eye, such as every student may easily make for himself on the eye of a sheep or an ox, if the sclerotic and cornea be carefully removed, there is brought into view a second coat, the *tunica vasculosa*, of which the iris is the anterior part, while the posterior part, corresponding in extent with the sclerotic, is called the *choroid*. The choroid coat consists of exceedingly closely-set small arteries and veins, imbedded in connective tissue, the branched corpuscles of which are loaded with pigment; and the capillaries uniting these vessels are thrown inwards to the deep aspect of them, where they form one of the closest networks in the body, the *membrane of Ruysch*. Behind the periphery

of the iris, the blood-vessels of the choroid form a corona of richly vascular projections directed inwards, and capable of considerable variation in size according to their degree of gorgement: these are called the *ciliary processes;* and connected with their roots is the ring of tissue which fastens the iris to the sclerotic, a white ring consisting principally of muscular fibres, the *ciliary muscle.*

The whole of the deep surface of the choroid and back of the iris is lined with epithelial cells loaded with dark brown pigment, which opposite the choroid are flat, hexagonal, and arranged in a single layer, but behind the iris are more densely accumulated. In persons with brown eyes, the colour of the iris is due to a deposit of pigment between its anterior fibres, corresponding with the branched pigment-corpuscles between the vessels of the choroid; but in those with blue eyes, the iris is devoid of pigment, and the colour is due to the effect of the dark pigment behind its white substance. In *Albinos*, persons in whom there is an absence of brown pigment from all the situations in which it is commonly found, the white hair and eye-lashes are accompanied with pink eyes, the colour of which is due to the blood, lighted up, not only with reflected, but also transmitted light.

The pigment of the choroid prevents reflection of rays from the parts of the interior of the eye on which they fall, to other points of the sensitive surface, which, were it to occur, would blur the image of the landscape, as is illustrated by the imperfect vision from which albinos suffer. But, if the student choose for dissection the eye of a sheep or some other domestic animal, he will find on the inner surface of the choroid a state of matters not existing in man, namely, a portion, opposite and above the pupilary aperture, which has an intense satin-like whiteness. This is called the *tapetum*, and by reflecting the rays to the part of the sensitive surface immediately in contact with it, is of service in utilising a dim light, and enabling these animals to see at night. It is this tapetum seen through the humours, which gives the brilliant greenish light to the pupil of the cat.

171. In the course of dissection, let the choroid coat be gently torn open and raised from the subjacent structures. If this be done with due care, there will be seen laid over a globe of

transparent substance, a soft, whitish, pulpy membrane, the *retina*, or internal tunic of the eyeball. The retina is a nervous structure, containing the distribution of the optic nerve, a layer of nerve-corpuscles, and the nerve-terminations on which the rays of light act; it is adherent to the other tunics at the *optic pore*, the place where the optic nerve pierces; and it comes to an apparent margin in front, not far from the ciliary processes. This margin, in the human eye, is scalloped, and called the *ora serrata*. In the human eye also, when a perfectly fresh specimen is examined, the retina will be seen to be nearly transparent, and of a delicate pink tint; and there will be noticed, directly opposite the centre of the pupil, that is to say, a tenth of an inch outside the optic pore, a structure which does not exist in domestic animals, namely, the *yellow spot of Sömmering*, an elliptical mark, of a yellow colour, with a depression in the middle, called *fovea centralis*.

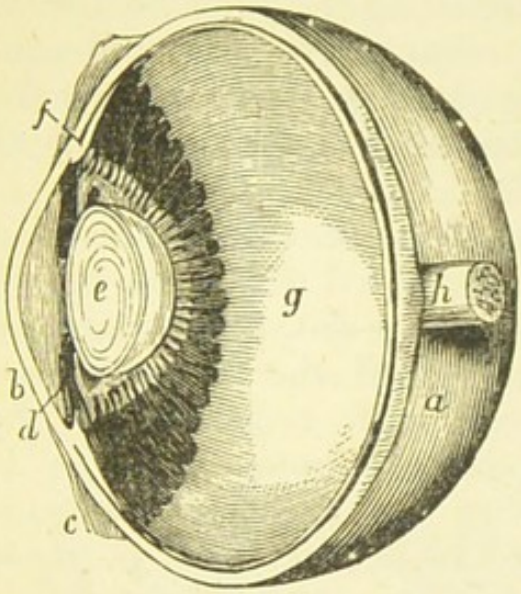


Fig. 116.—Section of Human Eye. *a*, Sclerotic; *b*, cornea; *c*, conjunctiva; *d*, iris; *e*, crystalline lens closely invested with its capsule, and, above and below, sections of the canal of Petit, bounded in front by suspensory ligament, and behind by hyaloid membrane. The radiating white lines round the lens are the most prominent parts of the ciliary processes, the only parts uncovered with dark pigment; *f*, ciliary muscle in section; *g*, retina, with ora serrata in front; *h*, optic nerve.

The retina, notwithstanding its being so thin, is one of the most complex structures in the body, and reveals this complexity when, after suitable preparation, it is examined under the microscope in sections made vertically through it. Close to the surface which rests on the transparent media of the eye, is a layer of fine nerve fibres, the expansion of the optic nerve, and beneath this a layer of multipolar nerve-corpuscles; and in these strata are the ramifications of the retinal artery, which breaks up into branches at the

optic pore, and is there placed on the surface of the retina. Subjacent to the multipolar corpuscles are other layers, marked by the presence of nuclear elements; and on the other side of these, resting on the choroidal epithelium, is what is termed the bacillary layer (fig. 118).

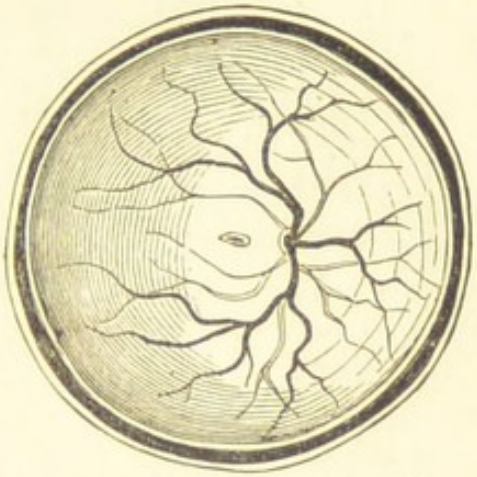
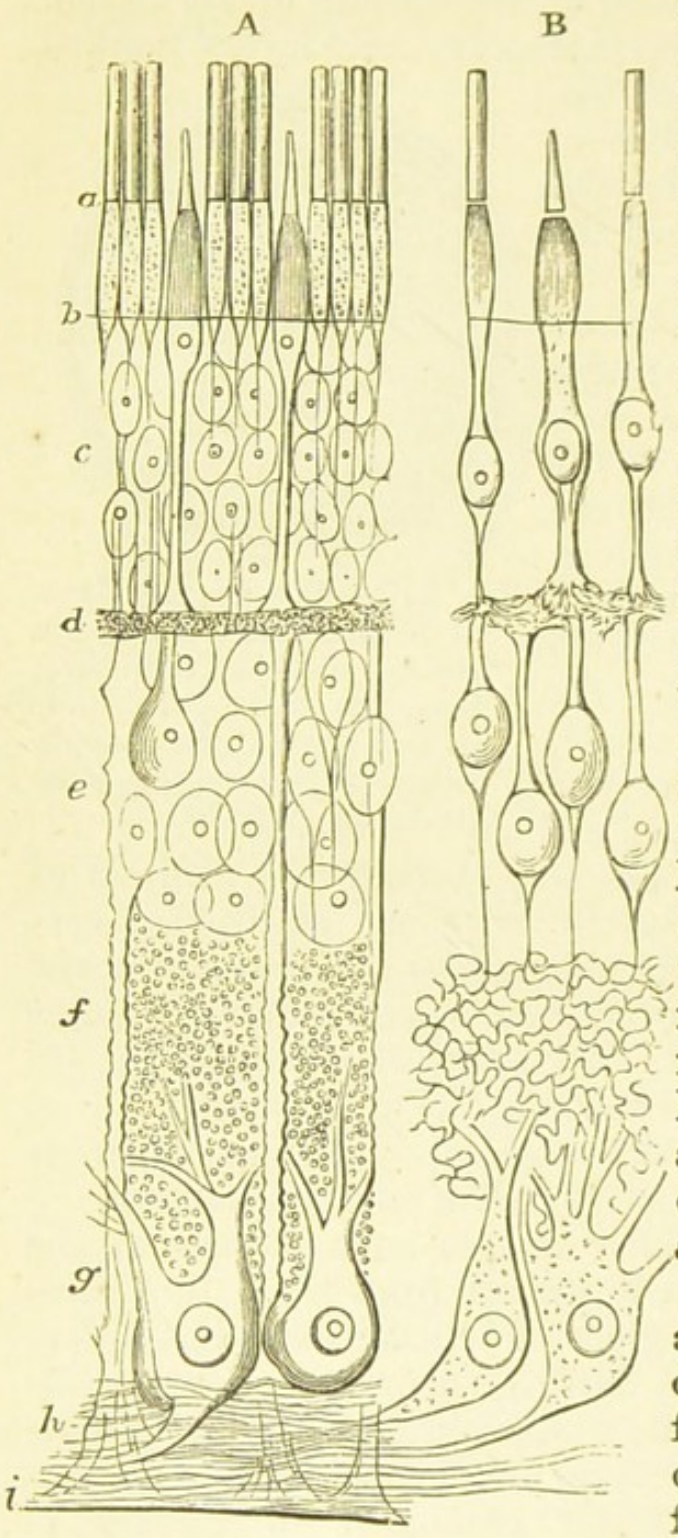


Fig. 117.—Posterior Half of Eyeball, exhibiting the retinal vessels ramifying from the optic pore, and, in the centre, the macula lutea of Sömmering with its fovea centralis.

The *bacillary layer*, or *Jacob's membrane*, consists of multitudes of minute structures, called *rods* and *cones*, placed vertically to the rest of the retina, like the elements of a columnar epithelium. The rods are the more numerous, and consist of an outer and inner part of dissimilar nature: the cones have an outer part similar to the rods, while the inner part is swollen to a flask-shape, and they are more distinctly connected, through the medium of structure in the nuclear layers, with the multipolar corpuscles. In the yellow spot, only cones are present in the bacillary layer, and these are crowded together, and of smaller size than elsewhere; also the multipolar corpuscles are numerous, and there are no fibres of the optic nerve.

172. When the choroid coat has been divided, the transparent structures which occupy the cavity of the eyeball can be removed in one mass. They adhere most closely to the ciliary processes, but, when separated from them, they have the appearance of a limpid globe of delicate jelly, in the fore part of which is placed a bead of denser consistence, surrounded by a plicated collar, whose plications fit in between the ciliary processes. The main mass is called the *vitreous humour;* it consists of water entangled in meshes of transparent tissue, and is limited by a structure of firmer consistence, called from its limpidity the *hyaloid membrane.* The denser bead in front is the *crystalline lens;* and if a score be made along the face of it with a needle or a point of a knife, the *capsule* which retains it in its place will be ruptured, and the lens will start out. It is expelled usually with



a distinct degree of force, because the anterior wall of its capsule is strong and elastic: the posterior wall is fused with the hyaloid membrane. The plicated collar outside the capsule of the lens is called the *zonule of Zinn;* and if a small tube be gently pushed into it near to its inner edge, and air be blown in, there will be seen to be a cavity surrounding the periphery of the capsule, the anterior wall of which is formed by a plicated fibrous membrane distinct from the hyaloid. This cavity is called *canal of Petit;* and the membrane in front of it, extending from the most prominent part of the hyaloid membrane to the anterior wall of the capsule of the lens, is named the *suspensory ligament.*

The crystalline lens is about a third of an inch in diameter, and a fifth from front to back, and is more convex behind than in front. It consists of layers

Fig. 118. — RETINA, diagrammatic view of the structures seen in vertical section. A, General view. B, The nervous elements. *a*, Bacillary layer; *b*, membrana limitans externa; *c*, external nuclear layer; *d*, external granular layer; *e*, internal nuclear layer; *f*, internal granular layer; *g*, ganglionic layer; *h*, branches of optic nerve; *i*, membrana limitans interna. After Schultze.

of substance, one within another, like an onion; and the layers increase in density towards the centre, which is so firm that it is sometimes called the nucleus of the lens. The layers are composed of fibres extending from front to back, each with a nucleus, and remarkable in having serrated edges by which they fit into one another.

The capsule of the lens is in contact in front with the inner edge of the iris, and there is a space left between it and the cornea. This is filled with fluid, the *aqueous humour;* and as much of the space as lies in front of the iris is called the *anterior chamber;* while the remaining part, forming a slight interval between the back of the iris and the lateral part of the lens, is distinguished as the *posterior chamber.*

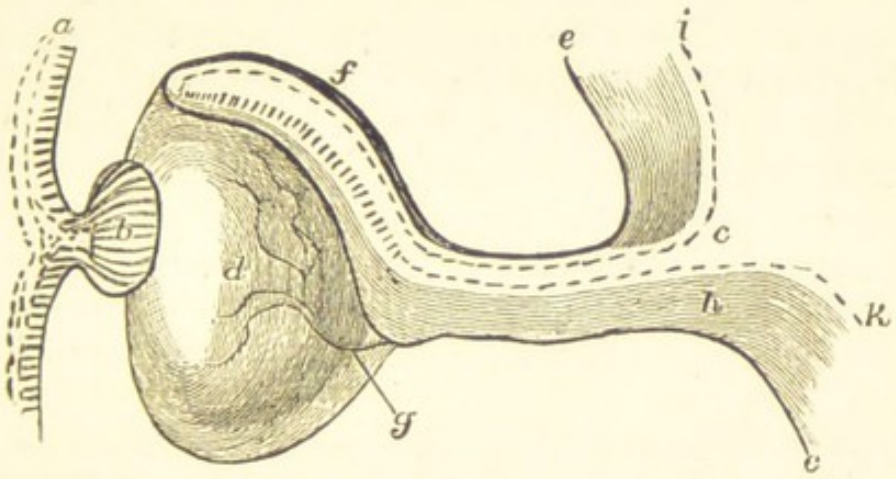


Fig. 119. — DEVELOPMENT OF THE EYE, a diagram. *a*, Cuticular epithelium; *b*, lens developed by invagination of cuticle; *c*, entrance from the cavity of the brain into the primary optic vesicle; *d*, secondary optic vesicle; *e*, *e*, pia mater; *f*, choroid coat; *g*, retinal artery entering at the bottom of the cleft of the eye; *h*, cerebral substance continued into the optic nerve and retina; *i*, epithelium of cerebral cavity continued into the pigmentary epithelium of the choroid; *k*, the same continued into Jacob's membrane.

173. Reviewing the whole structure of the eyeball, it may be interesting to the student to know that, in the early embryo, it is developed partly from the integument and partly from the brain. The lens is originally an invagination of the skin, which becomes converted into a closed sac; and its fibres may be fairly considered as elements of the same series as the elongated cells of the deepest stratum of the cuticle.

The optic nerve, the retina, and the choroid, take rise from a vesicular outgrowth of the brain, comparable with the olfactory bulb (p. 204), and called the *primary optic vesicle.* The neck of this vesicle remains as the optic nerve, while the distal half of the vesicle becomes invaginated from below upwards and backwards against the other half, so as to form with it a double cup, the *secondary optic vesicle*, with a cleft in its lower part. The pia mater or vascular covering in the half nearest to the optic nerve is developed into the choroid, and in the invaginated half remains as the retinal artery; while the nervous matter of the first-mentioned part disappears, and that of the invaginated portion is the main substance of the retina. Viewed in this light, the bacillary layer and the hexagonal pigment cells of the choroid are epithelial developments lining the opposed surfaces of the optic vesicle.* The vitreous humour, sclerotic, cornea, and iris, are later developments from subcutaneous tissue.

174. The eye may be likened to a camera obscura, such as that which is used in photography. In front are the refractive media by which the inverted image is produced, while, behind, the retina receives that image precisely as the ground glass or the sensitive plate in the artist's camera receives, when the focus is rightly adjusted, the picture of the object to be photographed.

It must not, however, be supposed that the eyes of all animals have the complexity of the eyes of vertebrate animals, nor that vision is a sense enjoyed in perfection by all animals possessed of eyes. The simplest forms of eyes met with, or of structures which may be taken for eyes, are little more than spots of colour; but even if we keep all doubtful structures out of view, eyes must be divided into those which are capable of receiving an image of the landscape and those which are not. A scallop (*Pecten*) is provided with numerous eyes, disposed like a double row of jewels, but it cannot distinguish objects. Neither can the starfish do so, although it has a group of eyes at the tip of every arm. In each of these eyes there is a dense transparent structure or lens in

* For this reason I object to considering the hexagonal pigment cells as belonging to the retina, as is done by Max Schultze, who has done so much to elucidate retinal structures.

front, with nerve-terminations behind it, and bright pigment round about: of the light entering the lens, no doubt the rays corresponding in colour with the pigment are reflected from point to point, and a sensation must thus be produced varying in intensity with the amount of that particular colour of light; but it can scarcely be supposed that any nearer approach to vision is made.



Fig. 120. — Ocelli of Starfish (solaster papposa). *a*, Pigment-cone; *b*, lens; *c*, *c*, nerve-corpuscles. H. S. Wilson.

Eyes which receive an image are divisible into two great groups, those in which the image is erect, and these in which it is inverted. To the first of these groups belong the eyes of insects and of crustaceans, such as lobsters; while to the second group belong the eyes of vertebrata and cuttlefishes. If the eye of a lobster or a dragon-fly be carefully examined, it will be seen to consist of numbers of minute facets, barely visible, crowded together; each of these is a transparent structure placed at the extremity of a long tube lined with black pigment, and with a nerve-termination at its deep extremity. Obviously no ray of light can reach the bottom of such a tube unless it fall vertically into it. Thus the point in the landscape vertically opposite each tube affects the nerve at its extremity, and a separate sensation is produced by as many points as there are facets in the eyes, and this will happen irrespective of the distances of objects.

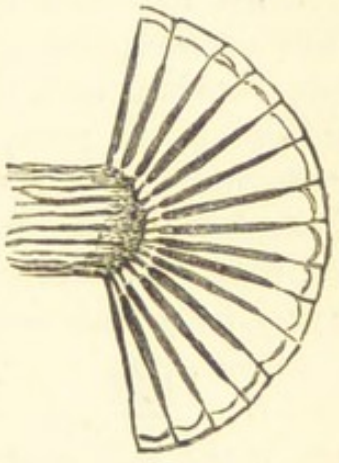


Fig. 121.—Diagram of Insect's Eye in section.

In eyes which invert the image, the inversion is produced by

the addition of lens and camera, which are probably necessitated by the enormous increase in number of the sensitive points; for every rod or cone of the bacillary layer is a separate nerve-termination. In the eye of the cuttlefish, the bacillary layer is the part of the retina turned towards the lens, and is, probably, like the lens, a development of the cuticle; but in the vertebrate eye, we have seen that it is the part of the retina lying against the choroid, and is a development of the brain.

175. If the analogy of nerve-terminations in other organs be attended to, it will be at once perceived that those of the retina are the rods and cones of the bacillary layer; and a variety of other considerations show that they really are so One might naturally expect that the surface of the retina which is turned towards the light, would be the one to be affected by the rays impinging on it; but this is not the case. For the part next the light is the layer of ramifying fibres of the optic nerve, and the spot where those fibres are most numerous is the optic pore, which happens to be wholly insensible to light.

This insensibility of the optic pore can be easily proved. The axis of the eye is always directed to the object looked at; in that axis lies the yellow spot, and to its inner side is the optic pore, receiving the rays entering from a point external to the object looked at. If, now, the left eye be shut, and the right eye fixed on the cross here represented, while the book is slowly moved towards and away from the eye, at a certain distance the round mark to





the right will suddenly disappear, to come again into view, as the book is brought nearer or held further off. The same result is obtained, if the experiment be made with white spots on a dark ground, or with colours; and the explanation obviously is that, at a certain distance, the round mark falls on a spot, internal to the axis, which is insensible to the presence or absence of light.

This experiment also shows the importance of the yellow spot as the seat of clear vision, that spot from which the fibres of the optic nerve are absent, and in which the rods of

the bacillary layer are entirely replaced by the more highly organized cones. It will be noticed that when the eye is fixed on the cross, not only is that mark the most distinctly visible object, but letters as far away from it as the position of the round ball, although still a long distance removed from the circumference of the field of vision, are so vaguely seen that they cannot be distinguished when the ball is hid from view, even though the figure is so arranged that this happens when the book is held at a good focal distance. But the optic pore, it will be recollected, is only one-tenth of an inch from the axis of the eye, therefore this observation shows that the retina, at the circumference of a circle with a radius of a tenth of an inch, and the axis of the eye as its centre, has much less acute sensibility than the yellow spot. And inasmuch as there is no interruption of the outline of the field of vision corresponding to the position of the optic pore, but the place where such an interruption might be expected to show itself is filled up with the appearance round about, whether light, dark, or coloured, there is evidence that the sensation originating in each cone or rod is not strictly limited; although in other parts of the retina it is practically limited by the sensations from the rods round about. This explains the spreading of the appearance of light round excessively luminous objects.

It being clear that the layer of nerve fibres is not the part of the retina in which the rays of light produce nervous impression, it is curious to observe that the rays have to pierce these fibres and the strata of the retina before reaching the rods and cones on which they act. This shows that the susceptibility to a stimulus so fine as light depends not on the nervous structure but on the peculiar terminal organ added thereto.

176. The most important of the structures through which the rays of light pass on their way to the retina is the crystalline lens. It is comparable with a biconvex lens of glass made by an optician. The rays of light from each visible point in the landscape pass through the whole aperture of the pupil, and are refracted towards one another as they enter the anterior convex surface of the dense substance of the lens, and again as they emerge from its convex surface behind.

They are thus gathered together at a certain distance behind the lens, in a focus situated in the direction of a line proceeding through the centre of that body, from the visible point; and the rays from every point being in like manner refracted, an inverted image of the landscape is produced.

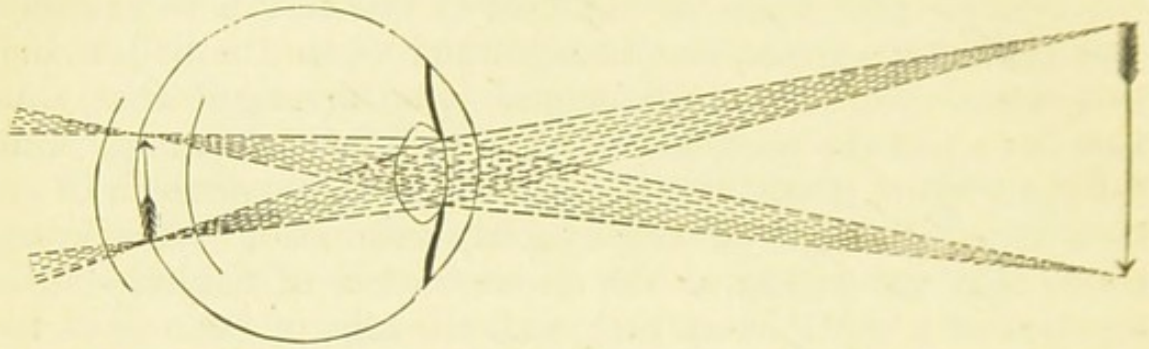


Fig. 122.—Diagram to illustrate the course of two cones of light to be focused on the retina, and that distinct vision requires that the focus for the object looked at correspond with the position of the retina.

But there are two sets of conditions required for the production of a correct image on the retina: one is, that all the rays from each spot, and their constituent colours, shall be gathered by the crystalline lens and other refracting media quite to a point; the other, that the position of the retina shall correspond with the focus.

As regards the first of these conditions, it will be remembered, in the first place, that only parabolic surfaces have the property of bringing all the rays from each point to a perfect focus, and that an ordinary glass lens has an imperfection dependent on its spherical curves, termed spherical aberration. The crystalline lens has its surfaces approaching, probably, pretty near to the parabolic form, but it must not be forgotten that it is not the sole refracting medium in the eye. Thus, persons who have had the crystalline lens extracted for the disease called cataract, have still an inverted image thrown on the retina, and continue to see, although imperfectly, without the use of spectacles; thus, also, the curvature of the cornea, when too great, produces short-sightedness, by making the refractive apparatus too powerful. It is, therefore, proper to note that it is a law of spherical aberration, that, while it is exhibited very greatly in the rays which pass through the lateral parts of a lens, it scarcely affects

those which fall vertically near its centre; and therefore the iris, by diminishing the pupil, prevents any such source of error.

Another difficulty in the manufacture of optical instruments is to make them achromatic; that is to say, to prevent the different colours of which white light is made up from being dispersed in passing through lenses, and so producing rainbow colouring in the image. The mechanician meets this difficulty by combining lenses of contrary form and different material, in such a manner that the dispersion of a converging lens is counteracted by the opposite and equal dispersion of a diverging lens of less refracting power. The same expedient is resorted to in the structure of the eye, the light having to pass successively through the cornea, aqueous humour, and the different strata of unequal density in the crystalline lens.

177. With reference to the correspondence of the position of the retina with the focus of the lens, it will be noticed that if that membrane be so placed that the images of distant objects shall be cast on it, it will be too far forward to receive the images of near objects; and, *vice versâ*, if it be so situated as to receive the images of near objects, it will be too far back for those at a distance, unless some arrangement of accommodation be specially brought into play. In a photographer's camera, the focus is arranged for different distances by moving the lens forwards and backwards; in the eye, the same object is attained by change in the form of the lens.

It is easy to make certain that a change of some sort takes place in the eye to accommodate it to different distances. One has only to shut one eye, and hold up a finger a few inches from the other, to perceive that, if the finger be steadily looked at, the background, even at the other end of the room, is quite indistinct; and, as soon as by an effort of the will the sight is fixed on the background, the finger in turn loses all distinctness of outline. But it is more difficult to determine the nature of the change. It has been discovered by careful observation of the reflections from the surfaces of the lens (Helmholtz). When a light is held in front of an eye, three images are reflected; one is from the surface of the cornea; another, of a dim description, is from

the anterior surface of the lens; and a third, small and clear, and inverted, is from the hinder surface of the lens. When the focus of the eye is changed from distant to near objects, without altering the direction, the inverted image retains its form and position, while that from the front of the lens becomes smaller, and approaches the corneal image. From this it is known that the posterior surface of the lens remains unchanged, while the anterior surface is made more convex; and by examination of the eye in profile, the lens has even been seen to project through the pupilary aperture when adjusted to short distances. The cause of this change of shape is not thoroughly understood, but the principal agent in effecting it would appear to be the ciliary muscle.

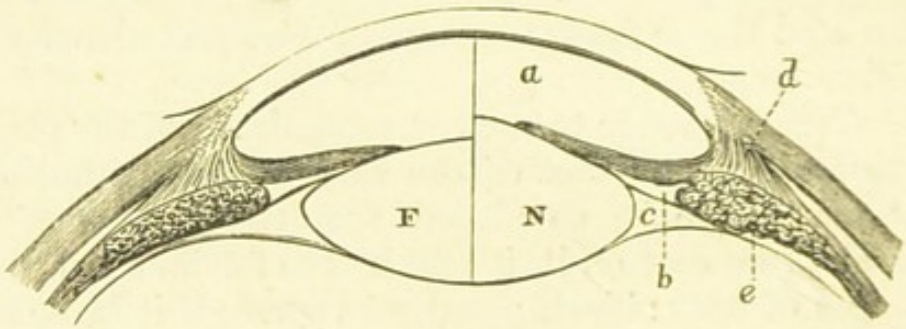


Fig. 123.—Accommodation to Distances. F, Lens accommodated to far objects; N, to near objects; *a*, anterior chamber; *b*, posterior chamber; *c*, canal of Petit; *d*, ciliary muscle; *e*, ciliary process.

Another change which takes place in adjustment to short distances is lessening of the pupil; and it has been suggested that the contraction of the circular fibres of the iris presses on the sides of the lens so as to alter its form. But this supposition is disproved, not only by the fact that the faculty of adjustment has been found unimpaired when the iris has been wanting, but by the size of the pupil being diminished still more by increase of light than by looking at near objects. The iris seems to act simply as a diaphragm, cutting off the lateral rays; and this is specially required in a bright light, to save the retina from undue stimulation, and in looking at near objects, because the rays from them are so exceedingly divergent.

178. When objects are looked at with both eyes, the muscles which move the eyeballs are brought into requisition. These

are four *recti* and two *obliqui* muscles. The recti come forwards from the back of the orbit, to be inserted, in front of the middle of the eyeball, into the sclerotic; and they are named from their positions, superior, inferior, external, and internal. The superior oblique muscle passes forwards from the back of the orbit to the inner and upper angle of its fore part; there, becoming tendinous, it passes through a pulley of fibres attached to the frontal bone, and, changing its direction, turns outwards and backwards to be attached to the outer part of the eyeball, behind the middle. The inferior oblique muscle, springing from a point at the lower part of the inner margin of the front of the orbit, takes a similar direction to the tendon of the superior oblique, passing backwards and outwards below the eyeball, to be inserted on its outer side.

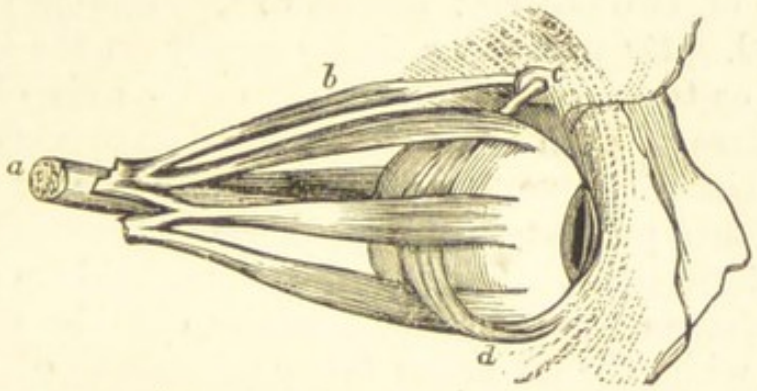


Fig. 124.—Muscles of the Eyeball. *a*, Optic nerve; *b*, superior oblique muscle; *c*, pulley for the tendon of the same; *d*, inferior oblique muscle. The other four muscles are the four recti.

The superior recti muscles of the two eyes always act in concert, as also do the inferior recti, but the external and internal recti act differently in different circumstances. In turning the head, while the eyes are fixed on a stationary object, or in following an object which crosses in front of us, the external rectus of one eye acts in concert with the internal rectus of the other; but, in turning the eyes from a distant to a near object, we make their axes converge on the object looked at, and the internal recti of both eyes act together. These limitations of the movements of muscles which must be considered voluntary are exceedingly curious, and find no parallel in the muscles of the limbs.

The use of the oblique muscles is not at first obvious; but it will be observed that when the eyes are converged, the

superior and inferior recti, acting by themselves, will be no longer capable of rotating them directly upwards and downwards, seeing that the axis of vision and the direction of these muscles are no longer in the same vertical plane; and the oblique muscles are so disposed that, by acting in concert with the superior and inferior recti, they are capable of compensating for the deviation of the direction of these muscles from the axis of vision, and so maintain the vertical diameters of the eyeballs parallel to one another, which we shall immediately see to be a condition necessary for perfect vision.

179. When we look at an object with both eyes directed full upon it, we see it as a single object, notwithstanding that two images of it are received, one on each retina. But by artificial expedients these two images may be made to give the appearance of two objects; that is to say, double vision may be produced. By pressing a finger gently on the side of one eyeball, so as to derange the position of its axis of vision, a second picture of each object in the landscape may be made to appear, either above, below, or to one side of the more distinct picture presented to the other eye, according to the direction of pressure. Or, if a finger be held up exactly in front of a more distant object, and the eyes be directed to the finger, while the attention takes cognisance of the object beyond, that object will be seen double. On the other hand, in looking through a stereoscope, two pictures have the appearance of one. All these phenomena depend on one law, which may be expressed thus: that rays which fall on points in the outer half of one retina, are referred by the mind to the same direction as those which fall on similarly situated points in the inner half of the other retina. Such points are therefore said to be *physiologically corresponding* or *identical*. When one eye is moved from its position by pressure of a finger on it, the different points of the landscape are no longer thrown on identical points of the retinæ, and they are therefore seen double. When the eyes converge on an object in front of another, the images of the hinder object are thrown on the inner halves of both retinæ, and therefore on points not identical. But, in looking through the stereoscope, although the pictures are two, each eye is directed full on the picture opposite it, and thus correspond-

ing parts of the pictures are thrown on identical points, and referred to identical positions in space.

Double vision, it may here be mentioned, can be likewise artificially produced when only one eye is used. The principle, however, is different from that which we have been considering. If, in a card, a few pin holes be made so close together, that they shall be within a space not larger than the aperture of the pupil, and the pin holes be held to the eye, objects at some distance will be seen perfectly; but a minute object, such as a pin head, held near the card will appear multiplied as many times as there are pin holes. The explanation is, that the pin head is out of focus, and, looked at without a diaphragm, would be invisible; but the diaphragm cuts off a large part of each of the pencils of rays which spread out towards the pupil and would have been diffused over an area of the retina so as to interfere with one another; and the perforations admit only very small portions of them, which fall on different parts of that area, and are so narrow that the deficiency in focus is not sufficient to produce confusion.

180. Physiologists have sometimes exercised their ingenuity in trying to account for our seeing objects erect, notwithstanding that the pictures on the retina are inverted. But a little reflection will show that the inversion of the retinal image is no reason why the landscape should appear inverted. What we perceive is not the retinal image, but a number of sensations excited by it; and it must be considered as an ultimate fact, that the sensation produced by irritation of a rod or cone of the retina is not perceived as being in that structure, but as situated vertically opposite it, outside the body. If we are to explain why the landscape is not seen inverted, we must explain why it is not seen inside our heads. A child does not rectify an inverted landscape by experience derived from touch, any more than it imagines the external world, as manifested by vision, to be concentrated in two small spots at the bottom of its eyeballs.

181. Distance, however, is a thing which the eye certainly learns to appreciate by experience. A child, from its entrance into the world, no doubt sees objects as things outside itself; but it learns only by practice the distances of different objects.

This might be gathered from watching the movements of infants; but it has been more distinctly demonstrated by observations made on persons born blind, who have gained sight after some years, by a surgical operation. Such persons see every thing at first as if close at hand, and, from not understanding the effects of distance, form most erroneous ideas of the sizes of objects; and they handle things when they look at them, so as to compare the results of vision with those of common sensation. The effects of distance on the eyes, which experience teaches us to translate, are of various descriptions. (1) The distance of the object looked at determines the degree of convergence of the eyes; (2) it determines the focus; (3) it affects the intensity of light and shade, and the colour, producing what is called perspective of colour; (4) it diminishes the apparent size of objects, producing linear perspective; so that when from custom or otherwise the size of an object is known, its distance is estimated. That the convergence of the eyes is of some use in enabling us to appreciate the exact distance of near objects, is illustrated by the difficulty which one has in threading a needle when one eye is shut. But by a little practice that difficulty is overcome, which shows that the use of two eyes is not essential to judging distances.

182. The appearances of solidity and hollowness depend partly on the apparent diminution of receding objects, partly on the way in which the light falls, and partly on the pictures presented to the two eyes being different, and bringing into view a larger amount of surface than can be seen from one point. The last of these three causes is supplemented materially by the other two; otherwise the appearance of solidity would be lost on shutting one eye. It is, however, a most important element, as is shown by the effects of the stereoscope, when geometrical figures are looked at.

I have already pointed out how it is that only one figure is seen when two pictures are looked at through the stereoscope. But stereoscopic effect depends on the circumstance that no solid or hollow body presents exactly the same view to both eyes. The artist provides on the stereoscopic slide two views of one object, such as would be presented in nature to the two eyes; and the eyes are directed by the construction

of the instrument, so that nearly similar parts of the pictures fall on identical points of the retina. In looking at a solid object, the portions of its sides brought into view are seen to a greater extent by the eye on the same side than by the other; but in a hollow object, they produce the broader image in the eye on the opposite side; and thus it happens that if the stereoscopic views of a solid body be clipped separate, and each be placed in the instrument in the position which was intended for the other figure, it is made to appear as a hollow. This effect can be obtained in perfection with geometrical figures without shading; but is aided by the reversal of the shading when an irregular figure is looked at. By means of another instrument, the *pseudoscope*, the rays coming from actual objects are directed in such a manner that the image which should be presented to one eye is made to fall on the other, and by this means raised objects seem as if hollow, and *vice versâ*. But the important part which experience plays in giving the idea of solidity and hollowness, is shown by the circumstance that neither with stereoscope nor pseudoscope can the reversal of appearance, or *conversion of relief*, as it is termed, be obtained when the objects looked at are of a complex description, and so appeal to our associations that they cannot be conceived otherwise than as they really are.

183. It has already been pointed out that impressions on the retina have a certain tendency to diffusion; they have likewise a tendency to endure after removal of the stimulus, particularly if this have been applied with much intensity, or for a length of time. After gazing at the sun, or any bright light, a *spectrum* or coloured figure remains before the eye for some time; and any object, whether brilliant or not, if moved rapidly, can be shown to leave impressions on the retina which endure after cessation of the stimulus. When a wheel of a carriage is in motion, the spokes become indistinguishable one from another, and a dull tinge of their colour, brightest near the nave, is diffused round about; because the spokes each affect the retina in every part of their revolution, the impression made by one at any part being immediately succeeded by another, and the spokes are placed most closely together near the centre. This imperfection of vision would

be much greater, were it not that the eye has a tendency to follow any object on which the gaze is fixed. The eye follows the wheel of a carriage, and the image continuing to be made on one part of the retina is correctly appreciated as circular; but it fails to follow the spokes, and therefore these affect successive parts of the retina with great rapidity. The duration of retinal impressions is the principle on which a number of optical toys depend. The simplest of them are cards with pictures on each side, and twirled round by a couple of strings, one at each end, so as to bring the pictures together. Thus, a bird on one side and a cage on the other gives the appearance of a bird within a cage; and a man riding a horse may be brought into view, the man being painted on one side of the card and the horse on the other. The *thaumotrope* and the *anorthoscope* are instances of much more complex toys dependent on the same principle (see *Glossary*).

The coloured spectra seen after gazing on bright objects are connected with something more than the mere duration of impressions, namely, the power of appreciating different colours. The appreciation of colour is not understood; we do not know by what mechanism the rods and cones are thrown into different conditions by lights of equal intensity but different wave lengths, so that both colour and intensity are appreciated by one set of structures. But it is known that the appreciation of colour is a separate power from the appreciation of light and shade, for there are various kinds of colour-blindness which occur uncomplicated with other defect of sight.

184. *Colour-blindness* is of three sorts. Some persons have been found unable to appreciate any difference of colour at all, to whom the world was like an engraving. A number of persons have an inability to distinguish allied tints one from another, and confuse blue with green, or confound pinks, crimsons, and scarlets together. In a third set of cases, colours totally unlike are confounded; and the most remarkable colour-blindness of this description consists in inability to distinguish red from green or blue. Curiously enough, this defect may exist without the object of it having any suspicion that his vision is defective. Thus, Dalton, the celebrated chemist, from whom colour-blindness occasionally gets the name of

Daltonism, was twenty-five years of age before he was distinctly convinced of his peculiarity of vision. Yet so great was this peculiarity that in describing it he wrote: "Crimson appears a muddy blue by day, and crimson woollen yarn is much the same as dark blue;" and further recorded that the one side of a laurel leaf seemed to him a good match to a stick of sealing-wax, and the other side to a red wafer. After Dalton had attracted attention to the matter, it was found that his case was so far from being solitary that colour-blindness in different degrees was not unfrequently to be met with. This being the case, it is evident that, on railways and at sea, danger signals dependent on the number or position of lights are preferable to those dependent on colour, and that red lights are specially objectionable.

185. The laws which regulate the colours of the ocular spectra, above alluded to, are curious, and not so easily explained as we are often asked to believe. If a brightly-coloured object on a white ground be steadily gazed at, on looking away from it to the surface on which it lies, or, still better, looking tc a dark surface, or shutting the eyes, the image of the object remains before the sight, in the *complementary colour*—that is to say, in the colour which, added to that of the object gazed on, would make white light. If the object be red, the spectrum will be green, and if the object be blue, there will be an orange spectrum; and the explanation commonly given is, that the part of the retina on which the coloured rays have fallen becomes by exhaustion less affected by the rays of the same colour in the light around, while it is affected by all the colours entering into white light. The following circumstances, however, show that explanation to be insufficient:—1. The brightest complementary-coloured spectrum is obtained by shutting the eyes, or looking into total darkness. 2. While continuing to gaze on the coloured object, a ring of light more brilliant than the surrounding surface makes its appearance round about, and the spectrum seen on the white surface is of the same shade as that ring of light. 3. If the object gazed at be on a dark ground, the ring about it will be, not one of light, but of greater darkness; and the spectrum, if cast on that ground, will be of the same shade. 4. If a very brilliant spectrum be obtained, its colour

can be temporarily changed by pressure on the shut eyes, and will again return.

186. The effects of pressure on coloured spectra afford an interesting illustration of the fact that mechanical irritation of the retina produces a sense of light, and not of pain. I gaze on the flame of the lamp beside me, and on shutting my eyes I see a spectrum, which, instead of being of the complementary colour, is bright yellow, with a red margin, and floating on a dark green halo. I press my fingers against my closed eyes, and obtain the complementary colour, namely, a violet spectrum with a green margin on a yellow halo. On removing the pressure the original colours return; and this can be repeated several times. The appearances are even more complex, if the experiment be made with sunlight.

Phenomena of light uncomplicated with colour can likewise be obtained by mechanical irritation. An accidental blow on the eye produces an appearance of sparks of fire; and by gentle pressure the effects called phosphènes are obtained. A *phosphène* is a luminous image produced by shutting the eyes, and touching one of them lightly but firmly on the outer, inner, upper, or lower border—in short, on any part where the retina extends. A luminous crescent, or complete circle, flashes into sight at the point diametrically opposite the pressure. This is called the larger phosphène, and is caused by irritation of the retina at the point touched, referred by the mind, like all retinal impressions, to the position vertically opposite. Besides this, a smaller phosphène may be obtained, visible at the part touched, which is caused by the contents of the eyeball being pressed against the opposite point. The smaller phosphène is a blush of light of variable intensity, extending over a space, larger or smaller, according to the size of the object with which pressure is made; the larger phosphène is always brilliant, evanescent, and confined to a ring. Phosphènes are much more easily produced at one time than another; and after reading to a late hour, the mere closure of the eyelids in a dark room may cause a bright circle of light to flash before each eye.

By means of pressure, patterns produced by a number of internal structures of the eyeball can be brought into view. The branches of the retinal artery may thus be seen as dark

or luminous lines; also another pattern, which appears to be the network of the choroidal capillaries; and sometimes patches of small points closely set together, which have exactly the appearance of the extremities of the rods and cones of the retina itself. These experiments may be carried to the extent of giving pain, and are certainly bad for the eyes.

The retinal vessels, however, can be seen in a less unpleasant way, by holding a light a few inches from the side of the eye in a dark room, and gazing forwards into the darkness while the light is gently moved. In a little while the field of vision becomes yellowish, and dark lines are seen ramifying in it in the position of the branches of the retinal artery. These are what are termed *figures of Purkinje*, and are occasioned by the vessels intervening between the light and the rods and cones behind them. The blood corpuscles, as they traverse the anterior layers of the retina, can also be seen as luminous spots, when one gazes intently into a clear sky.

187. *Lachrymal apparatus.* — The secretion of tears is primarily useful for keeping the surface of the cornea clear, and, in connection with this object, there are channels provided by which they may be removed without unduly accumulating or rolling over the cheeks. But the flow of tears is likewise influenced by the emotions; and any one who is familiar with the important effects which may be wrought by the action of one or two leeches, will be slow to doubt that a copious flood of tears may be of great utility in relieving a congested condition of the brain.

The lachrymal gland is similar in structure to the salivary glands, is about the size of an almond, is situated in the upper and outer angle of the orbit, under cover of the upper eyelid, and pours out its secretion by several ducts.

The eyelids are closely associated with the lachrymal gland in function. The upper lid is the more important of the two; it is larger than the lower, has twice as many eyelashes, has a special muscle for raising it, and is stiffened by a crescentic plate of thin cartilage (*superior tarsal cartilage*) beneath its mucous membrane, while the lower lid has only a linear strip of that substance inside its margin. The upper and lower tarsal cartilages are united at the inner

corner or *canthus* of the eye by a little tendon (tendo oculi) to the bone; and to the sides of this tendon are attached the fibres of the *orbicularis palpebrarum* muscle, a thin sheet of subcutaneous fibres which pass in circles round the eyelids, spreading over the adjacent parts of the cheek and forehead. This is the muscle by which the eyelids are closed; and its attachment to the tendo oculi explains why it is that, when the lids are forcibly shut, as, for example, by a reflex action on tasting something sour, their edges are drawn inwards to the nose. When the eyes are opened, the lower lid falls back into its place by elasticity, but the upper lid is raised by its *levator palpebræ* muscle, which comes forward from the back of the orbit, lying on the superior rectus, and is attached to the upper border of the superior tarsal cartilage. On everting either eyelid, a set of nodulated yellow streaks may be seen beneath the mucous membrane or *conjunctiva* (p. 229). They are the *Meibomian follicles*, and are a set of sebaceous glands which keep the margins of the lids oiled, and so help to prevent the tears from running over the cheeks.

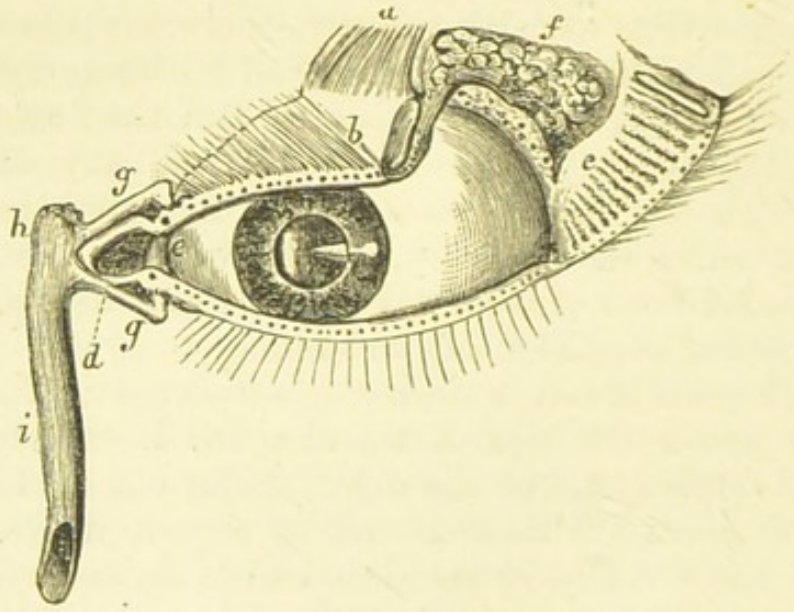


Fig. 125.—Lachrymal Apparatus. *a*, Levator palpebræ muscle; *b*, tarsal cartilage of the upper eyelid; *c*, Meibomian follicles, exhibited by division of the upper eyelid and reflection of the outer part; *d*, caruncula; *e*, plica semilunaris; *f*, lachrymal gland with the orifices of its ducts below it; *g*, canaliculi, with the puncta lachrymalia on the edges of the eyelids; *h*, lachrymal sac; *i*, nasal duct.

At the inner canthus of the eye, there is a little spongy-looking bit of mucous membrane, called the *caruncula*, resting on a fold of smoother membrane, the edge of which is laid against the eyeball. The fold is the *plica semilunaris*, and is the vestige or representative of a third eyelid, more distinct in many mammals than it is in man, and developed in birds, especially those of the nocturnal sort, as the *membrana nictitans*, a structure which rapidly sweeps across the eyeball to clear it, instead of the upper lid moving as it does when we wink. This can be readily seen in the owl.

Opposite the plica semilunaris, the margins of the eyelids, particularly that of the lower lid, change their direction; and on the elevation where this takes place there may be seen in each, when the lid is slightly pulled outwards, a little opening which rests against the eyeball. These openings are the *puncta lachrymalia*, which lead into two minute ducts called *canaliculi*, each of which passes vertically into the eyelid for a very short distance, then turns abruptly inwards to open into a *sac* behind the tendo oculi, whence the tears pass downwards by the *nasal duct* (p. 37) into the nose. Thus the tears, secreted by the lachrymal gland, pass across the eye, washing the conjunctiva; and every time a wink takes place, the puncta lachrymalia, and the parts of the canaliculi in connection with them, are lightly pressed against the eye, so that when the pressure is removed, the moisture is sucked into their interior; and only when there is a redundant secretion, or when by some irregular movement, as in laughter, the puncta lachrymalia are disarranged, do the tears accumulate within the lids, and overrun the cheeks.

188. **Hearing.**—The simplest form of ear may be studied with advantage in the cuttlefishes, in which animals the organs of hearing are imbedded in a cartilaginous collar in the neck, and consist each of a sac supplied with nerves, filled with fluid, and containing some loose particles of hard substance. The vibrations of sound are communicated to the fluid in the sac, and, according to an acoustic law, are strengthened by beating against the solid particles contained in it, and they stimulate the nerve-terminations. But in all vertebrate animals, the ear is much more complex, and, particularly in mammals, not only is the primary sac highly

complicated to produce an organ capable of appreciating the fine varieties of sound, but there are many accessory parts added, which bring sounds within reach of the sensitive structures, and likewise protect these from over-stimulation.

The human ear consists of three parts: the external, middle, and internal ear. The internal ear is the essential organ of hearing, filled with fluid, and containing the distribution of the auditory nerve. The external and middle ears contain air, the external ear being open to the outside, and the middle ear or *tympanum*, as it is called, communicating with the pharynx; and they are separated, one from the other, by a partition, the *membrana tympani*.

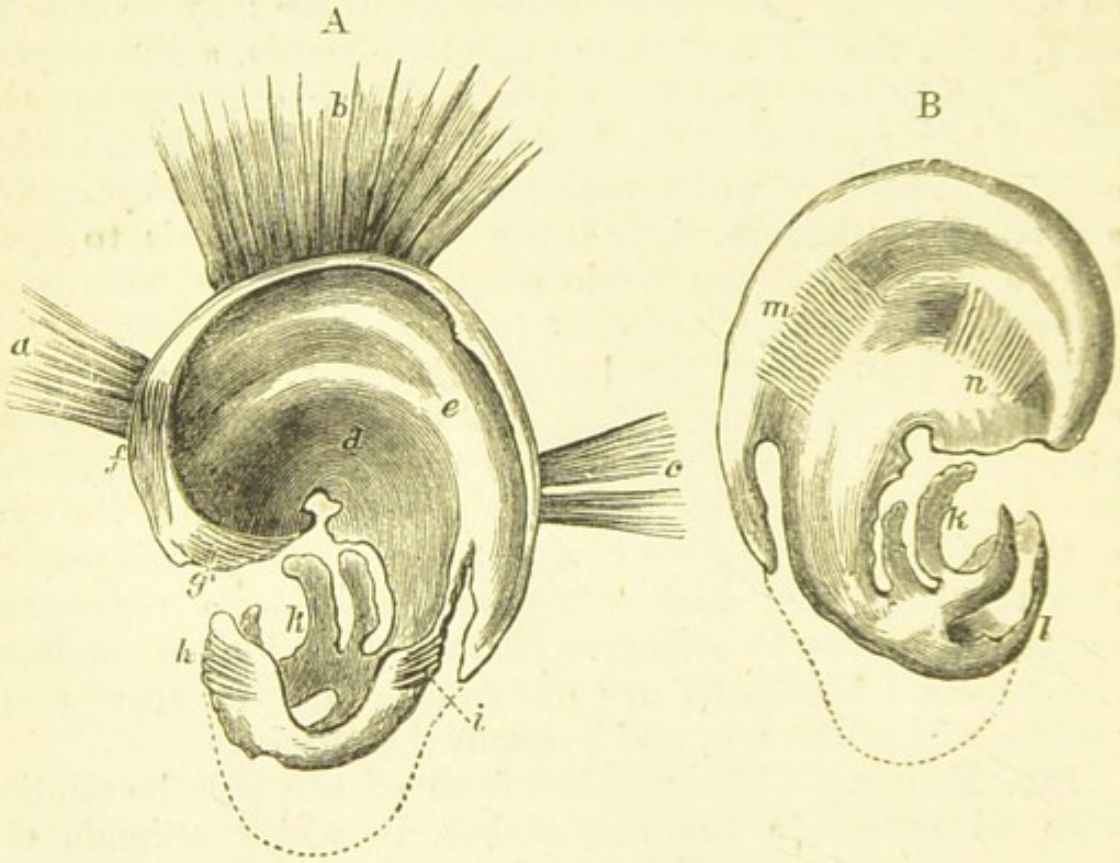


Fig. 126.—Cartilage and Muscles of External Ear. A, Outer aspect. B, Cranial aspect. *a*, *b*, *c*, attrahens, attollens, and retrahens auriculam muscles; *d*, concha; *e*, antihelix; *f*, *g*, large and small muscle of helix; *h*, tragus and tragic muscle; *i*, antitragus and antitragic muscle; *k*, the edge of the cartilage which is attached by fibrous tissue to the external auditory meatus of the temporal bone; *l*, tragus from behind; *m*, transverse muscle crossing the sulcus at the back of the antihelix; *n*, oblique muscle crossing sulcus at the back of the inferior branch of the antihelix. The lobule is represented in dotted outline.

189. *The external ear* consists of two parts, the pinna and the canal. The *pinna*, or that part which is understood when the ear is spoken of as a feature, presents various named inequalities of surface. The outer border, which extends round the back, and curves inwards in front, is called the *helix;* the elevation within it, forked at the upper part, is the *antihelix;* while the hollow at the bottom of which the canal is placed is called the cup or *concha.* The little elevation in front of the canal is called the *tragus*, the similar elevation behind is called the *antitragus*, and the pendulous part is the *lobule.* The pinna consists of a framework of cartilage covered with integument; but at the lower end of the helix, the cartilage comes to a point, and in the lobule there is nothing but a mass of firm adipose tissue. The lobule is sometimes absent, and is a human peculiarity, the beautifully rounded ears of monkeys having none. The pinna, in many animals, is obviously useful as an ear trumpet for gathering sonorous vibrations; but in man it is of comparatively little service, although it is provided with muscles which give it a slight degree of movement. One of these muscles passes from the parts in front, another from above, and a third from the mastoid process behind, to be attached near the root of the pinna; and they are named, respectively, the *attrahens, attollens, and retrahens auriculam* muscles. There are likewise various still smaller muscles which pass from one part of the pinna to another; thus, one bundle on the tragus, and another on the antitragus, pull these eminences very slightly downwards and apart; two slips are placed on the fore part of the helix, and the antihelix and its inferior branch are each crossed by short fibres on their cranial surface; but the only interest connected with these muscles is, that they represent more important structures in the lower animals. So also there is a little tubercle often present near the upper part of the margin of the helix, which is interesting as being the alleged representative of the tip of the ear in animals which have the pinna pointed (Darwin).

The *canal* or *external auditory meatus* of the ear, about an inch and a quarter in length, is partially bounded in its outer part by cartilage, continuous with that of the pinna; but, more deeply, for more than half its length, has osseous

walls, which belong to the temporal bone. The integument with which it is lined secretes *cerumen* from glands of a structure similar to sweat glands, and is furnished, towards the superficial extremity, with fine hairs inclined outwards, so as to offer an obstacle to the entrance of particles of dust. Additional protection is given by the direction of the canal, which is inclined slightly backwards at its commencement, under cover of the tragus, then turns a little forwards; and also in the outer half has an upward slope, which is suddenly changed for a downward inclination in the deep part.

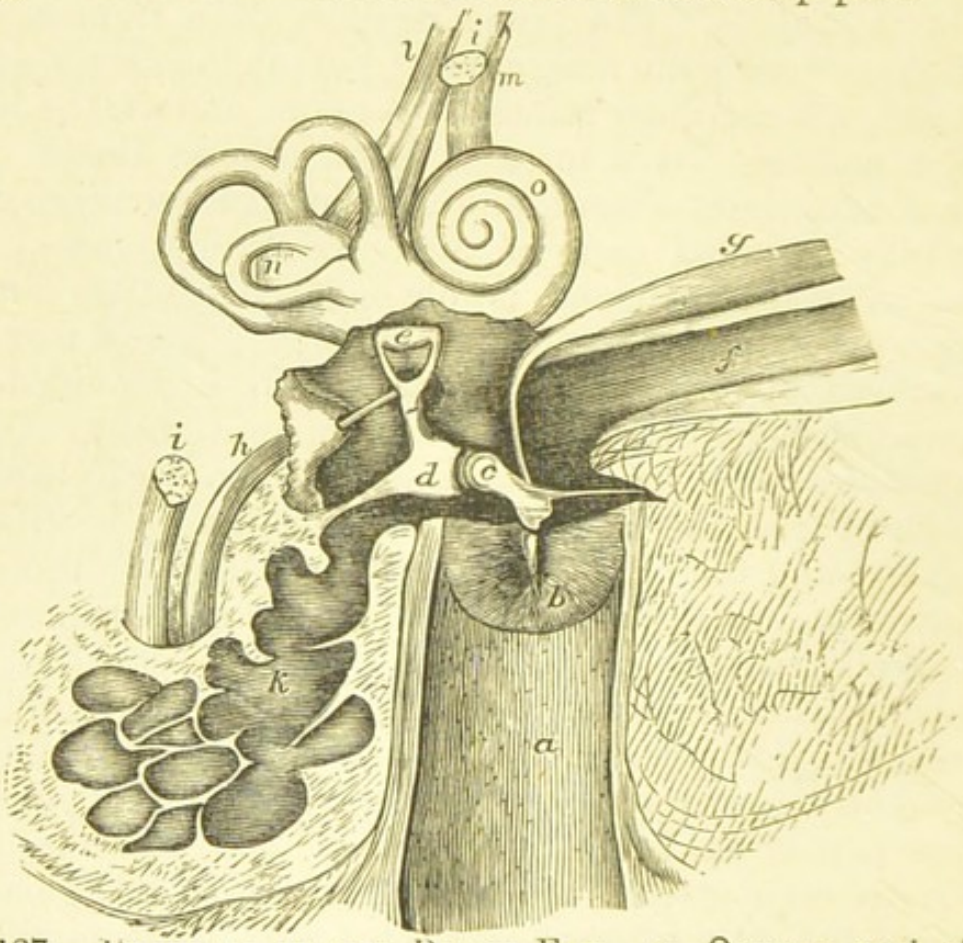


Fig. 127.—Diagram of the Right Ear. *a*, Osseous part of the canal of the external ear; *b*, membrana tympani with the upper part removed; *c*, malleus; *d*, incus; *e*, stapes with its base filling up the fenestra ovalis (the fenestra rotunda is seen a little lower); *f*, Eustachian tube; *g*, tensor tympani muscle; *h*, stapedius muscle; *i*, *i*, portio dura of the seventh nerve divided; *k*, mastoid cells; *l*, *m*, vestibular and cochlear divisions of the portio mollis or auditory nerve; *n*, vestibule; *o*, cochlea.

The *membrana tympani* blocks up the inner end of the canal. It consists of a fibrous membrane with a thin covering of integument on the outside, and of mucous membrane

within. Its fibrous part is attached to the bone round about, and has its principal fibres radiating from the lower end of a process of an ossicle in the tympanum, the *handle of the malleus*, which descends between the fibrous and mucous layers. The membrane is sloped so as to approach nearer the surface at its upper than its lower edge; and it is slightly concave on its outer side, being pulled inwards at the point where the malleus is attached.

190. The *middle ear*, called also the cavity of the *tympanum* or *drum*, is a space of greater vertical height than the canal, and still more extensive from before backwards, but narrow transversely. At its fore part is the opening into the *Eustachian tube*, a passage about an inch and a half long, leading into the pharynx (p. 89). This tube is small and bounded with bone for a short distance at its tympanic extremity; but in the rest of its extent is cartilaginous, and gradually widens. Its cartilaginous wall is replaced with membrane at its lower part, and is so related to the *levator palati* muscle that, in the act of swallowing, that muscle momentarily closes its pharyngeal extremity. It is lined with ciliated epithelium, as is also the tympanum. It allows the passage of air into the tympanum, but is very easily blocked up by the adhesion of its walls, near its fore part; and if, when this occurs, the tympanum have either too much or too little air in it, the effect is a disagreeable sensation and interference with hearing, liable to occur after violently blowing the nose, and producible by holding the nostrils, and making a strong expiration with the mouth shut, so as to force air into the tympanum. When the sensation is produced, it lasts for a variable length of time, according to the extent of contact of the walls of the Eustachian orifice, and the viscidity of the substance which causes them to cohere; and it is often removed by the instinctive repetition of the act of swallowing, and stretching the neck on the affected side, so as to make a greater pull on the floor of the orifice, as the parts fall back into their places on the cessation of the spasm of deglutition.*

* It is only fair to state that the opinion held by the late Mr. Toynbee, that the Eustachian tube is in ordinary circumstances shut, and is momentarily opened in swallowing, is held by many, both in

Posteriorly, the tympanum communicates with the *mastoid cells*, a set of small irregular spaces in the mastoid part of the temporal bone, which can scarcely be supposed to be functionally important, as they vary greatly in extent, and have little development in young persons.

On the inner side, the tympanum is bounded by the petrous part of the temporal bone, which contains the internal ear imbedded in it; and here there are two small openings, one above the other, which are important as establishing a communication between the middle and internal ear. The lower of these openings, the *fenestra rotunda*, about the size of a pin head, is blocked up with a membrane, the *secondary membrana tympani;* while the upper opening, the *fenestra ovalis*, somewhat larger, has fitted into it the base of the stapes, one of the small tympanic ossicles.

191. The *tympanic ossicles*, three in number, the *malleus*, *incus*, and *stapes*, make a communication between the membrana tympani and the internal ear. The ossicles termed malleus and incus, from a fancied resemblance to a hammer and anvil, lie one in front of the other, the malleus foremost. The malleus has at its upper part a head, which articulates behind with the incus; and descending from the head is the handle, or *manubrium*, the extremity of which we have already seen to be connected with the membrana tympani. Another process, *processus gracilis*, springs from below the head of the malleus, and passes forwards to be attached in a fissure of the temporal bone. The incus articulates by its thickest part with the malleus, and sends out two processes, one of which projects horizontally backwards, and has a ligamentous attachment in front of the mastoid cells, while the other, which is longer, descends vertically, and is turned

this country and on the continent. In such a work as this it is sufficient to mention two objections to that idea; namely, that it is anatomically impossible, and that I have myself, as elsewhere recorded, actually seen through a perforation in the palate, the extremity of the Eustachian tube lying open when the throat was at rest, and closed in the act of swallowing. And it is to be remembered that it is only about the extremity of the tube that there can be a question; since no one doubts the patency of the osseous part, and Rüdinger has demonstrated a permanently patent canal in the first part of the cartilaginous portion.

inwards at its extremity to articulate with the third ossicle, the stapes. The stapes, as its name implies, is shaped exactly like a stirrup; it lies horizontally, its head articulating with the incus, and two branches extending inwards to its base, which is fixed by means of a ligament which surrounds it in the fenestra ovalis. Thus, it will be perceived, the tympanic ossicles are suspended between the tip of the processus gracilis of the malleus in front, and the extremity of the horizontal process of the incus behind, and are capable of a swinging motion round the line joining those points, of such a description that the descending process of the incus swings outwards or inwards with the handle of the malleus, and communicates its movement to the stapes.

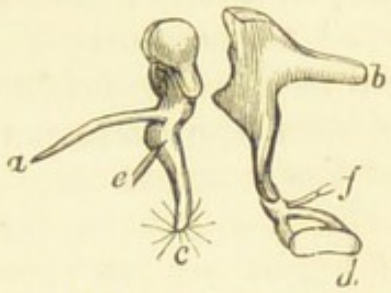


Fig. 128.—Tympanic Ossicles of Right Ear. *a*, Processus gracilis of malleus; *b*, posterior process of incus; the line *ab* is the axis of rotation. When *c*, the handle of the malleus, with fibres of the membrana tympani radiating from its extremity, is pulled inwards by *e*, the tendon of the tensor tympani, the incus likewise rotates and pushes *d*, the stapes, in at the fenestra ovalis; *f*, tendon of stapedius.

192. This is precisely the principal movement which takes place, and it is accomplished by two muscles. The *tensor tympani* muscle arises from the cartilaginous wall of the Eustachian tube, and entering the tympanum, is confined by a ledge of bone to the inner wall, till it is opposite the position of the malleus; it then becomes tendinous, and stretches across the cavity, to be attached near the base of the handle of that bone, pulling it inwards, and so increasing the concavity of the membrana tympani, and putting that membrane on the stretch. An antagonistic muscle, the *laxator tympani*, less distinct, arises likewise from the Eustachian tube, and is attached to the malleus above the level of the processus gracilis; thus pulling the head of the bone inwards, and swinging the handle outwards. Now, as has been mentioned, the internal ear is filled with liquid, which is incompressible; and it is surrounded with unyielding walls, save only at the two fenestræ; when, therefore, the tensor tympani pulls the handle of the malleus inwards, so as to make the membrana

tympani tense, and the incus, partaking of the movement of the malleus, pushes the stapes in at the fenestra ovalis, it is plain that the whole contents of the internal ear are subjected to pressure, and that the secondary membrana tympani is likewise made tense. Thus a harmony is maintained between the condition of the primary membrana tympani and the internal ear.

But it might happen that the nervous structures of the ear might require protection from violent noise, as the retina requires protection from excessive light, and gets it by exciting a reflex action which contracts the pupil; for this reason there is what may be described as a safety-valve arrangement connected with the stapes. To the neck of the stapes a tendon is attached, which passes back through a foramen in the posterior wall of the tympanum, and, when the bone is broken open, is seen to be continued into a muscle called the *stapedius* muscle. This muscle, when it contracts, pulls the stapes into an oblique position in the fenestra rotunda, and interferes with the pressure of the incus, thus relieving the inner ear from a state of tension. Judging from the anatomy of the parts, we may conclude that this is a correct view of their function, and that the stapedius muscle is stimulated to contract by a reflex action, of which the auditory is the incident or sensory nerve.

193. *The internal ear* is imbedded in osseous tissue; and the cavity which it occupies, the *osseous labyrinth*, can be well studied in a macerated temporal bone. The petrous portion of the temporal bone is a long three-sided pyramid of hard consistence, with its base turned towards the tympanum; and in its posterior wall, which looks into the cranium, there is a large foramen, the *meatus auditorius internus*, directed outwards. When this meatus is looked into, it is seen to terminate very soon in a perforated plate, which occupies its lower part, and leaves an opening into a canal above it. This canal, termed *aquæductus Fallopii*, gives passage to the portio dura of the seventh nerve, otherwise called the facial, and has nothing to do with the organ of hearing; but the perforated or cribriform plate transmits the portio mollis or auditory nerve to the internal ear; the perforations in its fore and nnder moiety leading respectively into the anterior and

posterior divisions of the labyrinth. The posterior part of the osseous labyrinth is called the *osseous vestibule*, and contains the *membranous vestibule* floating within it; the anterior part is called the *cochlea*, and in it the osseous and membranous parts are more intimately connected one with the other. However, in the dry bone, the parts seen are the cavity of the vestibule, with three *semicircular canals* coming off from it behind; and, in front of the vestibule, the cochlea, a spiral tube coiled on itself like a snail's shell.

The cavity of the vestibule is the part into which the fenestra ovalis opens. The three semicircular canals spring from its back part; they are about a twentieth of an inch in width, and each makes a circuit about a quarter of an inch in diameter. One of them, the *external*, is placed horizontally; the other two, called the *posterior* and the *superior*, are somewhat larger, and lie in planes at right angles one to the other; the posterior being close to the hinder surface of the bone, and the superior springing from a part which is common to it and the posterior canal, and arching outwards, touching the upper surface of the bone. Each semicircular canal has a dilatation or *ampulla* near one extremity.

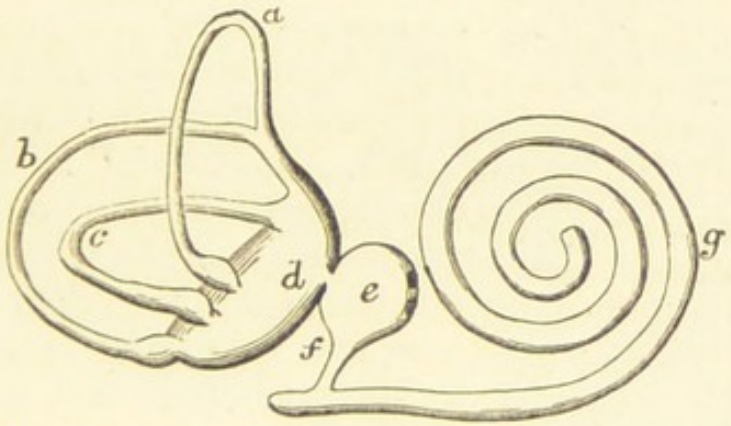


Fig. 129. — MEMBRANOUS LABRYNTH, diagrammatic view. *a*, *b*, *c*, Superior, posterior, and external semicircular canals; *d*, utricle; *e*, saccule; *f*, canalis reuniens; *g*, canalis membranacea cochleæ.

The *membranous vestibule*, lodged within the osseous, is connected with it merely by vessels and nerves. It presents two cavities separated by a thin partition: the anterior is named the *saccule*, and connected, as we shall see, with the cochlea; the posterior, which is larger, is called the utricle. and gives off membranous semicircular canals, which lie loose

in the osseous canals of the same name, and likewise exhibit each an ampulla. The fluid in which all these membranous structures float is called the *perilymph*, and that which they contain is called the *endolymph*. The nerves are supplied only to limited portions of the membranous vestibule, one branch passing to the saccule, another to the utricle, and one to a little crescentic elevation projecting into the interior of each ampulla. The interior of the membranous vestibule is lined with epithelium; and exceedingly slender straight hairs project through the epithelium at the parts supplied with nerves, and are probably in continuity with the nerve fibres. These hairs may be supposed to vibrate with sonorous vibrations; and to make such vibrations stronger, there is a collection of minute crystals of carbonate of lime, the *otoliths* or *otoconia*, in the neighbourhood of the termination of each branch of nerve.

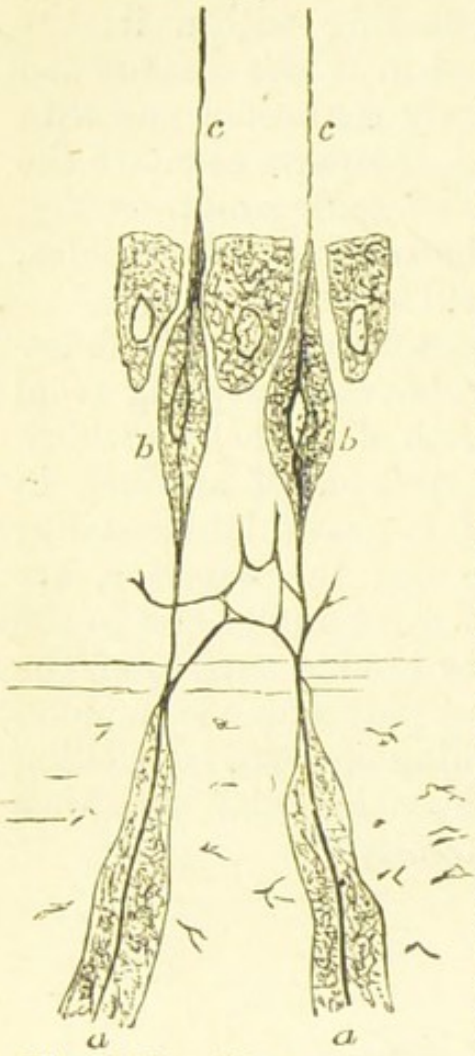


Fig. 130.—NERVE-TERMINATIONS IN AN AMPULLA, diagrammatic view. *a*, *a*, Medullated nerve fibres; *b*, *b*, fusiform cells; *c*, *c*, auditory hairs. Rüdinger.

194. The *cochlea* is, in its early development, an outgrowth from the vestibule, and as it elongates it becomes spirally coiled, taking two complete turns and a half, tapering to its extremity, and acquiring, as has already been remarked, the appearance of a snail's shell. The base of the shell is at the perforated plate of the inner auditory meatus, the apex abuts against the tympanic end of the Eustachian tube, the mouth is in connection with the vestibule, and in the centre of the coils of the tube is a pillar of bone, the *modiolus*, pierced with canals containing the cochlear branches of nerve. Around the modiolus is a spiral ledge of bone, the *lamina spiralis*, projecting into the interior of the tube; and continued directly

outwards from the edge of this is a fibrous partition, the *basilar membrane*, dividing the tube longitudinally into two parts, and attached at its outer edge to the wall of the tube by muscular fibres, which can keep it tense. Another and much more delicate partition, the *membrane of Reissner*, extends upwards and outwards from the lamina spiralis to the outer wall of the tube; and thus there are three parallel passages separated from one another. Of these, the upper or that turned towards the apex of the cochlea, is called the *scala vestibuli*, and commences in the cavity of the vestibule; the middle passage, placed between the basilar membrane and membrane of Reissner, is called the *canalis membranacea*, and is continuous with the membranous vestibule, being connected with the saccule by a little duct, the *canalis reuniens;* while the lower passage, the *scala tympani*, starts from the closed fenestra rotunda, and is separated from the vestibule by the basilar membrane, so that its only continuity with that cavity, in the fresh state, is by a small opening at the apex of the cochlea, the *helicotrema*, where it communicates with the scala vestibuli beyond the blind extremity of the



Fig. 131.—Cochlea of New-born Pig, section. *a*, Canalis membranacea; *b*, scala tympani; *c*, scala vestibuli; *d*, basilar membrane and organ of Corti; *e*, membrane of Reissner; *f*, spiral ganglion. Reichert.

canalis membranacea. It will be understood from this that the two scalæ are filled with perilymph, while the canalis membranacea is lined with epithelium, and contains endolymph.

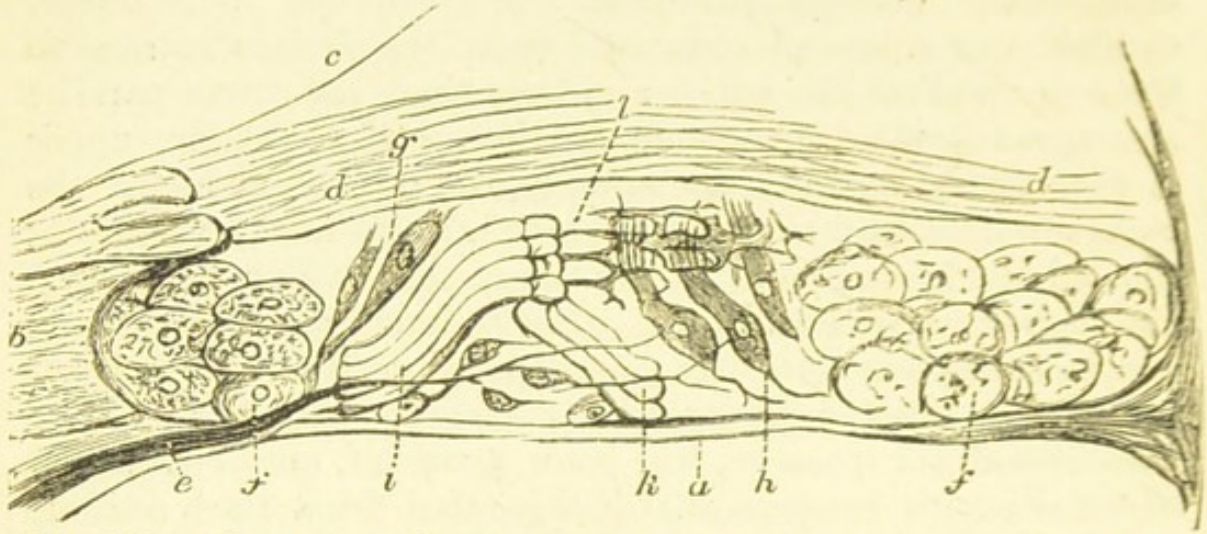


Fig. 132.—ORGAN OF CORTI, diagrammatic view. *a*, Basilar membrane; *b*, tough structure attached to the edge of the osseous lamina spiralis, termed its *limbus*, and presenting a toothed appearance; *c*, membrane of Reissner; *d*, *d*, membrana tectoria; *e*, nerve perforating the basilar membrane; *f*, *f*, epithelial cells; *g*, *h*, inner and outer groups of ciliated or hair-bearing cells; *i*, *k*, inner and outer rods of Corti; *l*, *membrana velamentosa*.

In the interior of the canalis membranacea, situated on the basilar membrane, is the sensitive part of the cochlea, an exceedingly complicated structure called the *organ of Corti*. This organ contains numerous sets of nucleated cells, some of them furnished with stiff cilia or hairs, and it is permeated with very fine ramifications of the cochlear nerve; and it also contains an outer and inner range of very remarkable strap-shaped structures of comparatively tough consistence, one range leaning against the other, like the rafters of a house. These strap-shaped structures are called the *rods of Corti*. It is curious to note that, while the osseous cochlea diminishes from base to apex, these rods increase in length (Urban Pritchard), and the basilar membrane on which they lie increases in breadth as the apex is approached (Henle).

195. It is difficult to understand the exact mode of action of the different parts of the internal ear. It has been long generally assumed that the semicircular canals are useful in determining the directions whence sounds proceed, and

that the cochlea is a kind of spiral harmonicon, vibrating in different parts of its extent in unison with sounds of different pitch; and these appear to be probable suppositions; but neither the actions of the semicircular canals nor those of the cochlea are understood in detail.

The most distinct hearing is, beyond question, that derived from sounds which enter by the external ear. We turn an ear towards a sound which we wish to hear distinctly, and hear very badly when the ears are stopped. The membrana tympani obviously receives principally sounds entering by the external ear; and if the vibrations of that membrane are converted into a swinging movement of the ossicles, as experiments seem to show, and are thus communicated to the labyrinth, it is very plain that vibrations entering by the external ear can be of no use in enabling the semicircular canals to determine the direction from which a sound is coming. It would appear from these considerations that direction, except in so far as it is determined by trying in what position of the external ear a sound is heard loudest, is appreciated by means of those vibrations which pass through the bones of the skull; and as bearing on such a supposition, it may be mentioned that sounds heard when the ears are thoroughly stopped are sometimes correctly judged as regards their direction, and that fishes, which have no external ears, or only minute pores to represent them, have very large semicircular canals. It is also possible that sounds conveyed to an ampulla, along the length of the semicircular canal to which it belongs, may affect it more than others; but nothing certain is known on the subject.

It must not, however, be forgotten, that we are often guided to the direction from which a sound comes by circumstances which have nothing to do with the ear, such as expectation of sound from a particular quarter, or the direction of the eyes of onlookers. So also the distance from which a sound comes is judged of altogether by experience. The art of the *ventriloquist* consists simply in correctly imitating the effects produced by sounds at different distances, and in stimulating the imagination, and directing the attention, so as to make his hearers believe that a sound comes from a particular quarter. The illusion would be destroyed if the

performer were to show any movement in his face indicating speech; but, nevertheless, his voice proceeds from his larynx, and the words are formed by the organs of speech, and the effect is produced entirely by imitation and persuasion.

The precise mode of action of the cochlea is as little determined as that of the semicircular canals. It is rudimentary in birds, and in its spiral form is peculiar to mammals. It may fairly be assumed that by this part of the ear we become cognizant, not only of pitch, but likewise of the quality or timbre of sounds, seeing that it has been discovered that timbre depends on the mixture, with a principal note, of a great variety of others in consonance with it. But the mode in which the characters of sounds are preserved unaltered in their passage to the cochlea, and the reason why the *rods of Corti* get longer as the diameter of the cochlea gets narrower, are subjects for further investigation. It cannot be doubted that the vibrations of the hairs, projecting from nucleated cells, are those which immediately affect the auditory nerve, and that they are produced by vibration of the walls of the membranous canal, but there is no evidence as to the part played by the rods of Corti. It ought not to be lightly assumed that they strengthen sound; they may possibly act as dampers, to check reverberation.

CHAPTER XVI.

VOICE AND SPEECH.

196. Voice.—The organ of voice is the larynx, a modification of the upper part of the trachea, consisting of a framework of cartilages, lined with mucous membrane, and moved on one another by muscles.

The lowest cartilage of the larynx is called the *cricoid cartilage.* It forms a complete ring above the first cartilage of the trachea, and, while narrow in front, rises to a height of more than half an inch behind.

Above the cricoid, and partially embracing it, is the *thyroid cartilage.* This cartilage is open behind, and, at the upper border in front, projects forwards, making the prominence called "Adam's apple." In front, its lower border is a little above the cricoid, and the space thus left is filled up with elastic tissue, the *crico-thyroid membrane;* but at the sides its depth increases, and it sends upwards and downwards two pairs of cornua; the inferior cornua articulating with the sides of the cricoid cartilage, so as to furnish a centre of

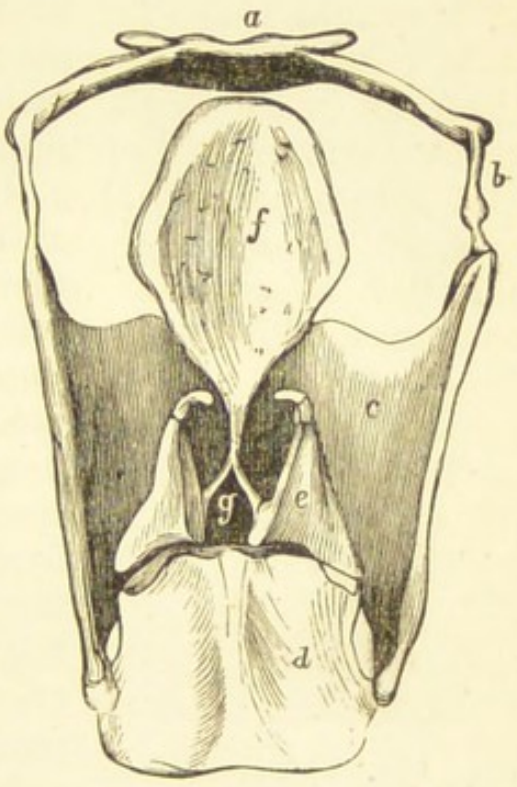


Fig. 133.—CARTILAGES OF THE LARYNX, from behind. *a*, Hyoid bone; *b*, lateral thyro-hyoid ligament; *c*, thyroid cartilage; *d*, cricoid; *e*, arytenoid cartilage, surmounted by cartilage of Santorini; *f*, epiglottis; *g*, aperture of glottis, with vocal cord on each side.

rotation, and the superior being united by ligaments of some length to the hyoid bone.

Surmounting the back part of the cricoid are the *arytenoid cartilages*, two bodies shaped like three-sided pyramids, articulated at their bases to the cricoid cartilage, and curved backwards at their apices, so as to give the mucous membrane which covers them an appearance in the middle line like the spout of a water-jug, from which they get their name. At the anterior angle of the base, they are prominent, and give attachment to elastic fibres which pass directly forwards to be attached to the thyroid cartilage close to the middle line. These are what in strict anatomical language are known as the *vocal cords*.

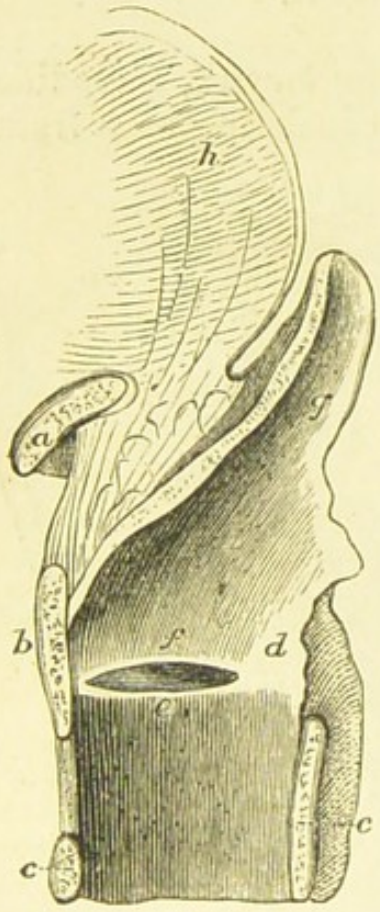


Fig. 134.—Mesial Section of Larynx. *a*, Hyoid bone; *b*, *c*, *d*, thyroid, cricoid, and arytenoid cartilages; *e*, true vocal cord; *f*, false vocal cord, and beneath it the ventricle of the larynx; *g*, epiglottis; *h*, tongue.

But by the term *vocal cords* are most frequently understood, not merely the few fibres mentioned, but likewise the folds of mucous membrane in which they lie. The mucous membrane, disposed cylindrically in the interior of the cricoid cartilage, approaches the middle line from each side to cover the elastic fibres described; and is then abruptly reflected outwards, forming on each side a hollow called the *ventricle*, prolonged into a little *saccule* in front, and limited above by a semilunar fold called the *false vocal cord*. The first-mentioned folds, or true vocal cords, are those by whose vibration the voice is produced; in vocalization they are approximated to the middle line; they are protected with squamous epithelium from the force of the air which whistles past them, and have their position and tension regulated by muscles. The space between them is termed the *glottis* or *rima glottidis*.

The most important muscles of the larynx are: (1) a transverse *arytenoid* muscle, uniting the posterior surfaces of the arytenoid cartilages, and drawing those cartilages together when the larynx is shut; (2) a pair of *posterior crico-arytenoid* muscles, passing up from the back of the cricoid cartilage to the arytenoid cartilages at their outer angles, and rotating the vocal cords outwards, so as to widen the glottis; (3) a pair of *lateral crico-arytenoid* muscles, passing backwards from the sides of the cricoid to the outer angles of the arytenoids, and rotating the vocal cords inwards to the middle line; (4) a pair of *thyro-arytenoid* muscles lying in the folds of the vocal cords, and shortening them by rotating the thyroid cartilage upwards on the cricoid; (5) a pair of *crico-thyroid* muscles, seen from the front, and stretching the vocal cords by rotating the thyroid cartilage downwards.

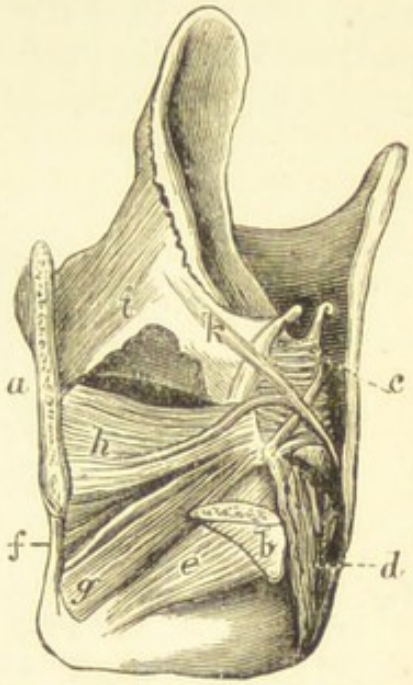


Fig. 135. — MUSCLES OF THE LARYNX; view from the left side behind. *a*, Section of thyroid cartilage, the left side of which is removed with the exception of *b*, the part articulating with the cricoid cartilage; *c*, arytenoideus muscle; *d*, posterior crico-arytenoideus; *e*, crico-thyroideus; *f*, crico-thyroid ligament; *g*, crico-arytenoideus lateralis; *h*, thyro-arytenoideus, its upper edge corresponding with the edge of the vocal cord; *i*, *k*, thyro- and aryteno-epiglottideus, resting on the aryteno-epiglottidean fold of mucous membrane. A portion of the mucous membrane is removed between *h* and *k* to show the position of the glottis.

197. If the larynx be examined by means of a *laryngoscope*, that is to say, a mirror placed in the back part of the throat, so as to throw light down on the larynx and reflect its image to the eye of the observer, it will be seen that, as soon as vocalization commences, the vocal cords spring toward the middle line, leaving only a chink between them, and that they as quickly recede when the voice ceases. Their edges are turned one toward the other when in action; but at other times they are everted. This agrees exactly with the results got by tying a bit of india-rubber or

other membrane to the end of a tube, and holding it so as to leave a chink between two tight edges. As long as the edges are inclined one to the other, or are parallel, a note is produced by blowing through the tube; but when the edges are everted, the sound ceases.

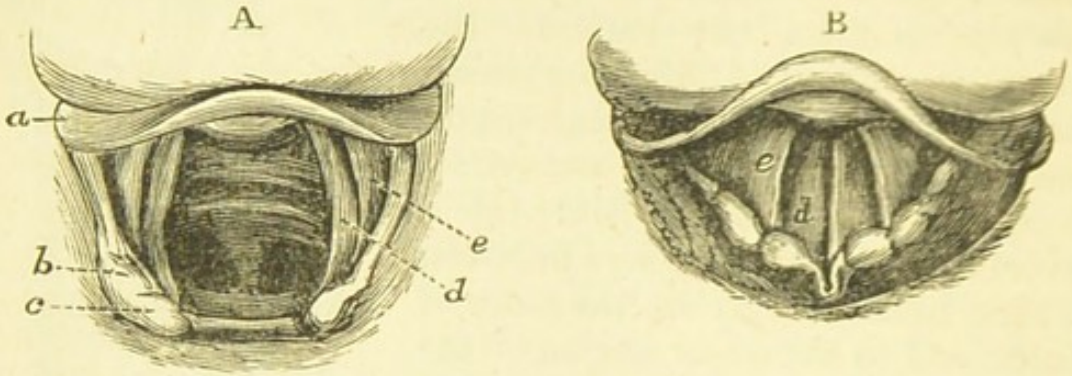


Fig. 136.—Larynx, from above; laryngoscopic views: A, in deep respiration, showing the trachea down to its bifurcation; B, in uttering a high pitched note. *a*, Epiglottis; *b*, *c*, swellings corresponding to cartilaginous nodules of Wrisberg and Santorini; *d*, true vocal cord; *e*, false vocal cord. After Czermak.

The note produced by vibrating strings and laminæ is dependent on two things, namely, the length of the string or free edge, and the degree of tension. Both these principles are illustrated in the human larynx. The reason why the voices of women and children are higher in pitch than those of adult men is, that in women and children the larynx is smaller and the vocal cords are shorter; and in boys, at the age when the voice begins to grow rough, an obvious enlargement of the larynx, as judged by the prominence of the *pomum Adami*, may be observed. But the different notes of any one voice are produced by varying tension of the vocal cords. This may be easily proved by placing a finger over the space occupied by the crico-thyroid membrane and running over the gamut, when the thyroid cartilage will be felt gradually coming down over the cricoid, in the manner which has been already shown to stretch the vocal cords. At the same time. the whole larynx rises more nearly to a level with the tongue, and hence the comparative clearness of the higher notes.

The various cavities above the level of the vocal cords, acting as resonating chambers, determine the timbre of the

voice. First of these come the ventricles of the larynx, while above are the pharynx, nasal fossæ, and frontal, sphenoidal, and maxillary sinuses (p. 222); and among various causes which combine to alter the tones of the voice in old age, may be mentioned the tendency of the entrances to these sinuses to get contracted or blocked up; for, although the dimensions of the various air-cavities of the skull get larger in advanced life, the entrances into them become smaller. From the low position of the larynx, in the utterance of deep notes, overshadowed as it then is by the root of the tongue, the voice is thrown more backwards in them, and reverberates more in the various sinuses.

198. **Speech** is to be carefully distinguished from voice. Voice without speech is an inarticulate sound; speech without voice is a *whisper*. Speech is accomplished by the modifying action of various organs on the expiratory currents of air passing through the mouth. The tongue is by no means the exclusive, nor even the principal organ of speech. In ordinary language, speech is referred to as the use of the tongue, and taste as the use of the palate; and even the word "language," etymologically, means action of the tongue. Yet the palate has little to do with taste, the tongue being the only part in which that sense resides; while the palate, the lips, the fauces, and even the nose are organs of speech as well as the tongue, and persons from whom the tongue has been completely removed by operation continue to speak sufficiently plainly to be understood. The sounds of the various *vowels* are made by varying the shape of the aperture through which the air escapes by the mouth; the *consonants*, on the other hand, are sounded by placing obstructions of different kinds, and in different places, in the way of the current of air.

In the following table an attempt is made to arrange all the possible consonant sounds, according to their mechanism, as labial, palatal or dental, and guttural. It will be observed that the fore parts of the tongue take no part in the formation of any labial or guttural sound; and that in the dental series there are two in which the tongue takes no part, namely, *sh* and French *j*, the only two sounds in which the lower teeth take part. The upper teeth take part in two

sounds ranged with the labials, namely, *f* and *v*. Corresponding hard and soft sounds are placed together in each series in the table. The consonant sounds *w* and *y* are omitted, because they are simply a rapidly sounded *ou* and *ee*.

	Labial.	Palatal and Dental.	Guttural.
Obstruction total	p, b	t, d	k, g (*gum*)
Incomplete contact of parts, without obstruction	f, v	th (*thirst*), th (*then*), s, z, sh, j (French)	h, the burr
Vibratory contact	Inarticulate sound like pw	r	Inarticulate gurgle
Current by the sides of an obstruction		l	
Current reflected into the nose from an obstruction	m	n	ng

CHAPTER XVII.

REPRODUCTION AND DEVELOPMENT.

199. The simplest method of multiplication observed in any set of living bodies is by splitting up into different parts, each of which becomes a distinct individual. This is called multiplication by *fissiparous division*, and is principally found in the very simplest forms, such as unicellular organisms. It is precisely the same mode of multiplication, occurring in distinct beings, as that by which cartilage-corpuscles and others increase in number.

When small portions, or buds, are separated from a parent, the mode of reproduction is said to be of a *gemmiparous* description; and if the bud should happen to be only a single nucleated corpuscle devoted to reproduction, separated from a large mass of such corpuscles, or from an organism however complex, yet it is plain that it may be none the less fairly considered as a bud or *germ* from the whole organism. Now, that is precisely what an *ovum* essentially is: but an ovum, whether vegetable or animal, has the peculiarity that it will not develop into a new individual unless there be incorporated with it another germ of dissimilar kind, though derived from the same species of organism; and herein consists the essence of *sexual reproduction*. The germ which appears to retain its individuality before and after fertilization is the ovum, or female element; while that which disappears by being incorporated therewith is the male element.

200. In the present state of science no explanation can be given why such a thing as sex should exist. It is difficult to say how far down in the organic world the distinction of sex extends, but it exists in organisms of exceedingly simple character; and in those of more complex descriptions, although in certain instances a series of generations are produced

by mere gemmiparous reproduction, sexual reproduction is always resorted to after a cycle has been passed through.

The modes in which such cycles are accomplished are very various. In many instances, both in cryptogamic plants and in the lower forms of animals, there is a manifest *alternation of generation.* Thus the spores on the frond of a fern are

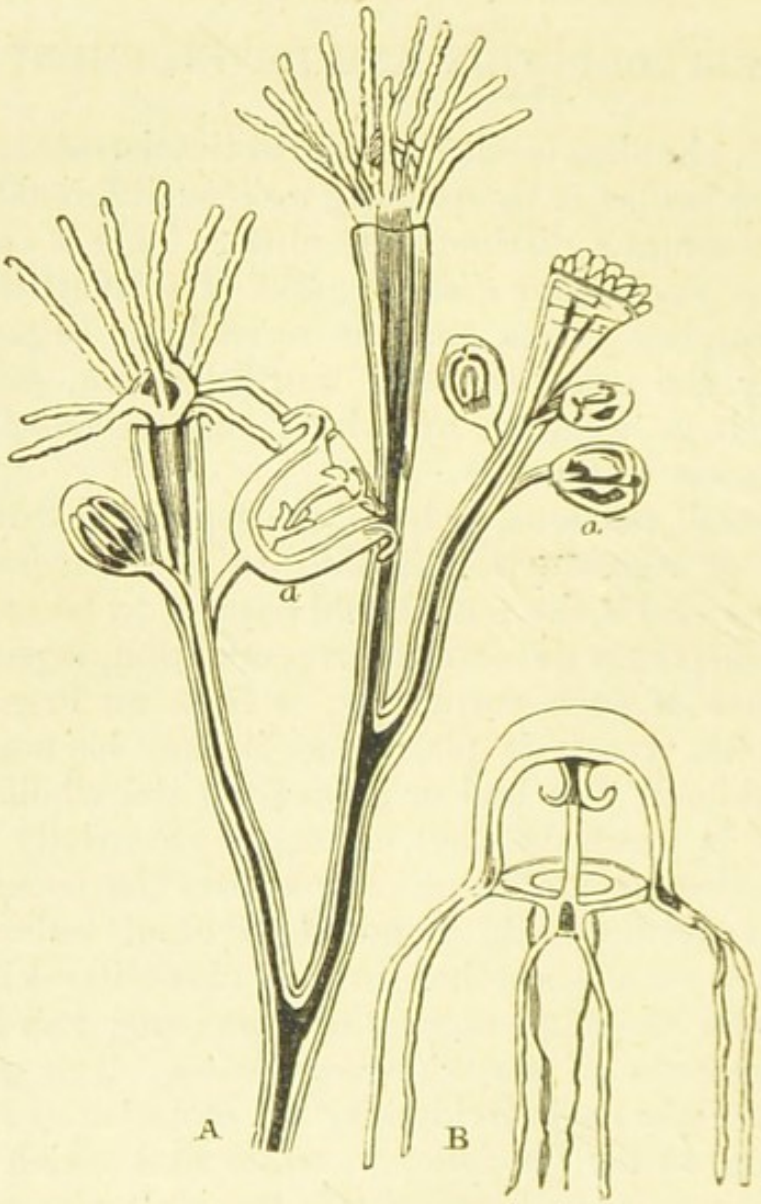


Fig. 137.—Alternate Generation of Hydroid Zoophyte (Bougainvillia ramosa). A, Zoophytic form; *a*, medusoid. B, Liberated medusoid. After Allman.

asexual germs, which grow up to form a lichen-like plant, the prothallus; the prothallus bears upon it male and female elements, and from the union of these the young fern takes its rise. So also among animals, in many hydroid zoophytes

the zoophytic form, which is the more largely developed condition, gives origin by gemmation to medusoids bearing male and female elements, and from the fertilised ova of these medusoids new colonies of zoophytes take origin. There are many other examples of alternation of generation among animals; but the interest in this case is increased by the circumstance, that in other hydroid zoophytes the buds which bear the sexual elements remain attached as mere organs of the zoophyte, never attaining to an independent existence; and thus one is enabled to see that the power of the medusoid to reproduce the zoophyte is but a modification of the more frequently exemplified power of a part to reproduce a whole, the modification being that the reproductive part is entirely severed before the sexes are developed. In the larger Medusæ, or jelly fish, a similar alternation takes place, only the sexual form is the more largely developed; the ovum takes root and grows into a body which breaks up into a series of discs, each of which is developed into a medusa.

In the Aphides, or plantlice, another cycle is exhibited. In the interior of the individuals derived from fertilized ova, another generation is developed from unimpregnated germs; and the insects so formed become parents of others in like manner; and only after several generations are perfectly sexual individuals produced, with whom the cycle again begins.

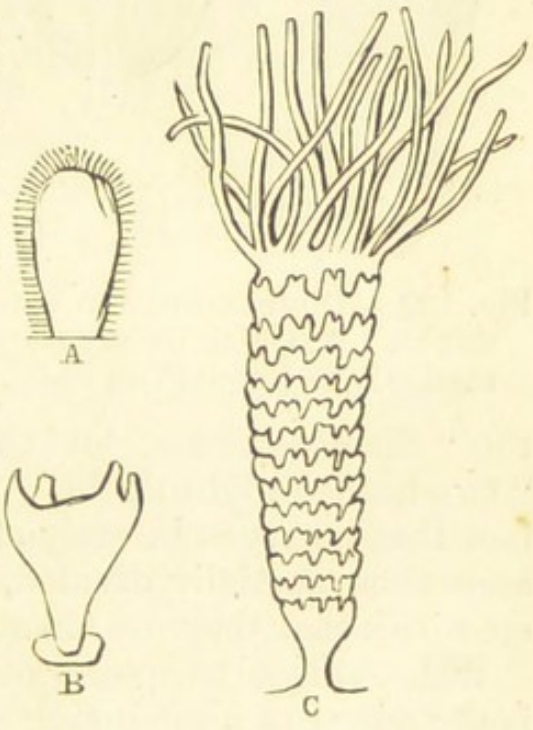


Fig. 138. — ALTERNATE GENERATION of Aurelia aurita. A, Ciliated ovum become adherent. B, The same at a later stage sending out processes. C, *Strobilus*, which breaks up into separate cups, each of which becomes an adult Aurelia. After Sars.

In bees there occurs a description of true *parthenogenesis*. The queen, in her marriage flight at the time of swarming, receives the male element into a sac provided for the purpose, and afterwards in laying her

eggs, adds or withholds a little of the contents of the sac; when this is withheld the egg produces a male; but when it is added a female is produced, which, according as it is fed, becomes a worker or a queen.

In vertebrata, sexual reproduction is the only kind which occurs. Yet in the development of the embryo there is a set of phenomena quite homologous with alternate generation; for the whole ovum is not converted into an embryo, but only a part of it, and, therefore, the embryo may be legitimately considered as a bud from the ovum; in which case the only difference between vertebrate reproduction and that of a medusa is, that in the medusa many buds are derived from an ovum, and in the vertebrata there is only one.* As an abnormal variation, the single vertebrate embryo may divide more or less completely; and this is the origin of all double monstrosities, such as two-headed calves, four-legged hens, the "Siamese twins," and the negress sisters exhibited as the "two-headed nightingale." The proof of this is found in the fact that embryos in early stages of development have been seen thus partially divided, and in the law of double monstrosities that they are always united by corresponding parts.

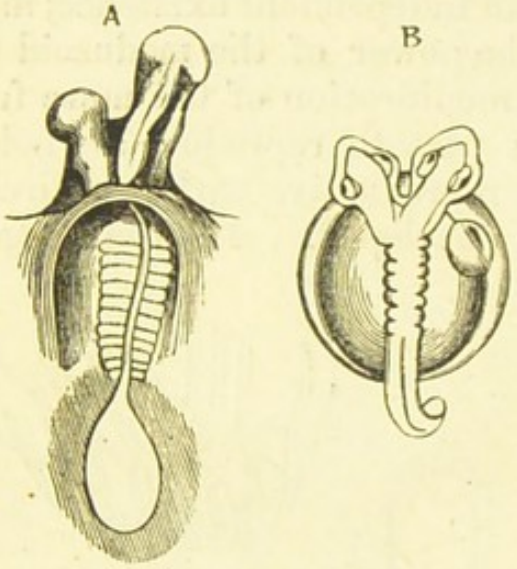


Fig. 139.—DOUBLE-HEADED EMBRYOS. A, Chick (in my possession). B, Perch (Von Baer).

201. Akin to the power of reproducing the whole individual is the power of reproducing lost parts; and the law may be laid down that the less advanced the development of the species or the individual the greater the power of such reproduction. So great is this power in some invertebrate animals that they may be multiplied by artificial division, each moiety retaining

* Viewing the vertebrate embryo as a bud from the ovum, a comparison by no means vague may be drawn between its development and that of a tooth. In both instances there is an elevation which becomes surrounded by a fossa, afterwards converted into a shut sac, and finally the shut sac is burst.

the power of completing a whole form. Even animals so complex as lobsters have notably the power of reproducing lost limbs. No such power exists in vertebrate animals after birth, with the exception that various reptiles and fishes renew their tails when they have been accidentally lost; substituting, however, calcified chorda dorsalis for the lost vertebræ. But before birth lost parts may be reproduced, even in man, to a surprising extent. Sometimes, from accidental causes, a limb of an unborn child suffers amputation by means of strangulation by a band of lymph; and in such cases it often occurs that fingers, or a whole hand, sprout out from the stump of an arm, although they fail to reach the full development. This is particularly interesting, as indicating the latent presence throughout the body of the reproductive power which is exhibited normally and in perfection by the reproductive organs alone. So, also, the occasional occurrence of ovarian tumours containing hair and teeth shows the presence of a power which is normally altogether latent till the addition to the ovum of an element containing similar qualities locked up within it causes it to culminate in full reproduction.

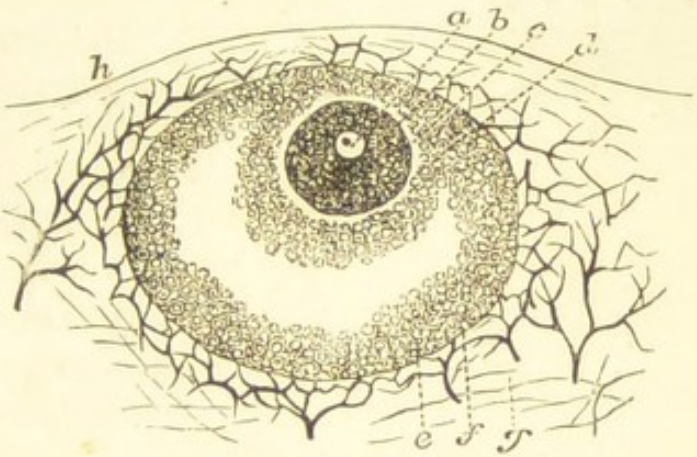


Fig. 140.—Human Ovum within Graafian vesicle. *a*, Germinal vesicle and spot; *b*, vitellus or yelk; *c*, zona pellucida; *d*, discus proligerus; *e*, membrana granulosa; *f*, vascular wall of ovisac; *g*, stroma of ovary; *h*, surface of ovary.

202. The *ovum* or *egg*, in birds and various other animals, is enlarged by the incorporation with it of a great amount of matter which does not undergo fertilization, useful only as material for the nourishment of the young animal. But the mammalian ovum is a structure microscopically minute, which is only discovered by scientific observation.

The human ovum is about $\frac{1}{120}$ of an inch in diameter. It consists of a transparent envelope, the *zona pellucida*,

surrounding a granular *yelk;* and, in the interior of this, to one side, is a clear nucleus called the *germinal vesicle*, with a distinct nucleolus, the *germinal spot.* The ova are developed within organs called *ovaries*, which are placed one on each side in the lower part of the abdomen, and are flattened oval bodies, about an inch and a half long, invested with peritoneum. Each is attached by a fibrous cord to the upper part of the uterus.

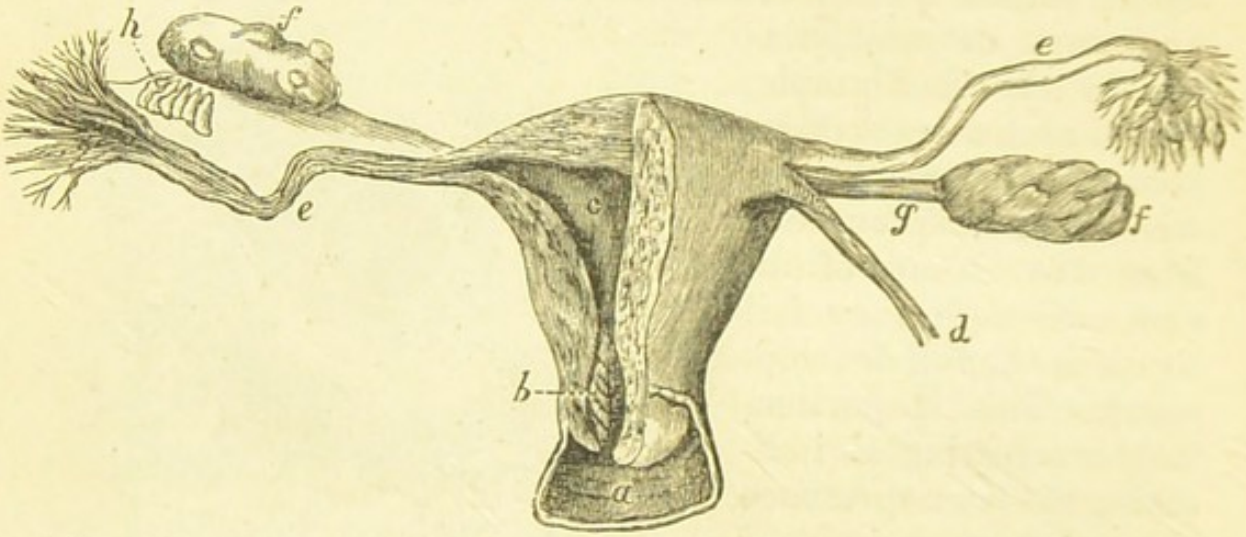


Fig. 141.—Uterus and Ovaries from the front. *a*, Vagina with os uteri depending into it; *b*, cavity of cervix uteri, with rugose mucous membrane; *c*, cavity of fundus uteri, exposed in the right half; *d*, round ligament of uterus; *e*, *e*, Fallopian tubes, the right one laid open; *f*, *f*, ovaries; *g*, round ligament of ovary; *h*, parovarium.

203. The *uterus* or womb is a muscular organ placed, in ordinary circumstances, within the pelvis. It is a pear-shaped body about three inches long, flattened from before backwards, and connected with the abdominal wall in each groin by means of a round ligament. When clipped open it is seen to have exceedingly strong walls; its lower portion, the *cervix*, extending for about an inch upwards from the mouth or inferior opening (*os externum*), surrounds a separate cavity with rugose mucous membrane, divided by a constriction (*os internum*) from the smoothly-lined main cavity, destined for the reception and development of the ovum. This main cavity, contained within the body or *fundus* of the uterus, although destined to undergo enormous temporary enlargement in pregnancy, is of small size at other times, with its

anterior and posterior walls in contact, and its three borders, one above and one at each side, all bulging inwards. The upper angles are distinguished as the *cornua*, being parts which in many of the lower animals are greatly elongated, so as to render the uterus completely forked. Into each cornu opens a long narrow duct, the *Fallopian tube*, which extends outwards in front of the ovary, and terminates immediately beyond it in an expanded and fringed opening, the *fimbriated extremity*, which leads from the peritoneal cavity, and makes a communication between it and the outside of the body. In animals in which the cornua are developed, they are the parts which lodge the young. Thus, in a sheep with one lamb, the lamb occupies one cornu; if there be twin lambs, they lie one in each cornu; and in animals which have a litter of young, the embryos are ranged in series in separate membranes along the length of each cornu.



Fig. 142.—Uterus of Sheep.
a, *a*, The cornua.

204. *The ovaries* of persons who have died in the prime of life present, scattered through their tough fibrous structure, and more or less distinctly seen from the surface, a variable number of clear vesicles, one or two of which may be like very large beads immediately beneath the peritoneum. These are called *Graafian vesicles;* each of them contains an ovum, and gradually enlarging, and approaching the surface as it enlarges, eventually ruptures and discharges its ovum, covered with a coating of granules, the *discus proligerus*. The ovum is caught up by the fimbriated extremity of the Fallopian tube, which would appear to be applied to the rupturing vesicle for that purpose.

While only a limited number of these vesicles are visible with the naked eye, the microscope reveals others of minute size in vast multitudes, which have been estimated at more than 70,000 in one individual (Henle). The ova, moreover, make their appearance prior to the vesicles which subsequently surround them, and already exist in large numbers

before birth. The germinal vesicle makes its appearance first, then the rest of the ovum; the ovum subsequently becomes imbedded in corpuscular matter, and this becomes separated by imbibition of fluid into two strata, one of which adheres to the ovum, and is the *discus proligerus* alluded to, while the other adheres to the ovisac, and is named *membrana granulosa.* In their early stages of development, the ova move from the circumference towards the attachment of the ovary, the smallest ova being found close to the peritoneum. It is only when the Graafian vesicles begin to fill with fluid that they push their way in the direction of least pressure, precisely as an abscess would, and thus approach the peritoneum again, at the same time that the ovum quits the centre of the vesicle, and adheres to the outer wall. The originally centripetal movement reminds us that although in all the higher vertebrata, and many fishes, the ova escape by peritoneal rupture, yet in the majority of osseous fishes they grow in festoons, directed to the centre of a hollow organ, which opens by a duct, like a secreting gland. Also the homologous organ in the male is a secreting gland, in which the secretion travels from the circumference towards the attachment; and a rudimentary appearance of secreting tubules, in which the ova are developed, has been noticed in mammalian ovaries by some observers. Thus the ovary may be regarded as an imperfectly developed secreting gland.



Fig. 143. — Ovary and Oviduct of Sunfish (Orthragoriscus mola) laid open.

At periodic intervals of a month's duration, one or more Graafian vesicles ripen, rupture, and discharge their contents. At the same time, the mucous membrane of the uterus shares in the vascular excitement which the ovaries exhibit, and this passes away with an extravasation of blood from the sur-

face. Each Graafian vesicle has an exceedingly vascular wall, embracing the proper ovisac, and when the vesicle bursts, its vessels, being no longer supported, give way, and fill the cavity with a clot. This clot and the sac around it undergo various changes; the clot disappearing, while the sac becomes yellow, and increases in thickness and size, particularly when impregnation has taken place. The structure which is thus formed is called a *corpus luteum*, and subsequently disappears, leaving nothing but a cicatrix. It does not seem to fulfil any function, but rather to be a growth resulting from the vascular excitement of the structures around.

205. In the male, the germ-preparing glands, corresponding to the ovaries in the female, are the *testes*. They differ, how-

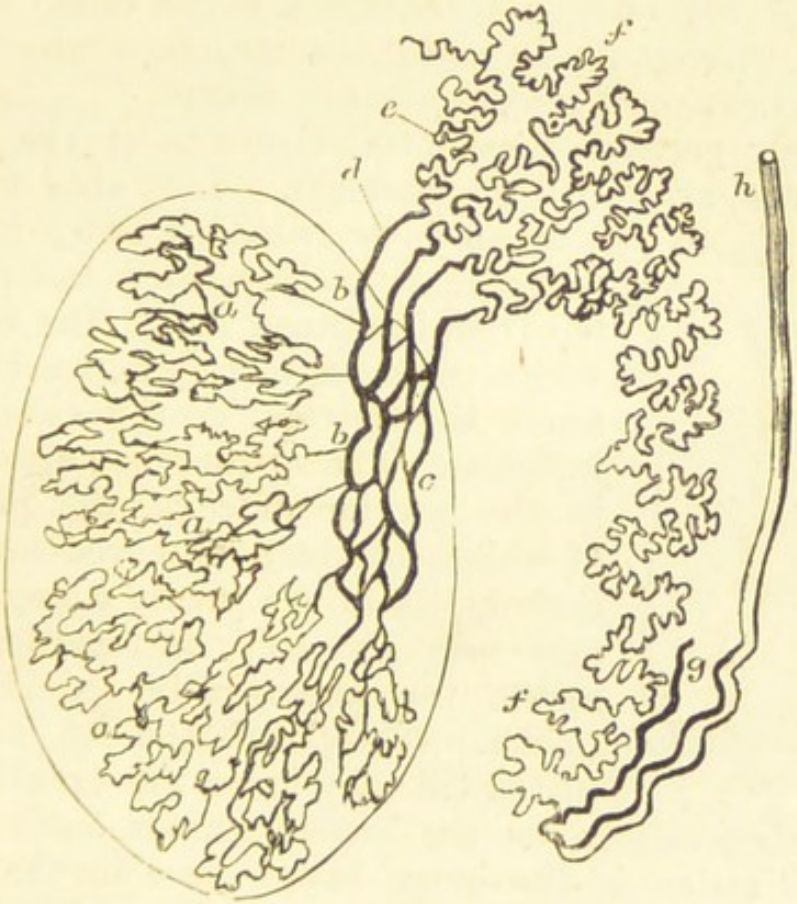


Fig. 144.—Diagram of Seminiferous Tubules and Ducts. *a*, *a*, Tubuli seminiferi; *b*, *b*, vasa recta; *c*, rete testis; *d*, vasa efferentia, from twelve to fifteen in number; *e*, coni vasculosi; *f*, *f*, epididymis; *g*, vas aberrans; *h*, vas deferens.

ever, from the ovaries, in leaving, before birth, their original situation within the body, and descending to a position external to the abdominal cavity; as also in being developed

into exceedingly complex tubular glands, with their ducts in structural continuity with them. The technical names of the different parts of the ducts are mentioned in the explanation of the accompanying diagram. It is sufficient to note that the length of channel through which the secretion has to pass is without parallel in the rest of the body; that the secreting tubules are upwards of two feet long, and that the duct called the epididymis is estimated as being twenty feet in length, and is ciliated. The advantage gained by this complexity is not known. The main ducts open into the urethra, a little in front of the bladder, where that passage is surrounded with a glandular structure called the *prostate;* and in the middle line, close to the two ducts, is a small pouch, just big enough to admit a probe, called the *sinus pocularis*, interesting as being the structure which, in the female, is developed into uterus and vagina.

The male germs, or essential elements of the secretion of the testes, are called *spermatozoa.* They are bodies varying from $\frac{1}{500}$ to $\frac{1}{400}$ of an inch in length, and consist of a pear-shaped body, with a tail extending out from the broad end. The tail moves with a rapid undulatory movement, which sends the spermatozoon forwards, body foremost. The spermatozoa are developed in the interior of cells, the protoplasm of which has been observed adhering to their heads in the young state, and they may very probably be regarded as elements morphologically equivalent to nuclei. Their development is not completed till they leave the secreting tubes.

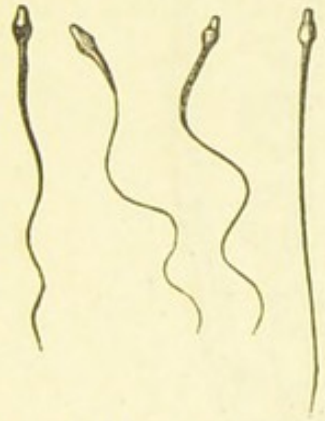


Fig. 145.—SPERMATOZOA.

206. Observations on the lower animals leave no doubt that fertilization of the ovum takes place by the entrance of spermatozoa into the interior of the zona pellucida, after which, both spermatozoa and germinal vesicle are melted down in the yelk, which thereby acquires new properties, and divides first into two parts, then into four, and so on, each part dividing always into two, until the whole yelk is converted by this process of *cleavage* into a mass of nucleated corpuscles, devoid of cell walls, from a certain number of

which the future animal is developed. These being the facts, the student may see that impregnation may be regarded as the fusion of two mutually attracted units of life into one; and that it is possible to consider the ancestry of every nucleated corpuscle of the body as an unbroken chain, through generations, from parents to children.

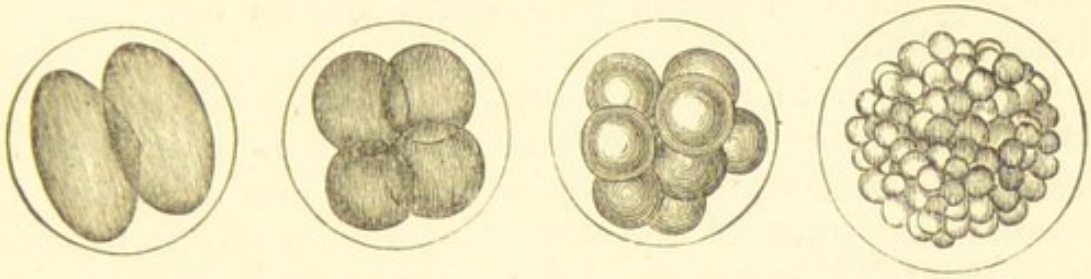


Fig. 146.—Cleavage of the Yelk. The dog. Bischoff.

In its passage downwards through the Fallopian tube, the ovum undergoes some enlargement, and the zona pellucida receives a coating of albuminous substance, gradually increasing in thickness. On reaching the uterus, the envelope of the ovum, henceforward called the *chorion*, proceeds to throw out branching processes or villi, by which it becomes closely connnected with the uterine walls, and receives nourishment from them; and in these villi blood-vessels subsequently appear, connected with the embryonic circulation. The mucous membrane of the uterus, rich in tubular glands, and ordinarily covered with ciliated columnar epithelium, begins, even before the ovum reaches it, to become thick and spongy; it forms a growth which, from being cast off at the birth of the child, is termed decidua; and where the ovum is situated, this rises up and invests it, forming what is distinguished as the *decidua reflexa*, while that which lines the rest of the uterine cavity is called *decidua vera*. A secretion of fluid like-

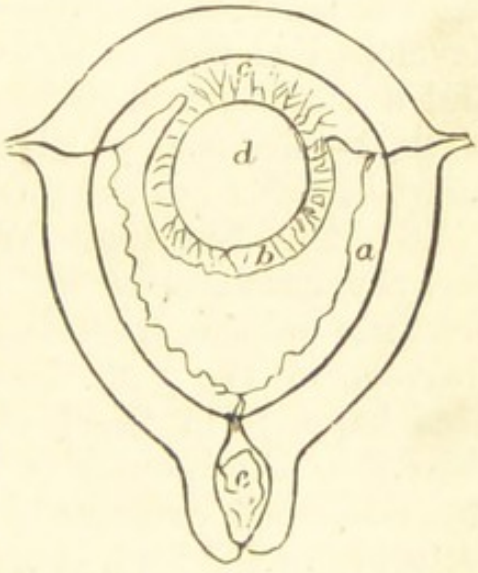


Fig. 147.—Diagram of Decidua. *a*, Decidua vera; *b*, decidua reflexa; *c*, decidua serotina; *d*, ovular space, with villi of chorion round about; *e*, mucus plugging the cervix.

wise takes place, and, for a period, two separate spaces exist within the uterus, namely, that of the general uterine cavity, and that which contains the ovum. It is some considerable time before this latter space grows sufficiently for the decidua vera and decidua reflexa to come into contact. Ultimately they are so closely blended that in the later months of gestation the decidua reflexa can no longer be recognised.

While the ovular space is separated, as has been said, from the uterine space by the decidua reflexa, it remains from the first in contact with the uterine wall on one side; and the mucous membrane of the uterus at this part exhibits, like the rest, an exaggerated growth, sometimes termed *decidua serotina*, destined to be more highly developed than the decidua vera, and becomes the medium of connection between the maternal structures and the child, after the vessels in the villi of the chorion at other parts have disappeared. The vessels referred to in the villi of the chorion are brought to it on the surface of a vesicular outgrowth of the embryo, named the *allantois* (p. 294); and, where in contact with the decidua serotina, the vessels of this allantois become greatly developed, as well as those of the uterine mucous membrane, and a structure is developed, called the *placenta* or after-birth, by means of which the formed embryo or *fœtus* receives nourishment from the mother till birth.

207. The Embryo.—We have seen that after impregnation the contents of the ovum are converted, by the disappearance of the spermatozoa and germinal vesicle, and the cleavage of the yelk, into a mass of nucleated corpuscles. This happens in the lower part of the Fallopian tube, and thereafter the interior of the yelk becomes transparent, and the nucleated corpuscles are aggregated beneath the zona pellucida in the form of a hollow sphere, which is termed the *blastoderm* or *germinal membrane*. Within a few days after the ovum has reached the uterus, a clear area, with an opaque border, makes its appearance on one side of the germinal membrane, and in this area a white streak, which is the first appearance of the embryo. This streak consists of a furrow with elevated margins, the *primitive groove;* and beneath the groove a rod-like body soon appears, the *chorda dorsalis*

or *notochord*. At the circumference of the embryo and beyond it, the germinal membrane splits up into two layers, and this division proceeds completely round the yelk; but if a section be made through the embryo, *three layers*, much more closely connected, are seen; the *innermost* of which is converted into the epithelial lining of the alimentary canal and its appendages, while the *middle* layer forms the principal part of the body, and the *outer* layer, so far as it lies within the primitive groove, is devoted to the formation of the cerebro-spinal axis, and, beyond the margin of the groove, is converted into the cuticle of the whole body.

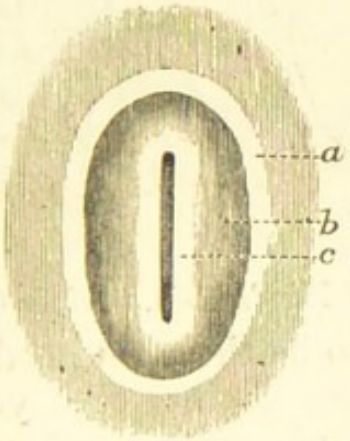


Fig. 148.—PRIMITIVE GROOVE OF RABBIT, magnified five diameters. *a*, Area opaca; *b*, area pellucida; *c*, primitive trace, with the groove in the middle. After Bischoff.

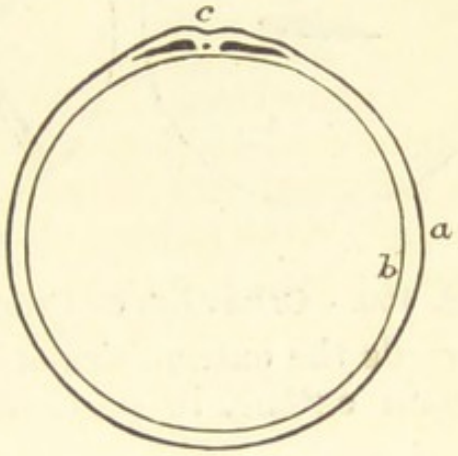


Fig. 149.—SECTION OF MAMMALIAN OVUM: diagram. *a*, Outer layer of germinal membrane; *b*, inner layer; *c*, primitive groove, and, beneath it, section of chorda dorsalis, with the rest of the middle layer on each side.

208. At this point it may be well to pause for a moment, and direct the student's attention to some of the peculiarities of the eggs of birds, since it is in the hen's egg that by far the easiest opportunity is obtained for studying embryology from nature. The hen's egg becomes impregnated in the upper part of the oviduct, and the cleavage of the yolk is confined to a white spot at one side called the *cicatricula*. This takes place by first one cleft appearing, then four, then others between them, radiating from a centre, and portions between these radiations being separated irregularly, and afterwards subdividing; but the yolk beyond the cicatricula

takes no part in the process. In succeeding parts of the oviduct, the albumen and the shell are deposited. If a hen's egg be placed on its side, and the shell be broken on the side which happens to be uppermost, the cicatricula is always found on the corresponding part of the yelk. The reason of this is, that the albumen first deposited round the vitelline membrane is prolonged in two twisted strings, *chalazæ*,

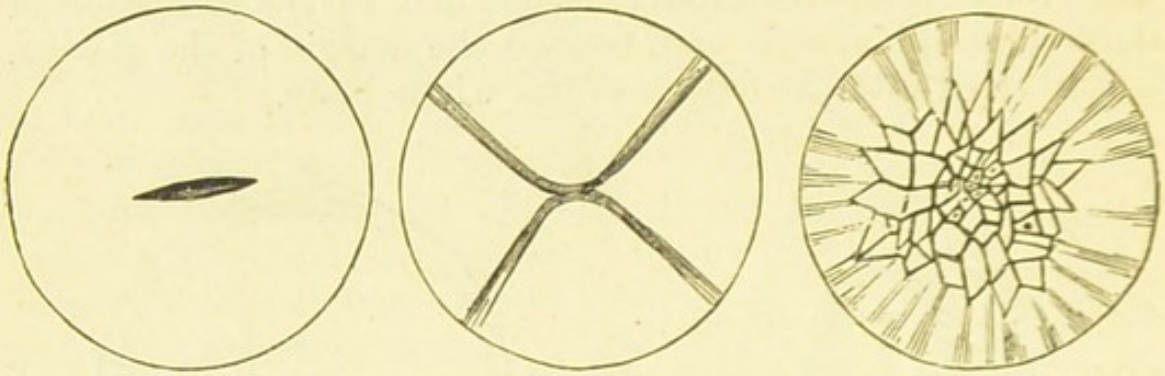


Fig. 150.—Cleavage of Cicatricula of Hen's Egg. After Coste.

towards the extremities of the egg, to be there retained, to a certain extent, in position. By these chalazæ the yolk is suspended, and being lighter on the side on which the cicatricula is placed, it turns that part always upwards away from the damp ground, and towards the warmth of the hen's body. In consequence of this arrangement, there is nothing easier than to obtain a view of the early stages of embryonic growth in the chick, from the appearance of the primitive groove onwards. If it be sought to hatch the eggs artificially, care must he taken not to allow their temperature to vary more than a few degrees above or below 102° F.

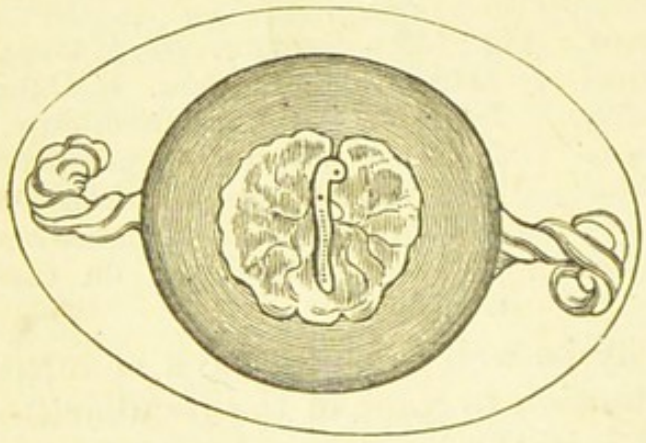


Fig. 151.—Hen's Egg, showing chalazæ, and embryo of three days incubation, with area vasculosa around it.

209. The *primitive groove* is the future cerebro-spinal canal,

and is converted from an open groove to a closed cylinder by its margins growing up and meeting together above it. In a similar way its contents likewise become cylindrical; the tube thus formed being converted in its lower part into the spinal cord; while in the cerebral part, which at this early stage is little less than half the length of the whole embryo, it is swollen into three successive vesicles. The first or foremost of these cerebral vesicles is that from which the third ventrical of the brain, with the hemisphere-vesicles coming off from it, is developed; the second is that from which the aqueduct of Sylvius, with the corpora quadrigemina and other parts surrounding it, is formed; and the third is the part from which the cerebellum, pons Varolii, and medulla oblongata take origin.

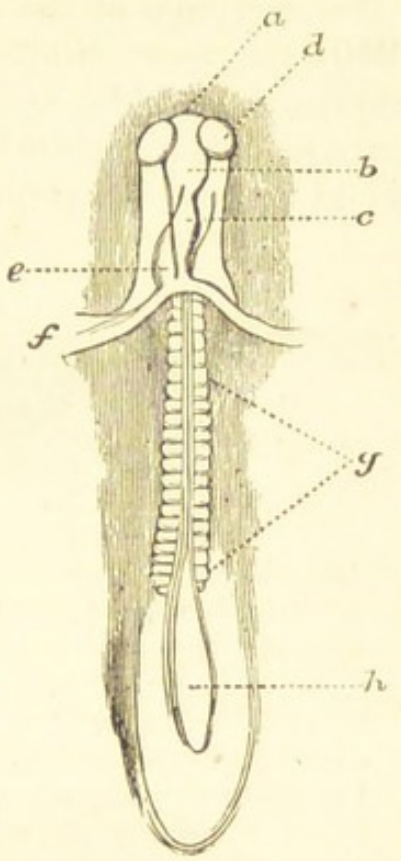


Fig. 152.—Embryo Chick, about two days old; under surface. *a*, *b*, *c*, First, second, and third cerebral vesicles; *d*, primary optic vesicle; *e*, rudiment of heart; *f*, fold at which the cephalic plate is continuous with the cephalic hood, and the yelk sac continuous with the *cul-de-sac* from which the pharynx is formed; *g*, primordial vertebræ; *h*, unclosed part of the primitive groove.

The *chorda dorsalis* or *notochord* runs down the centre of the middle layer of the embryo. It is a purely cellular structure, and continues so as long as it exists, but in most animals it is not permanent. In sturgeons, lampreys, and some other fishes, it continues through life, being developed into a thick column of large, distinctly-walled cells, with a thick fibrous sheath round about, which serves instead of a chain of bodies of vertebræ. In other vertebrate animals, the bodies of the vertebræ make their first appearance round the sheath of the chorda dorsalis, and constrict that structure so as to leave a bead-like dilatation in the position of each intervertebral disc; ultimately, however, in

the higher vertebrata the whole chorda dorsalis completely disappears, even the intervertebral discs being developments rather of its sheath than of its proper substance. The chorda dorsalis has been traced in young mammals into the region of the sphenoid bone, where it ends in a point imbedded in the cartilage of the base of the skull.

210. On each side of the chorda dorsalis, in the early embryo, the middle layer, except in the head, is divided into a part near the middle line called the *dorsal plate*, and a part beyond termed the *ventral plate*.

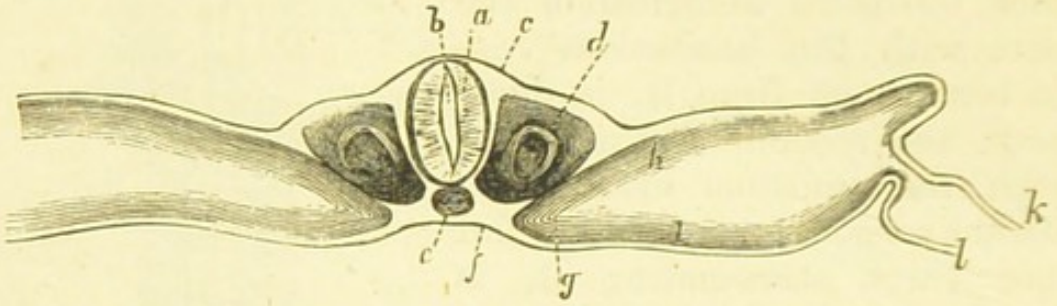


Fig. 153.—Transverse Section of Chick of two days incubation. *a*, Spinal cord; *b*, central canal of cord; *c*, outer layer of embryo, forming the cuticle; *d*, primordial vertebra; *e*, chorda dorsalis; *f*, inner layer of embryo, forming intestinal epithelium; *g*, ventral plate pushing towards the middle line; *h*, *i*, outer and inner division of the same; *k*, outer layer of blastoderm, from which the amnion and inner part of the chorion are formed; *l*, inner layer of blastoderm which surrounds the yelk.

The dorsal plates soon exhibit a distinct segmentation, a series of blocks of dense tissue, the *primordial vertebræ*, making their appearance on each side of the primordial groove, beginning behind the head, and increasing in numbers backwards. Each of these so-called primordial vertebræ contains superficially the rudiment of a segment of the muscular wall of the body, and, beneath that, the commencement of a spinal nerve, which afterwards pushes inwards to join the spinal cord; also between the successive pairs of spinal nerves appear the rudiments of the skeleton, namely, the vertebral and costal arches. The vertebral and costal parts of each segment are indivisible at first, but afterwards, as the common cartilaginous mass grows outwards, it becomes divided, in the thoracic region, into vertebra, rib, costal cartilage, and part of the sternum, and folds round to meet its fellow of the opposite side.

The ventral plates early split into a deep and superficial part, like the part of the germinal membrane beyond the embryo; but at their inner part, instead of so splitting, they become thicker and push inwards, so that the plates of opposite sides meet together below the chorda dorsalis, and form a *mesial plate*, in which appear the great blood-vessels and other organs. Among these organs may be mentioned the *Wolffian bodies* or primordial kidneys (fig. 88), which originally occupy the whole length of the abdominal cavity at the sides of the vertebral column, and are closely connected with the development of the reproductive organs; but disappear at a very early period of fœtal life, and are replaced by the permanent kidneys, which take origin between and behind them. The space between the superficial and deep divisions of the ventral plates is the great serous cavity of the trunk, subsequently subdivided into the pericardial, pleural, and peritoneal spaces. The superficial division is the source of the cutis and other connective tissues of the visceral wall; while the deep division adheres to the inner layer of the embryo, and completes with it the development of the alimentary tube (Remak).

The limbs make their appearance from the ventral plates as little buds, which very early display a division into fingers, the thumb or great toe of each lying nearest the head; and subsequently the elongation of the arm and leg takes place.

211. In the head, the middle layer of the embryo on each side and in front of the chorda dorsalis is called the cephalic plate. We have seen already how it encloses the brain, in the same fashion as the dorsal plates, continuous with it, rise up round the spinal cord. Very soon the brain and parts round it are sharply curved down towards the deep part of the ovum, the margins of the cephalic plate become folded in, and a deep fossa is formed round it, so that the head and neck become separated off from the ovum, while a hood of the outer layer of the germinal membrane rises up over them. In like manner the deep layer of the embryo within the head becomes converted into a *cul-de-sac*, surrounded with the continuation forwards of the mesial plate.

The margins of the middle layer in the head and neck are thrown into five pairs of processes called *branchial processes*,

separated by clefts; and the foremost of these, uniting with its fellow in the middle line, forms the lower jaw, while the upper part of the cleft behind it remains as the opening of the ear, and the other clefts entirely disappear in the higher vertebrates, although they are undoubtedly the same clefts as those which in fishes separate the gills throughout life. In front of the first branchial process, the eye is developed in a cleft of the cephalic plate, and separated by a little process (*lateral frontal*) from the nostril. Between the nostrils, the mesial termination of the cephalic plate is prolonged down to form the middle portion of the upper lip, and is called the *middle frontal process.* The cheeks are derived from the *maxillary lobe,* a projection sent forwards from the region at the base of the first branchial arch. The mouth makes its first appearance as a depression of the outer layer of the embryo, which, at a very early period, touches the *cul-de-sac* of the alimentary tube; and a perforation then takes place. The roof of the mouth, after this, is formed at first by the base of the skull, as it continues to be in fishes throughout life. The palate is a later formation, and is developed from the maxillary lobes, which each send a lamina inwards to meet its fellow of the opposite side in the middle line. Sometimes the union fails to be completed, and the result is a permanently cleft palate. The groove over the upper lip, and the part of the jaw supporting the upper incisor teeth, are derived from the middle frontal process; and when this fails to unite with one or both maxillary lobes, the result is a single or double hare lip.

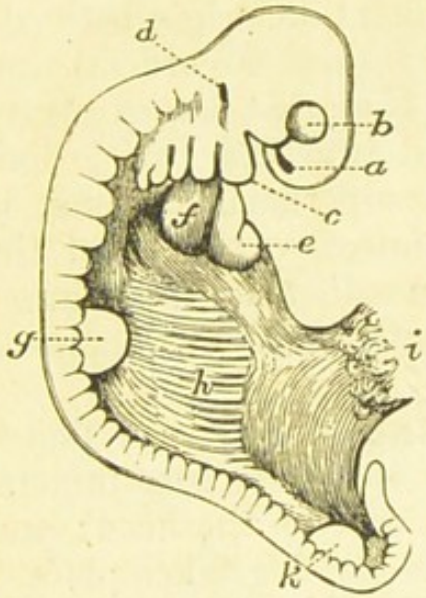


Fig. 154.—Embryo Lamb, magnified six diameters. *a*, Nostril, and, beneath it, the middle frontal process; *b*, eye, and, beneath it, the lateral frontal process; *c*, first branchial process, and, between it and the eye, the maxillary lobe; *d*, ear; *e*, ventricular part of the heart; *f*, right auricle; *g*, fore limb; *h*, Wolffian body; *i*, place where the allantois and umbilical vesicle have been torn across; *k*, hind limb.

212. The process of separation of

the embryo from the rest of the ovum, so as to complete its visceral walls, is effected by the folding-in of the layers at the sides, by the prolongation backwards of the folding-in which has been spoken of as occurring in the head, and by a similar folding-forwards at the pelvic end of the body, until at last the neck of communication of the embryo with the rest of the ovum is narrowed to the navel, where the vessels of the allantois pass in and out.

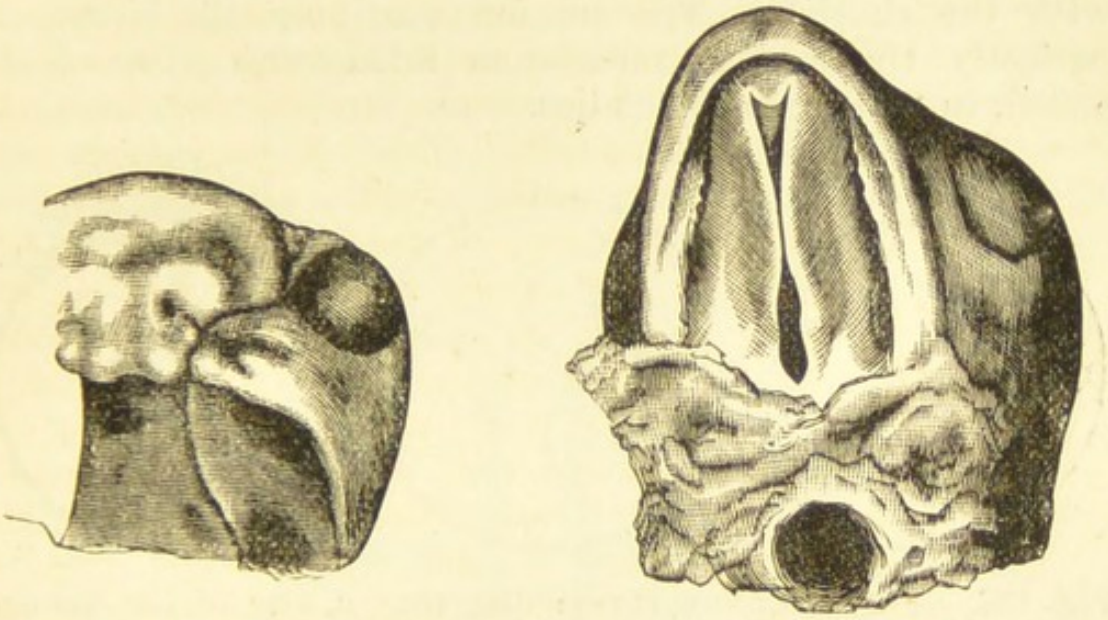


Fig. 155. — Development of the Palate in the Embryo Lamb, in two stages more advanced than that exhibited in the previous figure. From drawings by Professor Dickson.

By this means both the cylinder of the visceral walls and that of the alimentary tube are completed. For a time the remains of the yelk sac continue connected with the alimentary tube, which projects in a loop at the navel from the completed wall of the abdomen, and they go by the name of the *umbilical vesicle*, while the pedicle of connection is called the *vitelline duct;* it is not, however, a hollow pedicle; and even in those classes of animals which have large yelk sacs, the contents do not pass into the alimentary canal, but are absorbed by the blood-vessels round it, for the nourishment of the young animal. The place where the vitelline duct is attached to the intestine, is near the lower end of the ileum.

As the walls of the embryo become folded in, the outer layer of the germinal membrane, which is gradually expand-

ing, and removed from the inner layer or yelk sac by an increasing amount of fluid, rises up round the whole embryo, as it has previously risen round the head; and thus the embryo is dipped into a deepening hollow, and at last the entrance into the hollow becomes narrowed and obliterated above the dorsum of the embryo, and the embryo is completely enveloped in a sac, which is filled with fluid, and is called the *amnion*. The part of the outer layer of the germinal membrane beyond the amnion becomes incorporated with the chorion. The amnion continues, till birth, as a perfectly transparent membrane filled with clear liquor amnii, in which the fœtus lies.



Fig. 156.—Fœtal Connections: diagram. *a*, Sac of the amnion; *b*, yelk sac; *c*, allantois becoming developed into the fœtal part of the placenta.

213. We have still to consider the development of the vascular system. The first traces of embryonic blood-vessels seem to make their appearance external to the embryo, in the opaque border of the clear area which surrounds it. Here there is a circular *vena terminalis*, and a development of blood-corpuscles. A network of vessels springs up over the clear area, and the blood is brought to the embryonic heart by two trunks, which enter the embryo transversely, one on each side, the *omphalo-mesenteric veins*. The circular vena terminalis advances on the inner layer of the germinal membrane, until the network of vessels of which it forms the limit, the *omphalo-mesenteric system*, surrounds the whole yelk sac. This is the earliest system of blood-vessels for the nourishment of the embryo; and in the eggs of oviparous animals, which are comparatively large, it is of great import-

ance in absorbing the yelk as nourishment. But in mammals, we have seen that the ovum is minute, and grows by nourishment drawn from the mother; and it seems probable that in them the omphalo-mesenteric vessels absorb from other sources besides the contents of the yelk sac.

214. The heart is at first a straight tube which runs forwards towards the head, from the point where the omphalo-mesenteric veins unite. But it soon elongates so much that it is thrown into a loop, the prominence of which becomes converted into the ventricular portion of the organ, while the lower part forms the auricular portion, and the upper a common arterial trunk, the *truncus arteriosus*. Subsequently, the truncus arteriosus is divided longitudinally into aorta and pulmonary artery, and the auricles and ventricles are

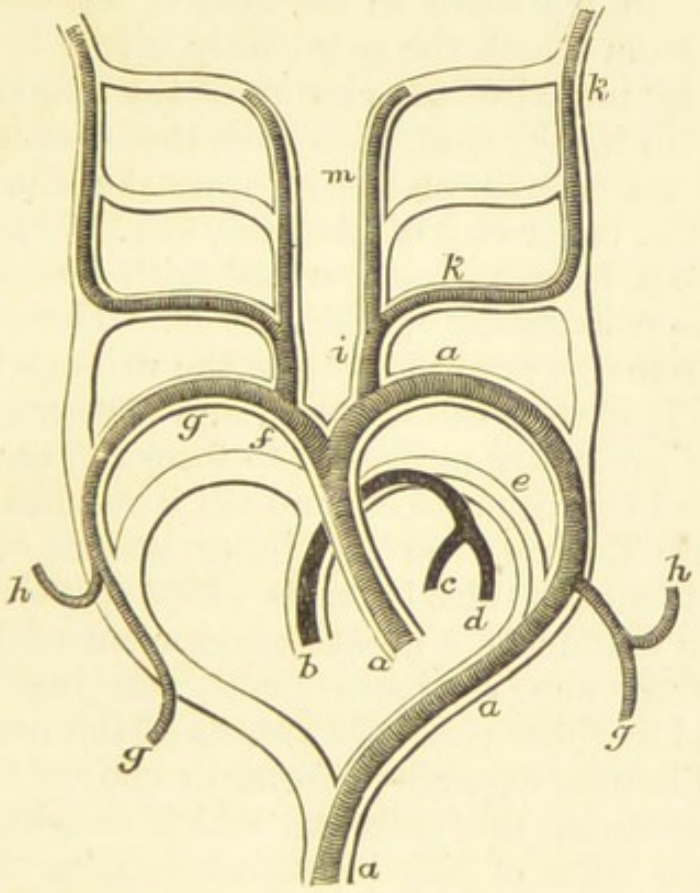


Fig. 157.—Plan of the Branchial Arches in Mammals. The portions in outline are obliterated. *a*, *a*, *a*, Aorta; *b*, pulmonary artery; *c*, *d*, right and left pulmonary arteries; *e*, truncus arteriosus, obliterated after birth; *f*, innominate artery; *g*, *g*, *g*, subclavian arteries going to the upper limbs; *h*, *h*, vertebral arteries; *i*, common carotid; *k*, *k*, internal carotid; *m*, external carotid artery. Rathke.

each in like manner divided into right and left cavities. But the truncus arteriosus originally passes up and splits into two divisions, from which come off five pairs of *branchial arches*, not, however, all existing at one time, but the foremost of them disappearing as the hinder arches come into view. These arches, which seem to correspond with the branchial processes, pass partially round the œsophagus, and open into two vessels which descend side by side in front of the vertebral column, the *primordial aortæ*. The two aortæ afterwards become fused into one, which continues at first to arise by a right and left root, and permanently does so in the lower classes of vertebrates; but in birds the right root alone remains, and in mammals only the left root, while the other is obliterated. The fourth branchial arch of the left side remains in mammals as the arch of the aorta, and the fifth is that from which the pulmonary artery is developed.

215. At the period of the closure of the amnion, while the yelk sac is still widely connected with the intestine, the *allantois*, already mentioned, makes its appearance in front of the embryo, at the lower end of the body (fig. 156). It rapidly expands into a large vesicle covered with blood-vessels, and soon becomes constricted in the middle. The vesicular part at the base remains permanently as the urinary bladder; the constriction is termed the *urachus*, and emerges at the opening which is gradually narrowed to form the navel; and the vesicle beyond continues to expand till it reaches the chorion, then becomes flattened on the inner surface of that membrane, and furnishes blood-vessels which penetrate into all its villi. In mammals, a great development of blood-vessels takes place at one or more parts, varying in different families; and at these parts the vessels of the uterine mucous membrane likewise expand to form, in conjunction with the allantoic structure, the placenta, which consists essentially of aggregated tufts of blood-vessels belonging to the fœtus, projecting into sinuses filled with maternal blood, whence they suck up supplies both of nourishment and oxygen. In the human subject, the placenta is circular and limited to an area which, at the full term, is only about 7 or 8 inches in diameter. In birds and reptiles the allantois spreads out as in mammals, but retains its membranous and hollow

construction, and has principally, if not entirely, a respiratory function. In amphibia the allantois is a mere urinary bladder, and the period of allantoic circulation is not represented.

As development in the mammal proceeds, the placenta is separated by a greater distance from the embryo; the original hollow of the urachus and placental part of the allantois disappears, and the placenta is united to the navel by an *umbilical cord*, consisting of vascular trunks, gelatinous connective tissue, and an investment of thickened amnion. The arteries which convey the blood to the placenta are two in number, arising within the pelvis, and pass up one on each side of the urinary bladder. While within the abdomen, they are termed *hypogastric*, and in the cord they are called *umbilical arteries*. The veins which return the blood from the placenta to the fœtus are also at first two in number, but the right one speedily disappears, so that in the cord there are only three vessels, namely, two umbilical arteries and one umbilical vein. These are twisted spirally, the arteries having the appearance of winding round the vein. The umbilical vein, entering at the navel, passes up to the under surface of the liver, where it lies in the longitudinal fissure between the right and left lobes of that organ, communicates freely with the portal vein, and is prolonged backwards, under the name of *ductus venosus*, to join the inferior vena cava.

216. When it is considered that throughout fœtal life the lungs are of no service, and that respiration is carried on by means of the placenta, it will be at once perceived that the course of the circulation must be very different then from what it is afterwards, and that a sudden change must take place at birth. This is really the case; and in connection with the course of the circulation there are some fœtal peculiarities of the heart and pulmonary artery. In the fœtal heart the annulus ovalis of the right auricle is an open *foramen ovale;* and the pulmonary artery, after giving off the right and left pulmonary arteries, which are but small branches, is continued straight on to open into the arch of the aorta, where that artery is about to be continued, as the descending aorta, down through the thorax. This continuation of the pul-

monary artery is called the *truncus arteriosus;* and it may be mentioned that fibrous vestiges of this, as well as of the ductus venosus, umbilical vein, and hypogastric arteries, remain in the body permanently.

The oxygenated blood, returning to the fœtus by the umbilical vein, passes partly into the vena cava inferior

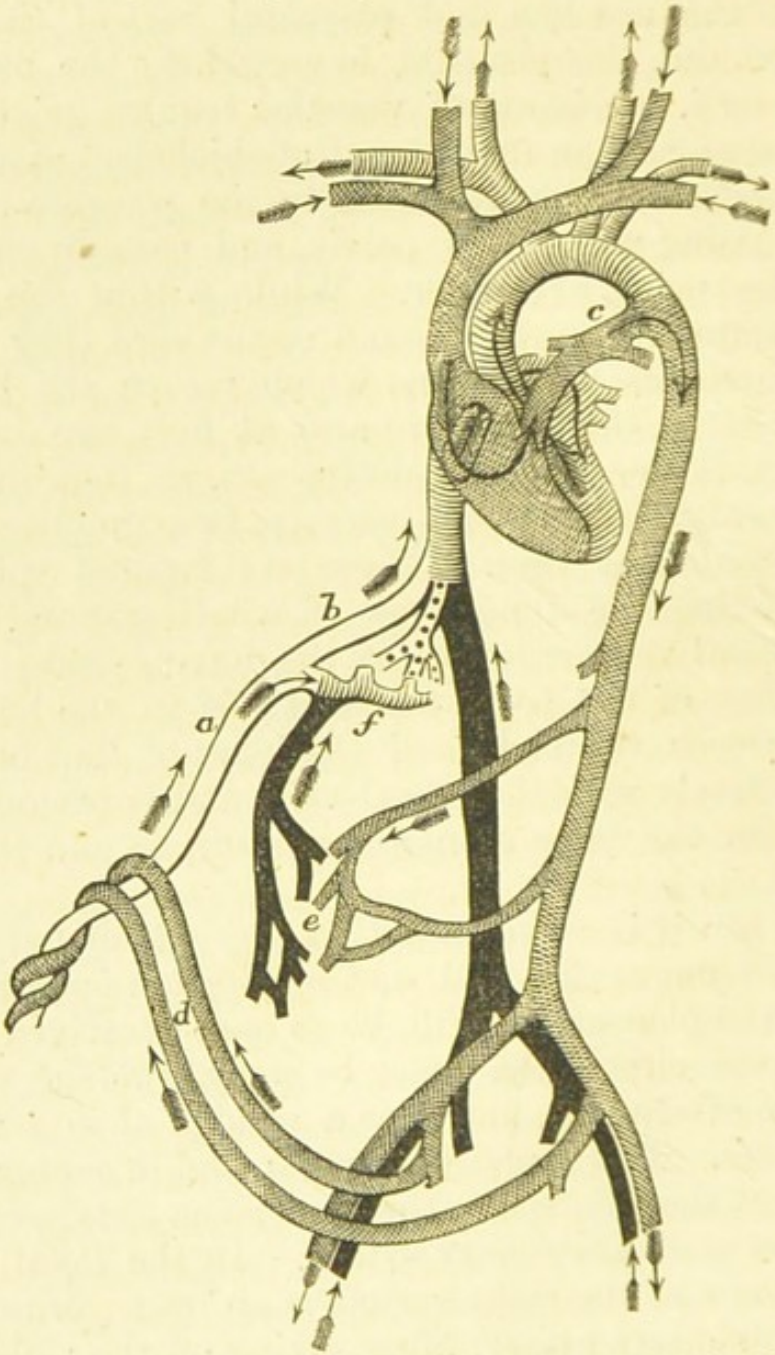


Fig. 158.—Fœtal Circulation. The course of the blood is indicated by arrows, and its quality by shading. *a*, Umbilical vein bringing back aërated blood from the placenta; *b*, ductus venosus; *c*, ductus arteriosus; *d*, hypogastric arteries; *e*, mesenteric vessels; *f*, portal vein, and above it the hepatic vein.

directly, and partly into the liver, which is, throughout fœtal life, exceedingly large. There are, therefore, four kinds of blood mixed in the vena cava inferior above the level of the liver, namely, vitiated blood from the lower limbs, oxygenated blood from the placenta, blood which has passed through both placenta and liver, and venous blood from the portal system, acted on by the liver, but not oxygenated. This mixture of blood, entering the heart behind the Eustachian valve, is directed on through the back of the right auricle and the foramen ovale, into the left auricle, and so into the left ventricle and arch of the aorta, to supply the head, neck, and upper limbs; but it is prevented by a fold in the aorta from passing down into the descending part. Returning from the head and upper limbs by the superior vena cava, the blood enters the anterior part of the right auricle, and mixing but little with the stream crossing through the back part of that cavity, passes into the right ventricle, and is propelled through the pulmonary artery, ductus arteriosus, and descending aorta, partly to supply the lower parts of the body, but in larger part to proceed again to the placenta by the hypogastric arteries. Thus, curiously enough, there is no part of the fœtus nourished with blood the whole of which has been purified. The whole of the blood returned from the lower limbs is mixed with the current to the head and arms; and the trunk and lower limbs are entirely supplied with blood which has previously circulated in the head and arms and been filled with further impurities.

Immediately on birth, the circulation through the placenta ceases, the impulse to breathe begins, and with the first inspiration, not only air but blood is drawn into the expanding lungs; the right and left pulmonary arteries are filled, and blood ceases to pass through the ductus arteriosus; the current in the arch of the aorta is continued on into the lower parts of the body; and a fold of membrane, the valve of the foramen ovale, which springs from the back of that opening, and projected into the left auricle, now occludes the opening, and in a short time becomes firmly bound down to the walls.

217. The period of gestation in the human species is about two hundred and seventy days, but is undoubtedly liable to a

certain amount of variation. Toward the end of that time, a great relaxation of parts takes place, even the ligaments which bind the bones of the pelvis being considerably slackened; the cervix uteri begins to dilate, and the muscular walls of the uterus are seized with recurrent spasmodic contractions. Usually the uterine contractions burst the membranes which retain the liquor amnii, and afterwards the child is expelled, its head first, and is shortly followed by the placenta and ruptured membranes. In healthy parturition, the contraction of the uterus is sufficient to prevent much bleeding ensuing from the tearing across of the blood-vessels which united the placenta with its substance. Forthwith, the uterus begins to undergo a rapid process of *involution*. Its muscular walls, which had undergone great enlargement, both by increased size of the individual fibres, and continual growth of others from connective-tissue corpuscles, become daily diminished by degeneration and disappearance of the exaggerated fibres; and the organ returns to its original proportions.

218. Within a day or two after the birth of the child, the breasts of the mother, which have previously been enlarging, come into functional activity, and there is a copious secretion of milk.

The breasts, or *mammæ*, have their proper secreting structure, at other times, so closely connected with the areolar tissue in which it is imbedded that it is difficult to trace; but during lactation, it is much more distinct. From about fifteen to twenty separate ducts open at the extremity of the nipple; each of these is dilated into a small reservoir between one and two inches from its extremity, and, traced further back, is found to branch repeatedly, till the radicles are reached, connected with the ultimate lobules, which consist of aggregations of rounded secreting saccules.

Milk, examined microscopically, is a clear fluid, with oil globules of many different sizes floating in it. In the process of churning, the oil globules of milk are thrown together in a solid mass, and constitute butter; while in milk which is allowed to remain at rest, so that the larger globules rise to the top without running together, the stratum in which these accumulate is the cream. The solid constituents of milk are

casein, butter, sugar of milk, and a small quantity of salts. As compared with the milk of the cow, that of the human species has a smaller proportion of solid matter, and the solid matter contains a third less of casein, twice as much sugar, and not half the quantity of salts; and on that account, in feeding infants with cows' milk, it is customary to mix it with sugar and water.

The first milk which is secreted after parturition exercises a purgative influence on the infant, and is termed *colostrum;* it is characterised by the presence of corpuscles consisting of heaps of granules gathered together into balls. After prolonged lactation the milk secreted becomes poor in quality, and the continuance of suckling becomes hurtful, both to the mother and to the child; suckling for an inordinate length of time is, therefore, to be avoided. The best food, however, for the new born infant is the mother's milk; and no more disgraceful custom can well be imagined than a healthy mother neglecting the duty of suckling, unless it be that of medical practitioners encouraging such an impropriety.

219. *Growth after Birth.*—The proportions of the body of the new born infant are very different from those of the adult. The umbilicus is about the middle, the lower limbs and the chest are small, and the head, as compared with the rest of the body, is much larger than afterwards. In representing the adult figure, the rule recognised in art is to allow eight times the perpendicular length of the head for the height of the whole body, thus: from the crown to the chin, from the chin to the level of the nipples, from that level to the navel, and from the navel to the pubis, each one head; and from the pubis to the lower part of the knee, and thence to the sole, each two heads. The position of the umbilicus is, as will be perceived from this, considerably higher in the adult than the child.

The pelvis in the child is remarkably small, and is so situated at birth that the sacrum lies pretty nearly in a continuation of the line of the vertebral column; but when the child begins to walk, the stretching out of the thighs is effected much more by bending the sacrum back than by movement at the hip joints, and the brim of the true pelvis is thrown into a nearly vertical plane; whereas in the adult

it is at an angle of about 30° with the vertical plane. This circumstance, in conjunction with the shortness of the chest, is the cause of the prominent appearance of the abdomen in children.

The growth of the head deserves especial attention. The maximum proportion of the cranium to the rest of the body is found in the early state of the embryo, and it continues to diminish till maturity is reached. At birth, the parietal region is particularly prominent, while both frontal and occipital regions are comparatively small. During childhood, the forehead becomes sufficiently developed to produce that projection forwards at the level of the frontal eminences, which gives a characteristic appearance to the child's head; but these eminences continue to ascend to a higher level above the eyes, and to separate one from the other for a number of years; and the projection forwards of the lower part of the forehead, including the frontal sinus, is not completed till after puberty. A comparatively small development both of the frontal and the occipital region is characteristic of the female sex.

The face is exceedingly small in children. It undergoes development in connection with both first and second dentition; but it does not reach its full proportions till after puberty, and remains permanently smaller in females than in males.

The eyeballs and the internal and middle ear are nearly as large at birth as in the adult.

Probably the period of maximum vital energy is best indicated by the vital capacity of the chest, which is greatest about the age of thirty. As age advances, the diminished rapidity of the pulse, and greater difficulty in repair of injuries, indicate the decline of nutritive activity, and at last, as years accumulate, this becomes insufficient to support the processes necessary for life.

220. Death.—The precise causes of diminished vitality in old age are not known; but it is worthy of note that the corpuscular elements of the tissues have each, apparently, a life of only limited duration, and that they diminish in number as the individual becomes older, being excessively abundant before birth, and most sparingly distributed in old age. Thus

the limit to the duration of vitality, which necessitates a system of reproduction for the continuance of the species, is not confined to the organism as a whole, but is found in the vital elements of which it is composed.

During health, we have seen that though the microscopic constituents of the body are continually changing, and the vital elements dying and replaced by others, yet so perfect are the arrangements for the removal of debris, that no accumulation of effete matter takes place. The baneful effects of even minute quantities of putridity in contact with living textures are now well known to surgeons, and the knowledge furnishes the basis for the proper treatment of sores. But sometimes it happens that in consequence of irritation, either from without or within the body, the nutritive actions in the textural elements are deranged, the living particles attract different constituents from the blood than they are wont to do, act differently on them, and undergo rapid proliferation and disintegration. Examples of such a process are found in ulceration and suppuration, in which, although the *pus* thrown out consists of living corpuscles, and is the result of vital action, yet there is increased mortality of textural elements and disruption of texture. Sometimes it happens that a whole mass of texture is deprived of vitality by over-irritation, chemical alteration, withdrawal of the supplies of nourishment, or other interference with its nutrition. Such a mass undergoes decomposition all the more rapidly that it is in contact with the warm body; it is called a *slough* or *sphacelus*, and when the texture which has died is bone, the death is termed *necrosis* and the dead part a *sequestrum*.

221. As it is with portions of the body, so also with the whole being; death, considered physiologically, is the permanent cessation of nutrition. The cessation of consciousness is not death; life may continue when consciousness is gone; and the relation of consciousness to the body is that it is dependent on the nutrition of the brain.

Death is sometimes spoken of as beginning either at the heart, the lungs, or the brain, which constitute the tripod of life; but the cessation of circulation, leading to the withdrawal of fit nutriment from all the textures, the nervous

system included, and their saturation with debris, may claim to be the immediate cause of death in all instances.

If it be suggested that it would be better to define death as the separation of the spirit from the body, the answer is simply that the presence or absence of the spirit does not immediately affect, as far as can be seen, the vitality of the organism; and that physiology has no means to ascertain the moment of the spirit's withdrawal. Rare, fortunately exceedingly rare, cases have occurred of persons apparently dead returning to life after days of pulseless trance. In these instances, the body remained, throughout the trance, fit to resume its functions. This it cannot do where there is decomposition. Thus, in the case of muscular fibre, we have seen that even a very slight chemical change is incompatible with vitality, as tested by electric instruments. Decomposition is the infallible evidence of death.

GLOSSARY.

Abomasum, *ab* from, and *omasum;* leading from the omasum, the fourth stomach of a ruminant.

Absorption, *ab* from, and *sorbeo* I suck; the taking up of anything into the system, whether from without or from the tissues.

Acetabulum, a cup for holding vinegar, the cavity in the innominate bone for the hip joint.

Acromion, ἄκρον a summit, and ὦμος a shoulder; the process of the scapula which forms the summit of the shoulder.

Adipose, *adeps* fat; fatty: thus, adipose tissue, the tissue in which oil is stored.

Agminated, *agmen* an army or company; agminated glands, named from being disposed in groups.

Albino, *albus* white; an Italian word for a person destitute of pigment in the hair and eyes.

Albuminoid, *albumen* white of egg, and εἶδος form; belonging to the same chemical group as albumen.

Alimentation, *alimentum* nourishment; the taking of nourishment into the system.

Allantois, ἀλλᾶς a sausage; a hollow outgrowth from the embryo, from which are developed the urinary bladder and the placenta.

Amnion, ἀμνίον from ἀμνός a lamb; the inner membrane round the fœtus.

Amœboid, ἀμείβω I change, and εἶδος form; like an amœba, a genus of exceedingly simple animals of changeable form.

Ampulla, anything blown out into a swelling.

Amyloid, ἄμυλον starch, and εἶδος form; like starch. Amyloid substance of the liver is closely akin to starch; but the substance peculiar to amyloid or waxy degeneration of the liver, kidneys, muscles, &c., is nitrogenous, and has no chemical affinity to starch.

Amylolytic, ἄμυλον starch, and λύω I loose; having the power of converting starch into dextrin and sugar.

Anatomy, ἀνά up, and τέμνω I cut; etymologically means dissection; the science founded on dissection, and treating of structure in organisms.

Annulus ovalis, oval ring; a structure in the right auricle of the heart.

Anorthoscope, ἀνορθόω I set straight again, and σκοπέω I behold; an instrument so constructed that distorted images drawn on cards prepared for the purpose, on being placed in it and whirled rapidly round, are seen restored to their just proportions.

Antihelix, ἀντί opposite, and *helix* the bifurcated elevation within the circle of the outer ear.

Antitragus, ἀντί opposite, and *tragus* the hinder of the two little elevations opposite the opening of the ear.

Antrum, a cave.
Aorta, *ἀείρω* I raise up; in the passive, to arise; the artery of origin.
Aphasia, *ἀ* privative, and *φάσις* speech; loss of the mental faculty of speech, as distinguished from paralysis of the organs of speech.
Aponeurosis, *ἀπό* from, and *νεῦρον* a sinew; white fibrous tissue of tendinous consistence spread out in a sheet.
Arachnoid, *ἀράχνη* a spider's web, and *εἶδος* form; the serous membrane which surrounds the brain and spinal cord.
Areolar, *areola* a little space; areolar tissue, a form of white fibrous tissue named from the spaces between the felted fibres.
Artery, *arteria* an air vessel, as *arteria aspera* the wind-pipe; a vessel carrying blood away from the heart, supposed by the ancients to contain animal spirits.
Arteriole, a little artery.
Arthrodia, *ἄρθρον* a joint; an articulation permitting little movement.
Arytenoid, *ἀρύταινα* a ewer or ladle, and *εἶδος* form; the name given to two cartilages of the larynx, on account of the spout formed between them.
Asphyxia, *ἀ* privative, and *σφύζω* I throb; cessation of pulse caused by cessation of breathing, choking, suffocation.
Assimilation, *similis* like; the power by which living bodies convert matters from without into their own substance.
Astragalus, *ἀστράγαλος* the bone by which the foot articulates with the leg. That of the sheep was used by the ancients as a kind of dice.
Atlas, the god who bore up the pillars of heaven; the first cervical vertebra.
Auricle, *auricula* the outer ear. The auricles of the heart are named from a fancied resemblance of the auricular appendages to dogs' ears.
Automatic, *αὐτόματος* self-moving; applied to movement in which the body acts like a machine, without apparent intervention of consciousness.
Axis, a pivot; the second cervical vertebra.

Bacillary, *bacillum* a little staff; bacillary layer of the retina, consisting of rods and cones.
Bicuspid, *bis* twice, and *cuspis* a pointed extremity; two pointed, as the bicuspid teeth, and the bicuspid valve guarding the left auriculo-ventricular opening of the heart.
Biology, *βίος* life, and *λόγος* discourse; the science treating of living bodies.
Blastoderm, *βλαστός* a shoot or germ, and *δέρμα* a skin; the germinal membrane in which the embryo appears.
Branchial, *branchiæ* gills; belonging to gills.
Bronchus, *βρόγχος* the wind-pipe; technically a name given only to each of the two tubes into which the trachea divides.
Bronchia, or bronchial tubes, the smaller tubes into which the bronchi divide.
Buccal, *bucca* the hollow interior of the cheeks; belonging to the cavity of the mouth.
Bursa, a pouch; a membranous sack interposed between parts which are subject to movement one on the other, to allow them to glide smoothly.

Cadaveric, *cadaver* a dead body; cadaveric rigidity is the stiffness after death.
Cæcum, *cæcus* blind; the blind intestine, *intestinum cæcum* or *caput cæcum coli*.
Calcaneum, *calx* the heel; the heel bone.
Camera, a chamber.
Canthus, the corner of the eye.
Capillary, *capillus* hair; capillary

vessels, those of the minutest order; capillary blood-vessels, those between the arteries and veins; capillary lymphatics, those which make the network of origin in the tissues.

Caput cæcum coli, the blind head of the colon.

Carbonaceous, possessing carbon; applied to organic substances which contain no nitrogen.

Carotid, *κάρα* the head, and *οὖς* the ear; the name of arterial trunks ascending to the head, close to the ears.

Carpus, *καρπός* the wrist; the eight small bones at the wrist.

Cartilage, *cartilago* gristle.

Caruncula, *caro* flesh; a little fleshy mass.

Cauda equina, horse tail; the collection of large nerves descending from the lower end of the spinal cord.

Caudal, belonging to the tail, as caudal vertebræ.

Cerebellum little brain; the part of the brain overhanging the medulla oblongata.

Cerebrum brain; technically applied to the part of the brain above the cerebellum and pons Varolii.

Cervical, *cervix* the neck; belonging to the neck, as cervical vertebræ.

Cerumen, *cera* wax; the wax of the ears.

Chalaza, *χάλαζα* hail, a pimple; the string which suspends the yolk of an egg.

Chlorophyll, *χλωρός* green, and *φύλλον* a leaf; the green colouring matter found in leaves.

Cholesterin, *χολή* bile, and *στέαρ* suet; a greasy substance which crystallizes in quadrilateral scales, found in bile, and obtained by decomposition of various textures, especially brain substance.

Chondrin, *χόνδρος* cartilage; a substance nearly allied to gelatin, obtained from cartilage.

Chorda dorsalis, dorsal cord; an embryonic structure in the position afterwards occupied by the bodies of the vertebræ.

Chorda tympani, cord of the tympanum; a nerve which traverses the tympanum of the ear.

Chordæ tendineæ, tendinous cords; the threads which retain in position the cusps of the auriculo-ventricular valves of the heart.

Chorion, *χόριον* skin; the outer membrane surrounding the fœtus.

Choroid, *χορός* a choir, and *εἶδος* form; a structure formed of numbers of small blood vessels combined, as the choroid plexuses of the brain, and choroid tunic of the eye.

Chyle, *χυλός* juice; the substance taken up by the lacteals.

Chyme, *χέω* I pour; the pulp sent from the stomach into the intestine.

Cicatricula, a little cicatrix, the part of the yolk of a bird's egg in which the embryo appears.

Cicatrix, a scar.

Cilium, an eyelash; a lash such as those which keep constantly moving on some nucleated corpuscles.

Circumvallate, *circum* around, and *vallum* a rampart; surrounded by a rampart, as certain papillæ of the tongue are.

Clavicle, *clavis* a key; the collar bone.

Coccyx, a cuckoo; the caudal vertebræ of man, named from being united to form a structure like a cuckoo's beak.

Cochlea, a snail's shell; the spiral part of the labyrinth of the ear.

Colloid, *κόλλα* glue, and *εἶδος* form; like glue or gum. In chemistry, a substance whose solutions are imperfect and indiffusible through membranes.

Colon, *κῶλον* a member of the body; the great intestine.

Colostrum, the first milk after the birth of the child.

Coma, *κῶμα* a deep sleep; unconsciousness from morbid causes

other than deficient pressure of blood on the brain.

Commissure, *commissura* a joining; a connecting link between two parts in the cerebro-spinal axis.

Concha, a shell; the cup of the ear.

Conjunctiva (*membrana*), conjoining membrane; the mucous membrane folded over the front of the eye-ball and the interior of the eye-lids, joining them together.

Condyle, κόνδυλος a knuckle; usually applied to a prominent articular surface.

Coracoid, κοραξ a crow, and εἶδος form; shaped like a crow's beak, coracoid process of scapula.

Corium, skin; a name for the cutis vera.

Cornea (*tunica*), the corneous or horny tunic; the transparent part of the outer tunic of the eye-ball.

Cornu, a horn; applied to things projecting like horns, as the cornua of the ventricles of the brain, and of the grey matter of the spinal cord.

Coronoid, κορώνη a crow, and εἶδος form; like a crow's beak; thus coronoid process of ulna and of lower jaw.

Corpora albicantia, whitish bodies; a pair of bodies on the base of the brain.

Corpora quadrigemina, bodies four at a birth; a part of the brain exhibiting four elevations.

Corpora striata, striped bodies; a pair of structures in the brain.

Corpus callosum, hard body; the great transverse commissure of the cerebral hemispheres.

Corpus luteum, yellow body; a body found in the ruptured Graafian vesicle, from which the ovum has escaped.

Cortical, *cortex* bark; applied to outside portions of organs.

Costal, *costa* a rib; belonging to a rib.

Cribriform, *cribrum* a sieve; perforated with small holes.

Cricoid, κρίκος a ring, and εἶδος form; the name of the lower cartilage of the larynx.

Cruorin, *cruor* gore; the colouring matter of the blood.

Crus, a leg, shank, or column of support; thus, the crura cerebri, crura cerebelli, and crura of the fornix.

Crusta petrosa, stony crust; a substance allied to bone, coating the fangs of teeth, and in many animals filling depressions in the enamel.

Crystalloid, κρύσταλλος crystal, and εἶδος form; a substance, the solutions of which are diffusible through membranes, such substances being generally capable of crystallization.

Cuboid, κύβος a cube, and εἶδος form; the name of a bone of the foot.

Cuneiform, *cuneus* a wedge, and *forma* form; the name of one bone in the hand and of three bones in the foot.

Cusp, *cuspis* a spear-point, or other pointed extremity; thus, the cusps of the crowns of teeth, and of the auriculo-ventricular valves.

Cutis vera, true skin; the integument beneath the cuticle.

Cyanosis, κύανος dark blue; a blue-skinned condition, the result of deficient aeration of the blood, in consequence of patency, after birth, of the foramen ovale between the auricles of the heart.

Cystic, κύστις a bladder; belonging to a bladder, as the cystic duct, the duct of the gall bladder; also, having bladders or cysts, as a cystic tumour.

Decidua, things subject to falling or to be shed; growths of the mucous membrane of the uterus during pregnancy; distinguished as decidua vera, reflexa, and serotina—the true,

the reflected, and the late decidua. The milk-teeth are called deciduous, on account of being shed.

Decussation, *decussatio* a cutting across in the form of the letter X; a crossing of fibres or other structures, at right angles, and also otherwise.

Deglutition, *de* down, and *glutio* I swallow; the act of swallowing.

Dentine, *dens* a tooth; the texture of which the teeth in greater part consist.

Depuration, *de* away from, and *purus* pure; the clearing away of impurities.

Derma, δέρμα a skin; the cutis vera.

Desquamation, *de* and *squama* a scale; falling away of scales.

Diaphragm, διά across, and φράγμα a fence; any partition (as the diaphragm of a microscope), by means of which the aperture for the admission of light is diminished; the midriff or muscular partition separating the thoracic from the abdominal cavity.

Diaphysis, διά right through, and φύσις growth; the centre of ossification of the main length or shaft of a long bone.

Dicrotism, δίς twice, and κροτέω I beat; the double beating of the arterial pulse.

Digestion, *digero* I divide; the conversion of the food into a substance capable of absorption.

Discus proligerus, disc bearing the offspring; a coating of granules on the ovum.

Dorsal, *dorsum* the back; is properly used in opposition to ventral; but in the case of the dorsal vertebræ, it is applied to the twelve vertebræ which bear the ribs, and ought to be supplanted by the word thoracic.

Ductus communis choledochus, χολή bile, and δέχομαι I receive; the common bile duct.

Duodenum, *duodeni* twelve; the part of the intestine immediately succeeding the stomach; named from being considered about twelve finger-breadths long.

Dura mater, hard mother; the name of the tough fibrous covering of the brain and spinal cord.

Electrotonus, ἤλεκτρον amber, and τόνος tension; the electric condition into which a nerve is thrown when a continuous current of electricity passes along any part of its course.

Embryo, ἔμβρυον (ἐν within, and βρύω I swell); the young before birth; applied principally to the very early stages of existence, and used in reference to plants as well as animals.

Embryology, ἔμβρυον, and λόγος discourse; the study of development.

Emunctory, *emungo* I wipe; any part by which waste matter is got rid of.

Enamel, in French *émail*, in Italian *smalto*, μέλδω I melt; a fused substance spread on a surface; the name given to the exceedingly hard texture which covers the crowns of the teeth.

Encephalon, ἐν within, and κεφαλή the head; the whole brain down to where the medulla oblongata is continued into the spinal cord.

Endogenous, ἔνδον within, and γεννάω I bring forth; growing in the interior of the pre-existing structure.

Endolymph, ἔνδον within, and *lympha* water; the fluid within the membranous labyrinth.

Endosmosis, ἔνδον within, and ὠθέω I push; the current from without inwards, when diffusion of fluids takes place through a membrane.

Endothelium, ἔνδον within, and θάλλω I bloom; an exceedingly delicate coating of squamous corpuscles found in the interior of capillary blood-vessels and lymphatics.

Epidermis, *ἐπί* upon, and *δέρμα* the skin; the cuticle or scarf skin.

Epigastrium, *ἐπί* upon, and *γαστήρ* the belly; the upper abdominal region, below the sternum and between the costal cartilages of opposite sides.

Epiglottis, *ἐπί* upon, and *glottis;* the cartilaginous lid which lies above the glottis.

Epiphysis, *ἐπί* upon, and *φύσις* growth; a supplementary centre of ossification, such as those found at the extremities of long bones and at the tips of the spinous and transverse processes of vertebræ.

Epithelium, *ἐπί* upon, and *θάλλω* I bloom; a coating of one or more strata of nucleated corpuscles on a free surface.

Ethmoid, *ἠθμός* a sieve, and *εἶδος* form; one of the bones of the head, so named from being perforated with a number of little holes, through which the filaments of the nerve of smell pass.

Excretin, *excreta* things excreted; a crystalline substance obtained from fæces.

Excretion, *ex* out, and *cresco* I grow; any waste material thrown out from the body.

Exogenous, *ἔξω* without, and *γεννάω* I bring forth; growing outside the pre-existing structure.

Exosmosis, *ἔξω* without, and *ὠθέω* I push; the current from within outwards, when diffusion of fluids takes place through a membrane.

Fæces, dregs; the discharges by the bowel.

Falx, a sickle; *falx cerebri* a process of dura mater between the cerebral hemispheres.

Fascia, a bandage; felted white fibrous tissue disposed in the form of a membrane.

Fasciculus, a little bundle, as those of muscular and nerve fibres.

Fauces, *faux* the gullet; the passage beneath the soft palate, between the mouth and pharynx.

Femur, the thigh; the thigh bone.

Fenestra ovalis and **fenestra rotunda,** the oval and the round window; two apertures in the bone between the tympanic cavity and the labyrinth of the ear.

Fibrilla, a little fibre; one of the longitudinal threads into which a striped muscular fibre can be divided.

Fibrin, *fibra* a fibre; a variety of albuminoid substance, named from its coagulating and exhibiting a fibrous structure.

Fibrinogen, *fibrin,* and *γεννάω* I bring forth; the substance in the blood and elsewhere which coagulates on addition of fibrinoplastin.

Fibrinoplastin, *fibrin,* and *πλάσσω* I fashion; the substance which, added to fibrinogen, causes it to coagulate.

Fibula, a clasp or buckle; the small or outer bone of the leg.

Filiform, *filum* a thread, and *forma* form; thread-like, as the filiform papillæ of the tongue.

Filum terminale, the terminal thread which descends from the extremity of the spinal cord.

Fimbriated, *fimbria* a fringe; fringed.

Fissiparous, *fissus* cleft, and *pario* I bring forth; multiplying by division into equal parts

Fœtus, the young of any animal; the unborn offspring.

Follicle, *folliculus* diminutive of *follis* a bag; a simple gland or other pouch, as the follicles of Lieberkuhn and closed follicles.

Foramen, a hole.

Fornix, an arch; a part of the brain.

Fossa, a ditch; a depression, particularly in a bone.

Fovea centralis, the central pit; a part of the retina.

Frontal, *frons* the forehead; the

name of the bone which forms the forehead.

Fundus, the bottom of anything; used with reference to hollow viscera, such as the uterus and bladder.

Fungiform, *fungus* a mushroom; thicker at the extremity than at the attached part, as the fungiform papillæ of the tongue.

Ganglion, both Greek and Latin, a swelling or hard knot or lump; in anatomy, a swelling on a nerve, and any nervous centre.

Ganglion impar, ganglion without fellow; the mesially situated lowest ganglion of the sympathetic chain.

Galvanometer, galvanism (from *Galvani*), and *μέτρον* a measure; an instrument which indicates the presence, direction, and strength of a galvanic current by the deviations of a magnetic needle.

Gastrocnemius, *γαστήρ* a belly, and *κνήμη* the leg; a muscle named from forming, in part, the swelling of the calf of the leg.

Gelatin, *gelo* I freeze; a nitrogenous substance, obtained by boiling integument and other tissues, the solutions of which form a jelly on cooling.

Gemmiparous, *gemma* a bud, and *pario* I bring forth; reproducing by buds.

Ginglymus, *γίγγλυμος* a hinge; a joint which admits of movement in only one plane—that is, flexion and extension.

Glenoid, *γλήνη* the pupil, or a shallow depression, and *εἶδος* form. The glenoid fossa is the name given to the articular surface of the scapula.

Glomerulus, *glomus* a clew of thread; the clump of vessels within a Malpighian corpuscle of the kidney.

Glottis, *γλῶττα* the tongue; the aperture into the wind-pipe, between the vocal cords.

Glycogen, *γλυκύς* sweet, *γεννάω* I bring forth; a substance formed in the liver, convertible into grape sugar or glucose; called also amyloid substance.

Gyri operti, hidden convolutions; another name for the Island of Reil; the convolutions at the bifurcation of the fissure of Sylvius.

Hæmoglobin, more properly hæmatoglobulin, *αἷμα* blood, and *globulin* (*globulus* a globule); the globulin of the blood; a variety of albuminoid substance, characteristic of the red blood corpuscles.

Hæmatin, *αἷμα* blood; an insoluble substance, containing in an altered form the colouring matter of the blood.

Helicotrema, *ἕλιξ* a spiral, and *τρῆμα* a hole; the opening by which the two scalæ communicate at the summit of the cochlea.

Helix, *ἕλιξ* a spiral; the elevation which forms the greater part of the margin of the outer ear.

Hepatic, *ἧπαρ* the liver; belonging to the liver.

Hippocampus, *ἵππος* a horse, and *καμπή* a bending; a fish with a head like a horse, and a curly tail; the name of certain curved structures in the brain.

Hilus, *hilum* the mark on the concavity of a bean; the concave part of the kidney where the ureter emerges.

Histology, *ἱστός* a web, and *λόγος* discourse; the study of the textures.

Homologous, *ὅμοιος* similar, and *λόγος* a word; similar in structure, or having structural affinity, as contradistinguished from similarity of function.

Hyaline and **Hyaloid**, *ὕαλος* crystal; clear as crystal.

Hyoid, *υ*, and *εἶδος* form; U shaped; the name of the bone above the larynx.

Hypoaria, *ὑπό* under; a pair of

bodies on the under surface of the brain in fishes.

Hypochondrium, ὑπό under, and χόνδρος cartilage; the upper lateral region of the abdomen, under cover of the costal cartilages.

Hypogastrium, ὑπό under, and γαστήρ the belly; the lower mesial region of the abdomen.

Hypoglossal, ὑπό under, and γλῶσσα the tongue; under the tongue; the name of the last cranial nerve.

Ileum, εἴλω or ἴλλω I twist; the lower three-fifths of the small intestine.

Ilium, εἰλέω I twist: the upper division of the os innominatum.

Imbricated, *imbrex* a roof-tile; sloped one over another, like tiles.

Incisor, *incido* I cut; *incisor* (*dens*) a cutting tooth.

Incus, *in* and *cudo* I hammer; an anvil; one of the ossicles in the tympanum.

Infundibulum, a funnel; a hollow process descending from the third ventricle of the brain to the pituitary body.

Innominate, *nomen* a name; unnamed; innominate artery and innominate bone.

Intercostal, *inter* between, and *costa* a rib; between two successive ribs.

Invagination, *vagina* a sheath; the pushing of one part of a hollow structure into the interior of another part, as may be done with the finger of a glove.

Involution, *volvo* I roll; rolling in; backward growth, such as the return of the uterus after parturition to its ordinary dimensions.

Iris, a rainbow; the coloured curtain in the eye.

Ischium, ἰσχίον the hip; the lower and hinder division of the innominate bone, on which we sit.

Jejunum, empty; the upper two-fifths of the small intestine succeeding the duodenum.

Jugal, *jugum* a yoke; another name for the malar or cheek bone.

Jugular, *jugulum* the fore part of the neck; the name given to certain large veins in the neck.

Kreatin, κρέας flesh; a soluble nitrogenous substance contained in flesh, and probably a product of decomposition of albuminoid substance.

Lachrymal, *lachryma* a tear; having to do with the tears; as lachrymal gland.

Lacteals, *lac* milk; the absorbent vessels of the small intestine, named from the milky appearance of the chyle which they convey.

Lacuna, a wet ditch or hollow; a microscopic hollow in the matrix of bone, occupied in the recent state by a bone corpuscle.

Laryngoscope, λάρυγξ and σκοπέω I behold; an instrument consisting of a mirror held in the throat, and a reflector to throw light on it, by which the interior of the larynx is brought into view.

Larynx, λάρυγξ the upper part of the wind-pipe, extending down to the lower border of the cricoid cartilage.

Lenticular, *lens* or *lenticula* a lentil; the closed follicles of the stomach are called lenticular.

Leucocyte, λευκός white, κύτος a hollow; a white blood corpuscle; an objectionable word, seeing that those corpuscles are not hollow cells.

Leucocythemia, λευκός, κύτος, and αἷμα blood; a malady in which the number of white corpuscles in the blood is greatly increased.

Ligament, *ligamentum* a band, *ligo* I bind; a band uniting two structures, usually bones.

Liquor sanguinis, fluid of the

blood; the blood minus the corpuscles.

Locule, *loculus* (diminutive of *locus*) a little space; a minute hollow.

Lumbar, *lumbus* the loin; belonging to the loins, as lumbar region, lumbar vertebræ.

Lymph, *lympha* water; the colourless fluid brought back from the textures by special absorbent vessels called *lymphatics;* also used in pathology to denote clear coagulable substance thrown out from the textures in abnormal circumstances.

Malar, *mala* the prominence of the cheek; the name of the cheek-bone.

Malleus, a hammer; one of the ossicles in the tympanum of the ear.

Mamma, the breast.

Mandible, *mandibula* (*mando* I chew) the lower jaw.

Manubrium, a handle; manubrium of the malleus and of the sternum.

Mastication, μασάομαι I chew; the whole mechanical breaking up of the food in the mouth.

Mastoid, μαστός a breast, and εἶδος form; nipple shaped; the name of the process of the temporal bone, behind the ear.

Matrix, a womb; the substance in which anything is embedded.

Maxilla, a jaw; applied to both jaws, the bones being respectively called superior and inferior maxillary.

Meatus, a passage; external and internal auditory meatus; and superior, middle, and inferior meatus of the nose.

Meconium, μήκων a poppy; poppy juice; the fæces of the newborn infant.

Medulla oblongata, elongated marrow; the part of the brain continuous with the spinal cord.

Medullary, *medulla* marrow; usually applied to central parts of organs, in opposition to cortical; but the medullary sheath of a nerve fibre is named from having a consistence like marrow.

Meninges, μῆνιγξ a membrane; a name given to the membranes of the brain and spinal cord.

Mesentery, μέσος middle, and ἔντερον intestine; structure formed by duplication of peritoneum, intervening between intestine and abdominal wall.

Metacarpus, μετά after, and ταρσός the wrist; the five bones beyond the carpus, and supporting the digits of the hand.

Metatarsus, μετά after, and ταρσός the flat of the foot; the five bones beyond the tarsus, and supporting the toes.

Mitral, like a mitre; a name given to the bicuspid valve of the heart.

Modiolus, a nave of a wheel; the central column round which the cochlea winds.

Molar, *mola* a mill; a grinder or back tooth.

Morphology, μορφή form, and λόγος discourse; the study of the laws of form or structure in living beings.

Mucus, discharge from the nose; any such viscid secretion; containing a peculiar nitrogenous substance, *mucin*.

Multicuspid, *multus* many, and *cuspis* a pointed extremity. The molar teeth are multicuspid, having several cusps on their crowns.

Musculi papillares, papillary muscles; the muscular projections in the interior of the ventricles of the heart, to which the chordæ tendineæ of the auriculo-ventricular valves are attached.

Myographion, μῦς a muscle, and γράφω I write; an instrument by which the rapidity of the nervous current is determined by the time at which a muscle contracts after application of stimuli to different parts of the course of the nerve supplying it.

Myosin, *μῦς* a muscle; muscle-fibrin obtained from living muscle.

Nares, the nostrils; *anterior nares* the nostrils proper; *posterior nares* the openings of the nasal cavities into the pharynx.

Necrosis, *νεκρός* a dead body; the death of a mass of bone.

Nitrogenous, containing nitrogen; organic substances containing nitrogen are so called.

Notochord, *νῶτος* the back, and *χορδή* a string; the embryonic structure round which the bodies of the vertebræ are developed, called also *chorda dorsalis*.

Nucha, an unclassical word for the neck; *ligamentum nuchæ*, the ligament which in many animals suspends the head from the spines of the vertebræ.

Nucleus, a kernel; a firm albuminoid structure in the interior of a living corpuscle, or such a structure in a matrix, though no corpuscle be seen to surround it.

Nucleolus, diminutive of *nucleus*; a dense body within the substance of a nucleus.

Occipital, *occiput* (*ob* and *caput*) the hinder part of the head; the name of the hindermost bone of the skull.

Ocellus, diminutive of *oculus*, a little eye; applied to a minute eye or a unit of a compound eye in the invertebrata.

Odontoid, *ὀδούς* a tooth, and *εἶδος* form; like a tooth; the name of the process surmounting the body of the second cervical vertebra.

Œsophagus, *οἴσω* future of *φέρω* I bear, and *φαγεῖν* to eat; the bearer of things eaten; the digestive tube from the point at which it becomes a completely separate tube at the termination of the pharynx, down to the entrance of the stomach.

Olecranon, *ὠλένη* the elbow, and *κρανίον* the top of the head; the summit of the ulna.

Olivary, like an olive; olivary eminence of medulla oblongata, and olivary process of the sphenoid bone.

Omasum (*ὠμός* raw) a tripe; the third stomach of a ruminant, called in French *feuillet*.

Omphalo-mesenteric, *ὀμφαλός* the navel (see Mesentery); the name of vessels in the young fœtus which return blood from the walls of the umbilical vesicle.

Operculum, a lid. The opercula of the tooth sacs cover in those cavities.

Ora serrata (*serra* a saw), the serrated margin; the anterior border of the retina, so called from its serrated appearance in the human eye.

Orbit, *orbita* the tract in which anything rolls; the socket of the eyeball.

Organ, *ὄργανον* an instrument (*ἔργον* work).

Organic world, all structures having organs; namely, animals and vegetables.

Organic matter, such chemical compounds as are derived from the organic world.

Organic functions, processes of nutrition, independent of consciousness; in contradistinction to animal functions, in which consciousness is involved.

Organism, a being with organs; any plant or animal.

Organized, having organs; differentiated structure.

Os magnum, large bone; the largest of the eight carpal bones.

Os uteri, mouth of the womb. The os externum and internum are distinguished at the lower and upper end of the cervix.

Osmosis, *ὠθέω* I push; the diffusion of fluids through membranes.

Ossification, *os* bone, and *facio* I make; the formation of bone.

Osteoblastic, *ὀστέον* bone, and

βλαστέω I shoot up; *osteoblastic corpuscles*, those from which bone is immediately formed.

Otoconia, οὖς an ear, and κονία dust; minute hard particles in the vestibule of the ear.

Otolith, οὖς an ear, and λίθος a stone; used instead of *otoconia*; also applied to larger bodies found in the ears of some animals, as fishes, to which the name *otoconia* would be inapplicable.

Ovum, an egg; applied only to a germ which requires impregnation before being developed.

Palatal, *palatus*; the name of a bone which, besides completing the wall of the nasal cavity, forms the back part of the hard palate, behind the superior maxillary.

Pancreas, πάν all, and κρέας flesh; the organ called by butchers the sweetbread.

Papilla, a nipple. The papillæ of the skin are the minute elevations into which the cutis vera is thrown.

Paralysis, παρα-λύω I loosen from beside; the loss of nervous power, either motor, sensory, or both.

Parietal, *paries* a wall. The parietal layers of serous membranes are those lining the walls of the cavities within which the viscera which they surround are situated; parietal bones, those which form the middle part of the roof of the skull.

Parotid, παρά beside, and οὖς the ear; the name of the salivary gland which lies between the lower jaw and the ear.

Parthenogenesis, παρθένος a virgin, and γένεσις birth; reproduction by means of an unimpregnated germ.

Patella, a dish; the knee-pan.

Pelvis, a basin; the cavity bounded by the ossa innominata and sacrum. The part below the line extending round from the base of the sacrum to the symphysis pubis is the *true pelvis*; the part between the expanded blades of the iliac bones is the *false pelvis*.

Pepsin, πέσσω or πέπτω to cook or digest; the active principle of the gastric juice.

Peptone, πέπτω; a nitrogenous substance rendered by action of the gastric juice fit for absorption.

Pericardium, περί around, and καρδία the heart; the serous investment of the heart, with the fibrous bag in which it is contained.

Perichondrium, περί around, and χόνδρος cartilage; a fibrous membrane containing blood-vessels, surrounding cartilage.

Perilymph, περί around, and *lympha* water; the fluid in which the membranous labyrinth of the ear is suspended.

Periosteum, περί, and ὀστέον bone; the fibrous membrane surrounding a bone, and containing the ramifications of arteries, small twigs of which penetrate into the interior.

Periphery, περί, and φέρω I bear; circumference; the surrounding parts as contrasted with any centre. Thus the spinal nerves are called peripheral nerves, as contrasted with the nerve fibres within the brain and spinal cord.

Peristaltic, περί, and στέλλω I dispose; the name given to that kind of movement which takes place in the walls of the intestine, the wave of contraction embracing the viscus, and travelling onwards; likewise called vermicular movement.

Peritoneum, περί, and τείνω I stretch; the serous membrane of the abdominal cavity.

Petrous, πέτρος a stone; stony. The basal part of the temporal bone is called the petrous portion, on account of its hardness.

Phalanx, φάλαγξ a line of soldiers; a rank; a bone of a digit; named from those bones being disposed in rows.

Pharynx, *φάρυγξ* the throat; the part behind the nose, mouth, and larynx, and above the œsophagus.

Phosphène, *φῶς* light, and *φαίνομαι* I appear; an appearance of light produced by pressure on the eye-ball.

Phrenic, *φρήν* the midriff; belonging to the diaphragm; as the phrenic nerve.

Phrenology, *φρήν* the mind, and *λόγος* discourse; a study of the brain or skull, with a view to discovering the mental qualities. The particular theory originated by Gall is usually meant.

Physiology, *φύσις* nature, and *λόγος* discourse; the study of the operations which take place in living beings.

Pia mater, pious mother; the vascular covering which closely invests the brain and spinal cord.

Pineal, *pinea* a pine. The pineal body is a portion of the brain in front of the corpora quadrigemina, shaped something like a fir cone, and also called *conarium*.

Pinna, a fin or a pinion; the expansion of the external ear.

Pisiform, *pisum* a pea; the name of one of the carpal bones.

Pituitary, *pituita* phlegm. The pituitary body is the name of a structure at the base of the brain, formerly looked on as a gland.

Placenta, a cake; the after-birth.

Plasma, *πλάσμα* a thing modelled. Is used to signify material from which structure is formed; thus, blood plasma is another name for liquor sanguinis.

Pleura, *πλευρά* a rib; the serous membrane which invests the lung.

Plexus, woven; a set of nervous trunks or twigs more or less closely matted together.

Plica sennilunaris, semilunar fold; the fold of mucous membrane resting on the inner part of the eye-ball.

Pneumo-gastric, *πνεύμων* a lung, and *γαστήρ* a belly; the name of a cranial nerve which sends branches to the lung, and to the stomach, and other abdominal viscera.

Pneumonia, *πνεύμων* a lung; inflamation of the lungs.

Portal vein, or *vena portæ*, vein of the gate; the gate alluded to being the transverse fissure of the liver, in which the portal vein divides to send its blood into the capillaries of the liver. A *portal system* is an expression applied to any redistribution of blood from a vein to a second set of capillaries.

Premolar, *præ* before; in front of molars; a name applied to the bicuspid teeth.

Process, *processus* a going forward; the technical term for any projection of bone or other tissue.

Prostate, *pro* before, and *status* set; the name of a gland set in front of the orifice of the urinary bladder in the male.

Protagon, *πρῶτος* first, and *ἄγω* I lead; the name of a chemical substance obtained from brain matter and other sources.

Proteid, *πρῶτος* first; derived immediately from *protein*, a supposed compound radicle, from which Mulder taught that the various substances of the albuminoid group were all derived. Proteid is therefore another name for albuminoid; but it is founded on an erroneous theory.

Pseudoscope, *ψεῦδος* a lie or cheat, and *σκοπέω* I behold; an instrument by means of which hollow objects are made to appear projecting, and projecting objects hollow.

Pterygoid, *πτέρυξ* a wing, and *εἶδος* form. The pterygoid processes of the sphenoid bone project downwards behind the palate bones, with which they articulate.

Ptyalin, πτύω I spit; the active principle contained in saliva.

Pulmonary, *pulmo* a lung, belonging to the lungs.

Pus, matter from a sore.

Pylorus, πυλουρός (πύλη οὖρος) a gate-keeper; the opening from the stomach into the intestine, or, more properly, the structures surrounding the opening.

Radius, a ray or spoke; the outer bone of the fore-arm.

Receptaculum chyli, receptacle of chyle; the dilated commencement of the thoracic duct.

Rectum, for *intestinum rectum* straight gut; the last part of the bowel. In many mammals it passes backwards in a straight course from a position well forward in the abdomen; but it is by no means straight in the human subject.

Renal, *ren* a kidney, belonging to the kidney.

Restiform, *restis* a rope; the name of the tracts of fibres of the medulla oblongata, which pass into the cerebellum; they have slightly spiral marks, like a rope, on the surface.

Reticular, *rete* a net; in meshes; as is the matrix of reticular cartilage.

Reticulum, a little net; the name given to the web of delicate connective tissue between the nervous elements in the spinal cord and some parts of the brain.

Rete mirabile, wonderful net; a number of branches, derived from the breaking up of one or more arteries, and uniting again into larger trunks.

Rete mucosum, mucous net; a name for the deep and soft part of the cuticle.

Rigor mortis, rigidity of death.

Rima glottidis, fissure of the glottis.

Sacrum, sacred; the bone which forms the part of the vertebral column succeeding the lumbar vertebræ, and articulating with the pelvic bones; an object of superstitious regard, probably on account of its triangular shape.

Sarcolemma, σάρξ flesh, and λέμμα a husk; the membrane which surrounds the contractile substance of a striped muscular fibre.

Scala, a ladder or staircase. The scala tympani and scala vestibuli are the two passages filled with perilymph in the cochlea.

Scaphoid, σκάφη a hollow vessel or boat, and εἶδος form; the name of one of the carpal and one of the tarsal bones.

Scapula, the shoulder-blade.

Sclerotic, σκληρός hard; the tough coat of the eye-ball, which, with the cornea, forms its outer wall.

Sebaceous, *sebum* tallow; sebaceous glands, those which secrete the oil of the skin.

Semilunar, *semilunaris* half-moon shaped; the name of a carpal bone.

Sensorium, *sentio* I perceive by the senses; the nervous centre which must be reached by sensory impressions before they can be perceived.

Sequestrum, *sequestro* I set aside; a dead portion of bone separated or destined to separate from the living parts.

Serum, whey; the fluid part of the blood, separated from the fibrin and corpuscles; *serous membrane*, a membrane forming a shut sac, and secreting serum or fluid sufficient to lubricate its opposed surfaces.

Sesamoid, σήσαμον a kind of seed, and εἶδος form; seed-like. Sesamoid bones are those like seeds in tendons.

Sigmoid, Σ and εἶδος form; shaped like an S, as the sigmoid flexure of the intestine.

Sinus, a hollow. *Osseous sinuses* are hollows in bones, filled with air, as the frontal sinus. The

venous sinuses in the interior of the cranial cavity are hollows in the dura mater which perform the function of veins.

Sinus pocularis, cup-like sinus; a minute hollow in the prostatic portion of the urethra, representing the uterus in the female.

Smegma, soap; the white soapy substance frequently adherent to the skins of new-born infants.

Solar, *sol* the sun. The solar plexus is the large plexus of sympathetic nerves in the upper part of the abdomen.

Soleus, *solea* a sole; the name of a muscle of the calf of the leg, shaped much like a sole.

Somnambulism, *somnus* sleep, and *ambulo* I walk; walking in sleep.

Spectrum, an appearance; in physics, the prismatic colours obtained by analysis of the rays of any luminous body; in physiology, the image which continues to be seen after gazing at any bright object.

Spermatozoon, σπέρμα a seed, and ζοόν a living thing; the essential male element of reproduction.

Sphacelus, σφάκελος gangrene.

Sphenoid, σφήν a wedge, and εἶδος form, the name of the central bone in the base of the skull.

Sphincter, σφιγκτήρ a tight band; a circular muscle which keeps an orifice habitually shut.

Sphygmograph, σφυγμός the pulse, and γράφω I write; an instrument with a lever which rises and falls with the pulse, and has a pen attached to it, by means of which it makes a tracing on a card moved by clock-work.

Spore, σπορά a seed; a vegetable germ which develops without impregnation.

Squamous, *squama* a scale; consisting of scales, as squamous epithelium; shaped like a scale, as the squamous part of the temporal bone.

Stapes, a stirrup; the name of a stirrup-shaped ossicle in the tympanum of the ear.

Stercorin, *stercus* dung; a crystalline substance obtained from fæces.

Stereoscope, στερεός solid, and σκοπέω I behold; an instrument by means of which two views, such as might be presented by one object to the two eyes, being exhibited one to each eye, a single picture is seen with the solidity and perspective of reality.

Sternum, στέρνον the breast; the breast-bone.

Stigma, στιγμή a puncture; an opening leading into a respiratory trachea in an insect; the part of the pistil of a flower to which the pollen is applied, and which leads into the ovary.

Stroma, στρῶμα a thing spread out for lying on; the groundwork of a texture, in which other parts are imbedded; the matrix of a tissue.

Styloid, στῦλος a pointed instrument for writing, and εἶδος form; the name of certain processes, as the styloid process of the ulna and of the temporal bone.

Succus intestinalis, intestinal juice; the secretion of the glands of the mucous membrane of the small intestine.

Sudoriparous, *sudor* sweat, and *pario* I bring forth; the sudoriparous glands secrete the perspiration.

Sutura, *sutura* a seam. While in surgery it is applied to any seam for closing a wound, is in anatomy applied to an articulation in which two edges of bone are immovably united, with only periosteum between them.

Sympathetic, σύν together with, and πάθος suffering; the name given to the ganglionic system of nerves, on account of its connection with the cerebro-spinal system.

Symphysis, *σύν* together, and *φύσις* growth; a name applied to certain instances of incomplete articulation dissimilar in their nature, as the symphysis pubis and symphysis of the lower jaw.

Synchronous, *σύν* together, and *χρόνος* time; occurring at the same time.

Syncope, *συγκοπή* a swoon; unconsciousness, from failure of the heart's action.

Synostosis, *σύν* together, and *ὀστέον* bone; used with reference to the bones of the skull; means the premature obliteration of sutures.

Synovia, *σύν* together, and *ὠόν* an egg; secretion like white of egg; the fluid lubricating the interior of a joint.

Syntonin, *σύν* together, and *τείνω* I stretch; a peculiar variety of fibrin obtained from muscular fibre.

Tænia, a ribbon; *tænia hippocampi* and *tænia semicircularis*, parts in the brain.

Tapetum, a carpet; the shining layer existing in the choroid coat of the eye in many animals.

Tarsus, *ταρσός* the flat of the foot; the seven bones which form the instep and heel.

Teleology, *τέλος* an end accomplished, and *λόγος* discourse; the study of function.

Temporal, *tempus* time; whence *tempora* the temples or sides of the head where the ravages of time are liable to be shown by the whitening of the hair; the name of the bone at the side and base of the skull, in which the ear is situated.

Tendon, *tendo* a noun from *tendo* I stretch; a variety of white fibrous tissue through the medium of which muscle is attached.

Tentorium a tent; *tentorium cerebelli*, the process of dura mater which separates the cerebellum from the cerebral hemispheres.

Testis a witness; the gland secreting the spermatozoa.

Tetanus, *τέτανος* tension (*τείνω* I stretch); the spasmodic or involuntary continued active contraction of muscular fibre.

Thalamus, *θάλαμος* a chamber; *optic thalamus*, the name of a portion of the brain from which the fibres of the optic tract partly arise.

Thaumotrope, *θαῦμα* a wonder, and *τρέπω* I turn; an instrument, in which figures in series of different positions are painted near the circumference of a disc, and the reflections of these, being looked at in a mirror through openings in a card revolving with them, are seen in the form of figures, each of which performs the movement represented in stages on the disc. This instrument is also called a *stroboscope* (*στροβέω* I whirl).

Theca a sheath; a synovial sheath of a tendon.

Thorax, *θώραξ* a breast-plate; the cavity which contains the heart and lungs; or, when the skeleton is spoken of, the ribs, dorsal vertebræ, costal cartilages, and sternum.

Thymus, *θυμός* heart or soul; the thymus gland, a ductless gland in the upper part of the chest, in early life.

Thyroid, *θυρεός* a shield, and *εἶδος* form; the *thyroid cartilage*, the largest cartilage of the larynx; the *thyroid body*, a ductless gland on the front and sides of the upper part of the trachea.

Tibia a flute; the large inner bone of the leg, the shin-bone.

Tonicity, *τόνος* tightening; muscular contraction, of a slight degree, persistently continuous.

Tonsil, *tonsilla* a structure on each side of the fauces; also called *amygdala*, from being the size of an almond.

Trabecula, a little rafter.
Trachea, *τραχὺς* rough; the wind-pipe. See the word artery.
Tragus, *τράγος* a goat; the eminence in front of the opening of the ear; sometimes hairy, like a goat's beard.
Trapezium, a geometrical figure; the name of the carpal bone which supports the thumb.
Trapezoid, a geometrical figure; the name of one of the carpal bones.
Tricuspid, *tria* three, and *cuspis* a pointed extremity; the tricuspid valve of the heart, consisting of three cusps.
Trigone, *τρία* three, and *γωνία* an angle; the part of the bladder between the openings of the ureters and arethra.
Trochlea, a pulley.
Tuberosity, *tuber* a lump; a thick prominence of a bone.
Turbinated, *turbo* a turning round; the turbinated bones, all more or less curved.
Tympanum, a timbrel or drum; the cavity termed the drum of the ear.

Ulna, *ὠλένη* the elbow; the inner bone of the fore-arm.
Umbilicus, the navel.
Unciform, *uncus* a hook; the name of one of the carpal bones.
Urachus, *οὖρον* urine, and *ἔχω* I hold; the constricted part of the allantois, which remains as a cord ascending from the bladder.
Ureter, *οὐρητὴρ* the duct from the kidney to the urinary bladder.
Urethra, *οὐρήθρα* the excretory duct of the bladder.
Uvula, a little grape; the pendant body at the back of the soft palate.

Vallecula, a little valley; the hollow in the middle of the under surface of the cerebellum.
Valvulæ conniventes, valves approximating one to another; the folds of mucous membrane which project into the small intestine.
Velum interpositum, interposed curtain; a fold of pia mater prolonged beneath the fornix, and supporting choroid plexuses.
Velum palatæ, the soft palate.
Venæ comites, companion veins; two or more veins coursing in company with an artery.
Ventricle, *ventriculus* (*venter* a belly) a little cavity. The ventricles of the heart are the cavities, the walls of which propel the blood.
Ventriloquist, *venter* the belly, and *loquor* I speak; one who has the art of managing his voice so as to make it appear that the sounds emanate from a different direction.
Vermicular, *vermis* a worm; vermicular movement in waves, such as are seen in a worm.
Vertebra, *verto* I turn; a bone of the spinal column.
Vestibule, *vestibulum* an entrance. The vestibule of the ear is the part of the labyrinth from which the semi-circular canals come off.
Vitelline, *vitellus* the yolk of an egg; belonging to the yolk, as the vitelline membrane.
Vitreous, *vitreus* of glass; the vitreous humor is named from its glassy appearance.

Zona pellucida, the pellucid zone surrounding the yelk of the unimpregnated ovum.
Zonule of Zinn, the plicated zone formed by the suspensory ligament of the lens of the eye.
Zygoma, *ζυγὸν* a yoke; the arch formed by the malar bone and zygomatic process of the temporal bone.

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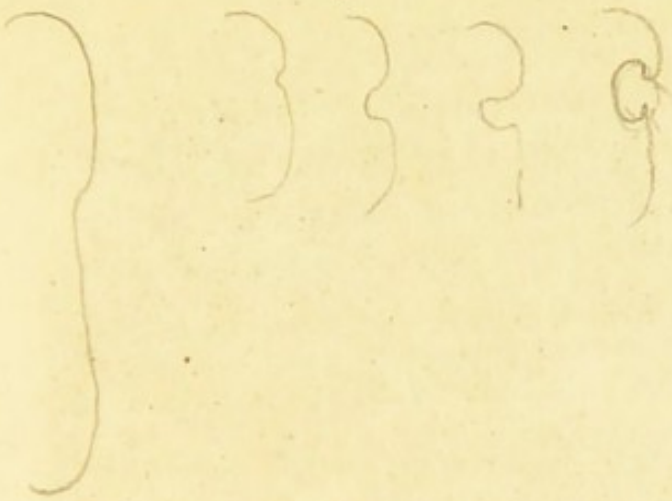
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