PHYSICAL DIAGNOSIS.

THE URINE IN DISEASE.

A GUIDE

TO THE

PHYSICAL DIAGNOSIS

OF

THE DISEASES

OF THE

LUNGS AND HEART;

TOGETHER WITH AN

INTRODUCTION TO THE EXAMINATION
OF THE URINE.

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Observer, c'est diriger de concert les sens et l'intellect vers un objet, afin de le mieux connaitre."—GINTRAC, PATHOLOGIE.

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TO

THE STUDENTS

OF

THE QUEEN'S HOSPITAL

THIS LITTLE VOLUME IS

DEDICATED,

BY THEIR FAITHFUL FRIEND AND

WELL-WISHER,

THE AUTHOR.

PREFACE.

In the following pages I have honestly endeavoured to assist the student of clinical medicine in some of the most important and difficult branches of the art of diagnosis. I have sought to aid the beginner in surmounting some of the difficulties which he must encounter at the bedside, when learning the practice of a laborious profession. I have striven to help him to recognize and appreciate for himself the physical evidences of disease; should I succeed in this, even in the slightest degree, I shall feel amply rewarded for my work.

Queen's Hospital, Birmingham,
June, 1870.

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CHAPTER I.

INTRODUCTION—SYMPTOMS—METHODS OF PHYSICAL DIAGNOSIS.

MEDICINE, a science and an art, comprehends all that is known concerning diseases; all that is known of their causes, history, and nature; and all that is known of the means of their recognition, of their prevention, alleviation, and cure. The science of medicine traces the causes of disease to their several effects, while the art of medicine puts into practice the rules which the science affords for the detection and discrimination of disease, and for the relief and prevention of human suffering.

I have mainly to do with the art of diagnosis—the art of the discrimination of diseases. This art can only be acquired at the bedside, by careful observation and laborious study. No amount of reading can ever make a student an accurate clinical observer; it can never teach him the art of practical medicine, unless it be supplemented and completed by continuous work in the wards, by faithful observation of disease, and by actual clinical experience. It is my purpose to attempt to help the student in the chief portions of his clinical work, to direct him what to observe and how to observe, and to teach him how to interpret symptoms of disease, base upon them his opinion, and so form his diagnosis. The importance of a correct diagnosis need scarcely be insisted upon; it is the first duty of the physician at the bedside, and no disease can be successfully and scientifically treated before its nature has been fully recognised.

Diseases are usually said to be revealed by their symptoms and signs. But these are not quite the same things. "Disease is a change of structure, or of function, or of both; 'symptoms' are those changes in structure, or function, or both, which we can recognise. The latter, the symptoms, are not separate from, but are parts of the disease, and their only characteristic is, that they are such parts as are appreciable during life."* Symptoms may be *subjective*, or they may be *objective*. The phenomena of disease, such as pain, &c., which are only appreciated by the patient, and which are made known to us by his language, expression, gesture, &c., are called subjective symptoms. The phenomena of disease, which only we can recognise and appreciate, such as tubular breathing, bronchophony, &c., are called objective symptoms. Each set of symptoms often interprets the other; but, of the two, the objective are by far the most reliable, for we directly observe them ourselves, while the subjective symptoms are liable to perversion, exaggeration, or suppression, according to the condition of the patient's emotions, senses, and intellect. The term "physical sign" is often used, and it is applied to symptoms which are directly evident to the observer only. "Interpreted by the observer, and not by the patient, incapable, except in the rarest instances, of being feigned, dissembled, or even

* A system of medicine. Dr. Russell Reynolds. 1866.

modified at will,—estimable in degree and extent with almost mathematical precision,—physical signs, like the whole class of objective phenomena of disease, are of immeasurably greater diagnostic, and considerably greater general clinical value than its subjective symptoms."* A physical sign is really an objective symptom ; and I think it is scarcely necessary to apply a distinctive term to such phenomena as dulness on percussion and cardiac murmurs, for they are only symptoms, like pain and palpitation. The indiscriminate use of the terms symptoms and signs has given rise to much confusion, even in the writings of authorities on medicine ; and it must always be remembered that all phenomena of disease which can be recognised, either by the observer, or by the patient, or by both, are symptoms of disease, and that these symptoms, strictly speaking, only become signs when conclusions have been drawn from them, and a diagnosis founded upon their consideration.

* Diseases of the Lungs. Dr. Walshe, 3rd Edit. 1860.

Various methods of physical diagnosis are employed in the investigation of disease; and it is of the first importance that the student should make himself fully acquainted with the principles of these methods, that he should know how to put these means of diagnosis into practice, and that he should first learn what phenomena they reveal in health, and then proceed to study the indications which they elicit in disease. There are six chief methods of physical diagnosis, viz., Inspection, Palpation, Mensuration, Succussion, Percussion, and Auscultation. Percussion and Auscultation are perhaps the most important of these, not only on account of their usefulness and wide application, but also because of the extended study which they demand. All these methods find their widest and most general application in diseases of the chest.

CHAPTER II.

CLINICAL TOPOGRAPHY OF THE CHEST.

REGIONS OF THE THORAX.

BEFORE we proceed to the consideration of the various methods of physical examination which are in use in the detection of diseases of the thorax, it will be necessary to glance at the clinical topography of the organs contained in the chest, and to consider briefly their relations in health to each other and to the surface.

THE LUNGS.—The inner margins of the lungs meet behind the sternum on a level with the first intercostal spaces, or a little lower. The inner edge of the right lung passes vertically downwards, behind the sternum, and slightly to the left of the middle line, and reaches as far as the base of the ensiform cartilage, on a level with the cartilage of the sixth rib. The inner margin of the left lung diverges from the right nearly opposite the level of the fourth costal cartilages, sometimes lower than this ; it then runs obliquely downwards, outwards, and towards the left, to a point just internal to the left nipple ; it then turns almost vertically downwards, behind the fifth left cartilage ; opposite the fifth intercostal space it curves inwards, towards the right, reaching a point about one inch to the inner side of the left nipple line ; and the inner margin of the left lung terminates below, on a level with the lower border of the sixth left costal cartilage. The lower edge of the right lung passes to the right from the ensiform cartilage, crossing behind the cartilage of the seventh rib, and reaching the lower edge of the sixth rib ; it then passes obliquely downwards, outwards, and backwards, crossing the seventh, eighth, and ninth ribs, to reach the spine behind, on a level with the eleventh dorsal vertebra. The lower margin of the left lung takes a similar course, but it extends a little lower, nearly a rib's breadth, than the right. "A line drawn directly downwards from the nipple would cut the lower edge of the right lung, where it appears through the sixth interspace, and a similar line from the left nipple would cut the lower edge of the left lung, where it lies behind the sixth rib. A line drawn downwards on either side from the centre of the axilla would cross the lower edge of the lung where it lies behind the eighth rib."* The triangular apices of the lungs rise above the clavicles, reaching on the right side usually slightly higher than on the left, and extending for an inch or an inch and a half above the level of the first rib. The external boundary of the apex of each lung lies a little to the outer side of the centre of the clavicle.

The Heart and Great Vessels.—The clinical observer must know exactly the position in the chest of the various parts of the heart—its valves, compartments, and orifices—and he must know precisely the points on the surface of the chest to which these parts, together with the great vessels, severally correspond. Such knowledge, the importance of which

* Medical Anatomy. Dr. Sibson.

cannot be over-estimated, is essential to the correct diagnosis of many diseases of the heart and neighbouring structures.

The heart is situated in the lower part of the anterior mediastinum, beneath the lower two-thirds of the sternum. It extends beyond the lateral edges of the bone, but to a greater distance on the left side than on the right. The base of the heart is its most fixed part, and it is maintained in its position by the great vessels which spring from it, and which are somewhat firmly bound to each other, and to the surrounding parts. The ascending cava, too, connects the base with the tendon of the diaphragm. The pericardium, a reflected serous sac and a fibrous aponeurosis, supports the heart indirectly. Below, the fibrous portion is united to, and may be said to originate in the diaphragm, while it is firmly attached to the great vessels at the base, and it also strengthens them by sending sheathing prolongations around them.

The heart is usually from four inches and a half to five inches in length, three inches and a half in width, and two inches and a half in thickness. The heart of a woman is smaller than that of a man.

The heart lies obliquely in the chest. The base is directed upwards, backwards, and towards the right; while the apex is directed downwards, forwards, and towards the left. The auricles, says Dr. Sibson, form the right side of the heart, the ventricles the left. The left cavities are placed on a plane posterior to the right. "The right ventricle is in front of the left half of the left auricle, and the right two-thirds of the left ventricle."* The base of the heart corresponds, anteriorly, to the upper borders of the third costal cartilages, and to a line drawn across the sternum on the same level. The impulse of the apex is felt during life between the fifth and sixth ribs on the left side, on a level with their junction with their cartilages, and at a point on the surface, to borrow the words of Dr. Williams, two inches below the nipple, and one on the sternal side.

* Medical Anatomy. Dr. Sibson.

Posteriorly, the base corresponds, by its upper margin, to the fourth or fifth, and, by its lower margin, to the seventh or eighth dorsal vertebra. The aorta, esophagus, and pneumogastric nerves, intervene between the base of the heart and the spine. The heart lies behind the cartilages of the third, fourth, and fifth right ribs, near the sternum, projecting, according to the amount of the distention of the right side, from an inch to an inch and a half beyond the middle line of the breast bone. On the left side it reaches about three inches or three inches and a half beyond the middle line, and it lies behind the cartilages of the third, fourth, fifth, and sixth left ribs. "The heart, then, as a whole, extends, vertically, from the second space to the sixth cartilage, and, transversely, from a little within the left nipple to a finger's breadth or more to the right of the sternum; these are the limits of the *deep cardiac region*."*

* Diseases of the Heart and Great Vessels. Dr. Walshe, 3rd Edit. 1862.

The region corresponding to the portion of the heart which is uncovered by the lungs is called the præcordial region or space, or the *superficial cardiac region.* The extent of this region will be readily understood when the positions of the anterior margins of the right and left lungs are remembered. The right auricle, and a portion of the right ventricle, are covered by the right lung. The left auricle, the upper part of the right ventricle, and nearly the whole of the left ventricle, are covered by the left lung. The superficial cardiac region corresponds almost entirely to the right ventricle, and this portion of the heart, uncovered by lung, lies beneath the hand when it is applied over the præcordial space. This region is usually triangular, but it is often irregularly quadrangular. It is bounded on its right side by the inner margin of the right lung, opposite the middle line of the sternum. The upper boundary of the space corresponds to the middle line, opposite the fourth cartilage, where the left lung diverges from its fellow. The left boundary of the space is limited by the diverging inner margin of the left lung, passing obliquely downwards internal to the left nipple. The lower limit, or base of the space, corresponds to the lower edge of the heart, between the middle line and the apex, and it is bounded by a line passing outwards to the left, and slightly downwards, from the point of junction of the sternum with the ensiform cartilage. The superficial cardiac region usually measures about three inches on its oblique or outer side, its base about two inches and a half, and its vertical inner margin about two inches.

Positions of the Valves of the Heart.—The valves of the pulmonary artery are situated opposite the upper edge of the third costal cartilage on the left side, and, according to Dr. Walshe, the left edge of the sternum has closely the same width of the vessel on both sides. The aortic valves lie behind the sternum, towards its left edge, on a level with the junction of the sternum and the third left cartilage. The aortic valves are situated a little to the right of the pulmonary, and they are also a little lower. The tricuspid valve is situated behind the centre of the sternum, on a level with the lower margins of the fourth costal cartilages. It is placed somewhat obliquely, the ventricular aspect of the right auriculo-ventricular orifice looking downwards, and towards the left. The mitral valve is placed on a plane posterior to that of the tricuspid, and behind the left edge of the sternum. It is vertically below the aortic valves, and it is on a level with the third left interspace.

The pulmonary valves are the highest and the most anterior of all. The aortic valves lie behind, below, and a little to the inner side of the pulmonary. The left auriculo-ventricular orifice lies behind and also below the aortic valves, and a very little to their inner side. The tricuspid valve is anterior to the mitral, and it lies from half an inch to three-quarters of an inch distant from and below the pulmonary valves.

A superficial area the size of a shilling will include a portion of all the valves, tricuspid, mitral, aortic, and pulmonary.

THE GREAT VESSELS.—The aorta springs from the left ventricle opposite the union of the cartilage of the third left rib with the sternum. The ascending portion is nearly wholly contained in the pericardium, and at first it lies behind the pulmonary artery. It reaches the upper border of the cartilage of the second right rib. The transverse position of the arch of the aorta crosses in front of the trachea, just above its bifurcation, and is opposite the centre of the first bone of the sternum, on a level with the first interspaces. It recedes from the sternum, passes backwards, and reaches the left side of the body of the second or third dorsal vertebra. From the transverse portion of the arch the three great vessels arise, and along its upper border is found the left innominate vein.

The pulmonary artery springs from the right ventricle, nearly opposite the junction of the cartilage of the third left rib with the sternum. It is directed upwards, inclining backwards and slightly to the left side, and it ascends on the left of the aorta. After a course of about an inch and a half or two inches it bifurcates, opposite the cartilage of the second left rib or first interspace, dividing into two almost equal branches for the lungs.

The innominate or brachio-cephalic artery is the largest and first of the branches of the transverse part of the aorta. It arises opposite the junction of the cartilage of the second rib on the right side with the sternum, or a little higher than this, and it is given off at the point where the arch of the aorta comes nearest to the wall of the chest. The artery is crossed by the left innominate vein; and at first it lies on the trachea, but it soon passes to its right side. The innominate artery divides opposite the right sterno-clavicular articulation.

"In as much as the sounds and murmurs produced in or transmitted along the arch of the aorta, the pulmonary and innominate arteries are, as a rule, severally best isolated at the second right, the second left, and the first right, costal cartilages. These cartilages may, for clinical purposes, be respectively called the aortic, pulmonary, and innominate."*

Modifications of some importance take place in the positions of the heart and lungs in health, owing to their normal movements; and the situation of the heart is somewhat affected by changes in the position of the body. Age, too, has some influence over the positions of the thoracic organs.

The lungs enlarge in all directions during inspiration; their apices ascend, their bases descend, and their anterior margins become more closely approximated. The opposite takes place during expiration. These changes influence the extent of the præcordial space. At the end of inspiration this region is lessened, while at the end of expiration this area is increased, and this influence is of course most obvious when the inspirations and expirations are forced and extreme. The tendon of the diaphragm, attached to the pericardium, descends

* Diseases of the Heart and Great Vessels. Dr. Walshe. 3rd Edit. 1862.

during inspiration, drawing downwards the heart and the great vessels. But, as Dr. Sibson has pointed out, the sternum and the ribs are raised at the same time, so that the apparent descent of the heart is greater than its actual descent. The heart ascends slightly when the recumbent posture is assumed, and it is a little lowered (it may be to the extent of an inch) when the body becomes erect. Turning on the right or left side will cause the heart to change its lateral position somewhat, and in the prone posture the heart approximates more fully to the chest wall than it does when the body lies supine. In childhood the heart usually lies higher in the chest than it does in advanced life. In children, too, the position of the thymus gland at the upper part of the sternum must be remembered.

Regions of the Thorax.—It has been customary to divide the surface of the chest into artificial regions, in order that the observer may localise his observations as precisely as possible, and that he may conveniently record and convey to others the results of his investigations. The limits of these regions are altogether arbitrary, although their boundaries are usually well defined and easily ascertainable points. It is to be regretted, however, that authorities have exhibited great discrepancy in the number, extent, and positions of these regions, so that the usefulness of such a systematic division of the parts to be studied has been very much impaired. Some such mapping out of the surface of the thorax and abdomen becomes an extremely useful aid to accurate clinical observation; for many of the regions are sufficiently indicated by their names, bounded, as they are, by prominent points of the skeleton. I am, however, fully convinced that whenever it is possible it is better in clinical descriptions to localise symptoms according to their anatomical sites, about which no confusion can arise, than to define their limits according to the arbitrary boundaries of artificial surface regions.

In the following account of the regions of the thorax and their contents, I have mainly followed the admirable description of Dr. Walshe.*

The chest is divided into three sets of regions: anterior, lateral, and posterior. The anterior regions are called: supra-clavicular, clavicular, infra-clavicular (subclavian), mammary, infra-mammary, supra-sternal, upper-sternal (superior-sternal), and lower-sternal (inferior-sternal). The three sternal regions are single, while all the rest are double. The lateral regions are: the axillary and infra-axillary. The posterior regions are: the upper-scapular (supra-spinous), the lower-scapular (infra-spinous), the infra-scapular (upper-dorsal), and the inter-scapular. All the lateral and posterior regions are double.

Supra-clavicular Region.—A small triangular space above the clavicle. Its boundaries are, above, a line drawn from the outer part of the clavicle to the upper rings of the trachea; below, the clavicle; on the inside, the base of the triangle, the edge of the trachea. In this region is found the apex of the lung, but there

* Diseases of the Lungs. 3rd Edit. 1860.

are also in this locality portions of the subclavian and carotid arteries, and portions of the subclavian and jugular veins.

Clavicular Region.—This is long and narrow, comprising that portion of the clavicle, a little more than its inner half, behind which the lung lies. The lung substance lies behind the bone on both sides of the chest. On the right side, at the sterno-clavicular articulation, is the innominate artery, while a portion of the subclavian artery is found at the outer edge of the region. On the left side the carotid and subclavian arteries are found, lying deeply, and passing upwards, almost at right angles to the clavicle.

Infra-clavicular Region.—This region is nearly square; bounded above by the lower border of the clavicle, below, by the lower border of the third rib, on the outside, by a line falling vertically from the acromial angle (the angle formed by the clavicle and the head of the humerus), and on the inside, by the edge of the sternum. In this region is found, on both sides, the upper lobe of the lung. In the right infra-clavicular region, close to its sternal boundary, lie the superior cava, and part of the arch of the aorta; while on the left side, close to the sternum, is the edge of the pulmonary artery. The inferior border of this region corresponds, on the left side, to a portion of the base of the heart. The main bronchus on either side lies opposite the sternal portion of this region, the right bronchus corresponding to the second costal cartilage, and the left to a point a little lower down.

Mammary Region.—The boundaries of this region may be stated as follows:— Above, the lower border of the third rib; below, the sixth rib; outside, a line falling vertically from the acromial angle; inside, the edge of the sternum. On the right side the lung occupies this region, lying immediately underneath the ribs, and extending downwards to the sixth rib, opposite which bone its inferior border turns off almost at right angles to the anterior. At the end of expiration the right wing of the diaphragm and the liver rise into the lower part of this region, on the level of the fourth interspace. A portion of the right auricle and ventricle lie between the third and fifth ribs, close to the sternum, in the right mammary region. The left mammary region contains the left auricle and the left ventricle, with a small portion of the right ventricle near the apex of the heart, together with a portion of the left lung.

Infra-mammary Region.—This region is more or less triangular. It is bounded above by a line slanting outwards from the sixth cartilage; below, by a line corresponding to the lower margins of the false ribs; on the outside, by a prolongation of the outer limit of the mammary region; and on the inside, by the edge of the lower part of the sternum. On the right side the liver, with the lung overlapping its upper third, occupies this region. On the left side are the stomach, the anterior edge of the spleen, and a portion of the left lobe of the liver.

Supra-sternal Region.—This is bounded below by the notch of the sternum, and by the sterno-mastoid muscles on either side. This region is more or less hollow, and contains no lung. It is almost entirely filled by the trachea; the innominate artery lies at its lower angle, on the right side; and sometimes the arch of the aorta may be felt pulsating at the lower border of this region.

Upper-sternal Region.—This region comprehends that portion of the sternum which is above the level of the lower borders of the third ribs. In this locality are found the left, and a small portion of the right innominate vein; the ascending and transverse portions of the arch of the aorta; the right side of the pulmonary artery, throughout the whole of the course of the vessel; the aortic valves, and a portion of the pulmonary valves; and, lastly, the trachea, bifurcating on the level of the second ribs. The inner edges of the lungs pass obliquely downwards and inwards to meet in this region, and here are also found the remains of the thymus gland.

Lower-sternal Region.—This region corresponds to the remainder of the sternum, to that portion of the bone which is below the level of the lower borders of the third ribs. It contains the greater portion of the right ventricle, and a small portion of the left, and it also corresponds to the tricuspid and mitral valves. The edge of the right lung decends nearly vertically, a very little to the left of the middle line, and at the upper part of the region is a small portion of the left lung. In the lower part, deeply seated, is a portion of the liver, covered by the diaphragm, and sometimes part of the stomach ascends into this region.

Axillary Region.—This, the superior of the two lateral regions, extends from the apex of the axilla above, to a line continued from the lower border of the mammary region below, and in front it is bounded by the outer borders of the infra-clavicular and mammary regions, reaching to the external edge of the scapula behind. This region comprehends a great mass of lung-substance, and, deeply seated, the large bronchi.

Infra-axillary Region.—This region is bounded by the axillary above, by the infra-mammary in front, by the infra-scapular behind, and by the edges of the false ribs below. Here we find on both sides the sloping lower edge of the lung, and, in addition, the liver on the right side, and the stomach and spleen on the left.

Upper Scapular and Lower Scapular Regions.—Comprehending the fossæ of the scapula, these regions correspond to lung-substance.

Infra-scapular Region.—Bounded above by the inferior angle of the scapula and the seventh dorsal vertebra, this region joins the infra-axillary, extending below, to the twelfth rib, and on the inside, to the spine. Just underneath the surface, as far as the eleventh rib, lie the lungs. On the right side we find the liver, and on the left the spleen and intestines. On both sides a portion of the kidney enters this region, and on the left side, close to the spine, is the descending aorta.

Inter-scapular Region.—This region occupies the space lying between the inner edge of the scapula and the spinous processes of the dorsal vertebræ. From the second to the sixth, it contains lung, the main bronchus on either side, and the bronchial glands. On the left side is found the esophagus, and, from the third or fourth vertebra downwards, the descending aorta.

In marking out the regions of the chest, it is important to remember that the nipples, in males, are generally situated opposite the fourth ribs; and that the junction of the manubrium of the sternum with the lower portion of the bone, the mucro, corresponds to the cartilages of the second ribs. The union between these two portions of the sternum, in men at least, is usually well defined, and in muscular subjects whose ribs are well covered it forms a good landmark in clinical explorations.

CHAPTER III.

INSPECTION—PALPATION—MENSURATION.
SUCCUSSION—SPIROMETRY.

INSPECTION.

Inspection means simply surveying the external surface of the chest. This mode of examination enables us to judge of the size and shape of the thorax, to observe the movements of the parietes, to notice the beat of the heart, and to ascertain the character of the respiration.

Mode of Inspection.—A good light is necessary, and the surface must be fully exposed; partial inspections really lead to no satisfactory results. Inspection may be performed in the erect, sitting, or recumbent postures; the sitting position, however, is usually preferred. All mechanical restraint must be removed, and care must be taken that nothing hampers the free expansion of the chest. The front of the thorax should be inspected first, but it must also be viewed from behind, and from either side. It is of the highest importance that the two sides of the chest should be compared from every aspect, as to their size, configuration, and movement.

Form of the Healthy Chest.—The transverse diameter of the healthy chest is greater than the antero-posterior, and a slight degree of subclavicular depression can usually be seen, especially in men. The angles formed by the ribs and the spine behind, and the costal cartilages and the sternum in front, appear equal. The chest is rounded in all its outlines. The intercostal spaces are hollow, both during inspiration and expiration. The nipples are equidistant from the middle line, opposite, in men, the fourth ribs. The spine presents the normal dorsal curve; the shoulders are upon the same level. The left præcordial ribs are not more prominent than their fellows on the opposite side.

A fair proportion of healthy chests are really symmetrical; all healthy chests may be said to *appear* to be so, corresponding in shape and size on the two sides. The two halves of the chest, however, frequently do not perfectly correspond. The right side is often found, on measurement, to be half an inch larger than the left; and the right infra-clavicular region in right-handed muscular men, owing to the thickness of muscle in this locality, may be a little more prominent than the left. In muscular subjects, too, in whom the right arm is called greatly into play, the spine may be slightly curved towards the right side. The left nipple is often somewhat lower than the right. These lateral deviations from perfect symmetry, compatible with health, have been called "physiological heteromorphisms."

Movements of the Chest in Health.—"The respiration is considered normal when the anterior and lateral parts of the chest dilate equally, distinctly, yet moderately, during inspiration."* In inspiration, the capacity of the chest is increased in all directions. "During

* Diseases of the Chest. Laennec. Dr. Forbes' translation.

inspiration, the clavicles, first ribs, and through them the sternum, and all the annexed ribs are raised. The upper ribs converge, the lower diverge ; the upper cartilages form a right angle with the sternum, and the lower cartilages of opposite sides, from the seventh downwards, move further asunder, so as to widen the abdominal space between them, just below the xiphoid cartilage : the effect being to raise, widen, and deepen the whole chest, to shorten the neck, and apparently to lengthen the abdomen. During expiration, the position of the ribs and cartilages is reversed, the sternum and ribs descend ; the upper ribs diverge, and the lower converge ; the upper cartilages form a more obtuse angle with the sternum, and the lower cartilages of opposite sides approximate, so as to narrow the abdominal space between them, just below the xiphoid : the effect being to lower, narrow, and flatten the whole chest, to lengthen the neck, and apparently to shorten the abdomen."* In inspiration, the move-

* Medical Anatomy. Dr. Sibson.

ments of the chest wall are made up of *expansion* and *elevation*, and in expiration, of *retraction* and *depression*. The mode of movement of the chest differs in the two sexes, and it varies also according to age. In young children, inspiration depends mainly upon the action of the diaphragm ; the movement of the abdomen, therefore, is very marked. This form of respiration is named *abdominal*. In women the movement of the upper part of the chest in inspiration is more obvious than that of the lower portion, while in men the movement of the lower part of the chest predominates. These types of respiration have been called *superior costal* and *inferior costal*. No doubt the fashion which exists among women of constricting the lower part of the thorax by some articles of their dress contributes to this difference in the thoracic movements in the two sexes ; but it is generally thought that there is an intrinsic difference in the costal movement of the sexes which is not due to this condition, and the cause of which has not yet been satisfactorily determined.

The movements of the chest in health during respiration resemble "the easy ebb and flow of a soft wave." No distinct interval can be observed between inspiration and expiration. Dr. Walshe says, if the entire time occupied by a respiratory act be represented by 10, the value of the duration of the inspiratory movement may be estimated approximately at 5, of the expiratory at 4, and of the pause between the expiratory and succeeding inspiratory movement at 1. In calm breathing the durations of inspiration and expiration are nearly equal. From sixteen to twenty inspirations occur in a minute, or about one to every four beats of the heart.

The impulse of the apex of the heart can be distinctly seen in health.

Inspection in Disease.—In disease important changes occur in the form, size, and movements of the chest, and inspection is of the greatest value in the detection of these morbid alterations. It will be best to speak in the first place of these changes in general terms, explaining the names which are used in their description, and afterwards the value of inspection may be illustrated by a brief account of the signs which are afforded in the chief diseases of the thorax, to which this mode of diagnosis is applicable.

Form of the Chest. (1.) Expansion.—Expansion means a general prominence of the whole of the chest, or of one of its sides. One side of the chest is expanded, and is evidently larger than the other in cases of abundant pleuritic effusion, in pneumothorax, and in hydro-pneumothorax, when air and fluid exist together in the cavity of the pleura. General vesicular emphysema produces general expansion of the chest. Emphysema of one lung may cause unilateral expansion, and when the disease exists to a greater extent on one side than on the other, both sides may be expanded, though unequally.

(2.) Bulging.—Bulging is a local expansion. It may occur at the lower part of the chest in pleuritic effusion, and in the supra-clavicular and infra-clavicular regions in emphysema. It may be due

to intra-thoracic tumour, aneurism, &c., and it may be seen in cases of emphysema, when the pus is making its way towards the surface. An enlarged liver may cause the ribs, under which it lies, to bulge outwards, and an enlarged spleen less frequently leads to a similar condition on the left side. In pericardial effusion, or when the heart is hypertrophied, the ribs in front of the cardiac region may bulge outwards, the intercostal spaces being also widened. Aneurisms of the arch of the aorta frequently cause a local bulging of the walls of the chest.

(3.) Retraction.—Retraction, or *contraction*, as it is sometimes also called, signifies a general sinking in of the walls of the chest on one side. When pleuritic effusion exists, the lung is reduced in size by compression, and if the effusion remains for some time, the elasticity of the lung is impaired or lost, and the organ becomes bound down by adhesions. When the fluid is removed by absorption or by tapping, the lung is unable to expand, and the side of the

chest sinks in—is forced in, one might almost say—by atmospheric pressure. A diminution in the bulk of the lung occurs in tubercular disease, and in some other disorders in which the density of the lung is increased and its size diminished, and in these cases there is a consequent retraction of the chest wall.

(*4.*) *Depression.*—Depression is a local retraction. It may be seen under one or both clavicles in cases of pulmonary tuberculosis, and it is occasionally observed in the cardiac region to follow the absorption of pericardical effusion.

Respiratory Movements.—In healthy inspiration the chest wall is expanded as well as elevated. When part of the lung is rendered solid and impermeable to air, the expansion of the chest is impaired, and, by contrast, the elevation often becomes unusually evident. This is especially marked, says Dr. Walshe, on forced inspiration; volition may drag the thorax upwards, but it cannot expand impermeable texture. In the infra-clavicular regions this elevation of the chest wall, unattended with expansion, is well seen in cases of tubercular consolidation of the apices of the lungs. In emphysema the expansion of the lungs during inspiration is considerably less than in health, and the elevation of the parietes of the chest becomes very obvious and extreme.

In the early and painful stage of pleurisy, and in pleurodynia, the thoracic inspiratory movements are diminished, while the abdominal are increased. In acute diseases of the abdomen, especially in peritonitis, and also in rheumatic affections of the abdominal muscles and diaphragm, the thoracic element of respiration predominates. These changes are due to "consensual avoidance of pain." When there is an obstacle to the expansion of the lung, due to accumulations, solid, liquid, or gaseous, in the pleura, to paralysis of some of the muscles of respiration, to obstructions in any part of the air-passages, or to consolidation or emphysematous distension of the lung tissue itself, the respiratory movements are diminished; locally, or generally, according to the position, nature, and extent of the cause. The respiratory movements are excessive when dyspnæa, a condition due to many and varied causes, prompts increased muscular effort to overcome some difficulty. When an obstruction exists high up in the air-passages, in the fauces, larynx, or trachea, from disease, or from the impaction of foreign bodies, a retraction of the lower and lateral parts of the chest may be often seen during inspiration. This is frequently observed in children, in cases of croup; their elastic chest walls become retracted at the sides, the descending diaphragm protrudes the yielding abdominal walls, and the hollowness of the supra-sternal region is at the same time often greatly increased.

The duration of the expiratory movement is increased, relatively to the inspiratory, whenever the exit of air from the lungs is impeded, either from impairment of the elasticity of the lungs, or from obstructions in the air-passages.

Emphysema.—Whenever vesicular emphysema exists to a considerable extent, it produces very marked changes in the shape and movements of the chest walls. The thorax, writes Sir Thomas Watson, remains nearly in that position which it assumes after inspiring. The lungs are enlarged from an increase in the size of their air-cells, and their diminished elasticity leads to less respiratory play, and to diminished subsidence on expiration. The thorax becomes barrel-shaped, and its walls are prominent and rounded, especially in the upper half of the chest, on its anterior aspect. The dorsal curve is increased, the shoulders are raised, and the obliquity of the ribs is diminished. The distended lungs rise high in the supra-clavicular spaces, causing more or less bulging of these regions. During respiration the sternum and ribs seem to move more together than they do in health, the elevation movements predominate over those of expansion, the intercostal hollows are more marked than in the normal condition, and retraction of the spaces, especially of the lower ones laterally, is seen during inspiration. The heart's impulse may frequently be seen at the epigastrium.

Pleurisy with Effusion—Empyema.—The side of the chest which contains the fluid is generally visibly larger than the opposite side. It may be generally expanded, or it may merely bulge below. The mobility of the affected side is either impaired or lost. The ribs are elevated, and the intercostal spaces are found on a level with the ribs, or bulging beyond them, and they exhibit no depression during inspiration.

Retraction of the Chest Wall following the Absorption of Pleuritic Effusion.—"General retraction of the affected side is very much more common than partial depression."* The dimensions of the affected side are diminished in every direction. Depression *(procidentia)* of the shoulder occurs, and the ribs are approximated and lowered. There is often some lateral curvature of the spine, but there is no rotation of the vertebræ, and the convexity of the curve is usually directed towards the healthy side. There is little or no respiratory movement of the affected side, while that of the other

* Diseases of the Lungs. Dr. Walshe. 1860.

side is generally increased. The muscles, too, appear wasted, and the nipple is lowered. "The subjects of this morbid alteration are sufficiently distinguishable even by their external shape, and by their gait. They seem always to lean towards the affected side."*

Phthisis.—Flattening and diminished expansion of the supra and infra-clavicular regions are valuable signs furnished by inspection.

Rickets.—"The deformity of the thorax is one of the earliest noted, and is most important in its influence on the patient's health. The enlargement of the cartilaginous ends of the bones is a striking feature; the back is flattened, the ribs form a well-marked angle at the junction of the back and sides, instead of a curve, as in health. From this point, at which the lateral diameter of the thorax is greatest, the ribs pass forwards and inwards to their junction with the cartilages, where the lateral diameter is least; the cartilages curve out before turning in to join the sternum. The

* Diseases of the Chest. Laennec. Dr. Forbes' Translation.

sternum is thrown forwards, and the antero-posterior diameter of the thorax is increased, having somewhat the shape, on a horizontal section, of a pear with its narrow end forwards."*

Inspection of the Heart in Disease.—The impulse of the apex of the heart against the wall of the chest is visible in health. The apex-beat is depressed when the heart is hypertrophied, and it is in the majority of cases also carried to the left. In emphysema of the left lung the apex is frequently observed pulsating at the epigastrium. Fluid accumulations in the pleuræ may change the position of the heart. In a case of empyema of the left side of the chest I have seen the apex beating below the right nipple. But this displacement does not always occur, for the heart may be retained by adhesions in almost its normal position. Abdominal tumours, pregnancy, ascites, and tympanites may alter the locality of the apex beat, carrying it upwards, and often slightly to the left. Pericardial

* Diseases of Children. Dr. Thomas Hillier. 1868.

effusion usually raises the apex beat. "The presence of a large quantity of exudation in the cavity of the pericardium will tend most materially to lower the heart's apex."* The heart maybe pushed downwards by an aneurism of the aorta.

The Arteries. — In well-nourished healthy persons the pulsations of the arteries are rarely *visible.* In cases of aortic regurgitation, the pulsations are visible and leaping. This is the "locomotive" pulse of Bellingham. "The arterial tubes are *seen* to move by elongation, leaping forth at each beat of the heart."† Dr. Walshe says he has never observed highly marked and extensive visible pulsation without aortic regurgitant disease. "The appearance caused by the movements of these vessels is sometimes very striking, and is so distinctive that aortic regurgitation is rendered highly probable by this symptom

* Diseases of the Lungs and Heart. Dr. Herbert Davies.

† Science and Practice of Medicine. Dr. Aitken. 5th Edition.

alone."* The vessels leading to an inflamed part sometimes pulsate visibly. General excitement of the circulation may lead to temporary visible arterial pulsation, but the movement is simply throbbing, no elongation can be seen. In old persons, visible pulsation of the smaller arteries is sometimes due to calcification of the walls of the vessels.

The Veins.—The external and internal jugular veins may be notably enlarged and distended. This is observed in cases of tricuspid regurgitation. It may be due to pressure on the superior cava, or on the innominate veins, exerted by an aneurism or other thoracic tumour. Visible pulsation is sometimes seen in the jugulars, more especially in the external jugular on the right side. This is usually due to tricuspid regurgitation. In examining these cases, the effect of respiration upon the flow of blood in the veins, and the presence of large neighbouring arteries must be remembered.

* Principles and Practice of Medicine. Dr. Flint, Philadelphia, 1866.

PALPATION.

Palpation, the simple application of the hand to the external surface, is a mode of examination capable of yielding valuable indications in many diseases of the chest. By palpation we can determine the form of various parts of the chest, and appreciate the presence of flattening, bulging, and depression; we can estimate the extent and character of the movements of the chest wall, its elevation, and expansion; we can detect the presence or absence of various vibrations, frictions, and fluctuations; we can appreciate palpitation and cardiac thrills, and we can examine the position, character, and extent of the impulse of the heart.

The palmar surface of the fingers and hand must be placed evenly upon the surface. By placing the hands upon the sides of the chest, with the thumbs towards each other, near the lower part of the sternum, we can judge of the extent of the respiratory movements by the approach and separation of the thumbs. By using both hands we can detect even slight differences in the mobility of the two sides of the chest. Palpation is especially useful in estimating and comparing the amount of local expansion, we can so easily feel the degree in which the chest wall fills out and expands under the hand. The respirations are best counted by palpation, by applying the hand to the upper sternal region of women, and to the epigastrium of men.

Vocal Vibration, Tactile Vibration, Vocal Fremitus.—When the hand is applied to the healthy chest, during the act of speaking, a delicate vibratile tremor or thrill, commonly called fremitus, and sometimes tactile vibration, is felt. The intensity of this vibration is in proportion to the graveness and loudness of the voice. The vibration is more marked in males than in females, and in adults than in children, in long-chested than in short-chested persons, in thin subjects than in those who are fat, and in the recumbent than in the erect posture. The vibration is deadened or destroyed by strong pressure of the hand, and in women and children it often cannot be felt at all.

As a general truth, says Dr. Walshe, the intensity of the fremitus is considerably greater on the right side of the chest than the left, the greatest amount of this excess existing in the infra-clavicular, infra-scapular, and inter-scapular regions. This is an important point, for much of the value of vocal fremitus in disease depends upon a comparison of the two sides of the chest. From careful observations, I am convinced that these differences may almost practically be disregarded. Dr. Herbert Davies has concluded, from an examination of a large number of healthy men, that little or no difference can be usually detected in the distinctness of the vocal fremitus in the posterior and lateral parts of the two sides of the chest, while, any difference, if existing, between the two sides can be observed only anteriorly, and close to the right side of the upper part of the sternum, near the right bronchus.* Vibration, of course, is absent in the præcordial region, and its marked cessation may be often felt at the boundaries of the lungs.

* Diseases of the Lungs and Heart. 1854.

In disease, vocal fremitus may be increased, diminished, or altogether lost. These changes are best appreciated by palpation of the two sides of the chest, either alternately, or, as is best, at the same time.

Vocal fremitus is diminished or lost when the lung is removed from the chest wall by accumulations in the pleuræ, whether these consist of air, or of fluid, inflammatory, hæmorrhagic, or dropsical. When these collections are considerable in amount, the fremitus is entirely lost. In vesicular emphysema, too, vocal fremitus is diminished. This vibration is exaggerated when the lung is consolidated, as in pneumonia and tuberculosis. But for this increase in vocal fremitus to occur, the larger bronchial tubes must remain open, and in close and direct connection with the solid lung, so that the vibrations of the voice, produced in the larynx, may be propagated along the bronchi, and reach the surface, through conduction, by the unnaturally dense pulmonary texture. The vibration is increased, too, when the bronchial tubes are dilated, especially when the surrounding lung texture is more or less consolidated. A vibration, which has been called *tussive fremitus*, may be felt during the act of coughing.

Rhonchial Fremitus.—Vibrations of the bronchial tubes, produced by sibilant and sonorous rhonchi, and sometimes so strong or so conducted as to be felt on the surface.

Pulmonary Friction Fremitus.—The movements of the healthy pleuræ cause no vibration perceptible to the hand. When the pleural surfaces are roughened by morbid changes, a thrill, having a rubbing character, may sometimes be perceived on palpation. This, however, is the exception in pleurisy.

Fluctuation.—Fluctuation may sometimes be perceived in the intercostal spaces in cases of pleurisy with effusion, and in empyema.

Palpation of the Heart.—Synchronous with the commencement of the first sound of the heart, and synchronous with the systole of the ventricles, the shock of the heart takes place against the side of the chest. This impulse can usually be felt in health two inches below and an inch to the inner side of the left nipple. In adynamic diseases the heart's impulse is weakened, and it is also weakened, or it cannot be felt at all, when emphysematous lung intervenes between the apex and the chest wall. The force and area of the impulse are markedly increased when the heart is hypertrophied. Dilatation, fatty degeneration of the heart, and pericardial effusions diminish the force of the apex beat. The impulse may be sharp and abrupt, or it may be heaving and forcible. The position of the impulse may be best determined by palpation, and in this way irregular or intermitting action of the heart may be detected. The præcordial ribs may be felt to be bulging, with widening of the intercostal spaces, when there exists pericardial effusion, or cardiac hypertrophy. This is especially apt to occur in the young.

Valvular Thrill.—This has been also called purring tremor, cardiac thrill, purring or whirring vibration or thrill, and *fremissement cataire.* Corvisart first described this condition.* Laennec said the purring vibration of the heart might be very exactly compared to the thrill which attends the murmur of satisfaction by the cat when stroked by the hand. This thrill is systolic, and in the vast majority of cases it depends on valvular disease of the heart—mitral regurgitation, mitral obstruction, and aortic obstruction. Dr. Walshe says purring tremor is observed to the maximum degree in cases of mitral regurgitation, and in aortic constriction attended with dilated hypertrophy of the left ventricle. A slight thrill is sometimes observed in anæmia.

Pericardial Friction-fremitus. — The movements of roughened pericardial surfaces sometimes cause a friction-fremitus which can be distinctly felt by the hand. This is distinguished from fremissement by its rubbing rather than thrilling character. It may be distinguished from pleural fremitus by directing the patient to hold his breath.

* Diseases of the Heart. Corvisart. Hibb's translation, 1813.

MENSURATION.

By mensuration we can determine the mobility of the chest wall in respiration, and we can compare the amount of expansion on the two sides. We can, too, by this means estimate the comparative bulk of the two sides, and easily detect inequalities in them.

The chest is usually measured by the graduated tape. Mensuration may be performed by fixing with the fingers the end of the tape on the sternum, in the middle line, and passing the tape evenly and horizontally round the chest to the same point. We may thus measure the circumference of the chest, and by noting the part of the tape which crosses the dorsal spine estimate the relative size of its sides. Dr. Hare's double tape is very convenient. This consists of two ordinary measuring tapes joined together, so that the commencement of each scale is the centre of the double tape. The line of union of the tapes is firmly held on the spine, while the tapes are carried round the sides of the chest to the middle line in front. In this way the circumferences of the sides can be observed simultaneously. By making an observation at the end of expiration, and also at the end of inspiration, the entire play of the chest walls can be measured, and the expansion of each side can at the same time be determined.

Circular measurements may be made at any point, but the tape is usually carried round the chest on a level with the nipples, or lower down, opposite the ensiform cartilage. It must be remembered that the right side of the chest is very often half an inch or so larger than the left ; perhaps the two sides of the chest are of unequal semi-circumference in about two-thirds of healthy adults. The average circular width of the chest varies greatly. In spare men, of medium height, says Dr. Hooper, it ought not to fall much below thirty-five inches. The difference between the circumferences of the chest at the end of extreme expiration, and at the end of extreme inspiration, shows the *respiratory mobility.* This usually amounts, in health, to about two and a half inches, or a little more.

Both lungs expand nearly equally, the right, however, sometimes a little more than the left. Each semi-circumference generally shows an expansion to the extent of three quarters of an inch to an inch and a half.

Practically, we usually use mensuration in the examination of cases of pleuritic effusion. The extent of the dilatation of the affected side, the diminution or loss of respiratory mobility on the same side, and the increased expansion on the healthy side, may be measured. The extent of contraction of the chest, following the absorption of pleuritic effusion, may be determined by mensuration. The chief diseases which lead to enlargement of the affected side of the chest are pleurisy with effusion, pneumothorax, hydrothorax, empyema, and emphysema; while pleurisy, when retraction has taken place, and pulmonary tuberculosis are the chief diseases which lead to diminution in the size of the affected side. In all these diseases mensuration shews diminished inspiratory expansion on the affected side, and it often detects increased expansion on the healthy side. In disorders, such as pleurodynia, in which the movements of the chest wall cause pain, diminished inspiratory expansion may be measured. In general vesicular emphysema, the increased bulk of the chest may be determined by measurements at various points. In this disease, too, there is lessened expansion, and frequently, in some regions at least, even retraction, during inspiration.

Various partial measurements may be usefully made; from the nipples to the sternal middle line, from the clavicle to the nipple, &c.

Mensuration may be used as an aid to the diagnosis of diseases of the heart. When pericardial effusion exists, or when hypertrophy of the heart is present, the distance between the left nipple and the sternal middle line is sometimes greater than on the right side, especially in young persons.

A pair of steel callipers may be used in transverse measurements of the chest. Dr. Sibson has invented a " chest-measurer," which is especially of use in determining the amount of the respiratory antero-posterior movement of the chest. Dr. Quain has devised an admirable "stethometer," consisting of a silk cord, which may be passed round the chest, and an index, acted upon by the cord, whose movements are recorded on a graduated dial. Dr. Scott Alison has invented a "stetho-goniometer" for measuring the various angles of the chest.

In diseases of the chest mensuration is of the greatest value in confirming the results arrived at by inspection and palpation. I have been compelled to treat the subject very briefly, but I trust enough has been written to indicate to the student the importance of this means of diagnosis.

SUCCUSSION.

Succussion, one of the oldest modes of examining the chest, was used by Hippocrates in the detection of fluids in the pleural cavity. In this mode of examination the chest is shaken while the ear is applied to the surface. In order to practice succussion, the observer may swing the patient's body to and fro, and then suddenly arrest the motion. The succussion sound is a splashing noise, and it is only produced when air and fluid existing in a cavity are violently set in motion and abruptly brought into collision. It is heard in cases of pneumo-hydrothorax, where air and fluid exist together in the pleural cavity, with or without a communication with a bronchial tube. This succussion-sound may be audible over a large tubercular cavity, which contains both air and fluid. It may be heard after tapping has been performed in empyema, when air, as well as pus, exists in the pleural sac. It must be remembered that a similar sound is produced in the stomach on shaking the body, when that viscus contains a mixture of air and fluid.

SPIROMETRY.

By instruments called spirometers the quantity of the expired air may be measured, and the capacity of the lungs ascertained. Some years ago Dr. Hutchinson devised a spirometer, and he afterwards published, in the Medico-Chirurgical Transactions, the results of his laborious researches.

The quantity of air which is expelled by an ordinary expiration, following an ordinary inspiration, is called the *breathing air*. The quantity of air which can be expelled by extreme expiration, after ordinary expiration, is called *reserve air*. The volume of air which can be taken into the chest after an ordinary inspiration is called the *complemental air*. The *residual air* is that which remains in the lungs after the most extreme expiration, and this cannot be expelled by any voluntary effort. The amount of air which a person can expel by the deepest expiration, following the deepest inspiration, indicates his *vital capacity*.

In health, the vital capacity has been shown to vary according to the weight, height, and age of the individual. Dr. Hutchinson proved that the vital capacity bears a close and direct relationship to height. 230 cubic inches is the average vital capacity of a healthy man, five feet eight inches in height.

The spirometer is not generally used in the investigation of disease, for we have other more easily applied and more trustworthy means of diagnosis. Great variations in vital capacity are compatible with health, and it is often very difficult to induce patients to breathe in such a manner as to render the results of spirometry reliable. This method of examination has been more especially employed in the diagnosis of early pulmonary tuberculosis, in which condition the vital capacity is markedly diminished. In men, five feet eight inches in height, it has been found that the average vital capacity in phthisis is, in the first stage, 159 cubic inches; in the second stage, 136 cubic inches; and in the third stage, 112 cubic inches.

Spirometry is sometimes used in the examination of candidates for life assurances, and sometimes it is employed to test the vital capacity of recruits. The spirometer may be found useful in assuring patients who are apprehensive of of phthisis, but whose lungs are sound, that their vital capacity is unimpaired.

Dr. Hutchinson's spirometer is a bulky instrument, like a small gasometer. Mr. Coxeter's spirometer, consisting of two air-tight bags, has the advantage of portability. Dr. Bain described at the meeting of the British Medical Association, at Leeds, 1869, a portable spirometer, formed somewhat like a small pair of bellows, and having a graduated scale at the side. He says he has used this instrument with very satisfactory results.

Dr. Lyons' method of ascertaining the capacity of the lungs may be sometimes useful. The patient is directed to make a full inspiration, and then proceed to count aloud until the chest is quite empty. Healthy persons can count in this way for a period of half a minute or more, while in phthisis, pneumonia, and pleurisy, the time is reduced to six or eight seconds.*

* The following references may be useful to those who desire to pursue the subject further than the limits of this book will allow :—

Dr. Hutchinson's paper. Med. Chir. Trans. Vol. xxix. 1846.
Diseases of the Lungs. Dr. Walshe.
Manual of Clinical Medicine. Drs. Tanner and Fox.
Hooper's Physician's Vade Mecum. Drs. Guy and Harley.
Kirke's Handbook of Physiology.
Diseases of the Lungs and Heart. Dr. Herbert Davies.
On a Portable Spirometer. Dr. W. P. Bain. *Brit. Med. Journ.*, Feb. 5, 1870.

CHAPTER IV.

PERCUSSION.

AUSCULTATION means the act of listening—the application of the sense of hearing to the investigation of disease. The term, in its widest sense, comprehends all that we learn by listening to the sounds which we produce by striking the surface of the body, and all that we learn by listening to the sounds which are produced within the body itself. But it is usual to call the first mode of examination *percussion*, limiting the term auscultation to the act of listening to internal sounds.

Percussion is the act of striking the surface of the body, and listening to the sounds which are thus produced. Percussion is said to be *immediate* or *direct* when the striking body falls directly on the surface of the part to be examined; and percussion is said to be *mediate* when some solid body is placed upon the part to be explored, interposing between the surface and the striking body, and receiving the stroke of the latter.

Avenbrugger, more than a hundred years ago, discovered percussion. After some years of work, *inter labores et tædia*, he published the valuable results of his researches.* For some years this great discovery attracted but little notice, until Corvisart introduced percussion into France, and made known its merits as a means of diagnosis in his celebrated treatise on diseases of the heart. Avenbrugger's method was immediate percussion, striking the chest with the ends of the fingers. Mediate percussion was invented by Piorry.† Piorry's plan, or some modification of it, is now generally adopted, and the immediate method has fallen into almost complete disuse.

By percussion, in the examination of the chest, we ascertain the density of the subjacent structures, and we learn the position and size of organs. When we have become acquainted with the sounds

* Inventum Novum, ex Percussione Thoracis Humani, ut Signo, Abstrusos Interni Pectoris Morbos Detegendi. Avenbrugger. Vienna. 1761.

† De la Percussion Mediate. Piorry. Paris. 1828.

which are yielded in the various regions in health, we can detect the changes in these sounds which are produced by alterations in the position, size, and density of the subjacent organs, and by the presence of solids, fluid, or air.

In percussion, it is necessary to notice the character of the sound produced, and the degree of resistance afforded by the part percussed. The sounds which are yielded by the chest in health and disease have been variously divided and described by authors, and the differences in the terms employed is perhaps mainly due to the difficulty which is always experienced in naming sensations. Thoracic percussion sounds are often, perhaps generally, said to be either clear or dull. The sonorous vibrations are modified according to the density and elasticity of the structures in which they are produced. M. Piorry, considering that the percussion sounds differ intrinsically according to the texture of the different viscera, describes nine primary sounds, viz., *femoral*, *jecoral*, *cardial*, *pulmonal*, *intestinal*, *stomachal*, *osteal*, *humoral*, and *hydatique*. The terms *full* and *empty*, *clear* and *dull*, are used by Professor Skoda, who also describes various modifications and combinations of these conditions. Professor Hughes Bennett writes :—" I consider that all these sounds may be reduced to three elementary ones, that, in point of fact, there are only three tones occasioned by percussion, and that all the others are intermediate. These three tones are respectively dependent, first, on the organ containing air ; second, on its containing fluid ; and third, on its being formed of a dense uniform parenchymatous tissue throughout. These tones, therefore, may be termed the *tympanitic*, the *humoral*, and the *parenchymatous*. Percussion over the stomach gives the best example of the first kind of sound ; over the distended bladder, of the second ; and over the liver, of the third."*

The spongy lungs are contained in a cavity bounded by thin, firm, and elastic

* An introduction to Clinical Medicine. J. Hughes Bennett, M.D., Edinburgh, 1862.

walls. When a portion of the surface of the chest, covering healthy lung, is struck, a clear, distinct, and *resonant* sound is produced. The proper tissue of the lung itself affords only very weak vibrations; it may, in fact, be said to be non-sonorous. The pulmonary resonance of the healthy chest is due to the vibrations of the air contained in the lungs, together with the vibrations of the thoracic parietes. The contained air and the chest walls resonate together, while the parenchyma of the lung muffles and damps the sound. On the other hand, when percussion is practised over the part of the heart which is uncovered by lung, a dull, short, *toneless* sound is produced, due to the slight amount of elasticity possessed by the organ and its contents.

The acoustic properties of thoracic percussion-sounds, which are found to be of clinical importance, are, according to Dr. Walshe, *amount* (or intensity) *of resonance*, *pitch*, *quality*, and *duration.*

1. *Amount of Resonance.*—The intensity of the sound depends, to a great

extent at least, upon the force used in percussion, this force necessarily determining the violence with which the particles of the sounding body are thrown into vibration. The amount of the resonance depends, too, upon the volume of air set in motion, and also upon the elasticity of the thoracic parietes.

2. *Pitch.*—The pitch of a sound depends upon the number of vibrations which take place in a given time. The greater the number of vibrations the higher the pitch of the resulting sound. "As a single property of percussion-sound," writes Dr. Walshe, "pitch seems to me the most reliable guide." The percussion-sound is higher in pitch over the heart than over the lungs. A dull note is higher than a resonant one. Considerable practice is required to distinguish delicate differences in pitch, and this most important discrimination comes more easily to some students than to others. The student must become thoroughly acquainted with the pitch of the normal lung percussion-sound. This

is lowered when the lungs contain an increased quantity of air, as in emphysema, and it is heightened when the quantity of air is diminished, as in tubercular consolidation.

3. *Quality or Timbre.*—The quality of the sound produced by percussion over the healthy lung can only be learned and appreciated by frequent observation. It is described by Laennec as a "clear and distinct" sound, and by Sir Thomas Watson as a "resonant or hollow" sound. The quality of the percussion-sound of the heart differs very markedly from that of the lungs. Differences in quality are due to differences in the vibrating structures.*

* "*Timbre.*—This means the difference between sounds, otherwise the same, proceeding from different materials, instruments, or voices. We recognise a qualitative difference between the flute and the violin, or between the trumpet and the clarionet. We can distinguish between one violin and another, and between different voices sounding the same notes with the same intensity. These differences are now explained by the presence of auxiliary upper tones in all instruments, which tones vary with the material and the instrument. It is supposed that perfectly pure tones, identical as regards pitch and intensity, would be undistinguishable, whatever might be their source." The Senses and the Intellect. Alexander Bain, M.A. London. 1868.

4. *Duration.*—While the pitch of a sound depends upon the number of vibrations which occur in a given time, the duration of a sound depends upon the number of times the vibrations are repeated. The percussion-sound is longer in duration over the lung than over the heart. When the lung contains an increased quantity of air, the duration of the sound is longer than when the quantity of air is diminished.

Now that the chief characters of sounds, so far as they concern the clinical aspect of percussion, have been described, it will be easily understood how and in what respects a dull percussion-sound differs from a resonant one. *A dull sound is less in intensity, shorter in duration, higher in pitch, and harder in quality than a resonant one.*

The Different Modes of Percussion.—Percussion may be either *mediate* or *immediate.*

In immediate percussion the striking body falls directly upon the part percussed. This method was the only one employed until a few years ago, but it has now fallen into almost complete disuse. Laennec, in his treatise on diseases of the chest, describes in the following words the mode of performing immediate percussion :— " Percussion ought to be made with the four fingers united in one line, the thumb being placed in opposition to them, at the junction of the second and third phalanges of the index, and used merely in maintaining the fingers in close and strong opposition. We must strike with the *ends* and not the face or pulpy portion of the fingers; not obliquely, but perpendicularly, and gently and quickly,—that is, raising the hand immediately from the skin." When a marked difference exists between the percussion-sounds of the two sides of the chest, as when a large portion of one lung is consolidated, or when there is a considerable quantity of fluid in one pleural cavity, immediate percussion renders the change very obvious. The clavicle and the spine of the scapula may be advantageously struck in the immediate fashion. Changes in the density of the apices of the lungs may be readily demonstrated by striking the clavicles with the knuckle of the bent index finger, the joint between the first and second phalanges. But this is really mediate percussion, the bones themselves becoming pleximeters. When immediate percussion is employed, the muscles covering the part examined should be put moderately on the stretch.

In mediate percussion some solid material is placed upon the part to be examined. The substance which is interposed between the part struck and the striking body is called the *pleximeter*. Piorry's pleximeter is a thin circular plate of ivory, about one inch and a half in diameter, and provided with a rim, so that it may be conveniently and steadily held in apposition with the surface. Various modifications of Piorry's instrument have been used—discs of wood, ivory, metal, leather, cork, and india-rubber. Dr. Fleming uses an oval plate of ivory, one inch and a half in length, one inch in breadth, and one-sixteenth of an inch in thickness, provided at each end with a little projecting lip or handle. A variety of hammers, called *plessors*, have been used for giving the stroke. Dr. Hughes Bennett uses the ivory pleximeter of M. Piorry, as modified by M. Malliot. This is two inches in length. Dr. Bennett employs the hammer devised by Dr. Winterich, and he says that he can produce with it a tone of great clearness and penetrative-ness, that it is especially applicable for clinical instruction, and that it enables those to percuss who are deficient in the dexterity required for the employment of other methods. The pleximeter can be very accurately applied to the chest in almost any situation; by its aid percussion can be more easily practised through the clothes than by other methods, and it is especially useful in the examination of yielding parts, such as the abdomen. The rim of the larger end of a stethoscope encircled by a ring of india-rubber is sometimes used as a plessor; or a thimble with its end covered with some elastic material may be employed. Dr. Sibson has devised a spring pleximeter, by means of which successive strokes of exactly equal force may be produced.

The middle finger of the left hand forms the best pleximeter, and it is generally used in preference to any other. The index finger is also frequently employed, and sometimes all the fingers are called into use. On this subject Dr. Walshe writes :—" The index or middle finger, on account of their always being within reach, on account of the accuracy with which they may be fitted, as it were, to the various depressions on the surface, and on account of the absence of parade in their employment, will no doubt always continue the pleximeters in most common use." Whether the finger or the ivory plate be used it must be applied evenly and firmly to the surface, and in comparing the resonance of different points, great care must be taken that the pleximeter is applied in each instance with an equal degree of force. In making comparisons of the results of percussion this is quite as important as the force of the stroke. It is best to apply the palmar surface of the finger to the chest, and the blow must be received on the centre of the middle phalanx. A few physicians, however, apply the dorsal aspect of the index finger to the part to be examined, and this mode possesses, perhaps, a little advantage when the supra-clavicular regions are explored. But the soft structures on the palmar surface materially deaden the sound, and it is difficult to regulate the force with which the dorsal aspect of the finger is applied to the chest. When the lateral and posterior surfaces of the thorax are examined, the fingers may often be placed parallel to the ribs, but it is usual in percussing the anterior surface, and especially its upper part, to place the finger at varying angles with the ribs.

The fingers of the right hand form the best plessors. The middle finger may be used alone, or the index and middle finger may be employed together, care being taken that their tips are exactly on the same level. It is best not to support them with the thumb. The direction of the stroke must be perpendicular to the pleximeter, and the blow must be made with the ends of the fingers, and not with their soft palmar surfaces. The nails of the percussing fingers must be kept short. Considerable practice is required to percuss properly. The movement must spring from the wrist only, and not from the elbow or shoulder. If this be not carefully attended to, no results of any value will be attained by percussion. The blow must be given with moderate force, sharply and lightly, and the striking finger or fingers must be withdrawn the moment the blow is given. But it is often necessary to vary the force of the stroke. Considerable force must be used to bring out deep-seated dulness, while a gentle force is required to elicit superficial resonance, and *vice versâ*. It is usual to rapidly repeat the blows three or four times over each part as we examine it. When we compare the two sides, it is necessary to percuss first on one side of the chest, and then on the corresponding point on the other side. All the parts of one side must not be examined before passing to the other.

We must strike on the two sides with equal force, with the finger or pleximeter applied with equal firmness to the surface, and at equal angles to the ribs; and when delicate percussion is required, we must select the same period of the respiratory movements.

Position of the Patient.—Whenever it is possible, the patient should be examined in the erect or sitting posture; perhaps the latter is the best. It is very important that the patient's position should be one that is convenient to the examiner. When the front of the chest is examined, the patient's arms must hang loosely by his sides, and the head must be a little thrown back. When the lateral portions of the chest are examined, the hands may be clasped over the head. When we wish to percuss the back, the patient should lean forwards, fold his arms tightly across his chest, and bend down his head. The anterior portion of the chest may be very effectually percussed while the patient is lying on his back in bed; the heart is examined with most advantage in this position. When mediate percussion is employed, the superficial muscles should not be put on the stretch ; when, however, the immediate method is adopted, the part examined should be as firm and as tense as possible.

"When we obtain from percussion only a slight difference of sound on the two sides, leaving the result doubtful, it is advisable to repeat the operation in changing our position to the other side of the patient. In this manner we frequently obtain a result entirely different, the side most sonorous in the former trial yielding now a note inferior to the other. This precaution is never to be omitted in doubtful cases ; for I repeat it, percussion yields exact results in the hands only of those who bring to its exercise experience, dexterity, and much attention."*

Percussion of the Chest in Health.—When a part of the chest wall is percussed, below which there lies a considerable portion of the lung, a hollow

* Laennec. Diseases of the Chest. Dr. Forbes' Translation.

resonant sound is produced, which has been called the pulmonary percussion note. This varies considerably in different situations. The resonance on percussion varies, too, in the same regions in different individuals. When the walls of the chest are thickly covered with muscle or fat, the sound is less resonant than when the parietes are thin. The note is less clear over the pectoral muscles than in the lateral regions. The sound is more resonant during and after inspiration than during and after expiration, it is more resonant in youth than in old age, and, as a rule, in females than in males.

The sound produced in the infra-clavicular regions is clear, and markedly pulmonary in quality. As we descend, on the right side, the sound becomes less clear on strong percussion opposite the fourth interspace. Below this point, the layer of lung in front of the liver is thin, gentle percussion yielding pulmonary resonance, and forcible percussion bringing out the dulness of the liver. A good pulmonary note is generally yielded as low as the sixth rib. Below this point, and as far as the lower margin of the chest, a dull sound is given by the subjacent liver. On the left side, a dull note is given over the præcordial region. Where a thin layer of lung overlaps the heart, firm percussion brings out a more or less dull sound, while the actual limits of the lungs can oniy be determined by light percussion. In the right infra-mammary region, the liver causes a dull sound ; on the left side, a similar note is yielded over the left lobe of the liver, and also over the spleen. Intervening between the two organs on the left side, a tympanitic or a dull sound is found, according as the stomach contains gas or food. The sound given at the sternal end of the clavicle is very clear and somewhat tubular ; at the middle of the bone the note is clear, while towards the acromial end it becomes quite dull. In the supra-sternal region, the trachea gives a decidedly tubular character to the sound. In the upper part of the upper sternal region, the note is still somewhat tubular. Below the point of convergence of the lungs, a true pulmonary sound may be obtained. The left half of the lower sternal region is dull, from the presence of the heart, uncovered by lung. Lower down, the dulness of the liver may be detected, and here, too, a tympanitic sound is often furnished by the stomach.

In the right lateral region, a good resonant note is given from the axilla to the seventh intercostal space; the hepatic dulness commences at the latter point, extending downwards to the lower margin of the thorax. In the left lateral region, too, a clear pulmonary note is yielded, about as far downwards as the seventh interspace; below this point, the stomach gives a tympanitic sound, and the splenic dulness may usually be detected opposite the tenth rib.

The muscular tissue which exists in the upper and lower scapular regions, serves to render the percussion note in these localities somewhat dull and muffled; nevertheless, a sound of fairly pulmonary quality, especially in thin persons and in women, may be usually elicited in these portions of the posterior aspect of the chest. A full and clear sound may be generally obtained in the interscapular regions. At the ninth intercostal space, on the right side, the hepatic dulness commences. On the left side, the lower portion of the infra-scapular region may be rendered unduly resonant, or almost tympanitic, by the presence of the stomach.

The præcordial region, corresponding to the portion of the heart uncovered by lung, can be pretty accurately mapped out by gentle percussion; the most absolute dulness is obtained opposite the middle of the cartilage of the fifth left rib. Wherever the heart is covered by lung, a gentle stroke reveals the pulmonary resonance. Strong percussion is required in order to define the outline of the heart itself, the limits of the deep cardiac region; a firm stroke being necessary to elicit the deep seated cardiac dulness. When we pass from the centre of the præcordial region, upwards and to either side, we find the cardiac dulness gradually merging into pulmonary resonance. Below, it is often very difficult to say where the heart's dulness ends, and that of the liver commences; the tympanitic resonance of the stomach frequently bounds the cardiac dulness inferiorly. The effect of the inspiratory expansion of the lungs, in diminishing the area of the præcordial space, must not be forgotten.

The great vessels at the base of the heart do not modify, in health, the pulmonary resonance of the region in which they are situated.

The inspiratory expansion of the lungs, which has been elsewhere alluded to, serves to extend the area of the pulmonary percussion-sound in every direction. This is especially marked on the right side of the chest, where the respiratory play of the lower margin of the lung over the convex surface of the liver may be readily observed. "The acts of inspiration and expiration, writes Dr. Walshe, modify the results of pulmonary percussion in three different manners: *a.* by altering the volume of the lungs; *b.* by altering their density; *c.* by altering the position of the heart and abdominal viscera." In comparing the two sides of the chest by percussion, whenever delicate accuracy is required, we must, therefore, be careful to make our observations at the same stage of the act of respiration. This is perhaps best attained by percussing while the patient holds his breath after an inspiration.

PERCUSSION OF THE CHEST IN DISEASE.

Diseases of the Lungs and Pleuræ.—Changes in the density of the lungs, and accumulations in the pleural cavities, whether these be of a solid, fluid, or gaseous nature, are detected by percussion. The four characteristics of the percussion-note, which have been before described, may be variously altered in disease. But we have practically to decide whether the note possesses its normal resonance or not; for it may be toneless and dull, or the resonance may be simply impaired, or it may be abnormally increased. Whenever a dull note is elicited on percussing a part, which in health yields the normal pulmonary percussion-sound, we know that the quantity of air in the part examined is diminished in amount, or absent altogether. This may arise from a change in the lung itself, or it may be due to a fluid accumulation in the cavity of the pleura. When the percussion-note possesses an exaggerated resonance, we know that the quantity of air in the part examined is increased.

The chief indications given by percussion in diseases of the thorax, excluding diseases of the heart and great vessels, which will be afterwards separately considered, may be tabulated as follows :—

DULL SOUND, OR DIMINISHED RESONANCE ON PERCUSSION.

CHANGES IN THE LUNGS.	CHANGES EXTERNAL TO THE LUNGS.
PNEUMONIC engorgement and hepatization. Abscess. Gangrene. Passive Congestion. Pulmonary extravasation. Œdema. Cirrhosis. Collapse. Syphilitic deposit. Cancer. Phthisis. Dilatations of the bronchi, when fluid accumulates within the tubes.	PLEURITIC effusion. Empyema. Hydrothorax. Hæmothorax. Pleuritic thickenings and adhesions. Cancer. Hydro-pneumothorax, at the lower part of the chest. Diseases of the Mediastinum; abscess, cancer, non-malignant tumours.

EXTRA-RESONANCE ON PERCUSSION.

CHANGES IN THE LUNGS.	CHANGES EXTERNAL TO THE LUNGS.
EMPHYSEMA. Tubercular excavation. Extreme anæmia. (Stokes.)	PNEUMOTHORAX. Hydro-pneumothorax, at the upper part of the chest.

Tympanitic Sound.—This sound, an exaggeration of the normal pulmonary percussion-note, resembling the tone of a drum, is never met with in health, It is usually observed in pneumothorax. But when the pleural cavity is extremely distended with air, the tympanitic character of the sound becomes impaired, or lost altogether. " Experiment, writes Dr. Herbert Davies, would seem to lead to the conclusion, that the sound cannot be elicited in perfection from spaces bounded by very tense membranous walls, for if we inflate a bladder, or stomach, we find that the true tympanitic tone is best obtained when a slight degree of flaccidity is allowed to the parietes." Although the most perfect tympanitic sound is met with in pneumothorax, this phenomenon may also exist, in a less marked degree, under other conditions. It may be sometimes elicited in emphysema, and the percussion-sound occasionally becomes more or less tympanitic over the portions of the lung which surround pneumonic consolidation. When pleuritic effusion exists in the lower part of the chest, a somewhat tympanitic note is occasionally yielded over the apex; and, as Skoda has taught, a similar note is given when the lung is gradually recovering itself, after it has been compressed by pleuritic effusion.

Amphoric Sound.—This sound gives the idea of hollowness. It may be heard in pneumothorax, and when a large cavity exists in the lung, lying near the surface, and having firm but thin walls.

Tubular Sound.—This sound, given over the healthy trachea, is decidedly hollow in quality. In disease, it may be produced when the bronchi are simply dilated, over small cavities, where a solid substance intervenes between a large bronchus and the surface, and, over the upper part of the lung, in some cases of pleuritic effusion occupying the lower part of the chest.

Bruit de pot fêlé.—A sound, obtained by percussion in certain diseased conditions, was compared by Laennec to the noise produced on striking a cracked pipkin, and it was called by that great observer the *bruit de pot fêlé.* This is also sometimes called the cracked-metal or cracked-pot sound. It may be closely imitated by folding the hands loosely together, and striking the back of one of them against the knee. This sound is produced when percussion is performed over a superficial cavity in the lung, of large size, communicating freely with the external air, and having thin, firm, and elastic walls. The theory of its production has been variously explained; the presence of fluid in the cavity does not seem an indispensable condition. When we seek to elicit this sound, we should direct the patient to keep his mouth open while we percuss, for if it be closed the production of the phenomenon is generally prevented. The blow must be sharply given, and the fingers must be allowed to rest for an instant on the pleximeter. We must not infer that a cavity does not exist because we cannot develop a cracked-pot sound; fortunately this somewhat fallacious sign is not the only one on which the diagnosis of a cavity depends. I have often heard this sound involuntarily produced by percussion in unskilled hands. Dr. Stokes pointed out that a sound, closely resembling the cracked-pot, is sometimes elicited in bronchitis, especially in children. This anyone who diligently employs percussion may frequently observe for himself.

The sense of resistance produced by percussion.—While a careful appreciation of all the characters of the sound yielded on percussion demands our most earnest attention, the sense of resistance which we feel, when we strike the part we examine, is not less important. The resistance of a body depends upon its elasticity; the greater the elasticity the less the resistance. Laennec writes:—"The sensation of elasticity perceived by the operator frequently confirms his judgment in cases where the difference of sound is only doubtful." The air is the most elastic content of the healthy chest; wherever the air is diminished, the sense of resistance is increased, and wherever the air is increased, the sense of resistance is diminished. The sense of resistance, therefore, is increased when the lung is consolidated from any cause whatever, and when fluid or solid accumulations exist in the cavity of the pleura. It is diminished in emphysema, and in pneumothorax; in the latter disease, however, the accumulation of air may be so great, that the walls of the chest are rendered very tense, and the sense of resistance consequently increased.

Locality and extent of changes perceived by percussion.—By observing the part of the chest in which a change in the percussion-note occurs, and by noticing, too, the extent of the alteration, we may very often infer the existence of a certain morbid change. Tubercular excavations, and early tubercular consolidations, usually occupy the apices of the lungs. Pneumothorax is almost invariably confined to one side; emphysema is frequently general. Hepatization, congestion, and œdema, usually occur at the bases, while the last is generally found in both sides. Only one cause of dulness is movable, fluid in the pleural cavity. The upper level of the dull space may be found to vary with the position of the patient; this, however, is far from being the rule.

DISEASES OF THE HEART, PERICARDIUM, AND GREAT VESSELS.—When we percuss the præcordial region in disease, we may find the area of cardiac dulness diminished, or we may find it increased.

Diminution of the præcordial dulness is generally due to emphysema of the lungs, it may, however, arise from atrophy of the heart, or from pneumo-pericardium.

In emphysema of the lungs, particularly when the anterior margin of the left lung is affected, the area of præcordial dulness is very commonly diminished. The heart becomes more or less completely covered by the dilated lungs, and a resonant note is substituted for the cardiac dulness, while the sense of resistance is at the same time decreased. In these cases the heart is somewhat displaced, being pushed downwards and towards the middle line. Dilatation and hypertrophy of the right side of the heart usually sooner or later accompany pulmonary emphysema, and this increase in the bulk of the heart is masked by the emphysematous lung intervening between the enlarged organ and the chest wall.

The heart becomes atrophied — diminished in size—in chronic disorders in which there is great emaciation, especially in tubercular and cancerous diseases. This change is frequently overlooked; but, although its detection is always difficult, it is sometimes indicated by a diminution in the area of præcordial dulness.

When air or gas collects within the pericardial sac the cardiac dulness is diminished or altogether lost. Pneumatosis pericardii is very rare indeed; it may, however, occur under certain conditions, but, as Dr. Flint well says, these cases belong among the curiosities of clinical experience.

The area of præcordial dulness is far more frequently increased. This may be due to enlargement of the heart itself, to fluid or solid accumulations in the the pericardium, and to changes in the parts which are adjacent to or connected with the heart.

The heart may be simply hypertrophied, it may be simply dilated, or hypertrophy and dilatation may exist together. One or both sides may be increased in size, and the increase of dulness takes place accordingly; when the enlargement is limited to one compartment or to one side, the dulness is extended in the direction of the affected part. When the heart is hypertrophied, although the area of dulness is augmented, it retains more or less perfectly its normal triangular form. The enlarged organ tends to sink in the chest, and the increase in the area of the dulness is found below the level of the third ribs. The area of dulness is widened in dilatation, and the shape of the heart is more square than in health. The resistance on percussion is perhaps not so marked in dilatation as in hypertrophy.

When, as often occurs as the result of pericarditis, fluid is poured out into the pericardial sac, dulness is found over an increased area. The distended sac is somewhat pyramidal in form; the base is a little below the level of the normal apex beat. The dulness extends considerably on either side; reaching beyond the nipple line on the left, and beyond the sternum on the right. The rounded apex of the pyramid often extends upwards to the second left cartilage, it may reach to the sternal notch, and it has been observed to attain the level of the clavicle, or even pass beyond it.

Cancerous growths in the pericardium may increase the præcordial dulness. Tubercular or pneumonic consolidations of the lung tissue lying adjacent to the heart or great vessels may lead to an increase in the extent of cardiac dulness.

When an aneurism of the thoracic aorta exists, dulness on percussion may be frequently elicited at the site of the disease. It is only when the aneurism is considerable that percussion yields any decisive evidence; but this mainly depends on the site of the lesion. An aneurism of the ascending portion of the aorta is very likely to be masked by the resonance of overlying lung. This is less likely to occur when the arch is affected. Aneurism of the descending aorta may give rise to dulness on the left side of the spine, and sometimes, too, on the right side also. In aneurism of the innominate artery, percussion, especially by comparing the two sides of the chest, may yield valuable results.

Abscess in the anterior mediastinum often leads to dulness on percussion. Tumours in this region may also modify the percussion-note.

Percussion helps us to determine displacements of the heart.

Auscultatory Percussion.—Drs. Cammann and Clark, American physicians, described auscultatory percussion in the New York Journal of Medicine. The following account of it is extracted from Dr. Aitken's Science and Practice of Medicine. "Another means of estimating the size of the heart is by *auscultatory percussion.* This requires two competent persons to determine the result, and is managed as follows :—" A solid cedar cylinder, six inches in length and one in diameter, cut in the direction of the fibres, and with an ear-piece attached, is applied to the centre of the præcordial region, while the ear is applied to the other end: percussion is then made by another person from the point near where the cylinder is applied towards the limits of the heart in every direction. So long as percussion is made over the body of the heart, a distinct sharp shock is felt directly in the ear ; but as soon as the limits of the heart are passed, this sharp shock immediately ceases, even in passing from one solid organ to another in contact with it, as from the heart to the liver." (Drs. Cammann and Clark.) Practice will enable a discrimination to be made between the characteristic sound of the heart and the diffused shock produced by striking the ribs." With a little care, this process may be managed by one person alone.

Mapping out organs by percussion.—The surface limits of percussion areas may be usefully marked out on the skin. This is excellent practice for the student. The parts may be marked out in ink, or, when we wish to render the lines more permanent, a stick of nitrate of silver may be lightly carried over the wet ink line. We may conveniently record the results of percussion by shading outline figures of the trunk.*

* These little outline figures, made according to Dr. Hughes Bennett's directions, may be obtained from Mr. Thin, Infirmary Street, Edinburgh. Similar figures, arranged by Dr. Aitken, are published by Messrs. Chas. Griffin & Co., of London

CHAPTER V.

AUSCULTATION.

Auscultation, the act of listening, is a means of physical diagnosis by which we appreciate various sounds which are produced in the interior of the body, and which are audible on its external surface.

Auscultation is said to be either *immediate* or *mediate*. In the immediate method, the ear of the observer is applied directly to part to be explored; in mediate auscultation, an instrument, the stethoscope, is interposed between the ear and the surface examined. Auscultation may be employed in the examination of various regions of the body; it finds, however, its widest and most useful application in diseases of the chest, in the examination of the sounds arising out of the exercise of the functions of respiration and circulation.

Immediate Auscultation.—When the immediate method is employed, the ear must be firmly and evenly applied to the surface of the chest, which may be either quite bare or covered with some thin article of clothing. The listener should be careful not to allow any of his hair to lie over his ear, and any covering that may be on the chest should be smoothly and tightly drawn over the surface. Immediate auscultation is not often adopted in the present day; it is, however, very serviceable under certain conditions. It may be employed when the surface to be examined is tolerably even and easily accessible, and when the disease is well-marked and of considerable extent. Immediate auscultation is generally to be preferred when we examine the chests of children, since the pressure of the stethoscope often annoys the little patient. In examining children, it is best to auscultate the chest before employing percussion. We must not percuss first and listen afterwards, as we often do in the adult; for even when practised with the greatest gentleness, percussion sometimes frets the child, and makes it cry, whereby any subsequent attempt to listen to the breathing will often be rendered unsuccessful.*

Mediate Auscultation.—The stethoscope is merely a conductor of sound, conducting the sonorous vibrations to the ear of the observer. By means of mediate auscultation we are enabled to circumscribe and closely localize the sounds we hear ; such accurate observation of the situation in which a morbid sound is heard is of the greatest importance in the diagnosis of many diseases, and it is especially necessary in the auscultation of the heart. When immediate auscultation is employed, all the parts of the observer's head which bear upon the chest, namely, the cheek-bone, the temples and the angle of the jaw, become, severally, conductors of sound, and may thus convey the sound of respiration to the ear, although none exists immediately beneath it.† The stethoscope can be easily used in many situations where important sounds are frequently audible, but where the ear

* Diseases of Infancy and Childhood.—Dr. West.

† Diseases of the Chest.—Laennec.

cannot be efficiently applied to the surface; as over the larynx and trachea, in the axilla, between the scapulæ, and above and below the clavicle. It is not pleasant to apply the naked ear to the chests of dirty patients, or when the surface is bathed in perspiration, and it may be thought somewhat indelicate to employ immediate auscultation in the examination of females.

Laennec's first stethoscope was a quire of paper rolled into a kind of cylinder, one end of which he applied to the chest and the other to his ear. After many experiments with various substances, the discoverer of mediate auscultation employed a wooden cylinder, "an inch and a half in diameter and a foot long, perforated longitudinally by a bore three lines wide, and hollowed out into a funnel-shape, to the depth of an inch and a half at one of its extremities." This stethoscope could be converted into a simple tube, with thick sides, by fitting a stopper or plug, traversed by a small aperture, into its excavated extremity. Stethoscopes made of glass, gutta-percha, india-rubber, metal, ivory, pasteboard, gold-beater's skin, &c., have been used, but wooden instruments are generally employed. Theoretically, solid stethoscopes are the best conductors of sound; hollow ones, however, are almost universally preferred. The stethoscope should be made of one piece of wood; light and porous woods, such as cedar and deal, are perhaps the best materials. The instrument should be of such a length that it can be easily carried in the crown of the hat. The chest-end should be small, about an inch in diameter; it may be circular, or oval, or in the form of a parallelogram with rounded ends. The edges of this end should be smoothly rounded, so that the pressure of the instrument may not be painful to the patient. The ear-piece, which should be about two inches and three-quarters in diameter, should be perfectly flat, so as to prevent the existence of any considerable volume of air between the stethoscope and the ear. But each one must fit his own ear.

Dr. Scott Alison has invented an instrument, which he has named the "differential stethoscope." There is a tube for each ear, and each tube has a cup or chest-piece attached. This instrument enables us to auscultate two different parts of the chest at the same instant. Sounds may be compared in this way, and the seat of their greatest intensity ascertained, which renders this bin-aural stethoscope useful in the diagnosis of diseases of the heart. Dr. Leared has devised a bin-aural stethoscope, which has a tube for each ear and one chest-piece. With this instrument a sound can be heard by both ears at once. A similar stethoscope has been since contrived by Dr. Cammann, of New York. With a view to intensifying the sounds, it has been suggested that a little india-rubber bag, a hydrophone, should be fitted into the funnel-shaped extremity of the stethoscope.

When we perform auscultation, the chest should be uncovered; if this be inadmissible, as little clothing as possible should be allowed. When we examine the anterior portions of the lungs, the patient may sit in a chair, with his arms hanging loosely by his sides. The apices of the lungs are perhaps most conveniently examined when the patient is standing. When the lateral regions are explored, the patient should clasp his hands over his head: when the chest is examined posteriorly, the patient should lean forwards, cross his arms over his chest, and bend down his head; male patients may sit astride a chair and lean forwards over the back. Sometimes it is unsafe to raise the patient in bed; in such cases, when we wish to examine the back, a flexible stethoscope becomes very useful. Generally speaking, the recumbent posture is the best when the heart and great vessels are explored. The position of the patient should be unconstrained and easy, the muscles covering the part examined being relaxed.

The examiner should never place himself in an uncomfortable position, all twisting of the neck should be avoided; it is better to kneel by the side of a low bed than stoop unduly over it, and both ears should be educated, and used with equal facility. The observer should concentrate his undivided attention upon the sounds to be heard through the stethoscope, he should be deaf to all besides. This power of abstraction can only be perfected by practice; it is sometimes useful to close the unemployed ear with a finger of the disengaged hand.

The stethoscope should be held tightly like a pen, immediately above its trumpet-shaped extremity, and placed flatly upon the part to be examined. The disengaged fingers may be used to make sure that the instrument is in perfect apposition with the surface. The stethoscope must be applied firmly, but gently, so as not to cause pain by its pressure, and the instrument should be at right angles with the part explored. The flat ear-piece should be accurately applied to the ear, no hair being allowed to intervene. The observer's fingers should be removed from the instrument when the observation is made. The stethoscope must be carefully prevented from coming in contact with the bed-clothes, or with portions of the patient's or observer's dress. It is important to remember that a crepitating noise is often produced by the pressure of the stethoscope, when the part examined is covered with hair.

When the patient is shivering with cold, or when his muscles are contracted, as when a strong effort is made to maintain an uncomfortable position, a dull rumbling vibrating sound, the sound of a contracting muscle, may be mistaken for sounds originating within the chest. This *bruit musculaire* is continuous and easily distinguishable, and can only cause difficulty to beginners.

The student must be content to devote much time and labour to the attainment of proficiency in the practice of auscultation; it is only in the hospital that the preliminary difficulties of the art can be fully mastered, and the student should seize every opportunity of making himself acquainted with the various sounds to be heard in disease. Diseases of the chest, however, are so common, that a little earnest work will do much towards making any careful observer a fair stethoscopist. In concluding these introductory observations, I trust I may be pardoned for quoting the eloquent words of Dr. Stokes :—" Physical signs form an addition,—constitute an assistance to diagnosis, but nothing more ; yet of their value every impartial mind must be convinced, who compares the state of our knowledge previous and subsequent to their discovery. It is on the discovery, explanation, and connexion of those signs with organic changes, and with the symptoms and history of the case, that Laennec's imperishable fame is founded. Time has shewn, that his principles of diagnosis were not the bagatelle of the day, or the brain-born fancies of an enthusiast ; the use of which, like the universal medicine, was to be soon forgotten, or remembered only to be ridiculed. It has shewn that the introduction of auscultation, and its subsidiary physical signs, has been one of the greatest boons ever conferred by the genius of man on the world. A new era in medicine has been marked by a new science, depending on the immutable laws of physical phenomena, and—like other discoveries founded on such a basis—simple in its application, and easily understood—a gift of science to a favoured son : not, as was formerly supposed, a means of merely forming a useless diagnosis in incurable disease; but one by which the ear is converted into the eye; the hidden recesses of visceral disease opened to the view; a new guide to the treatment, and a new help in the early detection, prevention, and cure, of the most widely-spread diseases which afflict mankind."*

* Treatise on Diseases of the Chest.—Dr. Stokes.

CHAPTER VI.

AUSCULTATION OF THE PULMONARY ORGANS, IN HEALTH AND IN DISEASE.

I.—SOUNDS PRODUCED BY THE PASSAGE OF AIR IN RESPIRATION.

1.—IN HEALTH.

Pulmonary or Vesicular Respiration.—If the stethoscope be applied to the healthy chest, we may hear, during inspiration and expiration, two gentle murmurs, the vesicular murmurs of inspiration and expiration. The pulmonary inspiratory sound is soft, equable, and continuous; the expiratory sound, only one-fourth the duration of the inspiratory, is weak in character, and often, even in the healthy condition, altogether inaudible. The murmur of expiration immediately follows that of inspiration, no interval can be observed between them; and then comes a pause, as long in duration as the two sounds put together. The character of the healthy respiratory sounds is generally described by the word "breezy;" the sounds have been compared to the "song of a gentle gale in the thick summer foliage," to the noise made in inspiration during a calm sleep (Laennec), &c., but the murmurs have a character of their own, which no description can faithfully convey, and which can only be appreciated by actual observation.

Tracheal Respiration.—The respiratory sounds, as heard over the larynx, or over the trachea, give to the ear the idea of air passing through a tube of considerable size. They are harsh, blowing, hollow, and tubular in character; the inspiratory sound is equalled in duration, or nearly so, by the expiratory, and a distinct interval exists between the two.

Bronchial Respiration is heard at the upper part of the sternum, at the sterno-clavicular angles, and generally, though not always, between the scapulæ. The sounds may be described as the diminutives of those heard over the trachea. These bronchial sounds are harsher than the vesicular, they possess no breezy character, but are somewhat tubular; the expiratory more nearly equals the inspiratory in length, and there is an interval between the two, decided enough, but not so marked as over the trachea.

Healthy Varieties of the Respiratory Sounds.—The respiratory murmurs of vesicular breathing are subject to various modifications, and these, within certain limits and under certain conditions, are compatible with health. The murmurs, still retaining their healthy and peculiar character, become increased in duration and intensity when the breathing is forced. Their intensity varies, too, in different parts of the chest. "The sounds," writes Dr. Walshe, "are fuller superiorly than inferiorly, especially in women, and in front than behind." The sounds differ, also, on the two sides of the chest, wherever there is a difference in the subjacent parts; thus, they are less loud over the left mammary region than over the right. The respiratory murmurs are a little more distinct at the right apex than at the left; but this difference, often of considerable diagnostic importance, is very slight indeed.

The age of the individual greatly influences the intensity of the respiratory sounds. In children, the sounds are very decidedly louder than in adults; in old age, the sounds often suffer a marked diminution in intensity. These peculiarities have given rise to the use of the terms *puerile* and *senile* respiration.

The intensity of the sounds varies in different adults. The sounds are usually more clearly audible when the chest walls are thin, than when the parietes are well covered with muscle, or laden with fat. In nervous and hysterical persons, the sounds are of more than usual intensity; in females, the vesicular murmurs are usually louder than in males. Very decided differences in the intensity of the sounds are frequently observed in healthy individuals, and these variations can often only be accounted for by supposing the existence of an idiosyncrasy.

2.—*IN DISEASE.*

The manifold modifications which the respiratory sounds undergo as the result of disease may, for convenience of description, be arranged into two classes :—A. Alterations of the natural sounds, modifications, merely, of the sounds audible in health ; B. Adventitious sounds, unlike anything heard in the normal condition of the respiratory organs.

A.—MODIFICATIONS OF THE HEALTHY SOUNDS.

The chief modifications of the breathing-sounds may be classified as follows :—

1. Intensity	Increased. Diminished. Absent.
2. Rhythm	Prolonged expiration. Wavy and jerking inspiration.
3. Character	Bronchial. Cavernous. Amphoric.

1. Intensity : a. Increased.—When, as Laennec observes, the vesicular murmurs can be distinctly perceived of uniform intensity in every part of the chest where lung structure is found, we may conclude that there exists neither effusion into the cavity of the pleura, nor any species of obstruction in the substance of the lungs. Sometimes we observe that the sounds are increased in intensity, *exaggerated* over the whole of one side, or over part of it. This species of morbid respiration is termed *puerile*, because it resembles the normal respiratory sounds of children; and *supplementary*, because it indicates an increase in the activity of respiration in the part, compensating for a diminished activity elsewhere. It is, perhaps, scarcely correct to call this kind of respiration puerile, for the respiratory sounds of children, besides being louder than those heard in the adult, have a distinctive peculiarity of their own. Pleuritic effusions, consolidations of the lung, due to tubercle, pneumonia, &c., obstructions in the bronchial tubes, and partial emphysema, may lead to the production of supplementary respiration in adjoining healthy tissue, either on the diseased side or in the opposite lung.

b. Diminished.—Diminished intensity of the respiratory murmurs, *weak inspiration*, may be due to a variety of conditions. This diminution arises when there is deficient muscular action of the chest-wall, due to debility, or paralysis, or the effect of pain, as in pleurodynia, pleurisy, and peritonitis; in spasm of the glottis and in asthma; when foreign bodies obstruct the air-passages, or when the bronchial tubes are thickened, or filled with fluid; when the lung is partially consolidated; in vesicular emphysema; in pneumonia, before engorgement, and when the lung is recovering itself after resolution; in pulmonary œdema and apoplexy; when the trachea or bronchi are pressed upon by tumours, cancerous, aneurismal, glandular, &c.; when the lung is pressed upon by fluid or solid accumulations in the pleura, by pericardial effusion, or by an enlarged heart.

Dr. Walshe speaks of two varieties of weak respiration—the *superficial* and the *deep-seated.* The deep-seated variety occurs in the effusion-period of pleurisy, in hydro-thorax of moderate amount, and in pneumo-thorax.

In early tuberculosis, the intensity of the respiratory murmurs is often diminished, but phthisis could scarcely be diagnosed from such diminution alone.

c. Absent. The respiratory murmurs may be totally absent, and then the respiration is said to be *suppressed.* The causes of a diminution in the intensity of sounds are capable, when operating to a greater extent, of producing this suppression of the respiratory murmurs. With some rare exceptions, total absence of audible respiration only occurs in cases of copious pleuritic effusion, in pneumothorax, and when a bronchus is completely obstructed.

2. *Rhythm. a. Prolonged expiration.*— In health, the inspiratory murmur is usually three or four times the length of the expiratory; in disease, the expiratory murmur is often prolonged, it may equal, or even exceed the inspiratory in duration. Any prolongation of the expiration, writes Dr. Herbert Davies, is made at the expense of the

period of rest, which, as disease advances, becomes proportionally shortened, until it is found in many cases to be entirely abolished, when inspiration follows upon expiration, with scarcely any appreciable interval of silence. Speaking generally, prolongation of the expiratory murmur is due to an obstruction to the passage of air through the bronchial tubes, or to an impairment of the elasticity of the lung. The greatest prolongation is met with in emphysema, when the expiratory sound is often twice, or three times the length of the inspiratory. Prolongation of the expiratory murmur is one of the earliest signs of pulmonary tuberculosis. "Prolonged expiratory murmur slight in degree, if heard only on the right side, is inconclusive, but if confined to the left, is far more significant. The more limited the space over which it is heard, the greater the probability that phthisis is the cause."* When, as the result of emphysema, or chronic bronchitis,

* Clinical lectures on Pulmonary Consumption. — Dr. Theophilus Thompson, London, 1854.

the duration of the expiratory murmur is changed, the sign is generally diffused over a considerable extent of lung, perhaps over the whole of the chest.

b. Wavy Inspiration.—The normal pulmonary inspiratory murmur is equable and continuous; in disease, this equableness is often lost, and the murmur becomes wavy. Sometimes the inspiratory murmur is divided into several unequal parts, sometimes it seems made up of a series of jerks, and sometimes it suggests the idea of the movement of a cogged-wheel. These conditions have given rise to the use of the terms "interrupted inspiration," "inspiration *entrecoupée*" (Laennec), "jerking inspiration," "inspiration *saccadée*" (Fournet), and "cogged-wheel inspiration." The expiratory murmur occasionally, too, presents these characters, but only when the inspiratory sound is similarly affected. When a local unevenness of inspiration is observed, the sign is generally due to commencing tuberculosis. Wavy inspiration, according to Thompson, is more frequently heard at the left apex than at the right. It undoubtedly often exists when there is no tubercle at all, it often persists for a long time without the development of any other phenomenon, and, on the whole, this variety of respiration is of itself of very little practical value, only possessing significance when it concurs with other and more trustworthy signs. Timidity, nervousness, and hysteria often produce jerking inspiration, it is then general and audible more or less throughout the lungs. The inspiratory murmur may be similarly modified in spasmodic asthma, and when breathing is painful, as in pleurodynia and in pleurisy, and when the even expansion of the lung is prevented by pleuritic adhesions.

3. Character. a. Bronchial Respiration.—In health, bronchial breathing is audible only at the upper part of the sternum, at the sterno-clavicular angles, and between the scapulæ. In disease, this variety of the respiratory sounds may be heard over any portion of the lungs, and it is variously modified in intensity and character according to the conditions which give rise to its production. Dr. Herbert Davies gives the following conditions as absolutely essential for the production of bronchial breathing in an abnormal situation :—

1. A bronchial tube, or space of certain size.
2. Consolidated or compressed lung—*i.e.*, airless parenchyma surrounding the tube or space.
3. Absence of secretion in the tube or space, so that a perfect freedom of communication may exist between the cavity and the upper part of the respiratory passages.

Bronchial breathing is heard when the lung substance is consolidated : the solidified lung becomes a good conductor of sound, vesicular breathing is necessarily absent, and the sounds of the passage of air through the bronchial tubes of the part, unmasked by the pulmonary murmurs which normally conceal them, are conveyed to the ear through the solid tissue which intervenes between the bronchi and the thoracic parietes, the bronchial sounds becoming louder and more distinct according as the lung-tissue is more condensed. Professor Skoda, whose views have been fully adopted by Dr. Davies and others in this country, considers that bronchial respiration is produced by the consonance of the respiratory sounds of the larynx, trachea, and main bronchi, in the air contained in the bronchi, which traverse the consolidated lung-parenchyma.

Bronchial respiration may be *blowing* in character: during inspiration, as Laennec wrote, the air appears as if drawn from the auscultator's ear, while in expiration it appears blown into it. This, however, only occurs when the blowing character of the sounds is very marked. Blowing respiration is divided by Dr. Walshe, into two main varieties, the *simple* and the *hollow*. Simple blowing respiration is sub-divided into the *diffused* and *tubular* forms. "The diffused form occurs, or may occur, in all conditions of diffused solid consolidation, intra or extra-pulmonary, simple, tuberculous, carcinomatous, fibro-fatty, &c., and in dilatation of the bronchi."* In the tubular form, the intensity of the sounds is considerable, the idea of air passing through a tube is very decidedly given, and the sounds are often also

* Diseases of the Lungs.—Dr. Walshe.

distinctly metallic, almost brassy, in character. This is best heard when the lung is hepatised, from pneumonia.

When a considerable amount of fluid exists in a pleural cavity, bronchial breathing may be very generally heard behind, between the scapula and the spine. Bronchial breathing may be elsewhere heard, in cases of pleuritic effusion, where adhesions between the pleuræ bind the lung, compressed by the pressure of the fluid, to the side of the chest. In such cases, bronchial respiration is rarely marked in intensity, and it is never sufficiently tubular in character to suggest the idea, at least to a practised auscultator, of the existence of pneumonic consolidation.

Harsh Respiration is the diminutive of bronchial breathing. The breezy character of vesicular breathing is absent, the sounds are increased in intensity, becoming dry and harsh, and the expiratory murmur is prolonged. This species of respiration is heard in the dry stage of bronchitis, in emphysema, dilatation of the bronchi, early tuberculosis, and when the lung is recovering from the consolidation of pneumonia, or from the pressure of pleuritic effusion.

b. Cavernous Respiration.—Cavernous respiration, resembling the bronchial variety and separated from it by no decided qualities, conveys to the ear the idea of air entering and leaving a hollow space or cavity of considerable size. Well-marked cavernous respiration undoubtedly indicates the presence of a cavity in the lung, containing little or no fluid, having firm walls, and in direct communication with a bronchial tube of considerable calibre. This modification of the respiratory sounds may be produced by a greatly dilated bronchus, or by an excavation in the lung, the result of gangrene or abscess; but, as a rule, cavernous respiration, at the apex more especially, indicates a cavity of tubercular origin.

Cavernous respiration is sometimes decidedly blowing in character. According to Laennec, there is a modification of this variety of morbid respiration, the veiled puff (*souffle voilé*). "In this case, it seems to us as if every vibration of the voice, cough, or respiration, agitates a sort of moveable veil interposed between the excavation and the ear."

c. Amphoric Respiration.—The respiratory sounds may become amphoric in character, resembling the sound produced by blowing into a wide-mouthed bottle. This has been called *utricular buzzing*, and, by Laennec, *bourdonnement amphorique*. Amphoric breathing, an exaggeration, to a great extent, of the cavernous variety, indicates the presence of a very large cavity, and the passage of air through it. The cavity may be in the substance of the lung, but this rare modification of the respiratory sounds is usually only heard in cases of broncho-pleural fistula, when a communication exists between a bronchial tube and the pleura.

B. ADVENTITIOUS SOUNDS.

In disease, various sounds, unlike anything heard in health, are produced by the passage of air in respiration, through the bronchial tubes themselves, or through cavities communicating with them. These sounds are called *râles*, *rhonchi*, or *rattles;* the three words being used as synonyms, and employed as generic terms to include all morbid sounds belonging to the class under consideration. " A rhonchus, writes Dr. Walshe, may be defined as an adventitious sound, audible in inspiration or in expiration, or in both; of dry or moist character; masking the natural breathing more or less completely; persistent or intermittent; originating in the air cells, the minute or large bronchi, the trachea or larynx, and in excavations of the pulmonary substance; and produced either by the passage of air along bronchi of altered calibre, by air bubbling through fluid contained in the sites mentioned, or by the vibrations of semi-solid plastic matter in the tubes, or of prominent folds of their own lining membrane."

In the systematic classification and description of the various rhonchi, considerable confusion has often arisen from the employment of different terms by different authorities to describe the same sounds; useless over refinements have been made, and some sounds have been described according to pathological theories as to their origin. In order to perplex the student as little as possible, I shall endeavour to describe the chief varieties of rhonchi according to the impressions they convey to the ear, adopting the terms most generally in use, and giving any synonyms which have received the sanction of authorities, and which may serve to further elucidate a somewhat difficult subject.

Rhonchi may be divided as follows:—

1. Bubbling.	Large. Small. Hollow.
2. Crackling.	Moist. Dry.
3. Crepitating.	Primary. Secondary.
4. Vibrating.	Sonorous. Sibilant.

1. Bubbling Rhonchi.—Bubbling rhonchi are produced by the passage of air through fluid—mucus, serum, blood, or pus—collected in the bronchial tubes or in cavities communicating with them, the sounds resulting from the breaking of the bubbles of air upon the surface of the fluid..

a. Large-sized bubbling Rhonchus.—Synonym, mucous rhonchus or râle. The bubbles are of large size, being produced in the larger or medium-sized bronchi ; they are unequal in size, vary in number, and occur irregularly. They co-exist with inspiration and expiration, and the sounds are materially modified by coughing and expectoration. This rhonchus may be widely diffused over the chest, but it is usually heard over the central and lower parts of the lungs. It is usually produced by the bubbling passage of air through the mucus in the bronchial tubes; in bronchitis, when secretion has become established. It may be heard in cases of hæmoptysis, in dilatation of the bronchi, bronchorrhœa, and occasionally in other conditions.

b. Small-sized bubbling Rhonchus.—Synonyms, rhonchus sub-crepitans, sub-mucus rhonchus or râle, muco-crepitating rattle. The bubbles are smaller than in the former variety; they vary in size, occur irregularly, and attend both inspiration and expiration, though usually predominating during the former. This rhonchus is produced in the smallest bronchial tubes. Its common seat is the bases of the lungs, indicating capillary bronchitis. When limited to the apex, it generally indicates the bronchitis attending tuberculosis; when heard at one base, it usually indicates pneumonia undergoing resolution.

c. Hollow bubbling Rhonchus. — Synonyms, gurgling rattle, cavernous rhonchus or râle. The bubbles are large in size, few in number, possessing a hollow gurgling, loose, and sharply liquid character, and they usually co-exist with both inspiration and expiration. This rhonchus indicates the presence of air and fluid in a hollow space. Its usual cause is tubercular excavation; but this rhonchus may be also heard in pneumonic vomicæ, in dilatations of the bronchi, and when fluid exists in the pleura together with a bronchial fistula.

Laennec describes the *tracheal rattle*, as a variety of the mucous râle. It depends on the accumulation of fluid in the larynx, trachea, and larger bronchial tubes; it is audible, without a stethoscope, at some distance from the patient, and it becomes developed in most cases of slow death.

2. *Crackling rhonchi. a. Moist crackling rhonchus.*—Synonyms, humid crackling rhonchus, humid crepitation, clicking. This rhonchus consists of a series of sounds, moist and clicking in character, few in number, equal, or nearly so, in size, and co-existing with both respiratory movements, but usually occurring during the whole of inspiration and the first half of expiration. Moist crackling has a very distinctive character, and it attends the softening of tubercle. Dr. Walshe suggests its origin in the interior of softening tubercles which have just commenced to communicate with the minute bronchi. Dr. Thompson says it probably never exists except when softened tubercle is present.

b. Dry crackling rhonchus.—Synonyms, dry crepitation, crackling. This rhonchus is made up of three or four sharp, dry, crackling sounds, limited to inspiration, and giving the ear the idea of distant origin. It is usually found in the infra-clavicular regions, indicating the very commencement of the softening process in tubercles. This rhonchus may, perhaps, occasionally exist when there is no tubercle at all, and tubercle undoubtedly often softens without the production of dry crackling at all.

When dry crackling rhonchus is once fairly established, it usually persists until it is superseded by the moist variety, while moist crackling is sooner or later replaced by the cavernous râle.

3. Crepitating rhonchi. a. Primary crepitating rhonchus.—Synonyms, crepitant râle, crepitation, intravesicular râle (Fournet). A rhonchus composed of numerous fine, sharp, puffing sounds, giving the idea of dryness, equal in size, wholly limited to inspiration, and often existing only towards its close. Neither coughing nor forced inspiration remove the rhonchus, they rather intensify it. Crepitation has been likened to the crackle of salt thrown upon the fire, and to the sound of the compression of healthy lung by the hand, but Dr. Williams hit upon the most apt comparison—"it may be tolerably represented by rubbing transversely, between the fingers and thumb, a lock of one's own hair close to the ear." This rhonchus is peculiar to the early stage of pneumonia.

b. Secondary crepitating rhonchus.—Synonyms, rhonchus crepitans redux, renewed crepitous rattle. This rhonchus is heard in pneumonia when the inflammation is undergoing resolution. It somewhat resembles true crepitation; but the crepiti of which it is composed are fewer in number, more or less moist in character, unequal in size, and co-existent with both inspiration and expiration, though occurring mainly during the former.

In pulmonary œdema, rhonchi, more or less crepitating in character, are audible at the bases and over the posterior surfaces of the lungs.

If a patient, whose habitual breathing is calm, be directed to make a deep inspiration, we may sometimes hear finely crepitating sounds over the bases of the lungs. These, the sounds of the expansion of lung-tissue which has been dormant for some time, have been called pulmonary pseudo-rhonchi; they closely resemble pneumonic crepitation, but after a few deep inspirations they disappear altogether.

4. Vibrating rhonchi. a. Sonorous rhonchus.—The sonorous rhonchus is grave and low-pitched, equable and continuous, of varying intensity and duration, and co-existent with both respiratory movements, but more especially heard with expiration, to which it may be entirely limited. This rhonchus may be *snoring* or *cooing* in character.

b. Sibilant rhonchus. The sibilant rhonchus is high-pitched, co-existing with both inspiration and expiration, or limited to either, but mainly occurring during inspiration. In character, it may be *whistling, chirping, piping, or hissing.*

These sonorous and sibilant rhonchi originate in vibrations, produced by the passage of air through narrowed bronchial tubes. The tubes are diminished in calibre by thickening of their lining membrane, or by the adhesion of viscid mucus to their walls. The sounds present infinite varieties of pitch and character, they differ, also, in intensity and duration, always tending to prolongation. The sonorous rhonchi, generally speaking, arise in the larger tubes, the sibilant in the smaller; but the large tubes may become so narrowed as to produce sounds of the sibilant variety. These rhonchi are heard in acute and chronic bronchitis, in spasmodic asthma, and when the bronchi are obstructed or subjected to external pressure.

The dry crepitant rattle, with large bubbles, le râle crépitant sec, à grosses bulles ou craquement, is described by Laennec as follows:—"It conveys the impression as of air entering and distending lungs which had been dried and of which the cells had been very unequally dilated,—and entirely resembles the sound produced by blowing into a dried bladder. This variety is the pathognomonic sign of emphysema of the pulmonary substance, and of the interlobular emphysema." I have never been able to observe this myself.

II. SOUNDS PRODUCED BY THE MOTIONS OF THE LUNGS.

Pleural friction-sounds. In health, the pleura costalis and pleura pulmonalis, with surfaces perfectly smooth and adequately moistened, glide noiselessly over each other during the movements of respiration. In pleurisy, when the pleural surface becomes dry or roughened by inflammatory changes, the motions of the pleuræ give rise to various sounds. These are called *pleural friction sounds*, *pleuritic rubbing*, or, by French writers, *frottement ascendant et descendant.* Friction-sounds may be heard wherever the pleuræ have undergone the necessary morbid changes ; the greatest amount of respiratory movement of the chest-walls usually takes place at the middle and lower parts of the chest, hence pleural friction is especially produced in these situations. The friction-sound, of very evidently superficial origin, is made up of a series of jerking noises, more or less abrupt in character and varying in number, usually co-existing with both inspiration and expiration, often, however, heard with inspiration alone, and sometimes, though rarely, limited entirely to expiration. In its character, pleuritic friction presents infinite varieties, according to the nature of the change in the pleural surfaces—according as the pleuræ are simply dry, or roughened, or covered with new material of varying thickness and consistence; but, as a general rule, we are unable, however easy it may at first sight appear, to truly estimate from the character of the friction-sounds the exact physical condition of the pleural surfaces. When the diseased pleuræ are separated by copious effusion, no rubbing can take place and the friction-sound consequently ceases, to return as the surfaces are again approximated when the fluid is absorbed. This holds good as a general rule, but there may sometimes be considerable effusion and at the same time friction-sounds, when some portion of the pleura pulmonalis is kept sufficiently near the chest-wall by means of adhesions. The friction-sound may be soft in character, like the rustling of fine silk, and its more delicate form is often described as *grazing*.

Its other varieties may be expressed by the terms *grating*, *rubbing*, *scraping* (râclement), creaking *(craquement de cuir)*.

Pleural friction may be distinguished from the friction-sound of pericarditis by its cessation while the patient holds his breath; and the fact that it is unaltered by coughing and expectoration may help us to distinguish it from some kinds of rhonchi for which it may be mistaken.

Friction-sound as the result of pleurisy escaped the observation of Laennec, but in a later edition of his great work on mediate auscultation he describes friction-sounds, and acknowledges that his attention was drawn to them by Dr. Honoré. "This phenomenon," wrote Laennec, "which I shall call the *friction* of *ascent* and *descent*, is occasioned by the interlobular emphysema of the lungs." Later observation has established pleural friction as the diagnostic sign of pleurisy, and many distinguished authorities have doubted or denied its existence in interlobular emphysema. On this point Dr. Walshe has written as follows:—" But from some cases I have met with of very advanced emphysema, manifestly attended with a low degree of rubbing-sound at the postero-inferior part of the chest. where subpleural sacculi are very commonly developed, and presenting neither signs nor symptoms indicative of pleurisy, I am induced to think that Laennec's belief respecting the occurrence of friction-signs in some forms of emphysema was not erroneous." I have certainly occasionally detected a low-pitched friction-sound of decidedly jerking rhythm in some cases of advanced pulmonary emphysema.

III.—SOUNDS OF THE VOICE TRANSMITTED THROUGH THE CHEST.

1.—RESONANCE OF THE VOICE IN HEALTH.

In health the vocal resonance differs over the larynx, the trachea, the larger bronchi, and the pulmonary tissue. When we listen with the stethoscope applied over the larynx of a person who is speaking, the voice is distinctly and forcibly heard, being transmitted with perfect articulation through the instrument. This is called *laryngophony*. If we listen over the trachea we find a somewhat similar condition of the vocal resonance, but the voice is not so clear, and does not appear so distinctly to permeate the tube of the stethoscope. This is *tracheophony*. At the right and left edges of the manubrium of the sternum, in the inter-scapular regions, over the large bronchi, and over that part of the trachea which lies behind the sternum, the voice does not appear to traverse the stethoscope at all, but it seems to resound at its extremity. Although the vocal resonance is loud and distinct, the voice-sound conveys the idea of distant origin, it is diffused, and articulation is very imperfect. This variety of vocal resonance is called *natural bronchophony*. Over the general surface of the chest the voice is scarcely perceptible at all; no articulation can be heard, and the vocal resonance is obscure, indistinct, and buzzing, giving the idea of very distant origin. This is the *natural pectoral vocal resonance*.

Considerable variations in the resonance of the voice may occur among healthy individuals. The vocal resonance is greater in thin than in stout persons. When the voice is grave, the *intensity* of the resonance is increased, when the voice is shrill, an increase in the *distinctness* of the resonance is often observed. Vocal resonance, too, is more marked in the old than in the young, and in males than in females and children. As a rule, and this is of great clinical importance, the voice-sound is more distinct under the right clavicle than under the left.

When we wish to compare the vocal resonance at different parts of the chest, the same words should be uttered with the same loudness and in the same tone. It is best to desire the patient to count one, two, three, during each observation, slowly, distinctly, and monotonously.

2.—*THE VOCAL RESONANCE IN DISEASE.*

The modifications of the natural pectoral vocal resonance, which occur in disease, may be classified as follows :—

Diminution in intensity	Weakened. Suppressed.
Increase in intensity	Bronchophony. Pectoriloquy. Ægophony. Amphoric resonance.

Diminution in Intensity.—The natural vocal resonance may be simply diminished or it may be wanting altogether. When a main bronchus is obstructed, the voice-sound is impaired or lost over the corresponding lung. In emphysema the conducting power of the lung is impaired, and the vocal resonance suffers a corresponding diminution. In pneumothorax vocal resonance is usually completely lost. When a malignant growth in the pleura pushes the lung away from the chest-wall, vocal resonance may be wanting. In cases of liquid effusion into the pleural cavity, the resonance is weakened according to the amount of fluid and the extent to which the lung is separated from the chest-wall. In extreme cases complete suppression of the resonance occurs. The fluid compresses the lung towards the vertebral column, so that the voice-sound, though wanting elsewhere, is perceived, with its usual and often with increased intensity in the interscapular region.

Bronchophony.—The limits of bronchophony in health have been described. In disease the natural pectoral vocal resonance may be replaced at any point by bronchophony. This was called "accidental bronchophony" by Laennec. In bronchophony the voice-sound is loud and distinct; it does not appear to pass through the stethoscope, but rather to resound at its applied extremity, and there is no very distinct articulation. Speaking generally, bronchophony indicates an increase in the density of a portion of lung which is in communication with previous bronchi, or a dilatation of a bronchial tube, or the co-existence of both these conditions.

In phthisis, when the lung is more or less solidified by the growth of tubercle, bronchophony is produced. This varies in intensity from simple exaggeration of the natural vocal resonance to the most distinct bronchophony, according to the degree of the solidification of the part. In early phthisis we must be careful to compare the resonance on the two sides of the chest, and it must always be remembered that the natural voice-sound is usually louder over the right apex than over the left. Bronchophony may be heard in pulmonary apoplexy, and the vocal resonance is slightly increased in pulmonary œdema. In pneumonic hepatisation, decided bronchophony, often possessing a distinctly ringing and *metallic* character, is audible. In dilatation of the bronchi, especially when the surrounding lung substance is condensed, bronchophony, often markedly *diffused* in character, is produced. When pleuritic effusion exists in the lower part of the chest, the vocal resonance at the apex is frequently increased. When the fluid has become absorbed, and there is left a retracted chest-wall and a condensed lung, bronchophony is usually found.

Pectoriloquy.—"Pectoriloquism," wrote Laennec, "is perfect when the transmission of the voice through the stethoscope is complete." Articulation is perfect, resembling the natural voice-sound as heard over the larynx. Pectoriloquy may be *perfect*, *imperfect*, or *doubtful;* and, although in decided cases the difference is marked enough, between bronchophony and pectoriloquy no strong line can be drawn. Pectoriloquy was considered by Laennec to be the sign of a cavity in the lung. The value of this indication has been much disputed, but pectoriloquy is undoubtedly heard over certain pulmonary excavations, and most frequently over cavities of tubercular origin. Pectoriloquy is generally best developed by the whispered voice, and it is most likely to be produced when the cavity is of moderate dimensions, near the surface, surrounded by solid and smooth walls, empty, and in communication with a bronchial tube of considerable size. Pectoriloquy may exist without a cavity, and a cavity may exist without pectoriloquy. As a rule, bronchophony indicates consolidation of the lung, it may, however, be the result of excavation; pectoriloquy, on the other hand, usually indicates excavation, it may, however, be the result of simple consolidation.

Ægophony.—In ægophony, the voice-sound possesses a very peculiar character. Tremulous and silvery, often nasal, sometimes shrill and echo-like in character, it has been named from its fancied resemblance to the bleating of a goat. It has been compared to the voice of the exhibitors of Punch (*voix de polichinelle*), and to the voice of a man speaking with a coin between his teeth. This voice-sound does not appear to traverse the tube of the stethoscope, and it usually seems to accompany, sometimes to follow, the words of the patient. Ægophony, a sign upon which but little reliance is to be placed, is heard in some cases of pleuritic effusion, when the fluid is moderate in amount. This variety of vocal resonance is very limited in site; corresponding to the level of the surface of the fluid, it is usually heard about the inferior angle of the scapula, and sometimes it may be traced all round the affected side of the chest.

Amphoric Resonance.—Over a large and empty cavity, the voice-sound sometimes possesses a hollow and reverberating character, as when we speak into an empty pitcher. This is called amphoric or metallic resonance.

RESONANCE OF THE COUGH.

In disease, the sound of the cough, as heard through the stethoscope applied to the chest, may be *bronchial*, *cavernous*, or *amphoric*. After what has been said on the auscultation of the voice, these terms will be readily understood. Speaking generally, we can learn but little from the cough.

Metallic Tinkling.—Synonyms, tintement metallique, gutta cadens. Metallic tinkling may be heard when the patient breathes, speaks, or coughs, but coughing is generally required for its production. The sound resembles that produced when a drop of water falls on the surface of fluid contained in a half-filled decanter, or when a glass is lightly struck with a pin. It indicates the presence of air and fluid in a large space. Metallic tinkling may be heard in hydro-pneumothorax, and over a large tubercular cavity ; this rare sign is most frequently produced in cases of fistulous communication between a bronchial tube and the cavity of the pleura, of tubercular origin. I have heard it in empyema, when a portion of the pus had been removed by paracentesis and when air had found its way through the external wound into the cavity of the pleura.

CHAPTER VII.

AUSCULTATION OF THE HEART, IN HEALTH AND DISEASE.

1. HEALTHY CARDIAC SOUNDS.

OVER the cardiac region of a healthy person, two sounds are heard with each beat of the heart, followed by a period of silence. The first sound is called the *systolic*, because it coincides with the systole of the ventricles; and it is sometimes called the *inferior sound*, because it is best heard about the apex of the heart. The second sound is called the *diastolic*, because it is synchronous with the diastole of the ventricles; and it is sometimes called the *superior sound*, because it is audible with greatest intensity about the base of the heart. The first sound is dull and prolonged, while the second is comparatively clear and short. The two sounds may be closely imitated, according to Dr. C. J. B. Williams, by pronouncing the syllables, *lubb, dup;* or, as Dr. Hughes remarked, by the words, *too-to.* When the heart beats slowly, a very short silence can be distinguished between the first and second sounds. The sounds and silences occur in a definite order of succession, which constitutes the *rhythm* of the heart. This order is as follows :—*first sound;* short silence; *second sound*; long silence. The durations of these sounds and silences have been variously estimated; on this subject, Dr. Walshe writes as follows :—" If the period of an entire revolution of the heart, that is from the commencement of one first sound to the commencement of the next succeeding first sound, be divided into ten equal parts, the durations of the several periods of sound and silence will be found on an average very closely as follows :—

First Sound	$\frac{4}{10}$
First Silence	$\frac{1}{10}$
Second Sound	$\frac{2}{10}$
Second Silence	$\frac{3}{10}$

The first sound coincides with the systole of the ventricles, the passage of the blood through the pulmonic and aortic orifices and the diastole of the arteries adjoining the heart, the impulse of the apex of the heart against the side of the chest, and the closure of the auriculo-ventricular valves. The first sound barely precedes the radial pulse. The second sound coincides with the diastole of the ventricles, the passage of the blood through the auriculo-ventricular orifices, the falling back of the heart from the side of the chest, and the closure of the valves of the aorta and pulmonary artery.

2. *ABNORMAL CARDIAC SOUNDS.*

The abnormal cardiac sounds — the sounds which are produced by the action of the heart in disease—may be divided into two classes :—A. modifications of the healthy sounds ; B. adventitious sounds or murmurs.

A. MODIFICATIONS OF THE HEALTHY SOUNDS.

The chief modifications of the healthy cardiac sounds may be conveniently divided into changes as to *intensity*, *character*, and *rhythm*.

a. Intensity.—The sounds of the heart may be either increased or diminished in intensity. The sounds may be greatly increased in intensity in functional excitement of the heart; they are very decidedly increased when the heart's cavities are dilated and the walls hypertrophied; and the intensity of the first sound often undergoes a marked increase in intensity and clearness when the heart is the subject of simple dilatation. When the lung which is adjacent to the heart is consolidated, as in pneumonia and tuberculosis, the cardiac sounds are heard over a wider area than in health, while they are at the same time often increased in intensity.

When the muscular tissue of the heart is the subject of fatty degeneration, or when attenuation of the walls co-exists with dilatation of the cavities, the cardiac sounds are weakened. A diminution in the intensity of the sounds is observed when the heart is removed from the chest-wall by pericardial effusion, or when it is extensively overlapped by emphysematous lung In simple hypertrophy, the first sound of the heart is generally weakened.

b. Character.—In simple hypertrophy of the ventricle, the first sound is dull, *muffled*, and lengthened; an unnatural sharpness and clearness of the first sound is observed in simple dilatation. The second sound is often abnormally sharp and clear in anæmia. The first sound, at the apex, is often *murmurish.* This may mark commencing endocarditis, and be the herald of more decided changes; or it may last for years, appearing to be the natural condition of the sound. This change in character is often heard in chorea, and it is sometimes the effect of mere nervousness, passing away under our observation.

c. Rhythm.—The order of succession and the relative durations of the cardiac sounds and silences may be variously disturbed in disease, constituting abnormalities of rhythm. The rhythm may be *irregular*, the cardiac pulsations being of unequal force and duration, and occurring at irregular intervals. This irregularity may be the effect of emotion; it may be due to alterations in the size of the cavities of the heart, to changes in the walls as to thickness or structure, to pericardial inflammation, or to changes in the valves. Irregularity in the action of the heart is especially observed in advanced mitral disease.

"The sounds of the heart," writes Dr. Walshe, "are sometimes suspended for the precise length of time occupied by an ordinary revolution of the organ: they are said then to *intermit*." This intermittence, which often occurs at regular intervals, may be due to various changes in the cavities, walls, or valves of the heart; or it may persist for years without any organic lesion whatever.

Three sounds, instead of two, may be heard with each beat of the heart; four sounds have been sometimes observed. This change in the rhythm is called *reduplication* of the cardiac sounds. Reduplication is comparatively rare: the first or the second sound, or both, may be double; but reduplication of the second sound at the base is the variety most commonly met with, (lubb, dup-dup.) Reduplication of the sounds is thought to be due to a disturbance in the synchronism of action of the two sides of the heart : when we remember that the two sides are perhaps never equally affected by disease, the only wonder is that this change of rhythm does not more frequently occur.

B. ADVENTITIOUS OR PRETERNATURAL SOUNDS, CARDIAC MURMURS.

Abnormal cardiac sounds, totally unlike what we hear when we listen to the action of the healthy heart, produced either within the organ or upon its surface, are called *murmurs.* These murmurs may be divided as follows :—

1. Endocardial	Organic.	
	Inorganic.	Dynamic. Hæmic.
2. Exocardial.		

1. Endocardial murmurs.—Endocardial murmurs are usually *blowing* in character, hence they are described under the generic term *bellows murmur*, the *bruit de soufflet* of French writers. These murmurs vary infinitely in pitch, quality, duration, and intensity. The terms rasping, filing, sawing, booming, grating, whizzing, blowing, musical, &c., have been employed by English writers, and the terms *bruit de scie, bruit de râpe, bruit de soufflet*, &c., have been used by the French, in the description of the manifold variations of endocardial murmurs. As to time, these murmurs may occur with either the first or second sound, that is, they may be either systolic or diastolic in rhythm ; but they may also be pre-systolic or post-systolic, pre-diastolic or post-diastolic. A murmur, by being synchronous with one of the natural sounds, may drown it, or the murmur may replace the normal sound altogether.

a. Organic endocardial murmurs.— As the result of disease, the valves and orifices of the heart may become variously changed. The valves may be roughened, so as to offer an obstruction to the passage of the blood over their surfaces ; or the valves may be incompetent to close the orifices which it is their function to guard. The orifices may be constricted, so that the passage of the blood through them is impeded ; or the orifices may be widened, so that the valves are unable to close them. As the result of these changes, the blood is either obstructed in its normal course through the heart, or some of the stream is driven backwards through an imperfectly closed orifice. These alterations of the orifices or of the valves, or of both, leading to obstruction to the passage of the blood forwards, or permitting regurgitation of some of the blood backwards, usually give rise to such an amount of friction between the blood and the surface over which it passes, or cause such a commotion in the blood itself by the collision of opposing currents, as to produce endocardial murmurs. These murmurs may occur *with* the normal current, when they are said to be *direct*, murmurs of *obstruction ;* or they may occur *against* the normal current, when they are said to be *indirect*, murmurs of *regurgitation.*

As each orifice of the heart may be the seat of two murmurs, a murmur of obstruction and a murmur of regurgitation, the *possible* endocardial organic murmurs are eight in number; as will be seen as we proceed, the *probable* murmurs fall far below this number. In determining the exact nature of an organic murmur, we must ascertain three points :—the position of the maximum intensity of the murmur, the period of the heart's action at which it occurs, and the direction in which it is transmitted. We must ask ourselves three questions. *Where is the murmur heard? When is it heard? Whither is it propagated?*

Organic endocardial murmurs may be classified as follows :—

Left side of the heart.	*Systolic*	*Aortic obstructive.*
		Mitral regurgitant.
	Diastolic	*Aortic regurgitant.*
		Mitral obstructive.
Right side of the heart.	*Systolic*	*Pulmonic obstructive.*
		Tricuspid regurgitant.
	Diastolic	*Pulmonic regurgitant.*
		Tricuspid obstructive.

Aortic obstructive.—The murmur of obstruction at the aortic valves is systolic, being synchronous with the pulse at the wrist and the impulse of the heart. Its point of greatest intensity is over the middle of the sternum, on a level with the lower border of the third rib. It is inaudible, or nearly so, at the apex. It is heard, of considerable intensity, at the second right cartilage, the 'aortic cartilage,' it is not nearly so clearly audible at the 'pulmonic cartilage;' it is also clearly audible at the manubrium of the sternum, and it is often to be caught in the left vertebral groove, opposite the third or fourth vertebra, rarely lower than these. This murmur is frequently propagated into the carotid, subclavian, and other arteries. The murmur of aortic obstruction is generally high pitched and harsh, it arises at the aortic orifice, it is systolic in rhythm, and it is propagated along the aorta. A careful distinction must be made between this murmur and the murmur of anæmia.

Mitral regurgitant.—The murmur of mitral regurgitation, indicating insufficiency of the mitral valve, is systolic. Its point of greatest intensity is the left apex, where it may completely cover the natural first sound. It is faintly heard, often quite inaudible, at the ensiform cartilage and the base of the heart. This murmur is usually audible about the inferior angle of the left scapula, in the vertebral groove from the sixth to the tenth vertebra, about the lower part of the chest on the left side, and it is sometimes to be heard in the axilla. The pulmonary second sound, that is the second sound as heard over the third left costal cartilage, is generally, as Skoda pointed out, markedly accentuated in cases of mitral valvular disease. The murmur of mitral regurgitation is usually low-pitched, rarely harsh, and it is sometimes musical, even whistling in character.

Aortic regurgitant.—The murmur of regurgitation through the aortic valves is synchronous with the ventricular diastole. Its point of maximum intensity is the middle of the sternum, on a level with the lower border of the third rib. It is propagated along the aorta, but to a much less degree than the murmur of obstruction, as far as the 'aortic cartilage;' but it is conducted most distinctly downwards, along the sternum, and it is often as clearly audible at the ensiform cartilage as over the site of its production. Sometimes it is better heard at the ensiform cartilage than at the base, and it is occasionally propagated towards the left apex. The murmur replaces the normal aortic second sound, but the pulmonary second sound is often clearly audible. The murmur of aortic regurgitation varies considerably in character, it is usually low in pitch and it is rarely harsh.

Mitral obstructive.—The murmur of mitral obstruction, also called a *direct* mitral murmur, is diastolic in rhythm; more strictly speaking, it is an auricular systolic murmur, occurring just before the ventricular systole and running up to the first sound, hence it is often spoken of as a pre-systolic murmur. Its point of maximum intensity is the region of the left apex, but it is generally best heard between the fourth and fifth ribs on the left side. This murmur is sometimes audible alone, but it generally co-exists with a murmur of regurgitation. The murmur of mitral obstruction is rarely of great intensity, sometimes it is musical; the pulmonary second sound is generally accentuated.

Pulmonic obstructive.—The murmur of pulmonic obstruction is systolic. Its point of greatest intensity is the third left cartilage, close to the sternum. It is transmitted upwards and towards the left, along the left edge of the sternum, becoming inaudible about the level of the first interspace. It is not audible in the back, it is not transmitted towards the apex, and it is not transmitted along the aorta; it is more audible at the 'pulmonic cartilage' than at the 'aortic,' and it cannot be heard in the subclavian and carotid arteries. Such a murmur is exceedingly rare. Dr. Elliotson mentioned a case in which a systolic murmur was produced in the pulmonary artery from pressure on the vessel by an adventitious growth in the pericardium.* A systolic murmur, audible over the pulmonary artery, is sometimes heard in cases of pulmonary tuberculosis, probably due to pressure on the vessel by a tubercular

* Principles and Practice of Medicine.—2nd Edit., page 964.

growth. "The diagnostic value of murmur in the pulmonary artery is variously estimated. It is often present in many phthisical patients at the second left sterno-costal articulation."*

Tricuspid Regurgitant.—The murmur of tricuspid regurgitation is systolic, having its point of maximum intensity over the right ventricle, just above the ensiform cartilage. It is scarcely audible at the left apex, and it cannot be heard in the back, nor at the base. This is a very rare murmur, although dilatation of the tricuspid orifice is very commonly met with. A co-existing mitral murmur may drown the triscupid murmur completely. The veins are distended, and pulsations can be seen in the jugulars.

Pulmonic regurgitant and *tricuspid obstructive* murmurs are excessively rare. They are certainly possible, but it is useless to embarrass a description of cardiac murmurs by detailing the probable sounds produced by such pathological curiositiesas pulmonic insufficiency and tricuspid narrowing.

* Science and Practice of Medicine.—Dr. Aitken.—5th Edit. "Physical Signs of Phthisis."

Valvular disease of the right side of the heart is comparatively rare; practically, we have to deal only with murmurs originating in the left side, and the murmurs of mitral regurgitation, aortic obstruction, and aortic regurgitation are those usually met with. Organic endocardial murmurs occur in the following order of relative frequency:—mitral regurgitant; aortic obstructive; aortic regurgitant; mitral obstructive; pulmonic obstructive; tricuspid regurgitant.

Two, or more, cardiac murmurs may co-exist. The following combinations for example, are frequently met with:—aortic obstruction, aortic regurgitation; mitral regurgitation, aortic regurgitation and obstruction; mitral regurgitation, mitral obstruction.

b. Dynamic endocardial murmurs.—Violent and excited action of the heart, especially in nervous women, has occasionally been observed to produce a murmurish condition of the first sound at the apex, or even actually to develop a systolic murmur. The other signs of organic cardiac disease are usually wanting, and the abnormal sound disappears as the excitement subsides, this change often occurring while we are listening.

In chorea, the first sound at the apex is often murmurish, and sometimes a soft systolic murmur is audible. "I have observed," writes Dr. Flint, "a mitral systolic murmur during the continuance of chorea, and the disappearance of the murmur after recovery from chorea. This murmur may, perhaps, as has been conjectured, depend on temporary insufficiency at the mitral orifice caused by irregular contractions of the papillary muscles." The choreic murmur may vary in intensity from day to day, it may even vary considerably with different beats of the heart.*

c. Hæmic Murmur.—When spanæmia exists, a cardiac murmur, independent alike of organic changes in the heart and of functional perversion of the cardiac action, is frequently audible. This is often heard in anæmic and chlorotic girls, and it is called the anæmic or

* For a fuller discussion of this interesting subject than the limits of this book will allow, reference may be made to Dr. Walshe's exhaustive treatise on Diseases of the Heart.—3rd Edit., page 95.

chlorotic murmur. It is always systolic in rhythm, and heard at the base of the heart. It is never heard at the apex. This murmur is not conducted along the aorta to anything like the extent of the murmur of aortic obstruction, and it is very often more distinctly audible along the course of the pulmonary artery than elsewhere. An anæmic murmur is usually soft and blowing in character, but not always so, and we are certainly unable to distinguish this murmur by its character alone. The hæmic murmur may vary considerably at different times in intensity; it diminishes as the patient's condition improves, and it ultimately disappears altogether. It is generally better heard in the erect than in the recumbent posture. The second sound at the base is often unusually clear and distinct. When a murmur is anæmic, the general signs of anæmia are always well marked; a continuous venous murmur or hum, the "*bruit de diable*," may be detected in the veins of the neck, and a softly blowing systolic murmur is very generally audible in the arteries.

2. Exocardial or Pericardial Murmurs.—During the action of the healthy heart, the movements of the opposed surfaces of pericardial serous membrane do not give rise to any sound. Whenever the serous surfaces are roughened, pericardial sounds are produced. A variety of morbid conditions may give rise to this change in the serous membrane, but *pericarditis* is by far the most frequent cause of an exocardial murmur. The pericardial murmur has been named by Sir Thomas Watson a "*to* and *fro* sound;" "it conveys to the ear the notion of the rubbing of two rough surfaces, backwards and forwards upon each other." This friction-sound usually gives the notion of superficial origin. In character, it may vary greatly; it may be *grazing*, *rubbing*, *grating*, *creaking*, *rasping*, *churning*, *&c.*, it is never *musical;* the French use the terms, *frottement*, *râclement*, *craquement de cuir*, *&c.*, to describe its varieties. The pericardial murmur is almost invariably double, accompanying both the systole and the diastole, the systolic part of the sound being usually of greater intensity than the diastolic. The pericardial murmur, though corresponding in rhythm with the action of the heart, is not accurately synchronous with the cardiac systole and diastole, *it seems to follow the natural sounds.* An exocardial murmur is not propagated along the great vessels, it is limited to the region of the pericardium; as a rule, it is inaudible in the back. When fluid effusion completely separates the pericardial surfaces, the friction-sound disappears, to return as the fluid is absorbed. The sound may suddenly disappear, or it may gradually become obliterated from below upwards, and as gradually return from above downwards. The redux friction usually gradually disappears; a permanent pericardial friction-sound is very rare. An exocardial murmur may vary considerably in intensity and pitch from day to day, or even while we are making an examination. When the thoracic parietes are yielding, firm pressure with a stethoscope often intensifies the sound and raises its pitch. I have frequently observed an increase in the intensity of a pericardial friction-sound occur at the end of a deep inspiration; this fact, which has been noticed by a few writers, is sometimes most evident when the patient holds his breath after the deepest possible inspiration.

CHAPTER VIII.

THE URINE IN HEALTH. EXTRANEOUS MATTERS IN THE URINE.

Before we proceed to the study of the changes which the urine undergoes as the result of disease, it will be necessary to consider, as briefly as possible, the composition, quantity, appearance, and properties of that secretion in health. We may then pass on to discuss the alterations which take place in the urinary secretion, and see how far these changes are compatible with health, how far they are diagnostic of disease.

Healthy human urine is a transparent, watery fluid, having a pale yellow or amber colour, and a peculiar and faint, but not disagreeable odour. The average specific gravity, according to Prout, is 1020, according to Becquerel, 1017, and, according to Rayer, 1018. The density is liable to considerable variation, and it is usually said to have a healthy range from 1015 to 1025. After excessive drinking, especially when the stomach is comparatively empty, the specific gravity of the urine (urina potûs) may fall far below 1015. Dr. Roberts says he has known the density of healthy urine reach as high as 1036. Gintrac has well observed that the density of urine is in inverse proportion to its quantity. M. Rayer says the minimum density is 1001, the maximum, 1040.

The reaction of urine is nearly always slightly acid, owing to the presence of acid salts, together with some free acids. After a meal, there may be observed a marked diminution in the acidity; the urine may then become neutral, or even slightly alkaline, but in a few hours the acidity is gradually restored, perhaps increased. Dr. Bence Jones first pointed out the change in the reaction of the urine towards alkalinity which takes place after a meal, and he thought that the secretion of acid juice by the stomach, during digestion, was the cause of the diminution of the acidity of the urine. Dr. Roberts attributes the change "to the entrance of the newly digested food into the blood." He observes that the gastric juice flows into the stomach immediately after the entrance of food; whereas the change in the reaction of the urine is not expressed until after the lapse of two or three hours, when the meal, which usually contains a quantity of alkaline bases, has been more or less absorbed.

The average daily quantity of the urine is about 40 ounces, or perhaps a little more. This may vary considerably, chiefly according to the quantity of fluid drank; but it is also greatly influenced by the amount of the secretions of the skin, intestines, and lungs.* The quantity is increased mainly by dilution.

Urine in an aqueous solution of various organic and inorganic bodies, containing in suspension mucus and epithelium. These suspended matters, which are yielded by various portions of the mucous membrane over which the

* "La quantité de l'urine rendue par un homme sain, est en raison directe de celles des liquides qu'il a absorbés par la peau ou par les voies digestives, et en raison inverse des perspirations cutanée, pulmonaire et intestinale."—*Gintrac, Pathologie interne. Tome premier.*

urine flows, gradually fall down as a light flocculent deposit. 1000 parts of urine contain, according to the analysis of Becquerel, 33 parts of solid matter. Berzelius states that 1000 parts contain only 933 parts of water.

Dr. Roberts gives the following as the composition of healthy human urine, as the result of the comparison of a large number of the most trustworthy analyses.

Water		954·81
Solid Matters		45·19
Urea		21·57
Uric Acid		·36
Extractives	Creatine Creatinine, Ammonia, Hippuric Acid, Xanthine, Hypo-xanthine, Sarcine, Pigment, Unoxidized Sulphur and Phosphorus, Mucus, &c., &c.	6·53
Fixed Salts	Chlorine	4·57
	Sulphuric Acid	1·31
	Phosphoric Acid	2·09
	Potash	1·40
	Soda	7·19
	Lime	·11
	Magnesia	·12*

It will be seen that urine contains nearly one-twentieth part of solid matter, and that almost half of this is urea. Neubauer and Vogel give the normal daily quantity of urea as reaching nearly

* A practical treatise on urinary and renal diseases.—Dr. William Roberts, London, 1865.

an ounce. Dr. Roberts fixes the average at 500 grains, Dr. Golding Bird gave 270 grains. Dr. Flint, of New York, says the amount of urea excreted in twenty-four hours varies between four and six hundred grains.

Berzelius stated that 1000 parts of urine contain one part of uric acid, and, supposing the daily quantity of urine to be 40 ounces, this would give 19 grains as the amount of uric acid excreted in twenty-four hours. Other observers agree in thinking the proportion to be much less than this; about 8 grains of the acid are probably excreted by the kidneys in twenty-four hours.

EXTRANEOUS MATTERS IN THE URINE.

Various foreign bodies may become accidentally mixed with urine, or they may be added by patients or others with the intention of deceiving the attendant; these matters may be easily mistaken for urinary deposits, and thus cause considerable embarrassment or lead to awkward mistakes. The student ought to be able to easily recognise these bodies, and he ought to be aware of their sources, which in the majority of cases are very obvious, before he goes on to the study of the urine in disease. There can be no excuse for an ignorance of the appearance of these common objects.

Among the objects of extraneous origin likely to be met with in urinary deposits may be enumerated—cotton fibres; flax fibres; human hair; cat's hair; fragments of woollen hairs from blankets; portions of muscular or vegetable tissue, perhaps semi-digested; tea leaves; epithelium from the mouth and air-passages, derived from the sputa; wooden fibres from the floor; portions of feathers; fragments of fruits and seeds; potato starch; wheat starch; rice starch; oil globules, furnished perhaps by an oiled catheter; sand; soot; &c.

Fibres and hairs may be mistaken for tube-casts. Cotton fibres are long, flat, ribbon-like bands, often finely marked longitudinally or transversely, and they are generally folded over on themselves at one or more points. Flax fibres are narrower, but they have a more rounded appearance, they are jointed at intervals, and their ends are brush-like. Woollen hairs are often coloured by dye, they are a little larger than flax fibres, and have a solid, rod-like character. Muscular fibres are easily distinguished by the transverse markings, which, when the tissue is partially digested, are often beautifully distinct. Small shreds of deal from the floor, presenting the characters of coniferous wood, very closely resemble some kinds of tube-casts. Fragments of feathers are recognized by their jointed appearance. Spiral vessels may be seen in tea leaves. Care must be taken lest starch granules are mistaken for cells. Granules of rice starch are very small; the concentric markings of wheat and potato starch are peculiar. Air bubbles often get under the thin upper glass of the slide. Their dark coloured broad edges are characteristic. The smaller bubbles are round, but the larger ones flatten out into irregular shapes. The outline of oil globules is much lighter than that of air bubbles. They may be present as the result of disease, when they are exceedingly minute.

EXPLANATION OF PLATE I.

Extraneous Matters in Urine. — a. Cotton Fibres. b. Flax Fibres. c. Woollen Hairs. d. Portions of Feather. e. Wheat Starch. f. Rice Starch. g. Potato Starch. i. Fragments of Tea leaves. k. Epithelial Scales from the Mouth. l. Air Bubbles. m. Oil Globules.

CHAPTER IX.

DECOMPOSITION OF URINE. ODOUR. COLOUR. CONSISTENCE. REACTION. SPECIFIC GRAVITY. QUANTITY.

When urine is preserved for examination, the total quantity passed in twenty-four hours should be collected; from this a specimen may be taken, which should be set aside in a tall glass to allow the deposition of the sediment. It is important to notice the space occupied by the deposit, forming, it may be, a sixth or a fourth of the column. Important changes occur in urine after it is voided; it is necessary, therefore, to examine it soon after emission.

Urine containing much organic matter, especially when the specific gravity is low, becomes alkaline on keeping, by the production of ammonia from the decomposition of the urea. Urea and water easily pass into carbonate of ammonia, and this change is favoured by the presence of organic matter passing into decomposition, $C_4H_2N_2O + 2H_2O = (NH_4)_2CO_3$. It has been supposed by Dumas that the vesical mucus may undergo a putrescent change; and this mucus, acting as a ferment, may induce the metamorphosis of urea into carbonate of ammonia, just as yeast aids the conversion of sugar into alcohol.* The alkaline urine has an ammoniacal odour, and throws down amorphous and crystalline phosphates. Under these circumstances the urine is often rendered opaque by the presence of vibriones, minute confervoid vegetations in the form of fine filaments, which only occur when decomposition has taken place.

The acidity of the urine sometimes increases after emission, by a process of acid fermentation, which has been carefully studied by Scherer. This change favours the deposition of uric acid, the urates and oxalate of lime. Confervæ may also appear under this condition of increased acidity.

When urine is examined, it is very important to observe its physical proper-

* Urinary Deposits.—Dr. Golding Bird.

ties, more especially its odour, colour, consistence, reaction, density, and also its quantity.

Odour.—Ammoniacal urine is readily recognized by its odour. Diabetic urine has a peculiar sweetish smell. Turpentine, taken by the mouth, communicates to the urine the odour of violets; while other drugs, such as cubebs, &c., and some foods, such as asparagus, can be detected in the urine by their peculiar odours. The odour of urine containing cystine is thought to resemble that of the sweet-briar.

Colour.—Concentration serves to intensify the natural colour of the urine; when the urine is diluted, as in hysteria, it becomes pale and often exhibits a faintly greenish tint. Dr. Schunk has shown that the colour of urine is due to two different extractives.* A rose coloured pigment has been described by Bird, who gave to it the name of *purpurine.* This pigment is found only as the result of disease, and it is often seen

* A practical treatise on urinary and renal diseases.—Dr. Roberts.

in fevers and diseases of the liver. It has been called *uro-erethine* by Heller and Simon. Purpurine is very soluble in water, and it never occurs as a deposit; it has a great affinity for the urates, to which it often gives a beautiful pink or carmine tint. In jaundice, the urine is coloured by bile, which causes it to assume an olive green, blackish green, saffron, or dark orange appearance. Blood, when present in any considerable quantity, gives to the urine a reddish colour, or it may occur as a deposit resembling coffee-grounds; when blood is present to a slight extent only, the urine may appear like the "washings of flesh," it may present a dingy, smoky hue, or it may have a dull, pinkish colour.

Logwood, taken by the mouth, communicates a red colour to the urine; chimaphila and pereira are said to sometimes give it a brown colour; while creasote and carbolic acid, taken internally, have caused the urine to assume an almost blackish tint. Rhubarb may colour the urine yellow, reddish-yellow, or even blood-red. The *cyanourine* of Braconnot has been seen on rare occasions in the urine, giving it a deep blue colour, and forming a blue deposit.

Consistence.—The readiness with which urine froths on agitation is more or less a measure of its viscidity. In viscid urines, the bubbles remain on the surface, towards the sides of the glass, for a considerable time, as in diabetes mellitus and albuminuria.

Reaction.—The changes which occur in the reaction of the urine after a meal, and the effect of decomposition, in increasing the acidity or producing alkalinity, have been already alluded to. The urine of herbivorous animals is alkaline and opaque, but human urine is not easily rendered alkaline by the use of a vegetable diet.

Certain medicines have the power of influencing the reaction of the urine; a change to alkalescence is much more easily and certainly produced than an increase in the acidity. The urine is rendered more acid by the administration of benzoic acid.* This drug appears in the urine as hippuric acid, in combination with a base. Carbonic acid and the mineral acids possess, perhaps, the power of slightly increasing the acidity of the urine. Alkaline medicines, especially potash salts, communicate, when given in sufficient doses, an alkaline character to the urine. Alkaline salts containing a vegetable acid are excreted by the urine as carbonates, the change being effected by the oxidation of the salt. Dr. Roberts states that from 300 to 400 grains of the bicarbonate of potash, given daily in divided doses, are sufficient to keep the urine alkaline in an adult, and that by this means it may be safely maintained in that condition for weeks.

In disease, urine may be alkaline from the presence of either *fixed* or *volatile* alkali. To distinguish between these two conditions, it is merely necessary to dip a piece of reddened litmus paper into the urine and afterwards expose it to a gentle heat. If the alkali be fixed, the

* Dr. Farre's edition of Dr. Pereira's Manual of Materia Medica.

blue colour remains, if the alkalescence be due to ammonia, the red colour is restored. When the urine is ammoniacal, it is usually so from decomposition, and some local affection of the urinary organs, especially of the bladder, is generally present. Mere retention of urine in the bladder is scarcely sufficient to develop the alkaline change, unless there be some diseased condition of the mucous membrane. The ammonia produced under such conditions irritates the surfaces with which it is in contact and so perpetuates the local mischief. Alkalescence from fixed alkali is occasionally observed. I have seen it after rheumatic fever in debilitated subjects. Such a condition is indicative of weakness and feeble nutrition. Graves, Roberts, and Bird have occasionally observed the urine to be alkaline from volatile alkali when secreted. This rare condition is always diagnostic of serious danger and great prostration.

Specific gravity or Density. — The specific gravity of urine is best measured by pouring some of the fluid into a suitable glass vessel, and placing in it the instrument called the urinometer, hydrometer, or gravimeter. By specific gravity is *meant the weight of a body in relation to its bulk.* For solids and liquids the standard is distilled water at the temperature of 15·5°C. (60° Fahr.) The stem of the urinometer is usually graduated from 0 up to 60. When floating in distilled water, the instrument sinks to 0; if, when it is placed in a vessel containing urine, the degree 20 is on a level with the surface of the fluid, the specific gravity of the urine is said to be 1020. This indicates that 1020 grains of the urine occupy the same space as 1000 grains of distilled water.

In health, the specific gravity of the urine usually ranges from 1015 to 1025, but these limits are by no means absolute. The density of the urine is liable to considerable variation during the day, being greatly diminished by copious potation. The specimen for examination should be taken from a mixture of the entire twenty-four hours' urine, otherwise serious errors may be made; I have known the specific gravity of healthy urine reduced to 1002 by taking a few cups of tea.

Tables have been drawn up by Christison, Henry, Becquerel, and others, calculating the quantity of solid matter in the urine from the specific gravity. This method, however, is by no means to be perfectly depended upon; where accuracy is sought, it can never supersede the laborious but much more reliable process of evaporation. It is seen, from these tables, that by doubling the last two figures of the specific gravity we get, very nearly, the parts per thousand of solid matter in the urine. Taking, for example, the density at 1025, this would give 50 grains of solids in 1000 grains of urine. According to Christison's tables, 1000 grains, sp. gr. 1025, contain 58·25 grains of solids. The last two figures of the specific gravity pretty nearly indicate the grains of solids in one ounce of the urine. From the table, for example, we learn that, when the density is 1025, the solids are in the proportion of 27·9 grains in the ounce.

The density of the urine in saccharine diabetes varies, according to Becquerel, from 1030 to 1074. From a large number of observations, I find the average specific gravity to be 1043. In chronic Bright's disease the specific gravity of the urine is, as a rule, diminished, ranging from 1005 to 1020. This generally occurs when the quantity is comparatively large; when the urine is less copious, the density may be much higher. In a case of chronic albuminuria, the daily average of urine being 23 ounces, I have seen the density as high as 1039. Mental emotion or anxiety, or a paroxysm of hysteria, may give rise to the copious secretion of pale urine of low density. The specific gravity usually ranges from 1002 to 1008 in diabetes insipidus.

Optical Characteristics. — Bouchardat has applied the action of saccharine urine on polarised light to the detection of diabetes mellitus.

Quantity.—The quantity of urine is greatly increased in diabetes insipidus, and also in diabetes mellitus. I have known 500 ounces of urine passed in a day in diabetes insipidus. There is frequently a temporary excess of urine in various diseases ; mental emotion, fright, and hysteria often greatly increase the quantity of the secretion. When the kidneys are small and contracted, as in one variety of chronic Bright's disease, the quantity of urine is usually increased. The urine is scanty in fevers, congestion of the kidneys, acute Bright's disease, and in cases of "large white kidney." The urine is often diminished in dyspepsia, markedly so in the subjects of sarcinous vomiting.

CHAPTER X.

URINARY DEPOSITS.

URINARY deposits may be examined by the aid of the microscope, and by this means they may usually be easily distinguished, but it is often necessary also to employ chemical tests; the naked-eye appearances of many deposits are almost characteristic. The urine should be set aside in a tall cylindrical glass so that the sediment may fall; when the deposit is small in quantity, a considerable amount of urine must be also collected. The clear supernatant fluid may be poured off, and the remainder placed in a smaller glass; in this way a sufficient amount of deposit for examination may be usually obtained. To further facilitate the collection of the deposit, conical glass vessels may be used. When it is remembered that the urine undergoes important changes on keeping, the necessity of an early examination need hardly be insisted upon.

For the purpose of microscopic examination, a little of the urine containing the deposit may be removed by a pipette, and a drop allowed to fall upon a slip of glass. The drop should be covered by a slip of thin glass and gently pressed; the superfluous fluid, if there be any, may be removed by blotting-paper or by a cloth. Urinary deposits, with one or two unimportant exceptions, can be examined in a manner satisfactory for all practical purposes with a quarter of an inch objective.

All substances which interfere with the natural transparency of the urine may be considered as deposits. Cool healthy urine generally contains a slight cloud of mucus and broken down epithelial scales. A *sediment* is found at the bottom of the vessel, a *cloud* is suspended at varying heights in the fluid, while a *pellicle* floats like a scum on the surface. " La partie plus ou moins solide et pesante qui forme un dépôt quelquefois assez épais au fond du vase, se nomme *sédiment*, *hypostasis* des Grecs, *subsidentia*, *residentia*, *sedimenta*, *subjecta* des Latins."* Deposits

* Gintrac, Pathologie interne, tome premier.

may not appear until after the urine has cooled; this is more especially the case with the amorphous urates, which are soluble by heat alone. Some deposits, such as oxalate of lime and triple phosphate, may adhere to the sides of the glass or remain suspended in the urine as minute, glistening particles.

Deposits consist of the normal constituents of the urine, thrown down because existing in excess, or because the conditions of their solubility are not fulfilled, and of new substances which do not occur in normal urine. Most of the former are inorganic and ingredients of healthy urine, while most of the latter are organic and appear only as the result of disease.

The following form urinary deposits:—Urates of soda, potash, ammonia, and lime; uric acid; triple and amorphous phosphates; oxalate of lime; carbonate of lime; leucine; tyrosine; xanthic oxide; cystine; various casts of the uriniferous tubes; epithelial cells; pus; blood corpuscles; spermatozoa; various fungi; mucus; oil globules; cancerous matter, &c.

The deposits may be divided into two classes, the *inorganic* and the *organic*.

Uric Acid.— $H_2C_5H_2N_4O_3$. Synonyms, Lithic acid; urylic acid. Prout stated that uric acid does not exist in the free state in the urine, but that it is found as urate of ammonia. Liebig thinks that uric acid exists as urate of soda. Uric acid is often found as an urinary deposit, uncombined with a base.

Uric acid is always deposited in the crystalline condition. The crystals vary considerably in colour, being pale fawn, yellow, orange, or orange red. Occasionally the crystals are aggregated in the deposit, appearing to the naked eye like "grains of cayenne pepper." Uric acid is very insoluble in cold water, requiring, according to Brande and Taylor, 10,000 parts to dissolve it, 15,000, according to Roberts. It is soluble in about 1850 parts of boiling water. It is insoluble in alcohol and ether. Uric acid is soluble in liquor potassæ, heat being often also necessary. It is not affected by hydrochloric and acetic acids. Nitric acid dissolves it with effervescence. When urine containing this deposit is warmed, the uric acid is not dissolved; but it becomes more evident, from the solution by the heat of the urates which are often found in conjunction with it. Bird spoke of this method as the best mode of discovering this deposit. If a drop of nitric acid be added to urine, crystals of uric acid usually become deposited.

If a little uric acid is carefully heated in a porcelain dish or on a slip of glass and moistened with a drop or two of nitric acid, it dissolves with effervesence, and a red residue remains. On adding a drop of solution of ammonia, when the dish has cooled, a beautiful crimson colour results, owing to the production of *murexid*, the purpurate of ammonia of Prout, the ammonic purpurate of later authors. A drop of caustic potash deepens the colour and changes it to violet, which disappears on the application of heat. The murexid is formed by the action of ammonia on alloxan, a product of the oxidation of uric acid by the action of nitric acid. The formation of murexid in the way described is quite characteristic of the presence of uric acid: murexid derives its name from *murex*, a shell-fish, the reputed source of Tyrian dye.

The shape of a typical crystal of uric acid is a rhombic prism, but this is not so frequently met with as the various modifications of this primary form. Diamond-shaped laminæ, flattened cylinders, cubic plates, thick lozenges, ovoids, and halbert-shaped crystals are often seen. Modified crystals frequently aggregate to form beautiful stars; many other shapes are sometimes discovered.

Uric acid, according to Bird, may be traced to two great sources, viz.: the disintegration of the tissues and to nitrogenised food. It must not be forgotten that the acid urinary fermentation may determine the deposition of uric acid.

Urine depositing uric acid always has an acid reaction, and its specific gravity is generally rather high. Sediments of uric acid are common in children, when the density of the urine is often very low.

Uric acid is increased in amount and frequently occurs as an urinary deposit in acute diseases, in diseases of the heart and liver, in rheumatism and gout, during the paroxysm of intermittent fevers, in leucocythemia, and in some forms of dyspepsia. Uric acid is diminished in adynamic states, and during a paroxysm of gout. It must always be remembered that the existence of this acid, as a deposit, does not necessarily indicate its increased excretion.

Urates.—Uric acid is dibasic. Deposits of urates consist of urates of soda, ammonia, lime and magnesia.* They have been called *lateritious deposit*, amorphous lithates, nut-brown sediment, &c. " Every deposit which disappears on the application of heat consists of uric acid in combination with various bases."† Urates may be white, fawn-coloured, or brick-red. They are frequently coloured pink by purpurine. Urates, with the exception

* I do not say "potassic urate," "magnesic urate," &c., because the new nomenclature is not as yet generally used by medical writers in the description of urinary deposits.

† Odling, Practical Chemistry.

of urate of soda, are never deposited until after the urine has cooled. When a sediment of urates occurs in an urine-glass, a beautiful bloom forms on the sides of the glass, on a level with the upper surface of the fluid. By this peculiarity, says Dr. Roberts, the amorphous urates may be distinguished from all other urinary deposits by the unaided senses.

Urates are soluble in alkalies; and yield murexid when treated with nitric acid, heat, and ammonia.

Under the microscope, the amorphous urate appears as very minute granules; urate of ammonia appears as spheres, amorphous granular masses, or as very minute dumb-bells. The production of urate of ammonia is favoured by ammoniacal changes in the urine, the result of decomposition.

Urate of soda sometimes occurs in the urine during gout, and in the febrile states of children. Bird saw it in the urine of feverish patients who had been treated with carbonate of soda. It forms a white sediment even when the urine is warm, and often gives to the urine of children a milky appearance. It appears as "hedge-hog crystals," little globular masses covered with spiny prolongations. Urate of soda does not disappear so readily as the other urates when the urine is warmed.

Urates indicate increased tissue change, an acid reaction of the urine, together with more or less concentration.

Phosphates.—Acid phosphates of soda, ammonia, lime, and magnesia exist in healthy urine. About $6\frac{1}{2}$ grains of phosphoric acid, according to Bird, are thrown off by the kidneys in twenty-four hours. Liebig is of opinion that the acidity of the urine is wholly due to the presence of the acid phosphates; other authorities think that free acids, such as lactic, oxalic, &c., share in the production of the normal acid reaction. Phosphates are derived from animal and vegetable foods, and from the disintegration of tissues, being especially furnished by the brain, the nerves, and by the bones.

Phosphates frequently form an urinary deposit, and this has been called "white gravel," "mixed phosphates," "fusible matter," &c. The occurrence of this deposit does not necessarily indicate an increase of the phospates in the urine, for its appearance is generally due to an alkaline reaction of the urine, arising usually from the presence of ammonia, the result of decomposition.

The earthy phosphates which appear in the urine as deposits are the ammoniaco-magnesian or *triple phosphate*, and the *amorphous phosphate* of lime. Dr. Roberts, Dr. Beale and others, give also, on the authority of Dr. Hassall, the *crystallized phosphate of lime.* Phosphates form a bulky white deposit, which may, however, be coloured by blood. They are readily diffused through the urine by agitation, but this diffusion is prevented when mucus and pus, which frequently coexist with the phosphates, are also present. The reaction of the urine is generally alkaline, but an acid reaction is not incompatible with the occurrence of this deposit. Boiling the urine serves to further aggregate the sediment, Phosphates are soluble in acids, insoluble in alkalies. The earthy phosphates sometimes remain diffused through the urine ; they occasionally form a beautiful iridescent pellicle on the surface, or the triple phosphate may appear as brilliantly glittering specks suspended throughout the fluid. Healthy urine becomes turbid when ammonia is freely added to it, from the deposition of the triple and amorphous phosphates.

Amorphous phosphate of lime, or bone earth, has the composition, $Ca_3 2 P O_4$. It forms a very opaque and white deposit, and may exist alone when the urine is alkaline from the presence of fixed alkali. It presents under the microscope a finely granular appearance.

The triple phosphate, $Mg H_4 N, P O_4 6 H_2 O$, generally predominates in the phosphatic deposit. Examined microscopically, it is found to consist of exceedingly well-defined triangular prisms, with the ends bevelled, obliquely truncated, or replaced by terminal facets. Sometimes the triple phosphate assumes a feathery or foliaceous appearance, and occasionally the crystals are somewhat shuttle-shaped.

The crystallized phosphate of lime, $Ca H P O_4$ exists as small prisms or rods, aggregated together in bundles, or forming beautiful stars or rosettes.

The condition of the body in which a deposit of phosphates occurs in the urine, was called the *phosphatic diathesis* by Prout. But this term is likely to lead to error; it is now generally thought that there is no special state which leads to the increased excretion of the phosphates and their appearance as an urinary deposit. The earthy phosphates are deposited in various adynamic conditions and in certain cases of dyspepsia. They frequently appear in disease of the bladder and prostate, as the result of alkaline changes in the urine, due to the production of carbonate of ammonia from the decomposition of the urea. Mr. Curling thinks the bladder sometimes secretes an unhealthy mucus, which influences the reaction of the urine and so determines the deposition of the phosphates. The effect of the alkaline change in putrescent urine must never be forgotton. A clear knowledge of the conditions of solubility of the earthy phosphates, has done much to deprive their appearance as an urinary deposit of any special clinical significance.

"Phosphorus uncombined with oxygen appears, like sulphur, to be excreted in the urine (Ronalds), and it is said that the quantity is sometimes so large as to render objects dipped in the urine luminous in the dark."* Urine presents, says Gintrac, in some rare cases, a momentary phosphorescence. This has also been observed by Jurine and Pictet.†

Oxalate of Lime.—(Calcic oxalate; oxalate of calcium.) Dr. Golding Bird first established the frequency of the appearance of oxalate of lime as an urinary deposit. He said, "the oxalate is of far more frequent occurrence in urine than deposits of earthy phosphates." Dr. Aitken states that "the deposit occurs in one out of every three cases, taking the cases as they occur in an hospital."

Crystals of oxalate of lime have nearly the same specific gravity as ordinary urine, consequently they frequently

* Dr. Kirke's Handbook of Physiology.

† Journal général de Sedillot.

remain diffused through the urine for days, although they sometimes form a scanty deposit. The crystals often adhere in fine glistening lines on the sides of the urine glass. A large quantity of epithelium often accompanies the oxalate, and frequently serves to render the urine somewhat cloudy. Bird sometimes found octohedra of oxalate of lime crystallized on a hair in the urine, like sugar-candy on a string. If care be not taken, the presence of oxalate of lime in the urine may be overlooked altogether. To detect the deposit, pour off the upper portions of the urine that has been standing for some time, and warm the residue. The heat, by rendering the fluid specifically lighter, induces the deposition of the oxalate, and this is further favoured by giving the glass a rotatory motion. After the urine has been allowed to stand for a few minutes, pour off the greater portion of the fluid, and replace it by distilled water. A white glistening deposit of crystals of oxalate of lime now becomes apparent.*

* Dr. Bird.—Urinary Deposits.

Oxalate of lime occurs in the urine as octohedral crystals and as dumb-bells; sometimes as small, flattened discs or ovoids, which are easily mistaken for blood corpuscles.

The octohedra vary considerably in size. They are often very minute, and they frequently continue to grow considerably larger for some time after the urine has left the bladder. One axis of the octohedron is shorter than the other two. The crystals may be seen lying in various positions; by making them roll over in the field of the microscope all the different appearances may be seen. The opposite angles of the crystals very often appear to be joined by lines, assuming the form of a cross. When the crystals are examined microscopically, in the dry condition, they appear as black cubes, containing a bright square centre, with its angles directed towards the sides of the darker portion.

The dumb-bells are sometimes found together with the octohedra. They are oval in shape, with a thinned, transparent centre, and appear "like two kidneys with their concavities opposed." The dumb-bells, unlike the octohedra, do not increase in size after the urine is voided. Dr. Beale says the crystals may be found in the kidney. It must be remembered that oxalate of lime sometimes occurs in a dumb-bell form, that spherules of urate of ammonia often join and assume a similar shape, and that deposits of uric acid and phosphates have been occasionally seen as dumb-bells.

Crystals of oxalate of lime are insoluble in potash, alcohol, ether, water, and the vegetable acids; they are soluble, without effervescence, in nitric and hydrochloric acids. When exposed to a red heat, they become changed into carbonate of lime.

The specific gravity of urine containing oxalate of lime varies, according to Bird, from 1009 to 1030. The reaction of the urine is always acid, often highly so. Sometimes uric acid and the urates co-exist in the deposit, and in rare instances the triple phosphate is also found.

A large number of substances used as foods, but more especially rhubarb and sorrel, contain oxalic acid; lime exists in hard water.

Liebig and Wohler have shown that uric acid is easily changed by oxidation into oxalic acid. Starch, gum, sugar, &c., also yield oxalic acid when oxidized. Dr. Garrod has detected oxalic acid in the blood in albuminuria and gout, and he attributes its presence to the oxidation of uric acid.* Dr. Roberts says, "oxalic acid constitutes probably one of the penultimate stages in the series of decomposition through which the effete tissues pass preparatory to their final exit from the body."

Dr. Prout gave the name *oxalic acid diathesis* to that condition of the body in which oxalate of lime appears in the urine. Dr. Bird elaborately considered the symptoms accompanying the excretion of oxalic acid. He said:—"As a general rule patients affected with the disease under consideration are generally remarkably depressed in spirits, and their melancholy aspect has often enabled me to suspect the presence of oxalic acid in the

* Dr. Garrod.—Gout and Rheumatic Gout.

urine. They are generally much emaciated, excepting in slight cases, extremely nervous, and painfully susceptible to external impressions, often hypochondriacal to an extreme degree, and in the majority of cases labour under the impression that they are about to fall the victims of consumption."

More recent observation does not lead us to ascribe any particular set of symptoms to the occurrence of oxaluria. The appearance of oxalates in the urine is a sign, of little value by itself, of many various pathological states.

The variety of calculus named "mulberry" is composed of oxalate of lime.

Cystine. — $C_3H_6NO_2S$. — Cystic Oxide. Cystine was first discovered by Dr. Wollaston in a calculus. It is not a constituent of healthy urine. Calculi composed of cystine are extremely rare. It is interesting to note that these calculi have been found in dogs. Cystine may exist as an urinary deposit; it is found more frequently as a calculus than as a deposit. Cystine contains, according to Professor Miller, 25·5 per cent. of sulphur.

Cystine forms a whitish or fawn-coloured deposit, which may be easily mistaken for a sediment of urates. This deposit is not dissolved when the urine is warmed. It is insoluble in the vegetable acids, but it is soluble in the mineral acids and in alkaline solutions. It is freely soluble in ammonia; by the spontaneous evaporation of the solution characteristic hexagonal plates of cystine may be obtained. Its behaviour with ammonia is perfectly characteristic. Cystine is distinguished from the earthy phosphates by its insolubility in dilute hydrochloric acid; it must be remembered that cystine is soluble in strong hydrochloric acid. Cystine is insoluble in water, alchohol, and ether; it is suspended in the urine, and renders it turbid until it has stood a sufficient time for deposition to take place. The sulphur of the cystine may combine with the lead of the urine glass and produce a black colour. The urine may be neutral, or faintly acid, and it is extremely liable to the ammoniacal changes of decomposition. Various observers have concurred in describing the odour of urine containing cystine as resembling that of sweet-briar; Dr. Bird spoke of the occasional appearance of a fœtid odour, due, he believed, to the development of sulphuretted hydrogen.

Cystine appears under the microscope as regular six-sided plates, which may be regarded as shortened prisms. It is never amorphous. The laminæ of cystine form attractive microscopic objects, they very frequently exhibit a beautiful iridescent, mother-of-pearl-like brilliance. Several crystals are often aggregated, forming rosettes, or the plates may be placed upon each other in little piles. Cystine is occasionally observed in prisms, which may be grouped together to form stars.

Common salt sometimes crystallizes from urine in six-sided plates, and some of the artificial forms of uric acid resemble cystine.*

Notwithstanding the large percentage of sulphur contained in cystine, the internal administration of sulphur, even in large doses, has not been observed to

* My friend, Mr. Stokes Dewson, has kindly shown me hexagonal microscopic crystals of sulphocyanide of potassium, exactly resembling plates of cystine.

lead to the appearance in the urine of the deposit under consideration. Cystine has been observed to persist for a long period in the urine, especially in scrofulous patients, without any great impairment of the general health; one of the most remarkable facts connected with this curious deposit is its undoubted tendency to occur as the result of hereditary predisposition. Dr. Prout considered that cystine bore some relation to fatty degeneration of the liver, and Dr. Aitken says it is generally associated with functional or organic disease of that organ. When cystine is discovered in the urine, it serves to indicate a tendency to the formation of the cystine calculus.

Xanthine. $C_5H_4N_4O_2$ Synonyms. Xanthic oxide; Uric oxide; Urous acid. Xanthine is sometimes met with, but very rarely, forming an urinary calculus. Bird thought he once met with it as an urinary deposit. Xanthine was discovered by Dr. Marcet as a small calcubus, weighing eight grains. Langenbeck removed a stone weighing 338 grains, which was found to consist of xanthine. This rare substance has been generally found in the urine of children. When xanthine is rubbed, it aquires a waxy lustre. Xanthine differs from uric acid in containing less oxygen. It is soluble in nitric acid without effervescence, and the solution leaves a yellow residue on evaporation. It is freely soluble in alkalies.

Leucine and *Tyrosine* have been found in the urine by Stædeler and Frerichs, in patients suffering from acute yellow atrophy of the liver, typhus and typhoid fevers, and smallpox. Leucine has the composition, $C_6H_{13}NO_2$, it is viewed as amidocaproic acid by Professor Miller; Tyrosine has the composition, $C_9H_{11}NO_3$. Leucine crystallizes in spherical masses, which exhibit a radiated arrangement.* Tyrosine occurs in long, needle-shaped, fibrous crystals, and these are often grouped together in bundles or brush-like masses. Tyrosine may form a greenish deposit in the urine. The detection of these bodies is favoured by the evaporation of the urine. Leucine and tyrosine are products of the

* Beale. The Microscope in Medicine, 3rd Edit.

disintegration of the nitrogenous tissues of the body.*

Carbonate of Lime may occur together with the earthy phosphates, when the urine is very alkaline from carbonate of ammonia. It is amorphous, and soluble in dilute acids with effervescence. It is often seen in the urines of herbivorous animals, from which it may be obtained in transparent, globular spheres, and 'cornucopia-like' crystals.

* For a full account of the chemistry of leucine and tyrosine, reference may be made to the 3rd vol. of Professor Miller's Elements of Chemistry.

EXPLANATION OF PLATE II.

Inorganic Urinary Deposits.—a. Uric Acid. b. Phosphates. c. Oxalates. d. Cystine. e. Leucine. f. Tyrosine.

CHAPTER XI.

ORGANIC URINARY DEPOSITS.

Casts of the Uriniferous Tubes.—First in importance among organic urinary deposits are tube-casts, casts of the uriniferous tubes, found in the albuminous urine of patients suffering from organic disease of the kidney. It is essential to distinguish the different kinds of these casts, and to be able to appreciate the pathological changes of which they are indicative. An accurate knowledge of these deposits is necessary for the exact diagnosis of many renal diseases, and without such knowledge no reliable prognosis can be given. The whole subject has been carefully investigated by Dr. George Johnson, who has clearly classified the varieties of casts, and pointed out their several pathological significations.

The urine tubes of a healthy kidney are about $\frac{1}{700}$th of an inch in diameter; they are lined with nucleated epithelial cells, spheroidal in form, and lying in a single layer upon the basement membrane. The nucleus is round, and its diameter varies from $\frac{1}{4000}$th to $\frac{1}{3000}$th of an inch. It is surrounded with finely granular matter, and, in the convoluted tubes, a distinct cell wall cannot always be seen. The nucleus may be perfectly free. In the straight tubes, the epithelium is flatter and more squamous, the cell wall being very distinct. Renal epithelium is only found in the urine as the result of disease.

"A cast consists of a mould of a uriniferous tube, and is composed of some transparent material which is formed in, or poured out into, the canal, and there rendered firm, entangling in its meshes whatever may be in the tube at the time of its effusion." * Dr. Johnson classifies casts in the following manner: epithelial casts; large waxy casts; small waxy casts; granular casts; oily casts; bloody casts; purulent casts. Dr. Beale considers it convenient to divide tube casts into three classes, according

* Beale.—Microscope in Medicine.

to their diameter:—1, Casts of medium diameter; 2, Casts of considerable diameter; 3, Casts of small diameter.

Epithelial Casts. — These are also called desquamative casts, and consist of tubes or moulds of coagulable matter, exhibiting epithelial cells contained or entangled in, or adherent to, the transparent material. The cells are rarely perfectly normal in appearance, but, while maintaining generally their characteristics, they are usually more or less disintegrated. These casts measure about $\frac{1}{700}$th of an inch in diameter, and may be said to be of medium size.

"Opaque granular" casts contain disintegrated epithelium.

Waxy Casts.—These casts may be large or small. They are clear, transparent, glistening cylinders, and may be invisible until tinted by means of iodine. Sometimes they may be slightly granular, especially the larger ones, and they may contain a few epithelial cells. Dr. Johnson thinks the diaphanous material of these casts is secreted by the basement membrane of the uriniferous tubes, after the destruction and disappearance of the epithelial cells. Dr. Hughes Bennett suggests it may consist of the basement membrane itself. Small waxy casts have a diameter of about $\frac{1}{1000}$th of an inch, and do not generally exhibit any granular appearance. These latter are the *hyaline casts* of Barham and Vogel. Fatty and epithelial casts may co-exist with the waxy casts.

Fatty Casts.—These casts may appear as tubes filled with minute oil globules, and sometimes epithelial cells may be seen, more or less fattily degenerated, containing numbers of oily particles.

Tube casts may be observed filled with blood corpuscles, or with pus cells; the blood corpuscles may appear as if moulded into masses of cylindrical shape in the tubes of the kidney.

Deposits containing renal epithelium and tube-casts generally appear cloudy and flocculent to the naked eye.

Tube-casts may be generally said to indicate organic disease of the kidney, and the various forms of casts have different significations, both as regards diagnosis and prognosis. Epithelial casts and blood casts indicate acute disease: granular casts indicate sub-acute or chronic disease: waxy casts indicate a chronic disease, leading to serious textural changes in the kidney: fatty casts, frequently found in conjunction with the waxy, indicate fatty degeneration of the kidney: pus casts have been found in cases of multiple abscesses of the kidney.

No inferences must be drawn from the appearances of a small number of casts; our conclusions must be based, after repeated examination of various specimens of the urine, upon the general characters of the prevailing types seen in the deposit.

Extra-renal Epithelium. — Epithelial cells found in the urine may be derived from any part of the genito-urinary mucous membrane. The cells are often more or less disintegrated; they are frequently seen almost entire.

The epithelium of the pelvis of the kidney is tesselated, and the cells of this region are triangular or caudate. The epithelium of the ureter consists of several layers of cells, at the free and attached surfaces the cells are rounded, in the intermediate strata they are columnar (Ellis). The superficial epithelial cells of the bladder are flattened, and the deeper are columnar (Kölliker). These cells may be seen in the urine of patients suffering from vesical or renal calculus, or in cases of pyelitis, inflammation of the pelvis of the kidney. Dr. Roberts says that many of the epithelial cells of the bladder, ureter, and pelvis of the kidney closely resemble cancer-cells and may be easily mistaken for them.

The epithelial cells of the urethra are columnar, but they become scaly towards the orifice. Urethral and prostatic epithelium, oval, flattened, or caudate cells, are frequently seen in the urine, especially after gonorrhœa.

Mucus in the urine may appear as a flocculent cloud, as whitish flakes, or as a tenacious and viscid deposit of stringy or ropy consistence. The urine is frequently alkaline, and it is extremely liable to become putrescent.

In females, the characteristic epithelial cells of the vagina are frequently found in the urine. By their presence the sex of the patient furnishing the urine may be distinguished. The cells are large and flat, and resemble, but are larger than, the epithelial cells of the mouth. They may appear singly, or may be seen united by their edges. Vaginal leucorrhœa is an abundant source of these cells in the urine, and they may be furnished by the discharge from the more external portion of the vagina, which so often occurs in scrofulous children.

Spermatozoa.—Sometimes a few spermatozoa may be seen in the lower strata of the urine of healthy men. When semen is present in small quantity, it forms a deposit closely resembling mucus. When present in large quantity, it may render the urine opalescent, or appear in viscid flakes and masses as an urinary deposit. The spermatozoa consist of a rounded head, $\frac{1}{10,000}$th of an inch in diameter, to which is appended a tail-like filament. For a short time after emission, they may exhibit some degree of movement, but urine seems quickly to put a stop to this, and they are generally motionless when seen in deposits. It must be remembered that spermatozoa are not "minute beings," but, as Kölliker has shown, merely cell contents. They may be detected unchanged long after the urine has become putrescent. A high power is required for their demonstration. Vibriones, minute vegetable growths, may sometimes be mistaken for spermatozoa.

After coitus, spermatozoa may be seen in the urine both of the male and female. A slight discharge of semen may appear in the urine of men after the passage of hard fæces, and semen may collect behind a stricture and be expelled, mixed with urine. Involuntary nocturnal emissions may give rise to the appearance of spermatozoa in the urine.

"Spermatorrhœa means, strictly, the discharge of semen without the occurrence of the orgasm."* When spermatozoa *persistently* appear in the urine,

* Flint, Practice of Medicine, Philadelphia.

together with other symptoms, general and local, a condition of disease may be considered to exist. But the whole subject of spermatorrhœa has been much misrepresented by unprincipled quacks, who terrify their feeble victims by exaggeration and falsehood, and dupe them into believing their lying prognostications of consumption, insanity, and death.

Fatty Matter.—Minute globules of oil may be seen, lying free in the urine or enclosed in casts of the uriniferous tubes, indicating fatty degeneration of the kidney. Dr. Beale has detected cholesterine in this fatty matter. A disease, in which the urine is described as *chylous*, prevails endemically in some tropical climates; the urine is milky, and the appearance is due to the presence of fatty matter in a minute state of subdivision. Oil globules have been observed in the urine of patients taking cod-liver oil.

Kiestein.—This name has been given to a substance which has been described as existing in the urine of women during utero-gestation, and which has been considered by some authors as a minor sign of pregnancy. It has been described as resembling carded wool, or a cotton-like cloud. This cloud, in the course of two or three days, rises to the surface as a fat-like pellicle, which, after the lapse of a few days more, breaks up and sinks to the bottom of the vessel. The pellicle has never been observed to become mouldy, and it has been observed to contain triple phosphate, fat, and a peculiar caseous matter. The appearances described have been observed in the urine of women who were not pregnant.

Cancer Cells. Cancer cells have been found in the urine, chiefly in cases of cancer of the bladder and uterus; they may appear in malignant disease of any part of the urinary passages. It must be remembered that the epithelial cells of the urinary tracts may be easily mistaken for cancer cells, and it becomes in practice very difficult to distinguish them.

Confervoid Vegetations.—Various vegetable growths may be discovered in urine.

1. Sarcinæ. Sarcinæ have been occasionally observed in urine. They are probably produced in the bladder, and they are identical with the sarcinæ ventriculi of Goodsir. The sarcinæ consist of little square masses, either lying separate or aggregated into groups of four, eight, sixteen, or more cells, the mass having also a squarish contour. The sarcinæ seen in urine are generally smaller than those observed in vomited matters; they differ from other vegetations in being present in the urine when it flows from the bladder. All the other confervæ appear as the result of changes which occur in the urine on keeping.

2. Vibriones. Vibriones are frequently seen. They occur as minute linear bodies, about $\frac{1}{3000}$th of an inch in length. Active movements may be observed in these particles. The vibriones indicate putrefactive changes, and usually do not appear until after the urine has been kept some time; their production, however, is possible within the bladder in urine, which is undergoing decomposition.

3. Penicilium glaucum. Mould fungus. The penicilium glaucum is a species of the genus Mucedines. It consists of oval cells or sporules, mycelia of delicately interwoven and articulated filaments, and it presents a characteristic aerial fructification. "When the upper fertile layer is examined under the microscope, it is found to consist of pedicels terminating in a repeatedly but shortly bifurcated pencil, each ultimate branch of which bears a moniliform row of spores."*

4. Torula cerevisiæ. Torula Sacchari. Yeast fungus. Sugar fungus. The torula has but little filamentous mycelium, and it is distinguished from the penicilium glaucum by its aerial fructification. Instead of a group of branching pedicels, we find a globular head of aggregated sporules. The sporules of both fungi may fall to the bottom of the urine, and be mistaken for blood corpuscles.

Dr. Hassall has considered the growth of the torula cerevisiæ as a characteristic indication of the presence of sugar in the urine. While we may suspect sugar

* Micrographic Dictionary, Griffiths and Henfrey.

from its presence, and by observing that it grows abundantly in diabetic urine exposed to the air, it is by no means a sure indication of saccharine diabetes. The penicilium glaucum may also grow in diabetic urine. The torulæ cerevisiæ and penicilium glaucum are developed only in urine which has an acid reaction, an ammoniacal reaction infallibly arrests the growth of these plants. For their development, it is necessary that there should be exposure to air together with the presence of organic matter; the mould fungus grows well in albuminous urines, while the sugar fungus is luxuriantly developed in urines which are saccharine.

EXPLANATION OF PLATE III.

Organic urinary Deposits. a. Epithelial casts ; b. Fatty casts ; c. Waxy casts ; d. Vaginal epithelium ; e. Spermatozoa ; f. Penicilium glaucum ; g. Vibriones ; h. Torula cerevisiæ.

CHAPTER XII.

ALBUMEN, PUS, BLOOD, BILE, AND SUGAR IN THE URINE.

Albumen.—Albumen is not a constituent of healthy urine. The appearance of albuminous urine varies greatly; sometimes it is quite transparent, it is often opalescent, and it may be coloured by the presence of blood. The urine is generally somewhat viscid, so that the froth is retained, after the urine is agitated, longer than usual.

When urine containing albumen is heated, it becomes turbid, owing to the coagulation of the albumen. When the quantity of the albumen is large, coagulation takes place far short of the boiling-point, at a temperature of 60° C.; when a smaller quantity is present, a greater heat is required before turbidity is produced; when only a trace is present, the opacity is not exhibited until the urine has begun to boil. When the urine has its usual acid reaction, this coagulation forms a perfect test for albumen in urine. When the urine is alkaline, the albumen is not coagulated by heat, and it then becomes necessary to add a few drops of nitric or acetic acid. Heat, however, produces turbidity and a white precipitate in urine containing an excess of earthy phosphates. Such urine is alkaline, neutral, or feebly acid ; the precipitate of phosphates may be distinguished from coagulated albumen by the addition of a drop or two of any acid, the turbidity from phosphates disappearing and that due to albumen remaining unaffected.

When nitric acid is added to urine containing albumen, a characteristic white turbidity is produced. The test-tube should be inclined and the nitric acid carefully poured down the side, so that it may sink to the bottom, the urine forming a stratum above the acid. At the line of junction of the two fluids, an opalescence or opacity is produced by the coagulated albumen. When a drop of nitric acid is added to albuminous urine, coagulation of the albumen takes place; but, if the amount of albumen be very small, the turbidity disappears on agitation, and is restored by the further addition of the acid. It should be remembered that a great excess of nitric acid dissolves the precipitate of coagulated albumen. Occasionally, a little difficulty is experienced, owing to the production of turbidity by the precipitation of the amorphous urates by the nitric acid. But the urates are soluble by heat; a little experience suffices to enable the observer to distinguish this opacity, by the naked eye, from that due to the coagulation of albumen. Nitric acid frequently produces opalescence, when added to the urine of patients who are taking copaiba or cubebs. "If cold nitric acid be added to the urine of patients taking copaiba, a milkiness is produced, as from albumen, but this disappears when heat is applied; the turbidity is due to the separation of the copaivic acid, which melts and becomes transparent when the urine is heated."* Many chemical reagents coagulate albumen, but there are various objections to

* Materia Medica and Therapeutics, Dr. Garrod.

their use as tests for the detection of albumen in the urine. Nitric acid and coagulation by heat are the tests for albumen; of the two, nitric acid is the best and the least liable to lead to error, and, although in certain conditions of the urine, heat alone is sufficient, it is necessary in all doubtful cases to employ the two tests together.

Dr. Parkes distinguishes between *temporary* and *permanent* albuminuria. Temporary albuminuria occurs during the course of many diseases; a small quantity of albumen is often found in the urine in fevers and disorders of an inflammatory nature.

Permanent albuminuria may be due to congestion of the kidneys, the result of diseases of the lungs or heart, but, as a rule, it surely indicates disease of the kidney itself. Albumen sometimes occurs in the urine in cases of chronic poisoning by lead. The occurrence of albumen in the urine, it must be remembered, may possibly be due to the presence of some albuminous fluid, such as blood, pus, or semen. "When the urine is found albuminous," writes Dr. Roberts, "and there exists neither pyrexia nor thoracic disease, or other recognizable condition which can account for the albumen, the inference is almost irresistible that there exists primary organic disease of the kidneys."

Pus.—When pus is present in urine, it is merely suspended in the fluid, and the urine has, as a consequence, a more or less opalescent appearance when voided. If the reaction of the urine be acid, the pus settles at the bottom as a greenish yellow, creamy deposit, which can be easily diffused through the urine on agitation. If, however, the reaction of the urine be alkaline, as it frequently is when it contains pus, the appearance of the sediment is greatly changed, becoming viscid and very tenacious, resembling a deposit of mucus, and being incapable of diffusion by agitation.

If a deposit of pus be mixed with liquor potassæ, or with any strongly alkaline solution, it forms a gelatinous mass, which is often so viscid that it cannot be poured from the test-tube. Pus consists of corpuscles floating in an albuminous fluid; the urine containing pus yields, therefore, a trace of albumen. It is important to decide whether the amount of albumen in purulent urine is greater than can be accounted for by the presence of pus, or not. The occurrence in the urine of vaginal discharges may produce an appearance very much resembling pus.

Pus corpuscles are seen under the microscope as cells having a granular, opaque appearance, and these cells are larger than red blood corpuscles. If a drop of acetic acid be placed under the covering glass, the pus corpuscle clears up, and the nucleus, containing nucleoli, becomes visible. Ammonia readily dissolves white and red blood cells, while it scarcely affects pus corpuscles.

The pus may be derived from any portion of the genito-urinary passages. In pyelitis, the suppuration occurs in the pelvis of the kidney. Pus may also be derived from abscesses lying adjacent to the urinary apparatus, which have opened into the pelvis of the kidney or bladder. Pus, derived from distant suppuration, may burrow and find its way into the urinary passages. This has been observed even in cases of empyema. Pus is frequently seen in the urine of men suffering from gonorrhœa, when the urine is generally acid. When the pus is derived from the bladder, the reaction of the urine is usually alkaline.

Blood. Hæmaturia. When blood is mixed with urine, important colour changes are evident. When the blood is derived from the lower urinary passages, the urine has a pinkish red colour, and distinct *clots* may be often seen; when the blood is derived from the bladder, it frequently flows pure after the urine has been discharged. When the blood comes from the kidneys, it is diffused through the urine. Urine containing blood may have a port-wine colour, it may be pinkish, dingy, smoky, or sooty, and it may closely resemble "the washings of flesh." The urine has been said, by Rayer, to appear like *bouillon de bœuf*. A chocolate or claret-coloured deposit often falls down.

Blood corpuscles are easily recognized by the microscope. The blood cells are often seen as flat circles, an appearance due to the exosmosis of their contents, or they may be shrunken and present serrated margins. The corpuscles disappear when the urine is strongly ammoniacal. Sporules of confervæ may be mistaken for blood cells, but they may be generally distinguished by their nuclei. Discs of oxalate of lime sometimes look very like blood cells, but they may be usually recognized by the coexistence of dumb-bells.

The quantity of blood in urine is sometimes sufficient to lead to spontaneous coagulation. In hæmaturia, the urine is always and necessarily albuminous. When urine which is red from blood is boiled, it assumes a dirty slate colour, a change which is perfectly characteristic.

When blood comes from the kidney, tube-casts are generally also found in the deposit. When the blood is derived from the pelvis of the kidney, the hæmaturia is usually due to renal calculi, and long clots may be passed which have been moulded in the ureter. When the hæmorrhage is from the bladder, the urine often becomes more bloody as it flows, and there are usually symptoms indicating pretty surely the seat of the disorder. When the hæmorrhage is from the urethra, pure blood escapes without micturition.

The presence of blood in a solution may be detected by spectrum analysis. The beautiful absorption phenomena can be observed with delicacy and accuracy by means of a spectroscope, placed in connexion with a microscope.* Mr. Sorby states that a single drop of blood in a pint of urine can be detected by spectroscopic examination.†

Bile.—When bile is present in the urine, as in cases of jaundice, the colouring matter of the bile causes the urine to assume a dark yellow, orange, dark olive, or even almost blackish colour. If a few drops of the urine be placed upon a white plate, and a drop or two of nitric acid be allowed gradually to mix with

* Spectrum Analysis.—Professor Roscoe, 1869.

† Guy's Hospital Reports, 1870.

the fluid, a beautiful play of colours, passing through green, purple, and red, will be exhibited as the two fluids mingle. The urine may be placed in a test-tube and the nitric acid carefully poured down the side of the glass, so as to form a stratum under the urine; at the line of junction of the fluids, the play of colours is observed; the mixture assumes a bright green colour on agitation. If a drop or two of solution of iodine be placed in a test-tube, and a drachm or so of urine containing bile be added, the mixture, when agitated, will assume a fine emerald green colour. Dr. Hassall exposes the urine to the air for a few days, until crystals of triple phosphate are formed; if bile be present, the crystals have a yellow tinge.

The following is Pettenkofer's test for the detection of the biliary acids in the urine:—About a drachm and a half of urine is placed in a test-tube, and to this about one drachm of strong sulphuric acid is added, drop by drop. When the mixture is hot, a small piece of sugar is added, and in a few minutes a fine purple colour results, if the bile acids are present. This test is very unsatisfactory ; a reddish brown colour is produced by the action of the acid upon the sugar, even when bile is absent, especially when the urine is albuminous.

Sugar.—In the disease called diabetes mellitus, saccharine diabetes, glycosuria, or, by the nomenclature of the College of Physicians, diabetes, glucose or grape sugar appears in the urine. The urine is generally clear and pale; it is more viscid than in health. The specific gravity is high ; it may rise to 1070. The quantity of the urine is large, perhaps 150 ounces, or more, daily. Each fluid ounce of diabetic urine generally contains from 30 to 60 grains of sugar ; as much as 20 ounces of sugar may be excreted daily in the urine.

Various tests are in use for the detection of sugar in the urine.

1. Trommer's test. Some of the suspected urine is placed in a test-tube, and a few drops of a solution of cupric sulphate, just enough to give a faintly bluish tint to the mixture, are added.

Liquor potassæ must then be added in great excess, and the mixture must be boiled. If sugar be present, the yellow hydrated cupreous oxide, which soon changes into the red anhydrous cupreous oxide, falls down. Capezzuoli's test is somewhat similar to Trommer's.

2. *Moore's test.* This test, proposed by Mr. Moore of the Queen's Hospital, is the *liquor potassæ test.* It depends for its action on the conversion of the glucose of the diabetic urine into brown mellassic or sacchulmic acid. A little urine is boiled in a test-tube with an equal quantity of liquor potassæ; if sugar be present, the mixture assumes a dark brandy-brown or bistre tint. This test has the advantages of simplicity and easy application, but it is not very delicate.

3. Dr. Hassall has stated that the yeast plant or sugar fungus, torula cerevisiæ, is developed in saccharine urine, and that the growth of this plant is quite characteristic of the presence of sugar. But the penicilium glaucum may grow in diabetic as well as in other urines, and it is difficult to distinguish between the

sporules of the two plants. It is generally thought, too, that the torula cerevisiæ may be developed in urines which are not saccharine.

4. If a little yeast be added to diabetic urine and the mixture be kept in a warm place, fermentation takes place; carbonic acid and alcohol are produced, changes which are perfectly characteristic of the presence of sugar. The density of saccharine is lowered when it is fermented with yeast, owing to the destruction of the sugar and the presence of the resulting alcohol. Dr. Roberts estimates the quantity of sugar by observing the density of the urine before and after fermentation. He came to the conclusion, "that the number of degrees of density lost indicated as many grains of sugar per fluid ounce." Dr. Roberts calls this the "differential density method."

5. *Estimation of the quantity of the Sugar.*—Various modifications of Trommer's test have been made, for the purpose of ascertaining the exact amount of sugar present in a given quantity of diabetic urine. The quantity of the

copper salt reduced bears a direct relation to the quantity of the sugar. The following is Dr. Pavy's modification of Fehling's solution; 200 grains of the solution correspond to, and are decomposed by, one grain of sugar.

Sulphate of Copper. . .	320 grains.
Neutral Tartrate of Potash .	640 ,,
Caustic Potash. . . .	1280 ,,
Distilled Water . . .	20 fluid ozs.

In order to perform the analysis, 200 grains of the copper solution must be measured off, diluted with a little water, and heated to the boiling-point. The urine must be diluted to a known extent, and some of it placed in a burette graduated to grains. The diluted urine must be added from the burette, drop by drop, to the boiling test solution, until the blue colour is completely discharged. Suppose, the urine having been diluted by the addition of nine parts of water, 120 grains have been poured from the burette, 12 grains of the urine contain, in this case, one grain of sugar, and an ounce of the urine contains 40 grains of sugar.

"The urine of patients who have inhaled chloroform, when tested with sulphate of copper and potash, gives copious indication of the presence of sugar. The result, however, is not due to sugar but to chloroform. Traces of the latter substance in the urine cause a reduction of the oxide of copper in precisely the same manner as glucose."* If a few drops of chloroform be mixed in a test-tube with a little healthy urine, it will be found that the mixture gives rise to changes in the copper solution exactly similar to those which characterize diabetic urine.

The influence of a solution of glucose upon a ray of polarized light has been sometimes used as a test for sugar in urine.

* Journ. de Pharm. d'Anvers : Pharm. Journ. Feb. 1869.

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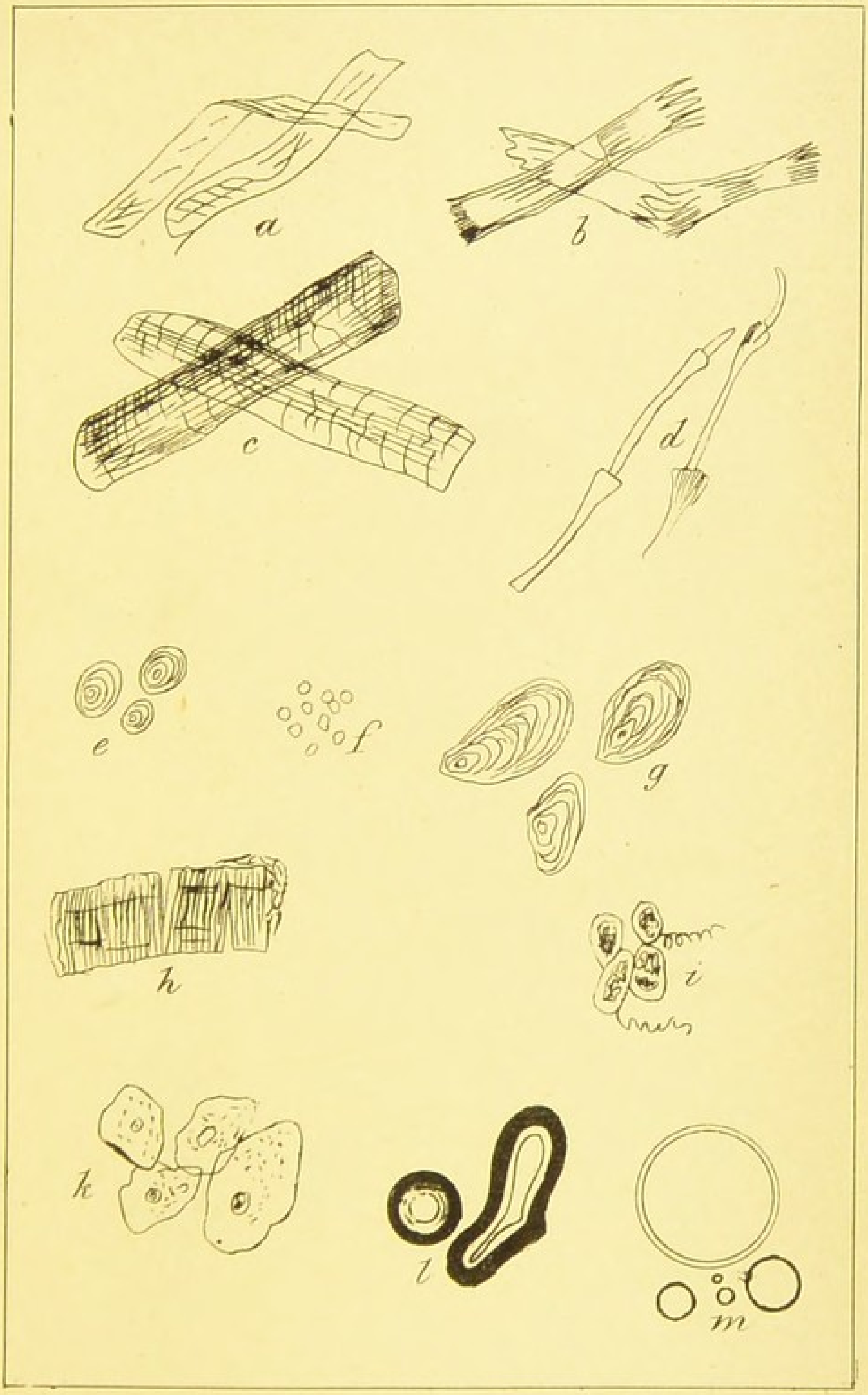
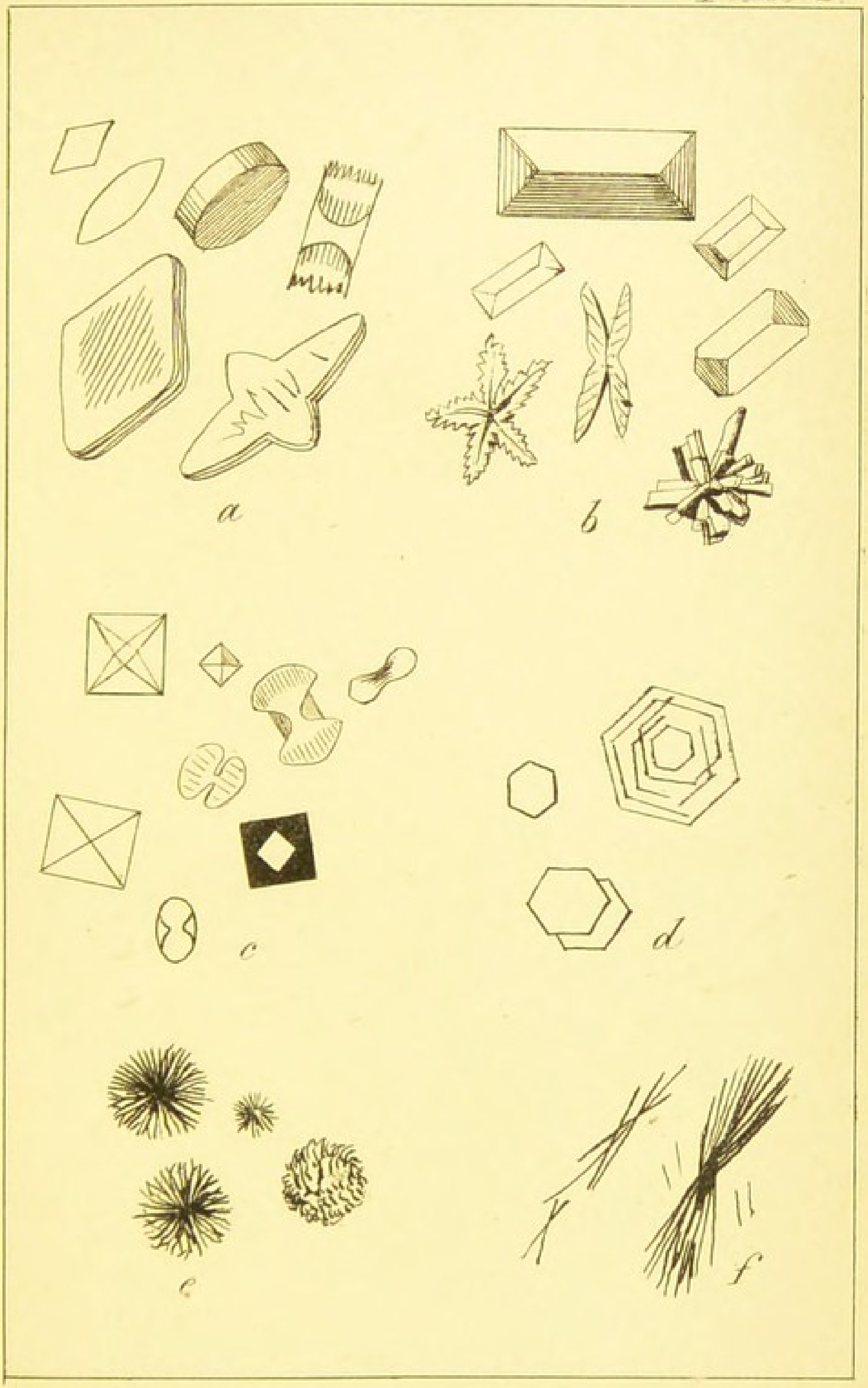
EXTRANEOUS MATTERS IN URINE.

Plate 1.



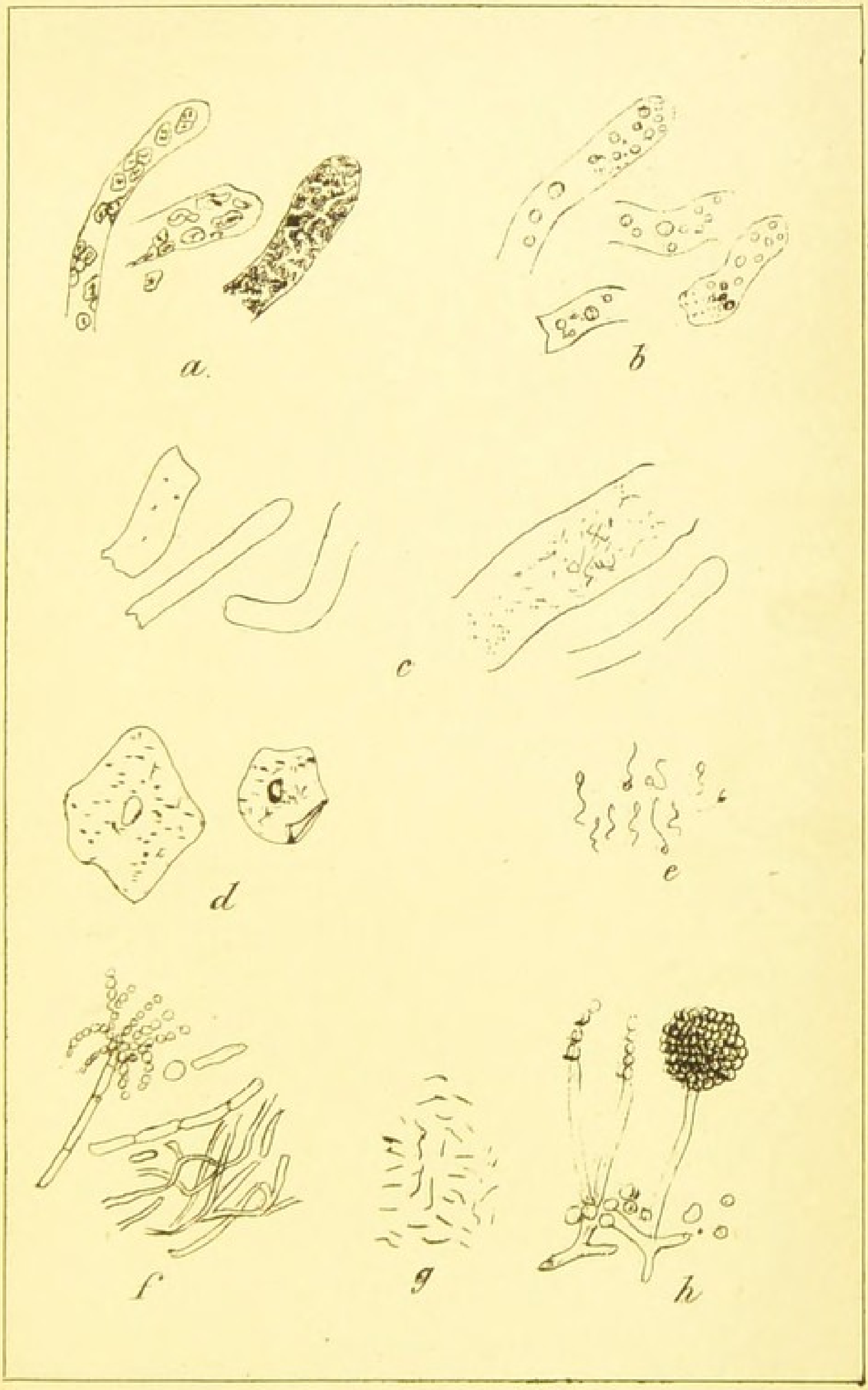
INORGANIC DEPOSITS.

Plate 2.



ORGANIC DEPOSITS.

Plate 3.



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