ANIMAL PHYSIOLOGY

FURNEAUX

Longmans' Elementary
Science Manuals.

[BRITISH P]HRENOLOGICAL SOCIETY

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ANIMAL PHYSIOLOGY

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BY

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PREFACE.

THIS work is intended for those who desire an easy introduction to the study of the Human Frame.

The matter embraces those parts of the subject which are contained in the Elementary Syllabus of the Science and Art Department, but is not confined strictly within those limits. A short chapter on the Ear has been added (thus completing the outline of the organs of special sense), and also another on the Larynx and the Voice. And again, although the students working according to this Syllabus are not required to obtain any 'information upon points of structure needing the use of the compound microscope' with the exception of the characters of the corpuscles of the blood, yet in many other instances such information has been given.

It is eminently desirable that the student should avail himself of every opportunity of making his study thoroughly practical. The author therefore has given, here and there, many hints as to how he should proceed in easy dissections; and has introduced a number of simple experiments, so that the knowledge gained may be of a sound character. It is too often felt that such practical and experimental methods of acquiring information are roundabout and tedious; but the author's experience has taught him to affirm that it is the readiest, surest, and certainly the most pleasant way of attaining the end in view.

In reading this book for the first time it may sometimes be advisable to omit those details which are printed in the smaller type, leaving them for the second perusal, when the broader features of the subject have been grasped.

No time or pains has been spared in well illustrating the work. A number of the cuts have been selected with care from Quain's 'Anatomy,' Gray's 'Anatomy,' and Owen's 'Comparative Anatomy and Physiology of the Vertebrate Animals'—some of these having been modified, to render them more suitable for the requirements of the elementary student. The remainder have been drawn specially for this work by the author, with a desire to satisfy a long-felt want for a profusely-illustrated elementary treatise on this particular subject.

W. S. F.

EAST DULWICH.

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ELEMENTARY PHYSIOLOGY.

LESSON I.

THE GENERAL BUILD OF THE HUMAN BODY.

THE word **physiology** is derived from the two Greek words *phusis*, nature ; and *logos*, a discourse. Literally speaking, therefore, the subject embraces all the various branches of natural science. But the term physiology is now generally applied only to the study of the functions of living beings.

Animal physiology deals with the functions of animals, but the term is now usually restricted to the study of man ; and accordingly the object of this work is to give a brief and simple outline of the life-processes of the human body.

Of course it is impossible to understand the functions or uses of the various parts of the body without a knowledge of their structure ; hence that branch of science which is called **anatomy** (Gr. *ana*, up, and *temno*, I cut) must go hand in hand with physiology.

The most obvious division of the **human body** is into *head*, *trunk*, and *limbs* or *extremities*.

The **head** includes the *face*, and a bony box called the *cranium* which encloses the brain.

The **trunk** encloses a large cavity which contains the parts that are engaged in the circulation of the blood, respiration, digestion, etc. The upper portion of the trunk is called the **thorax** or **chest**, and the lower portion the **abdomen** or **belly**. These two parts are separated by a fleshy partition called the **diaphragm** ; hence we speak of the cavity of the chest as distinct from the cavity of the abdomen.

The **limbs** are arranged in two pairs—the **arms**, or upper extremities, and the **legs**, or lower extremities.

The body is made up of a large number of parts, each of which has its own particular function to perform. These parts are called **organs**. Thus, we speak of the *heart* as the chief organ of *circulation*, the *stomach* as an organ of *digestion*, the *lungs* as organs of *respiration*, and the *muscles* as the organs for producing *motion*.

The various organs of the body may be conveniently arranged in groups or **systems**, according to their respective functions. The chief of these systems are :—

1. **The osseous, or bony system.**
2. **The muscular system.**
3. **The digestive system.**
4. **The absorptive system.**
5. **The circulatory system.**
6. **The respiratory, or breathing system.**
7. **The excretory, or purifying system.**
8. **The nervous system.**

All the organs of the body are more or less complicated in structure. Each one is built up of elementary structures which are called **tissues**. For example, the heart is composed of a fleshy substance which we term *muscular tissue*, some fatty substance or *adipose tissue*, *nervous tissue*, and a certain amount of *connective tissue*.

The **osseous** (Lat. *os*, a bone) **system** consists of a large number of bones, which constitute the **skeleton**, and form a strong framework, which supports and protects the softer structures of the body. These bones are connected together in such a manner as to form **joints** or **articulations** (Lat. *articulus*, a joint), and are bound firmly together at these joints by strong white fibrous bands called **ligaments** (Lat. *ligo*, I bind). In some parts of the body, where an elastic and yielding substance is required, which is at the same time very strong, **cartilage** or **gristle** takes the place of bone, as in the more prominent part of the nose.

We may regard the **backbone** as the central portion of the osseous system, for a glance at the accompanying figure will show that the other bones of the skeleton are connected either directly or indirectly with it. This bone (or, rather, column of bones) passes through the hinder part of the trunk of the body, part of it belonging to the neck, part to the back, and part to the loins. The **ribs** are connected with that portion which lies in the back, and, extending round the chest, are for the most part connected with the **breast-bone** in front. At the upper part of the chest are the **shoulder-bones**: to these the bones of the arms are attached. The lower portion of the backbone is wedged in between the **bones of the hip**, which form a hollow basin-like cavity, and support the organs of the abdomen.

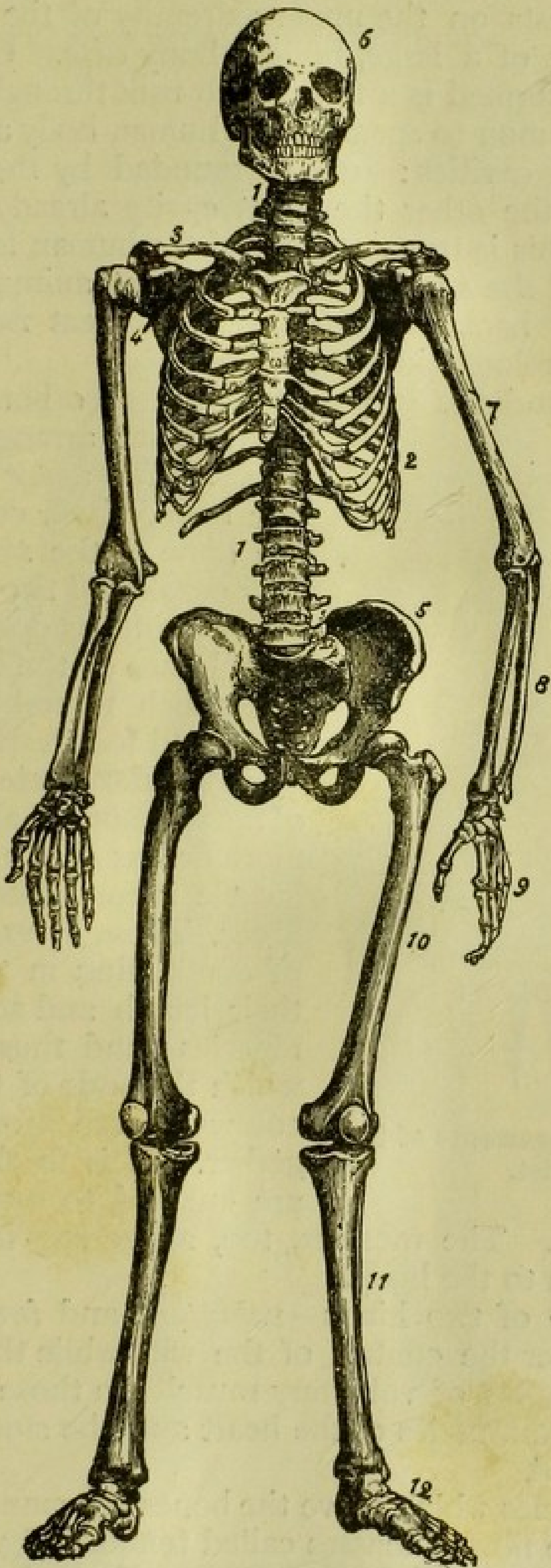


Fig. 1.—**The Human Skeleton.**

1, the backbone; 2, ribs; 3, collar-bone; 4, shoulder-blade; 5, hip-bones, forming the pelvis; 6, skull; 7, upper arm; 8, forearm; 9, wrist and hand; 10, thigh; 11, leg; 12, ankle and foot.

The **skull** rests on the upper extremity of the backbone. It consists in part of a large, hollow, bony case. Continuous with the cavity thus formed is a tube which runs through the backbone. Hence it is common to speak of the human body as enclosing two distinct tubes or cavities:—one surrounded by the skull and the backbone, and the other the great cavity already mentioned on page 1. And this is true not only of the human body, but also of the bodies of all the *back-boned* or *vertebrate* animals. The cavity formed by the backbone contains the great nerve called the spinal cord, a prolongation of the brain.

The **arms** and the **legs** resemble each other very closely in the general arrangement of their bones. The *upper arm* consists of one bone, which corresponds with the bone of the *thigh*. The *fore-arm* consists of two bones arranged side by side, as does also the leg. The bones of the wrist and hand, too, much resemble those of the ankle and foot respectively.

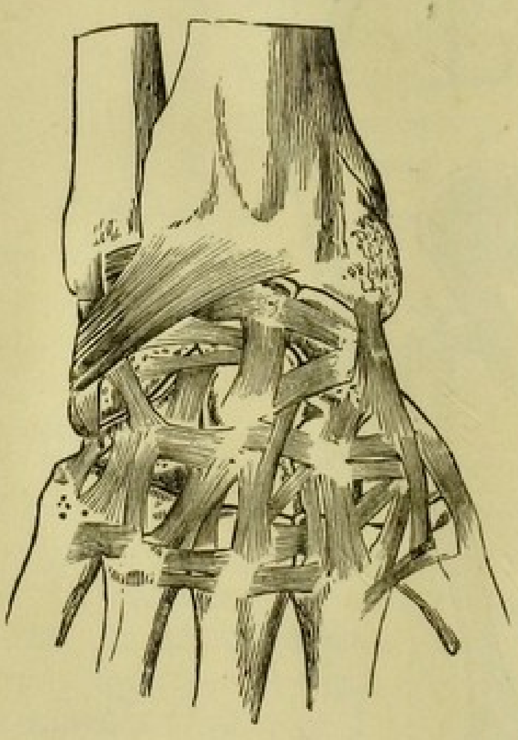


Fig. 2.—**The Ligaments of the Wrist.**

Muscular System.—The bones of the skeleton are all surrounded by more or less *flesh* or *muscle*. Each muscle is composed of bundles of fibres. These *fibres* have the power of contracting in the direction of their length and so shortening the muscles; and thus the bones with which the ends of the muscles are connected are brought nearer together. It is in this way that we are enabled to exercise the body in various ways. The muscles, too, assist very largely in giving a rounded form to the body.

Muscles are of two kinds—*voluntary* and *involuntary*. The former are under the control of the will, while the latter are not. We have examples of voluntary muscles in those of the face and the limbs. The muscles of the heart and the stomach are of the involuntary kind.

Those muscles which move the bones are connected with them by strong white fibrous masses called **tendons** (fig. 4).

The **digestive or alimentary system** (Lat. *alimentum*, nourishment) consists of the *food-passage* and the various organs which prepare the *digestive fluids*. The **food-passage** consists of the *mouth*, *pharynx*, *œsophagus* or *gullet*, *stomach*, and *intestines*. (See fig. 81.)

The **pharynx** (Gr. *pharunx*, the throat) is the cavity situated behind the mouth, with which it is continuous.

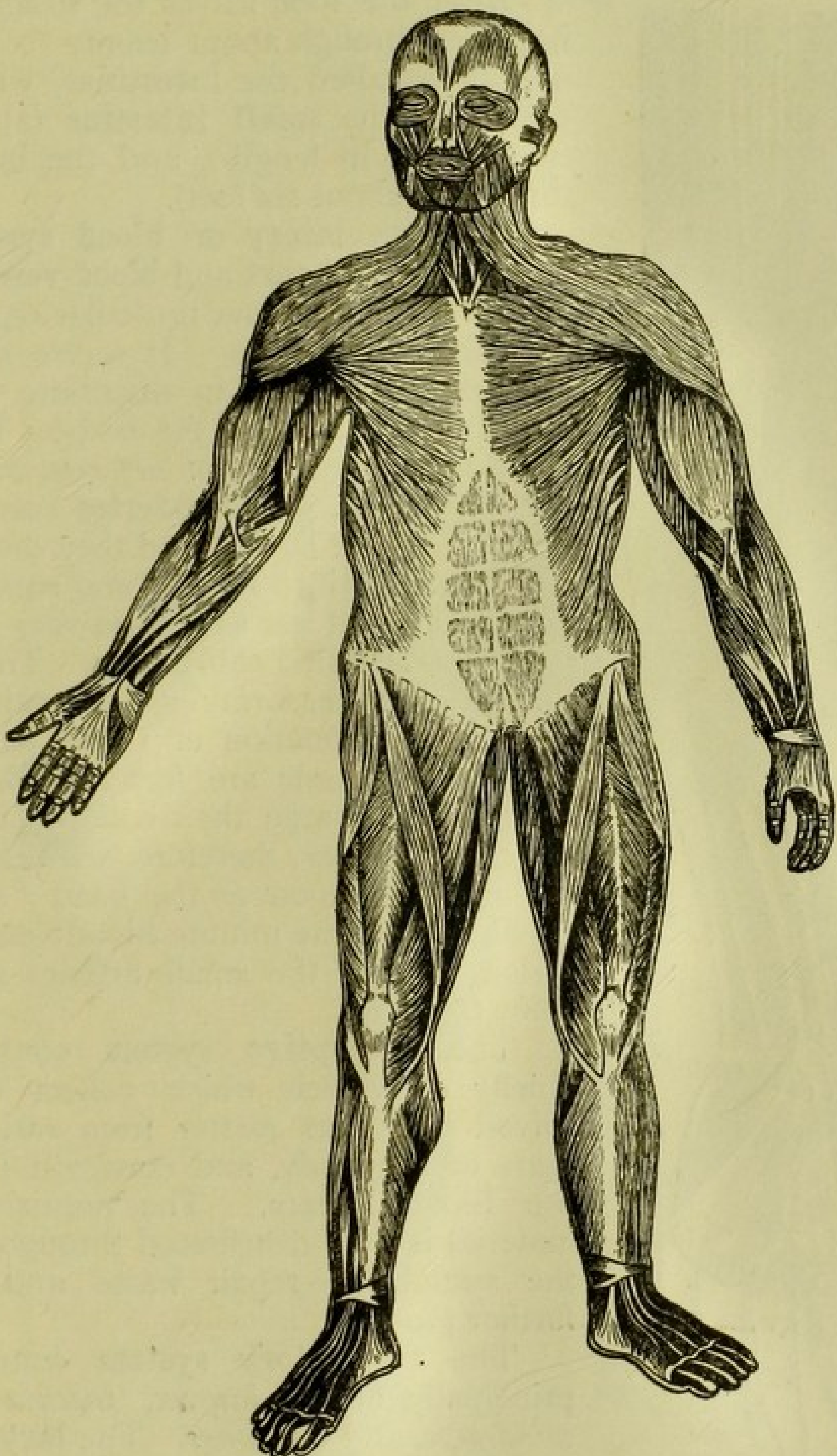


Fig. 3.—**The Superficial Muscles of the Body, viewed from before.**

The **œsophagus** (Gr. *oiso*, I shall bear ; and *phago*, I eat) is a tube, about ten inches long, connecting the pharynx with the

stomach—a large pouch-like organ, which serves to contain the food while certain fluids are acting upon it.

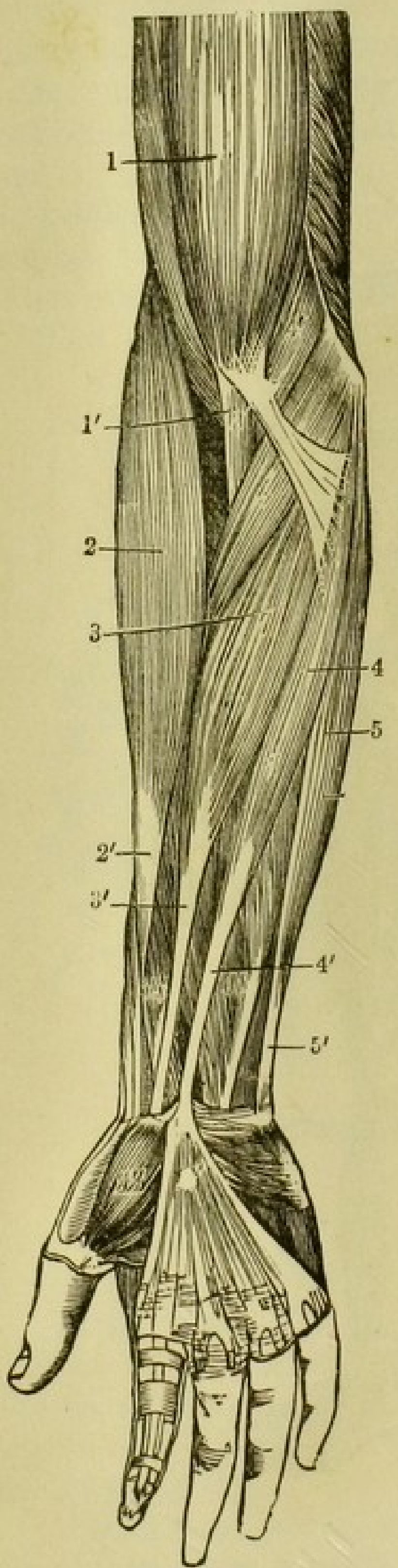


Fig. 4.—**The Muscles and Tendons of the Forearm, viewed from before.**

1 to 5, muscles; 1′ to 5′, their respective tendons.

After the food leaves the stomach, it passes through about twenty-six feet of tubing called the **intestines**, which consist of the **small intestine** (about twenty feet in length), and the **large intestine** (about six feet).

The **circulatory or blood system** consists of the **heart** and **blood-vessels.** The **heart** is a hollow, muscular organ, provided with valves. It serves as a kind of force-pump to distribute the blood to all parts of the body. The **blood-vessels** consist of *arteries, veins* and *capillaries.* The **arteries** convey blood *from* the heart; and they divide and subdivide into smaller and smaller branches, till at last they form very minute vessels called **capillaries.** These capillaries unite, forming small **veins**; and by the junction of these, larger and larger vessels are formed, which at length discharge their contents into the heart. Veins, therefore, are vessels which bring blood *to* the heart; and capillaries are the minute blood-vessels which connect the small arteries and veins together.

The **absorptive system** consists chiefly of vessels which collect dissolved nutritious matter from various parts of the body, and convey it into the blood system. The nourishing material is thus distributed throughout the system to repair waste and to further growth.

The **respiratory system** consists principally of the *larynx, trachea* or *wind-pipe*, and the *lungs.* The **larynx**, sometimes called the voice-box, because it contains the '*cords*' or membranes by means of which the voice is produced, is the enlarged, upper part of the passage leading from the mouth to the lungs. The **trachea** is a tube extending from the larynx to the upper part of the chest. Here it divides into two branches, one of which enters each lung. The **lungs** (often called the *lights*)

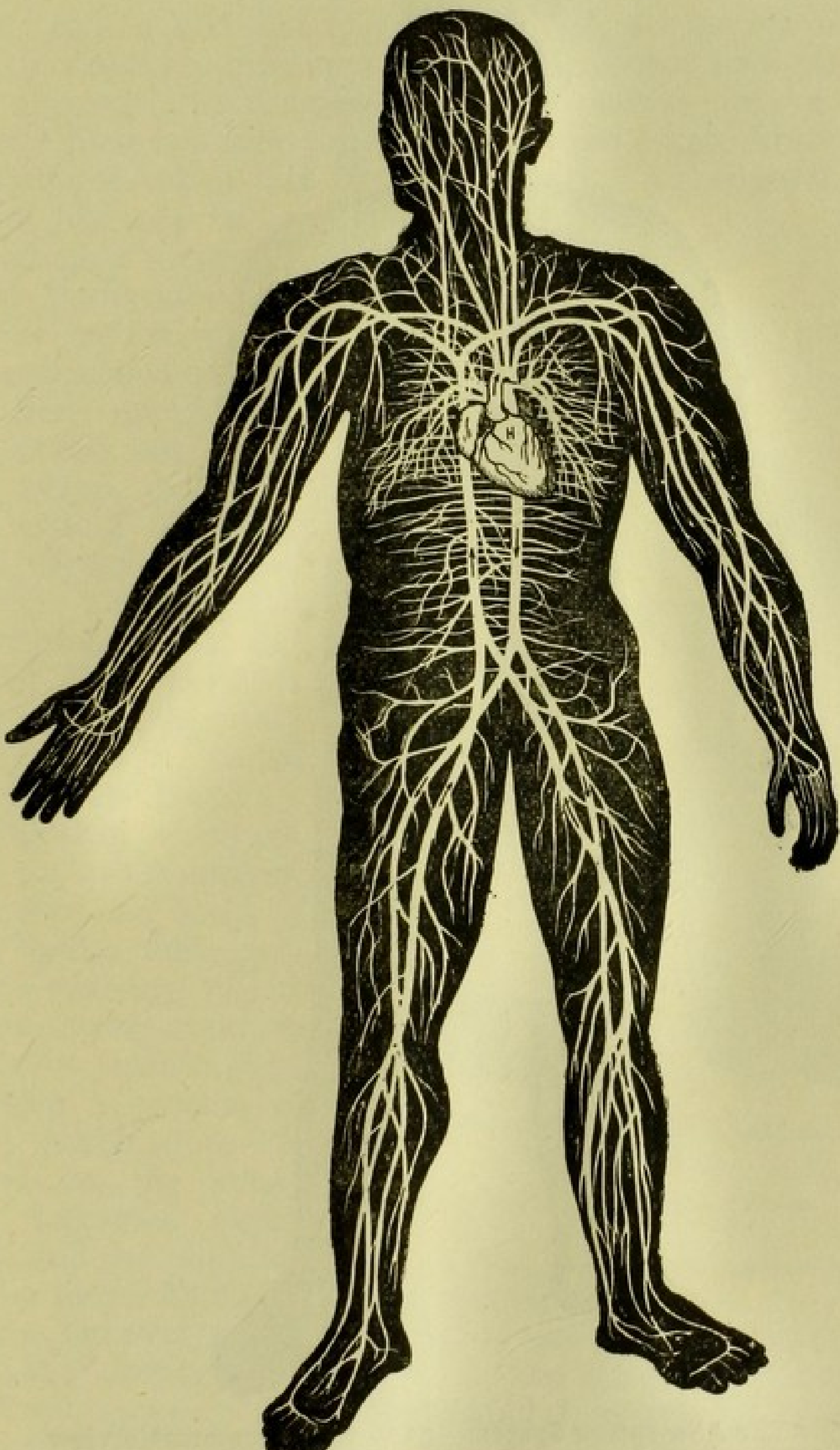


Fig. 5.—**General Diagrammatic View of the Circulatory System, showing the arrangement of the heart and the larger blood-vessels.**

H, the heart. The arrows indicate the direction of the blood-stream.

are large spongy organs. They contain a very large number of small air cavities, and are richly supplied with blood-vessels. It

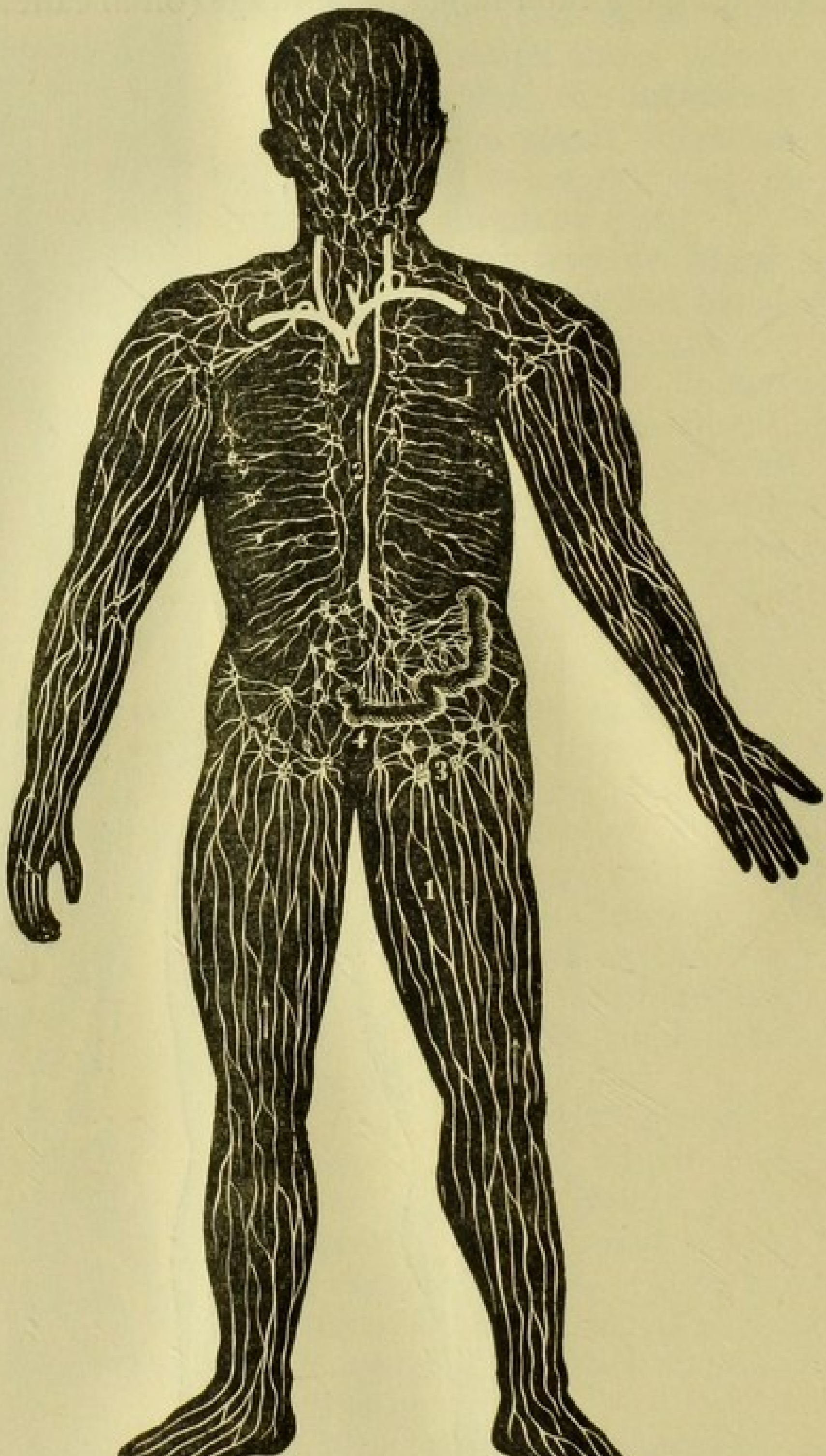


Fig. 6.—**The Absorptive System—general diagrammatic view.**

is in the lungs that the blood is aërated by being brought in contact with the air we breathe.

There are other organs, called the **excretory organs**, which perform the office of removing certain impurities from the blood as it circulates through them. The chief of these organs are the *liver*, the *kidneys*, and the *skin;* to which may also be added the *lungs;* for, in addition to being aërated, the blood, while in the lungs, is caused to give up a gas called carbonic-acid gas, which it has collected in its passage through the various parts of the body.

The **liver** is a very large reddish-brown organ, which prepares a substance called **bile** from the blood. Although the separation of bile may be regarded as a process of blood-purification, yet the bile itself is utilised in the digestion of food. The liver, therefore, is not simply an excretory organ, but may also be said to belong to the digestive system.

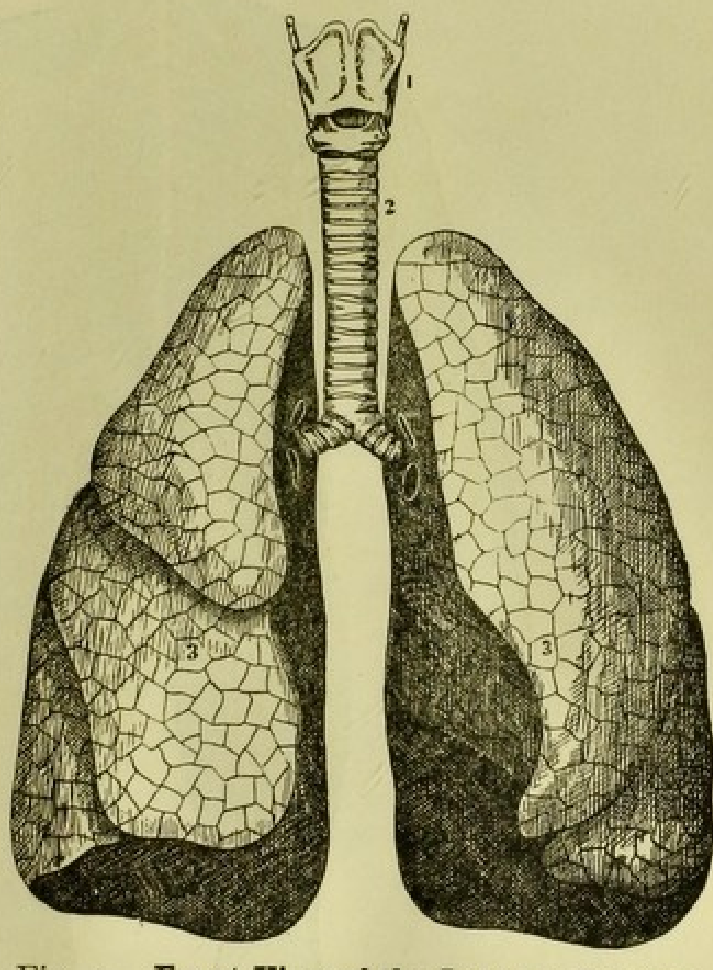


Fig. 7.—**Front View of the Larynx, Trachea, and Lungs.**

1, larynx; 2, trachea; 3, lungs.

The **kidneys**, two in number, are important blood-purifiers. They separate a poisonous substance called *urea* from the blood.

The **skin**, which entirely covers the exterior surface of the body, is more than a mere protective covering, for its deeper layer contains numerous small bodies, in which a process of blood-purification is carried on, the impurities separated being conducted by minute tubes to the **pores** or openings which may be seen with a lens on the surface of the skin.

The **nervous system** consists of two parts. One of these is called the *cerebro-spinal system*, and the other the *sympathetic* or *ganglionic system*. The **cerebro-spinal system** consists of the **brain** and the **spinal cord**, together with the numerous **nerves** which proceed from these organs to almost all parts of the body. The **sympathetic system** (see fig. 161) consists of a large number of small masses of nerve substance (ganglia), and the nerves connecting them and radiating from them. The former system supplies all the voluntary muscles and the organs of the five senses—the

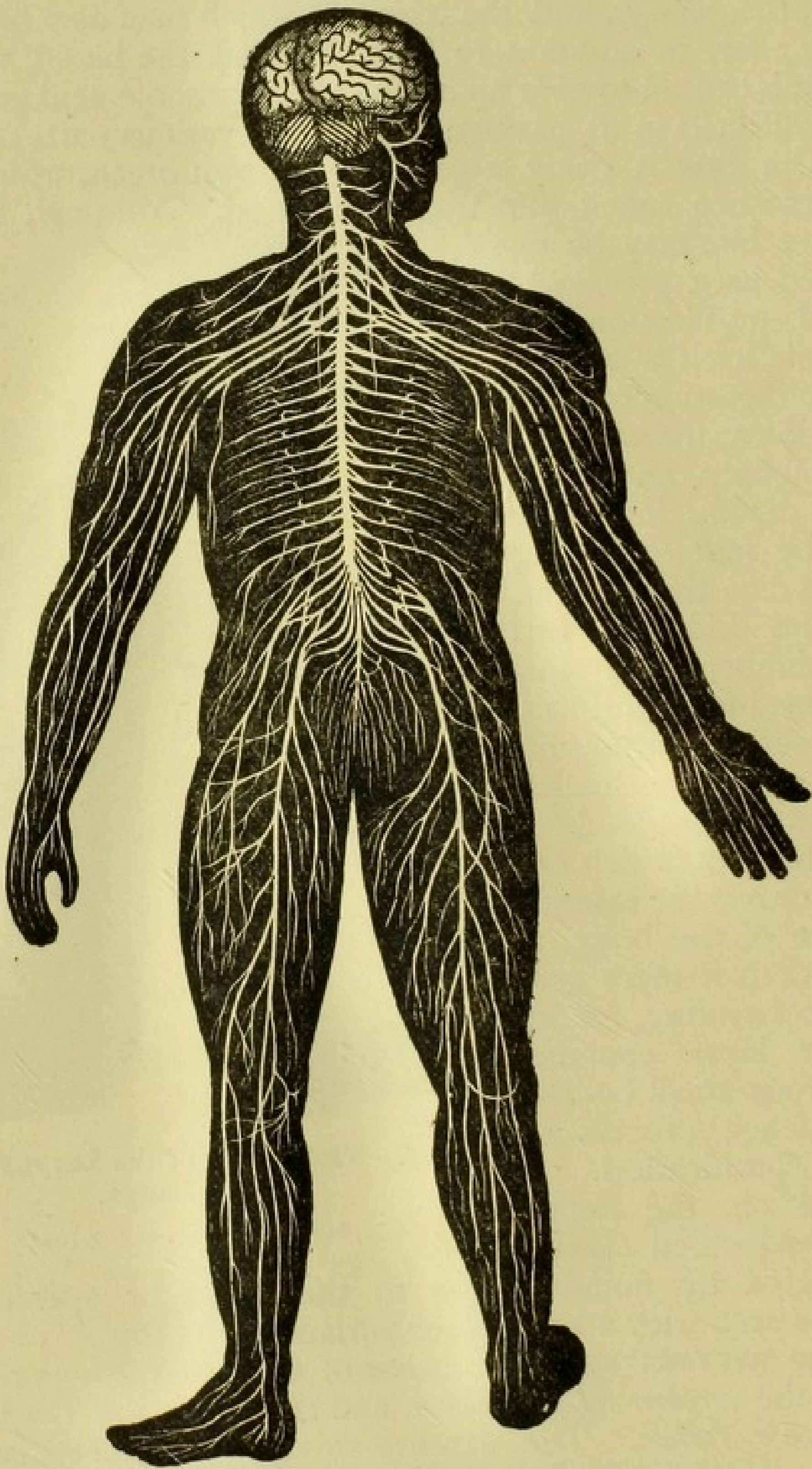


Fig. 8.—**The Cerebro-spinal System.**

skin, or organ of touch; the tongue, or organ of taste; the nose, or organ of smell; the eye, or organ of sight; and the ear, or organ of hearing. The sympathetic or ganglionic system supplies the involuntary muscles.

The two parts of the nervous system are not entirely separate, being connected by numerous nerve filaments.

By means of the nervous system we receive impressions from the external world through the organs of the senses. The nervous system also, by its connection with the muscles, causes and controls the motions of the body.

SUMMARY.

THE SYSTEMS OF ORGANS.	**The osseous system**		Backbone. Ribs. Breast-bone. Shoulder-bones. Bones of the hip. Bones of the skull. Bones of the limbs.
	The muscular system		Voluntary muscles. Involuntary muscles.
	The alimentary system		Pharynx. Œsophagus. Stomach. Small intestine. Large intestine.
	The circulatory system		Heart. Arteries. Capillaries. Veins.
	The respiratory system		Larynx, or voice-box. Trachea, or wind pipe. Lungs, or lights.
	The excretory system		Liver. Kidneys. Skin.
	Nervous System	**Cerebro-spinal**	Brain. Spinal cord. Nerves.
		Sympathetic	Ganglia. Nerves.

QUESTIONS ON LESSON I.

1. What are the uses of *ligaments*, *cartilage*, and *tendons*?
2. What are the chief characteristics of muscle?
3. Enumerate the chief systems of organs, giving the names of the various organs in each system.
4. Describe the organs of the *alimentary system*.
5. Give a short description of the organs belonging to the *circulatory system*.
6. What are the organs connected with *respiration*?
7. Name, and briefly describe, those organs which purify the blood by *excretion*?
8. Give a brief description of the *nervous system*.
9. Distinguish between the *cerebro-spinal* and *sympathetic systems*.

LESSON II

THE SKELETON.

Bones of the Trunk.

Having briefly considered the general build of the body, we will now study more particularly the nature of the skeleton. Although the title of this book is '*Animal* Physiology,' yet the description given will be that of the *human* body; and, unless otherwise stated, the diagrams and illustrations will all refer to man. Nevertheless, it must be remembered that the structure of the human body is in all its broadest features similar to that of many of the lower animals; so much so, that a description of the human body may be illustrated by the dissection of one of these animals. It is very desirable, therefore, that even beginners in the study of animal physiology should examine the bodies or parts of such animals as can be conveniently procured. Thus, a knowledge of the position and uses of the various parts of the skeleton may be obtained by a thoughtful inspection of the bones of a rabbit. Or the student may easily prepare for himself a complete skeleton of any small animal by burying the body just beneath the surface of a wet soil. In a few weeks the flesh will have decomposed to such an extent that the skeleton may be washed clean in running water, and afterwards bleached by exposure to the sun.

We shall first study the backbone, or central portion of the skeleton, and the bones directly connected with it.

The **backbone, vertebral column**, or **spinal column** is composed of a series of bones called *vertebræ* (Lat. *verto*, I turn), and forms a kind of axis with which all the other parts of the skeleton are connected. The base of the skull rests on the uppermost of these vertebræ, and the lower portion of the column is wedged in between the bones of the hip. The backbone is usually said to consist of thirty-three bones, but only twenty-four of these are jointed in such a manner as to be movable on each other, viz. the bones of the neck, back, and loins. The lower part of the column consists of nine bones fused together. The seven highest vertebræ belong to the neck, and are called the **cervical vertebræ** (Lat. *cervix*, the neck). The next twelve are called the **dorsal vertebræ** (Lat. *dorsum*, the back); these belong to the back and support the ribs. The remaining five movable vertebræ belong to the loins, and are called the **lumbar** (Lat. *lumbus*, the loin) **vertebræ**.

The lowest lumbar vertebra rests on the broad surface of a kind of curved wedge, formed by the next five vertebræ fused together into one firm mass of bone. This wedge is called the **sacrum** (Lat. sacred), and to its lowest and narrowest end is attached the **coccyx** (Lat. a cuckoo), which consists of four very imperfectly formed vertebræ, corresponding with the tail in other animals.

The sides of the sacrum are united with the two large **hip-bones**, and form a basin-like cavity called the **pelvis** (Lat. a basin). These will be more conveniently described with the bones of the limbs.

In order to understand clearly the construction and uses of the vertebral column it will be necessary to notice the form of a single vertebra; and though the vertebræ differ from each other in detail, yet all are constructed on the same plan, and a general description of one will answer for all.

A **vertebra** consists of a bony *body* from which spring two *arches*, the latter uniting in such a manner as to form a kind of ring which encloses the *spinal cavity*. From the outer circumference of this bony ring are given off three projections, which are called **processes.** The body is the front portion of the vertebra, and the process which projects from the arch, exactly opposite the

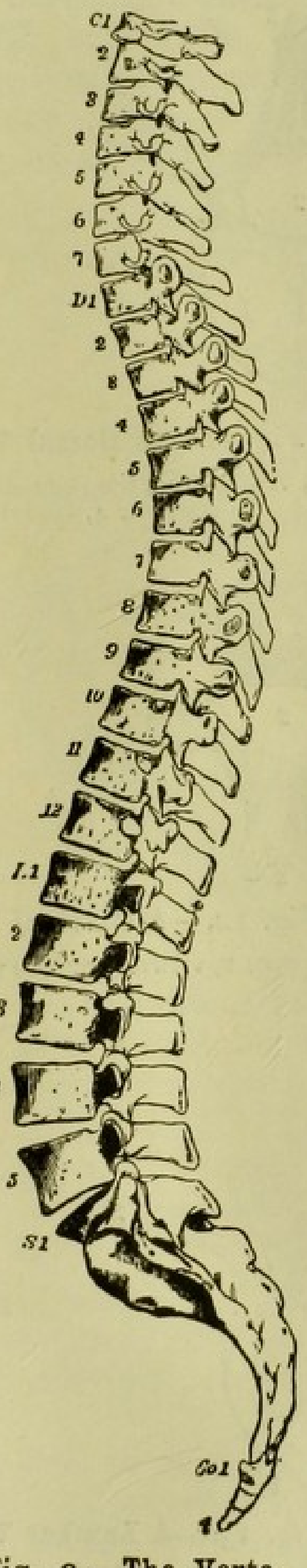


Fig. 9.—The Vertebral Column, viewed from the left side.

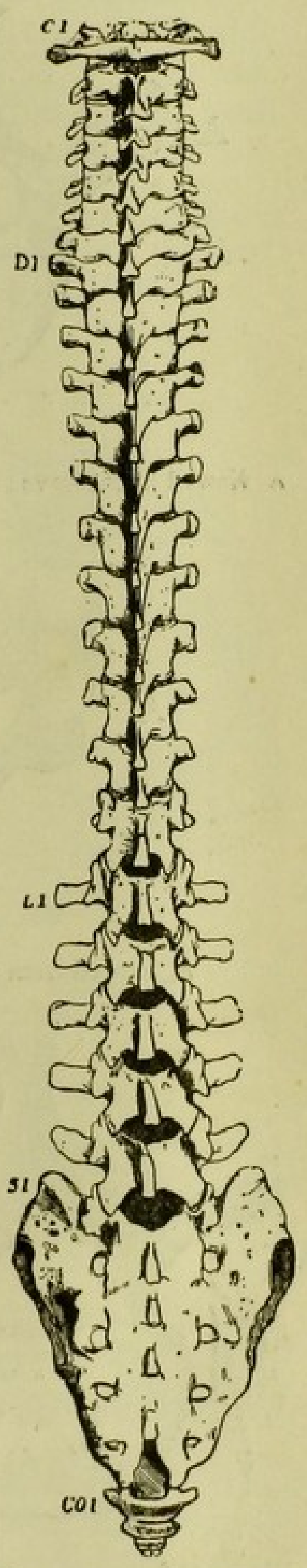


Fig. 10.—The Vertebral Column, viewed from behind.

C 1, first cervical vertebra; D 1, first dorsal vertebra; L 1, first lumbar vertebra; S 1, first sacral vertebra; Co 1, first coccygeal vertebra.

body, is called the **spinous process.** Two other processes arise from the sides of the ring, and are called **lateral processes.**

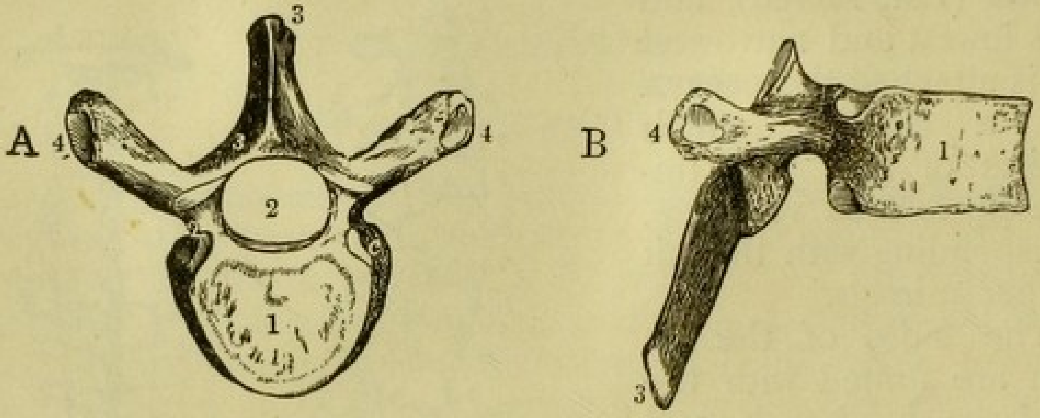


Fig. 11.—**A Dorsal Vertebra (6th).**

A viewed from above; B, viewed from the right side. 1, body; 2, spinal cavity; 3, spinous process; 4, lateral processes.

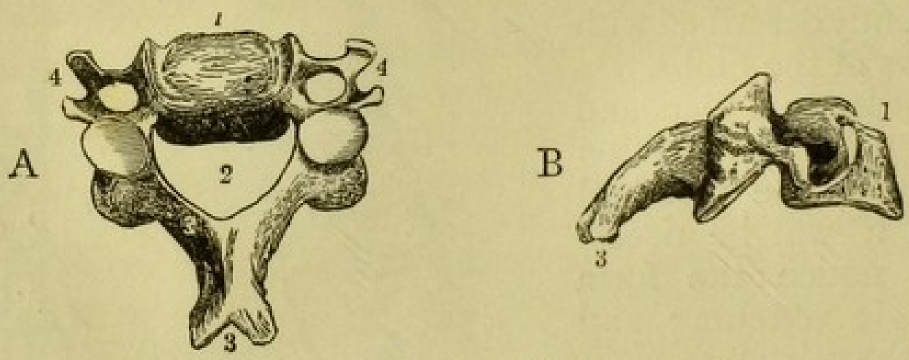


Fig. 12.—**A Cervical Vertebra (3rd).**

A, viewed from above; B, viewed from the right side. Numbers as in fig. 11.

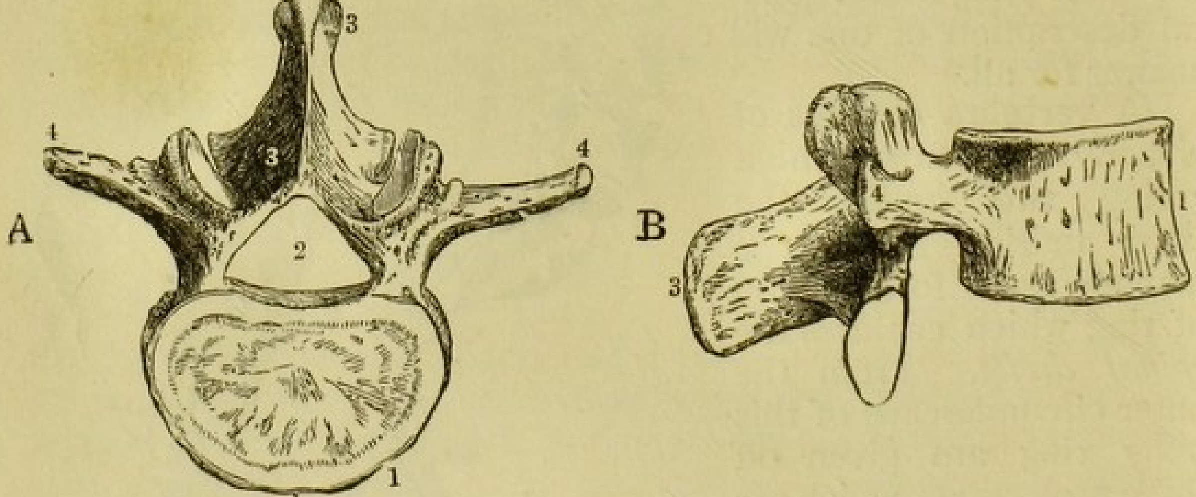


Fig. 13.—**A Lumbar Vertebra (3rd).**

A, viewed from above; B, viewed from the right side. Numbers as in Fig. 11.

These projections from the vertebræ serve as places of attachment for the ligaments which hold the bones firmly together; and also for the muscles by which we are enabled to bend the back and to move those bones that articulate with the vertebral column.

Between the bodies of the vertebræ are pads of elastic cartilage or gristle called **intervertebral cartilages.** These unite the vertebræ, and form with them a flexible column. In old age the cartilages of the backbone become hard and less flexible, so that the back can no longer be bent, except to a very slight extent.

The points in which these vertebræ differ from each other may receive a passing notice. The *bodies* of the vertebræ increase in size from the first cervical to the lowest lumbar, so as to be able to support the greater weight they have to bear. The bodies of the *cervical vertebræ* being small, we have seven joints in a short column of bones. This gives great freedom of motion to the head and neck. The first two cervical vertebræ will be specially described in our next lesson. The long spinous processes of the *dorsal vertebræ*, which show so plainly in the backs of thin persons, and the large spinous and lateral processes of the lumbar vertebræ, serve for the attachment of the powerful muscles by which we are enabled to bend the body. The *dorsal vertebræ* are also provided each with two *facets*, sometimes called the *articular processes*, with which the heads of the ribs form movable joints.

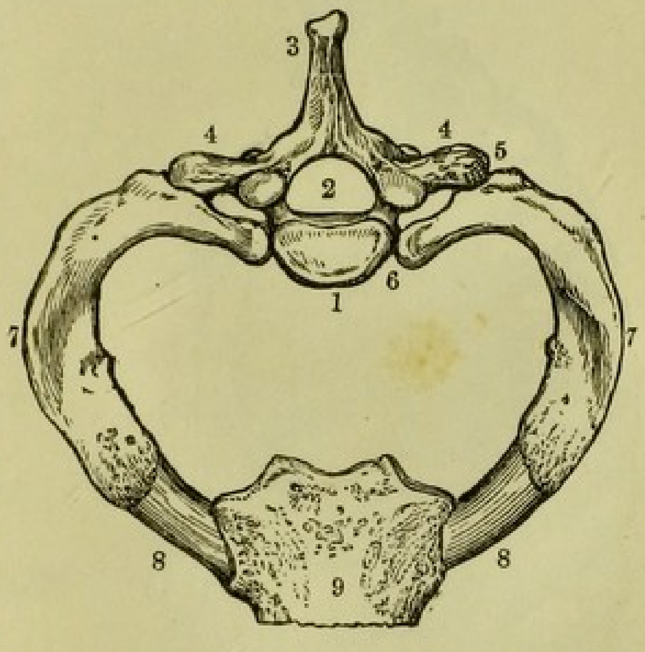


Fig. 14.—**First Dorsal Vertebra, with the first pair of Ribs, and a portion of the Sternum.**

1, body of the vertebra; 2, spinal cavity; 3, spinous process; 4, lateral processes; 5, articular facet of lateral process; 6, articular facet for the head of the rib. (These two facets form, with the rib, movable joints.) 7, ribs; 8, cartilage or gristle connecting the ribs with the sternum; 9, sternum, or breast-bone.

It will now be seen that a number of these vertebræ, arranged in a column, will not only form a powerful and flexible support, but that the vertebral arches will form a long bony tube. This tube is called the **spinal canal**, and contains the great nerve known as the *spinal cord*, to which the bones of the vertebral column serve as a strong protection.

The **ribs** or **costæ**, twenty-four in number, are curved bones, connected in pairs with the dorsal vertebræ behind, and, except the last two pairs, with the **sternum** (Gr. *sternon*, the breast) or **breast-bone** in front. Each pair of ribs thus forms a circular arch called a **costal arch** (fig. 14). That portion of the rib which forms a movable joint with the articular process of the dorsal vertebræ is termed its *head*. The other end is in most cases attached by means of **costal cartilage** to the **breast-bone**—a long, flat, and soft bone, the lower part of which is formed of flexible cartilage. It will thus be seen that the ribs, together with the backbone and the sternum, form an elastic framework with movable sides. This acts as a protection to the organs contained in the *chest* or upper portion of the trunk, and assists largely in the process of respiration.

The **ribs** are not placed horizontally, but incline *downwards*

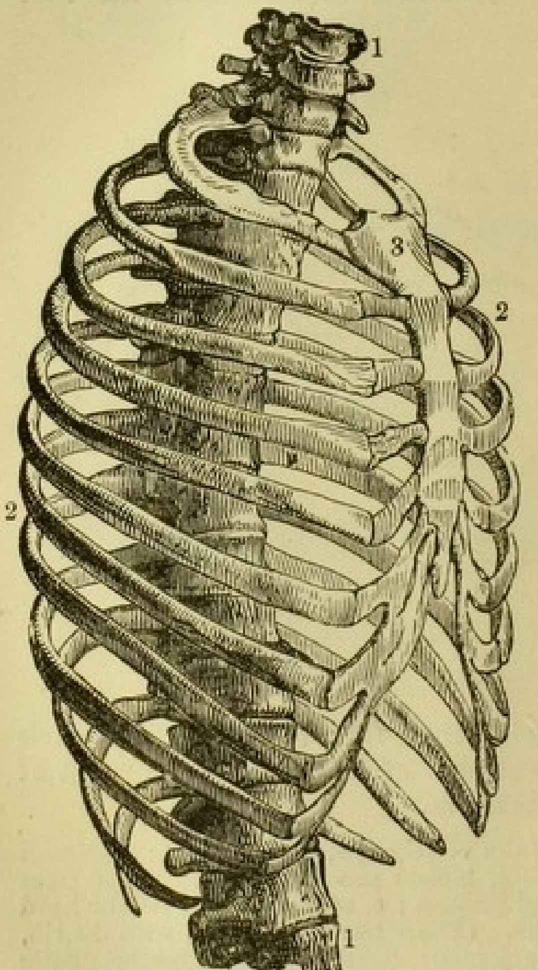


Fig. 15.—**The Bony Framework of the Chest, viewed from the right side.** (See also fig. 134.)

1, backbone; 2, ribs; 3, breast-bone.

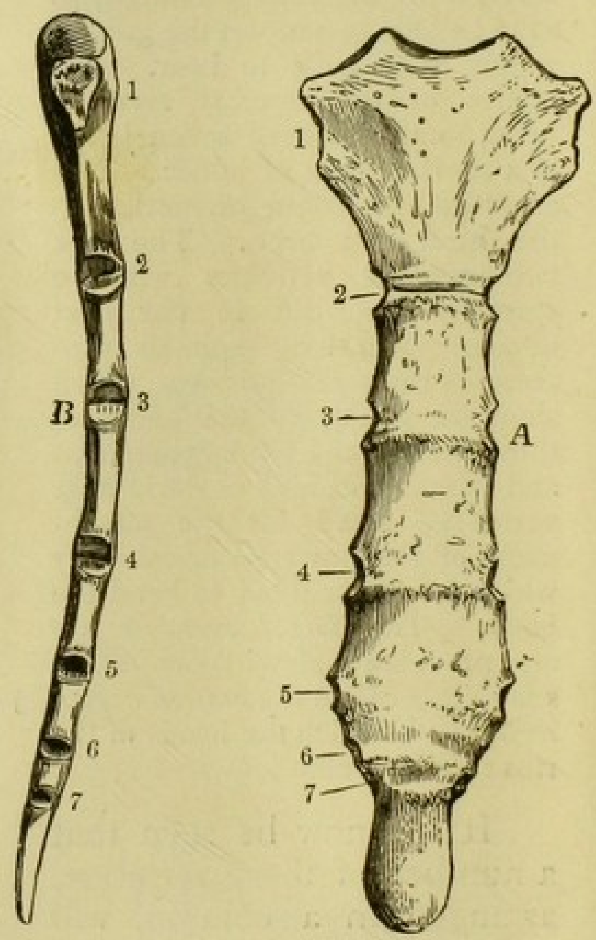


Fig. 16.—**The Breast-bone.**

A, viewed from before; B, viewed from the right side; 1, 2, 3, 4, 5, 6 and 7 are the surfaces to which the corresponding costal cartilages are attached.

from the backbone, so that when they are raised and depressed, as they are during the inspiration and expiration of air in breathing, the capacity of the chest is alternately increased and decreased.

We may now notice the manner in which the pairs of ribs differ from each other. In the first place we observe that the upper pairs form small arches, and that the size of the arches increases from above downwards, thus the framework formed is somewhat conical. The *first seven pairs* have their own costal cartilages, connecting them directly with the sternum. They are called *true ribs*. The *eighth*, *ninth*, and *tenth pairs* are each connected with the cartilage next above it, so that they are united to each other before they reach the sternum. The *eleventh* and *twelfth pairs* are not connected at all with the breast-bone. The *last five pairs* are called **false ribs** ; and of these the eleventh and twelfth pairs are termed **free** or **floating ribs.**

The **collar-bone**, which is attached to the sternum, and the **shoulder-blade**, which lies behind the upper ribs, will be best described with the bones of the arm.

SUMMARY.

Table of the Bones of the Trunk.

VERTEBRAL COLUMN	**Neck—7 Cervical**	Small bodies. Processes: Spinous. Lateral—small.
	Back—12 Dorsal	Give attachment to ribs. Larger bodies. Processes: Spinous—long. Lateral. Articular—united with heads of ribs.
	Loins—5 Lumbar	Very large bodies. Long processes: Spinous. Lateral.
	Sacrum—5 Sacral	United, forming a wedge. Fixed between hip-bones.
	Coccyx—4 Coccygeal	Rudimentary. Correspond with tail in lower animals.
RIBS	**7 Pairs true**	Connected by their own cartilages with breast-bone.
	5 Pairs false	8th, 9th, and 10th pairs—each connected with the cartilage above it. 11th and 12th pairs—floating or free—fixed at one end only.

QUESTIONS ON LESSON II.

1. Describe the structure of the *vertebral column.* What is the *spinal canal*?
2. Describe the structure of a *vertebra.* How many vertebræ belong to the neck, back, and loins respectively?
3. How are the vertebræ connected with each other? On what does the flexibility of the vertebral column depend?
4. In what respects do the *cervical*, *dorsal*, and *lumbar* vertebræ differ from each other? How do these differences affect their uses?
5. Describe the *sacrum* and *coccyx.*
6. Describe the general arrangement of the *ribs.* In what respects do they differ from each other?
7. What are the functions of the *vertebral column* and *ribs*?

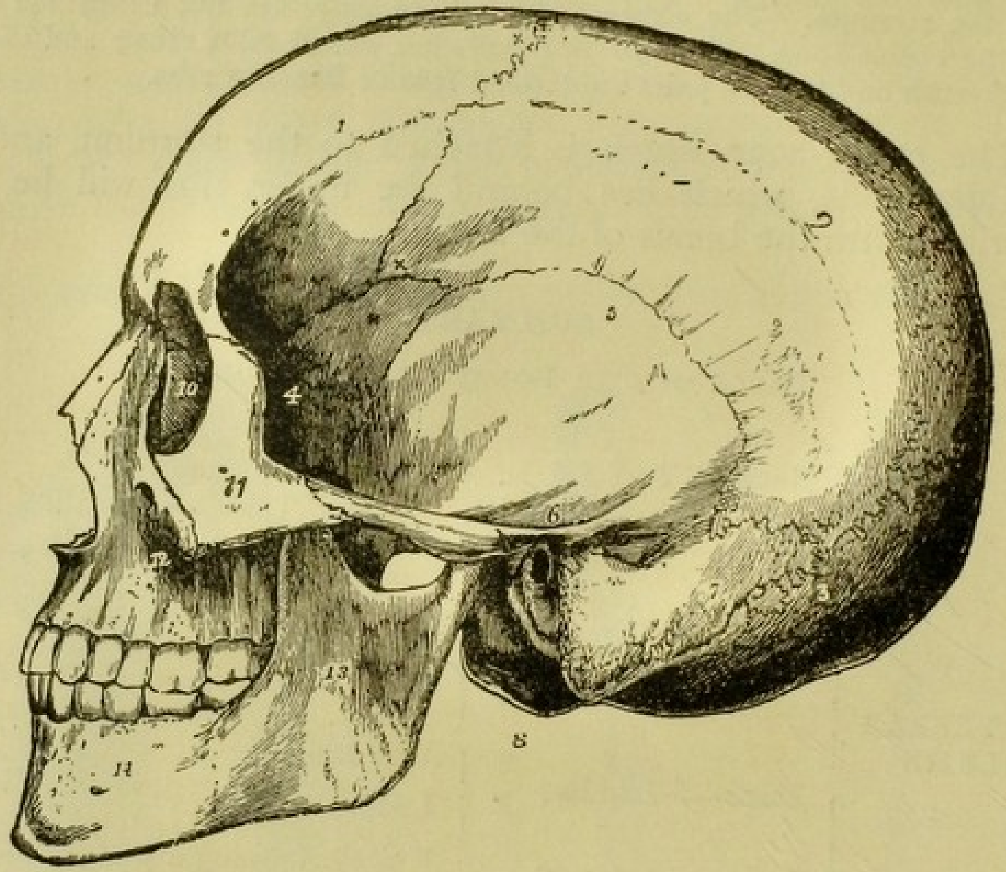


Fig. 17.—**Side View of the Skull.**

1, frontal bone; 2, parietal bone; 3 and 8, occipital bone; 4, wing of the sphenoid bone 5, 6 and 7, temporal bone; 10, lachrymal bone, in the inner wall of the orbit; 11, malar bone; 12, superior maxillary; 13 and 14, inferior maxillary.

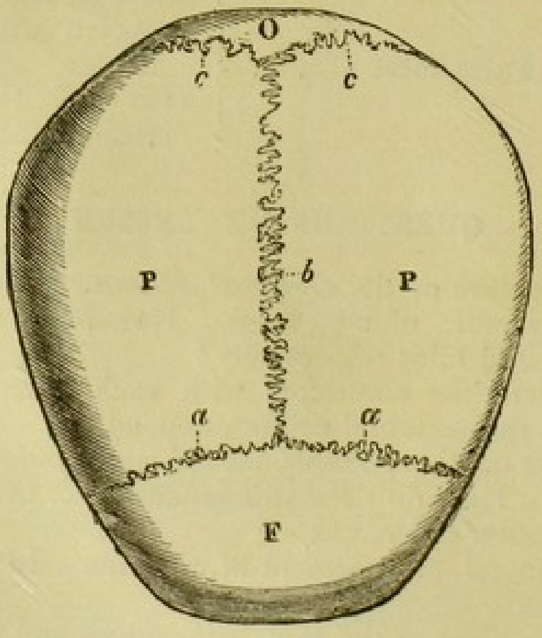


Fig. 18.—**Top View of the Skull.**

F, frontal bone; P, parietal bones; O, occipital bone; *a*, *b*, and *c*, sutures.

LESSON III.

THE SKELETON (*continued*).

The Skull.

The **skull** consists of the *cranium* and the *face*. The **cranium** is a large and hollow bony case which encloses the *brain*. The **face**

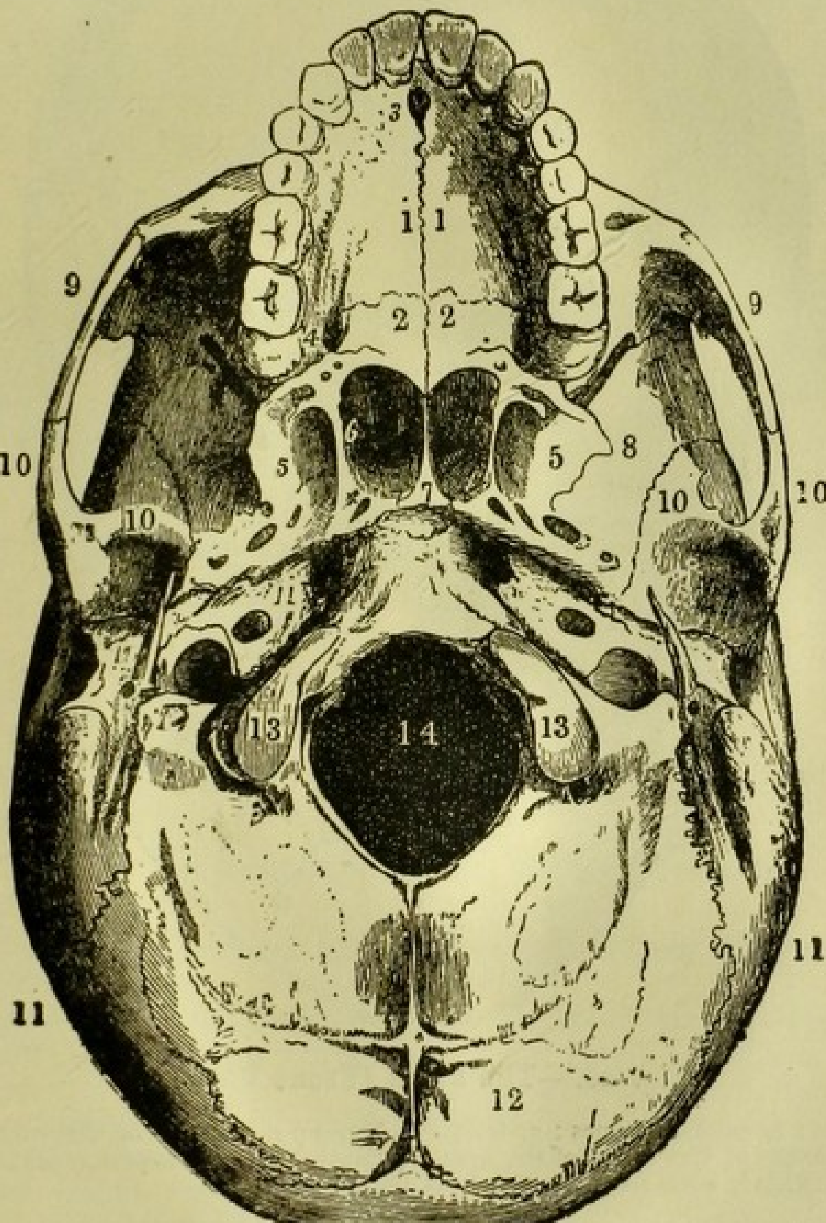


Fig. 19.—**The Under Surface of the Skull.**

1, superior maxillary bones; 2, palatal bones; 5 and 8 are on the sphenoid bone; 6, hinder opening of the right nostril; 7, vomer; 9, malar or cheek-bones; 10, temporal bones 11, lower portion of parietal bones; 12, occipital bone; 13, condyles of the occipital bone 14, foramen magnum.

forms the front and lower portion of the skull. The cranium is usually said to consist of eight bones and the face of fourteen;

but it must be understood that in early childhood some of these bones consist of parts which are quite distinct ; also that, in the adult, some of the bones which are considered to be distinct are fused together into one mass.

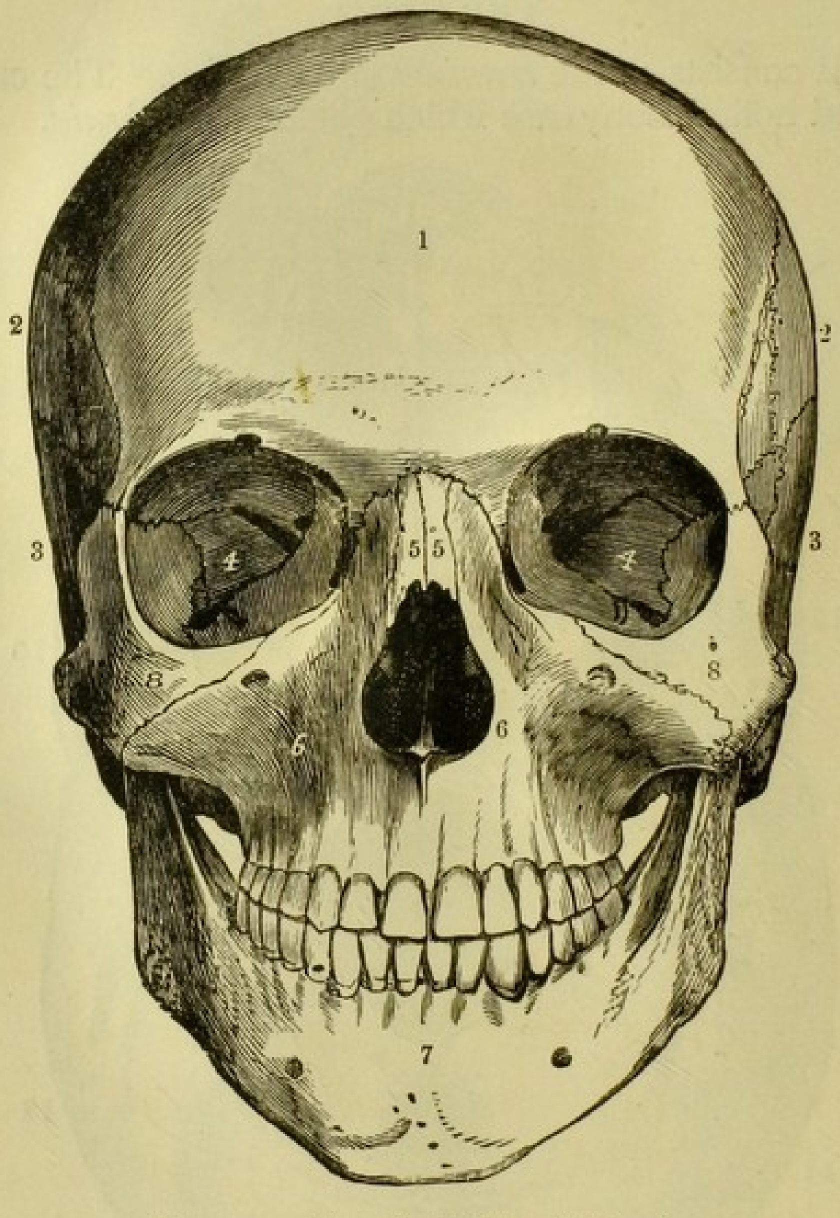


Fig. 20.—**The Skull (Front View).**

1, frontal bone ; 2, parietal bones ; 3, temporal bones ; 4, portions of the sphenoid bones, forming the backs of the orbits of the eyes ; 5, nasal bones ; 6, superior maxillary bones ; 7, inferior maxillary bone ; 8, malar or cheek bones.

The **bones of the cranium or brain-case** are

One **occipital.**	Two **temporal.**
Two **parietal.**	One **sphenoid.**
One **frontal.**	One **ethmoid.**

They are united by means of irregular saw-like edges which firmly lock them together.

The **occipital bone** (Lat. *ob*, against; and *caput*, head) forms the back and a part of the base of the skull. Its lower portion is perforated by a large circular opening, about an inch and a half in diameter, called the **foramen magnum** (Lat. *foramen*, a hole; *magnus*, great), by which the brain cavity is made to communicate with the spinal canal. On each side of the front portion of this cavity is situated a rounded projecting mass of bone called the **condyle** (Gr. a knuckle). These two condyles fit into two corresponding depressions in the first cervical vertebra, thus forming a pair of joints which permit of a rocking or nodding motion of the head.

The upper edge of the occipital bone is united with the **parietal bones** (Lat. *paries*, a wall), which form the side walls and the greater portion of the roof of the cranium.

The **frontal bone** (Lat. *frons*, the forehead) forms the front of the cranium. It is united with the two parietals behind, and extends over the forehead, forming the roofs of the sockets or orbits of the eyes. The frontal bone in a

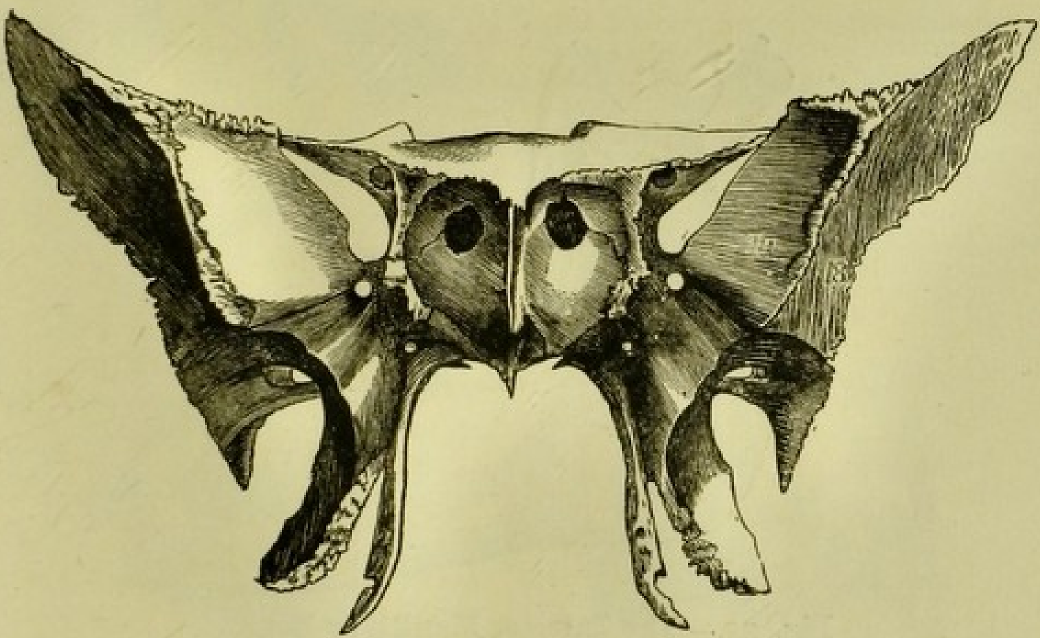


Fig. 21. - **The Sphenoid Bone, viewed from before.**

young child is divided into two parts by a space which is continuous with the line of division between the parietal bones.

The base of the skull, in front of the occipital bone, is formed by the **sphenoid bone** (Gr. *sphen*, a wedge; and *eidos*, form). It much resembles a bat in shape. It is wedged in between the other bones of the base of the skull, and extends forward to meet the frontal bone in the *orbits*.

The **ethmoid bone** (Gr. *ethmos*, a sieve; and *eidos*, form) fills the space between the sockets, and is so called because it is perforated by a large number of small openings, through which the branches of the nerve of smell pass from the brain to the nose. This bone is very irregular in form, and extends into the cavities of the nose.

The **temporal bones** (Lat. *tempus*, time) are so called because they are situated in those parts of the head (the temples) where the effects of time are so often first shown by the appearance of white hairs. They are attached to the sphenoid bone in front, the parietal bones above, and the occipital bone behind. They also send out processes which unite with the *cheek-bones*, forming bony arches.

The **bones of the face** are as follows :—

Two **superior maxillary.**	Two **inferior turbinated.**
Two **palatal.**	One **vomer.**
Two **nasal.**	Two **malar.**
Two **lachrymal.**	One **inferior maxillary.**

The **superior maxillary bones** (Lat. *maxilla*, a jaw) form the upper jaw, and the greater portion of the **palate** or roof of the mouth. In them are fixed the upper set of teeth. Behind these bones are the two **palatal bones** (Lat. *palatum*, the roof of the mouth), which form the hinder portion of the palate.

The **nasal bones** (Lat. *nasus*, the nose) are two very small bones, situated between the sockets of the eyes, and forming the upper and hard ridge of the nose. Very near these bones, separated from them by a narrow portion of the superior maxillaries, are two small bones called the **lachrymal bones,**

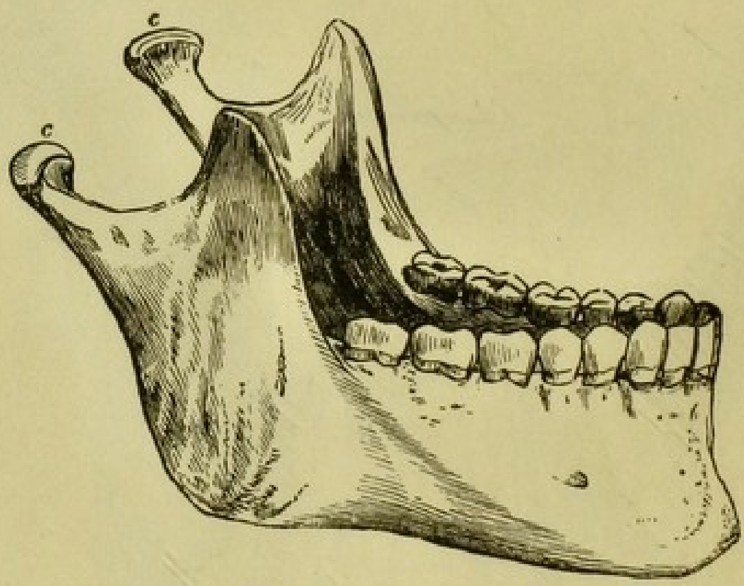


Fig. 22.—**The Inferior Maxillary Bone.**

c, the condyles, which articulate with the temporal bones.

lachrymal plates (Lat. *lachryma*, a tear), or **tear-bones.** They are so called because they are grooved for the *nasal ducts* which convey the tears from the eyes into the cavities of the nose.

A large portion of the face is occupied by the two *nasal cavities* and the bones which form their walls. The **inferior turbinated bones** (Lat. *turbo*, a turning round) are spongy bones which are curved round like scrolls, and project into the nasal cavities. These cavities are separated by a very thin bone called the **vomer** (Lat. a ploughshare). (See fig. 19.)

The **malar or cheek-bones** (Lat. *mala*, the cheek) are the two most prominent bones of the cheeks. They unite with the superior maxillaries in front, and send out processes behind which join with similar projections from the temporal bones, forming the arches which have already been mentioned. The cheek-bones also help to form the sockets of the eyes.

The remaining bone of the face is the **inferior maxillary** or lower jaw. It is the largest bone in the face, and in it is fixed the lower set of teeth. It is the only movable bone of the skull. It gives off two processes which form joints with sockets in the temporal bones ; and these joints are so constructed that the lower jaw has not only a vertical movement, but is capable also of motion sideways and backwards and forwards.

It will be observed that several bones enter into the formation of the **orbits or sockets of the eyes.** The upper part of each orbit is formed by the frontal and sphenoid bones ; the inner portion by the lachrymal plate ; the lower portion by the superior maxillary ; and the outer portion by the malar or cheek-bone. These orbits (Lat. *orbita*, a track in which a body turns) contain the eyeballs, the muscles which turn the eyeball, and a certain amount of fatty matter which acts as a padding to protect the delicate organ of vision.

We must now notice how the head turns on the vertebral column. It has already been seen that the skull rocks or nods

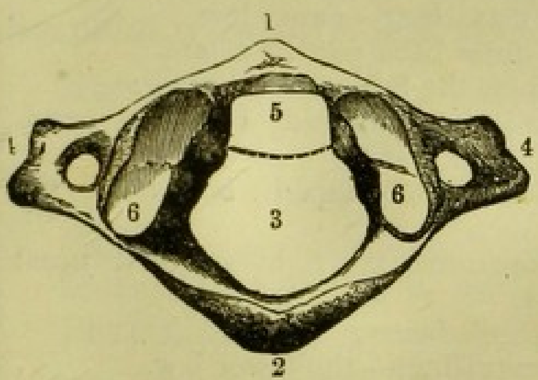
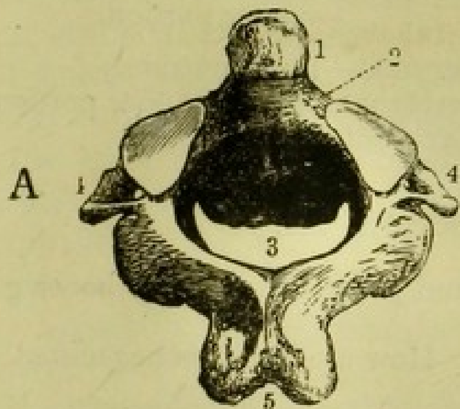


Fig. 23.—**The Atlas, or First Cervical Vertebra; viewed from above.**

1, the anterior arch ; 2, the posterior arch ; 3, spinal cavity ; 4, lateral processes ; 5 marks the position of the odontoid peg of the axis ; 6, concave surfaces which articulate with the occipital bone. The dotted line marks the position of the ligament which secures the peg. The body is absent, but is represented by the odontoid peg of the axis.



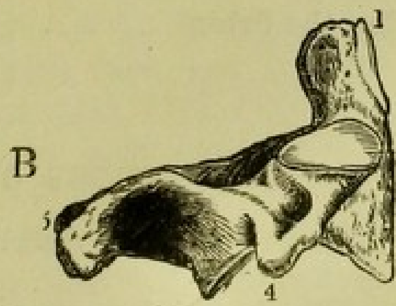


Fig. 24.—**The Axis, or Second Cervical Vertebra.**

A, viewed from above and behind ; B, viewed from the right side ; 1, odontoid process ; 2, body ; 3, spinal cavity ; 4, lateral processes ; 5, spinal process.

on the vertebral axis by means of a pair of joints, formed by projections (*condyles*) of the occipital bone, and the corresponding depressions or sockets in the first cervical vertebra, the **atlas.** But, were these the only joints permitting a movement of the head, that motion would be restricted to nodding. We know, however, that the head turns freely to right and left. This is explained as follows. The *second* cervical vertebra, the **axis**, sends upward a tooth-like projection called the **odontoid process** (Gr. *odous*, tooth ; and *eidos*, form). This peg forms an axis on which the atlas turns, and is kept in its position against the front inner surface of the atlas by means of a powerful ligament. Thus, when the head turns to right or left, the skull and the atlas move together, both rotating on the process of the axis.

SUMMARY.

- **SKULL**
  - **Cranium** (brain-case)
    - 1 **Occipital**—at back and base of skull—*foramen magnum.*
    - 2 **Parietal**—the side walls and roof.
    - 1 **Frontal**—the forehead bone.
    - 2 **Temporal**—bones of the temples.
    - 1 **Sphenoid**—irregular, bat-shaped.
    - 1 **Ethmoid**—spongy, between the nasal and brain cavities.
  - **Face**
    - 2 **Superior maxillary**—upper jaw.
    - 2 **Palatal**—form back part of palate.
    - 2 **Nasal**—form the bridge of the nose.
    - 2 **Lachrymal**—on nasal side of orbits—contain the tear ducts.
    - 2 **Turbinated**—scroll-shaped bones of the nose.
    - 1 **Vomer**—separates the right and left nasal cavities.
    - 2 **Malar**—cheek-bones.
    - 1 **Inferior maxillary**—the lower jaw.
- **Bones forming the Orbits**
  - **Sphenoid**, **Frontal**—upper portion.
  - **Lachrymal**—inner portion.
  - **Superior maxillary**—under portion.
  - **Malar**—outer portion.

QUESTIONS ON LESSON III.

1. Distinguish between *skull*, *cranium*, and *face*. How many bones go to form each of these?
2. Enumerate the bones of the cranium. How are these bones united with each other?
3. Describe briefly the positions and forms of the bones of the cranium.
4. What is the *foramen magnum*? Where is it, and what is its use?
5. Describe the arrangement by which the head is enabled to nod.
6. Give a list of the bones which form the face.
7. In which of these bones are the teeth fixed; and which of them form the roof of the mouth?
8. What is the character of the joint by which we move the lower jaw?
9. Name the bones which form the *orbits* of the eyeballs.
10. Describe the arrangement which enables us to turn the head to the right and left.
11. Make out a table of all the bones of the head.

LESSON IV.

THE SKELETON (*continued*).

THE BONES OF THE LIMBS.

EACH of the **upper extremities** consists of the *shoulder*, the *upper arm*, the *forearm*, the *wrist*, and the *hand*. The bones of these limbs may be classified as follows :—

Clavicle or *collar-bone*
Scapula or *shoulder-blade* } Together forming the *shoulder-girdle*.

Humerus or *bone of the upper arm*.

Ulna
Radius } In the *forearm*.

Carpal or *wrist-bones*.
Metacarpal bones, in the *palm of the hand*.
Phalanges or *finger-bones*.

The **clavicle** (Lat. *clavis*, a key) is so called from its fancied resemblance to an ancient key. It is commonly known as the **collar-bone**. One end of it articulates with the top of the sternum, and the other extremity forms a joint with the scapula near its junction with the bone of the upper arm. The clavicle tends to keep the shoulders back. It is short and imperfectly formed in the rounded shoulders of the cat and the dog ; and in the horse and the sheep it is wanting. It forms, however, an essential part of the skeleton of the monkey, the squirrel, and other climbing animals.

The **scapula** or **shoulder-blade** is triangular in form ; it consists of a broad flat portion, and a prominent ridge or spine at the back of this. The front surface is smooth and concave, and glides over the back convex surface of the chest. The outer end of the clavicle articulates with one of the two processes which project from the top of the scapula, and is attached to the other process by means of strong ligaments. At the upper and inner part of the scapula there is a shallow concave surface—the **glenoid cavity** (Gr. *glene*, the pupil ; and *eidos*, form)—which receives the rounded head of the bone of the upper arm. It will thus be seen that the scapula is united to other bones only at or near the shoulder-joint. It has, therefore, great freedom of motion.

The **humerus** or **bone of the upper arm** is very strong. It consists of a long portion called the *shaft*, and two enlarged extremities called the *heads*. As already mentioned, the upper head

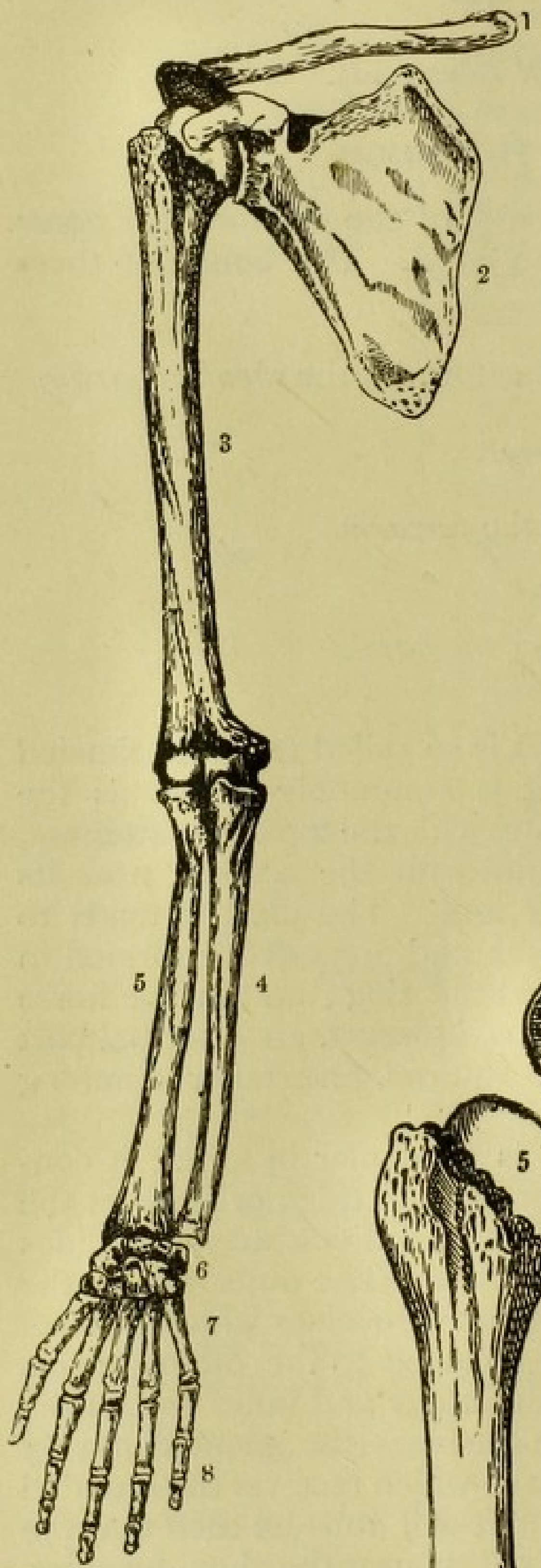


Fig. 25.--**Bones of the Upper Limb.**

1, clavicle ; 2, scapula ; 3, humerus ; 4, ulna ; 5, radius ; 6, carpal bones ; 7, metacarpal bones ; 8, phalanges.

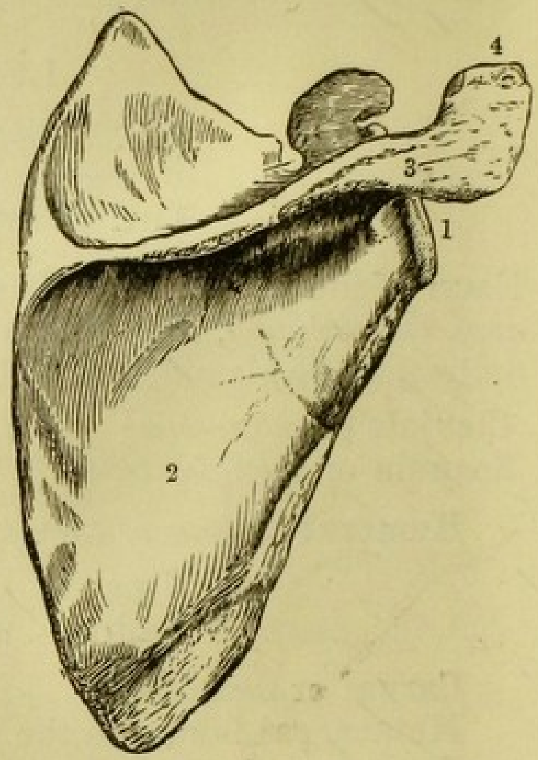


Fig. 26.—**The Right Scapula from behind.**

1, edge of the glenoid cavity ; 2, the blade ; 3, the spine ; 4, the process which articulates with the outer extremity of the clavicle.

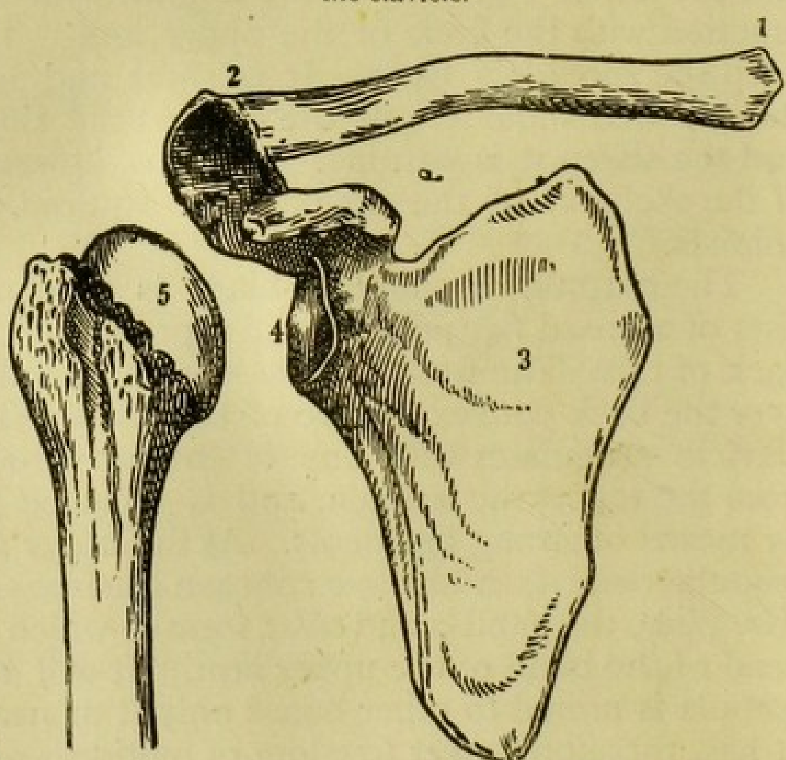


Fig. 27.—**The Shoulder-Girdle and Head of the Humerus.**

1, clavicle ; 2, process of the scapula ; 3, blade ; 4, glenoid cavity ; 5, head of the humerus.

fits into the glenoid cavity of the scapula. The joint thus formed permits of a greater freedom of movement than any other joint in the body. This is due to the fact that the head of the humerus is much larger than the shallow cavity which receives it. On this account, too, the shoulder-joint would be very easily dislocated, were it not that the two processes of the scapula bend over the

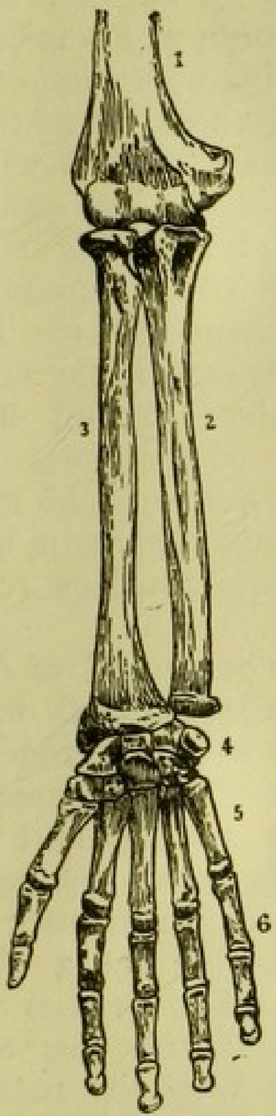


Fig. 28.—**The Bones of the Right Fore-arm in Supination.**

Fig. 29.—**In Pronation.**

1, humerus ; 2, ulna ; 3, radius ; 4, carpal bones ; 5, metacarpal bones ; 6, phalanges.

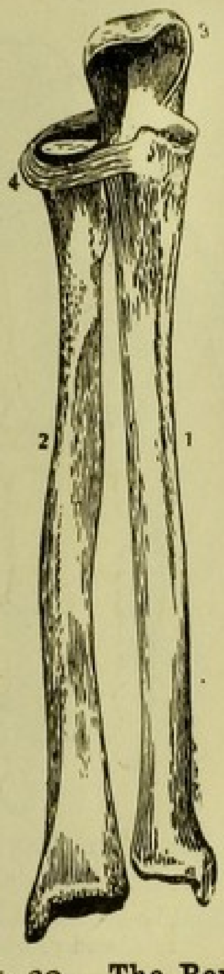


Fig. 30.—**The Bones of the Fore-arm, with the Orbicular Ligament.**

1, ulna ; 2, radius ; 3, olecranon process ; 4, orbicular ligament.

head of the humerus and prevent its getting out of joint when too great pressure is brought to bear on it.

In the **forearm** there are two bones—the *ulna* and the *radius*. The **ulna** (Lat. the elbow) is thick at its upper extremity, which forms a *hinge joint* (a joint which allows of motion in one plane only, like the hinge of a door) with the lower head of the humerus. This extremity of the ulna also sends a projection behind the humerus, forming the **olecranon process** (Gr. *olene*, the elbow; and *kranion*, the top) or prominence of the elbow, which gives attachment to certain muscles, and prevents the forearm from moving too far back. The **radius** is slender at the top, where its shallow cup-like end articulates with a convex surface furnished by the humerus. Its lower extremity is enlarged, and gives attachment to the bones of the wrist. If we rest the forearm flat on a table, with the palm of the hand uppermost (an attitude which is called *supination*), the ulna and the radius are parallel with each other. If we now turn the hand round till its back is uppermost (*pronation*) the ulna does not change its position; but the lower end of the radius turns round this bone, crossing it, and carrying the hand with it. Thus the upper slender end of the radius rotates on a pivot formed by a rounded portion of the lower head of the humerus, and is held in its position by a circular ligament, while its lower extremity revolves round the ulna.

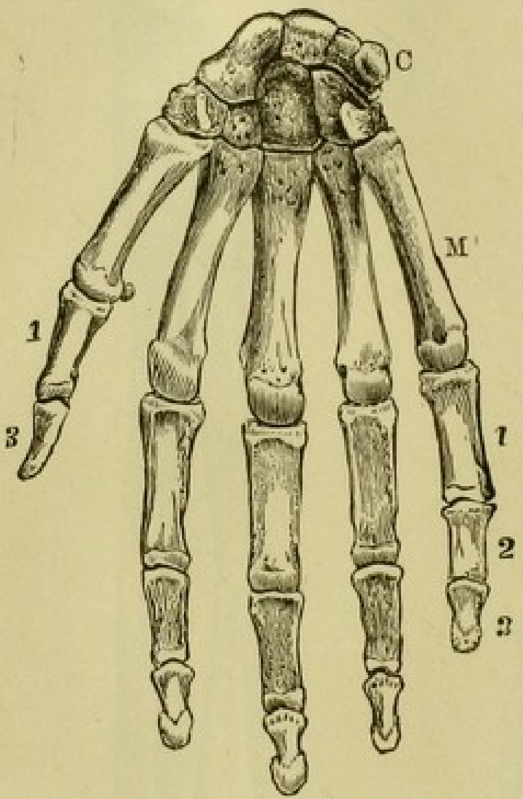


Fig. 31.—**The Right Hand from before.**

C, carpal bones; M, metacarpal bones; 1, 2, and 3, phalanges.

The **wrist** is composed of eight small bones, called **carpal bones** (Gr. *karpos*, the wrist), arranged in two rows of four. These bones are united with one another and with the neighbouring bones by means of ligaments, in such a manner that each one is capable of a slight gliding motion. The wrist is thus rendered flexible; and this flexibility, combined with the rotatory motion of the radius, gives great freedom of movement to the hand.

Five long bones, called **metacarpal bones** (Gr. *meta*, beyond; and *karpos*, the wrist), form the palm of the hand. One of these passes from the wrist to the thumb, and the other four from the wrist to the fingers. These bones may be easily felt by pressing the fingers of one hand over the back of the other. It will, of course, be observed that the metacarpal bone which is connected with the thumb is capable of motion to a far greater degree than the others. It is on this that the utility of the thumb depends, for we are enabled to move the thumb round till it is in opposition to the fingers, and thus to firmly grasp large objects and to pick up small ones.

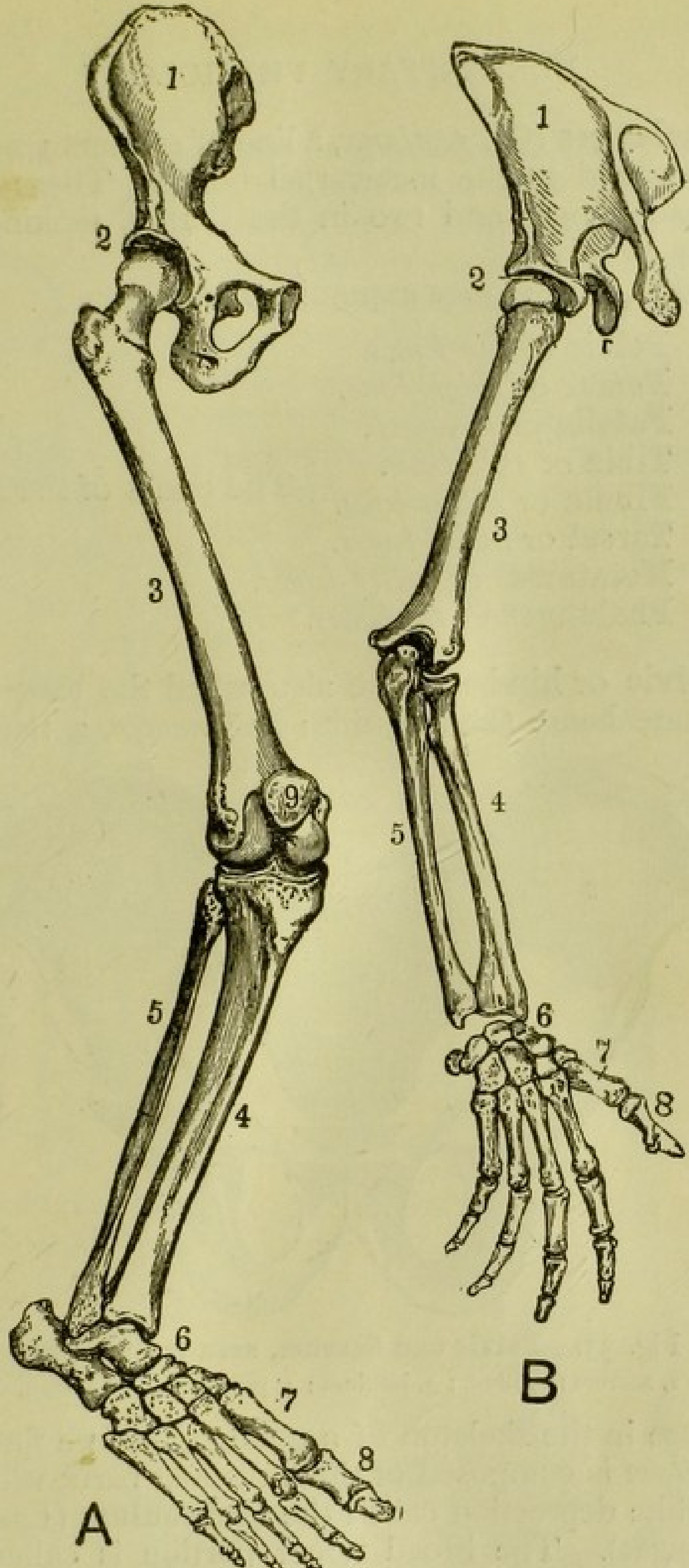


Fig. 32.—The Bones of the Upper and Lower Limbs, so placed as to show corresponding parts.

A, *The Lower Limb.*

1, os innominatum.
2, acetabulum.
3, femur.
4, tibia } lower leg.
5, fibula }
6, tarsus or ankle—7 bones.
7, metatarsus.
8, phalanges of toes.
9, patella.

B, *The Upper Limb.*

1, scapula.
2, glenoid cavity.
3, humerus.
4, radius } forearm.
5, ulna }
6, carpus or wrist—8 bones.
7, metacarpus.
8, phalanges of fingers.
The patella has no corresponding part in the arm.

The **phalanges** (Gr. *phalanx*, a line of soldiers ; a rank) of the fingers are united to the metacarpal bones. There are three of these in each finger and two in the thumb, making a total of fourteen for each hand.

The bones of the lower extremities are :—

Pelvic or *hip-bones.*
Femur or *thigh-bone.*
Patella or *knee-cap.*
Tibia or *shin-bone.* } The bones of the *calf.*
Fibula or *splint-bone.* }
Tarsal or *ankle-bones.*
Metatarsal or *instep-bones.*
Phalanges or *toe-bones.*

The **pelvic** or **hip-bones** are also called the **ossa innominata** or **innominate bones** (Lat. *in*, not : and *nomen*, a name). If we

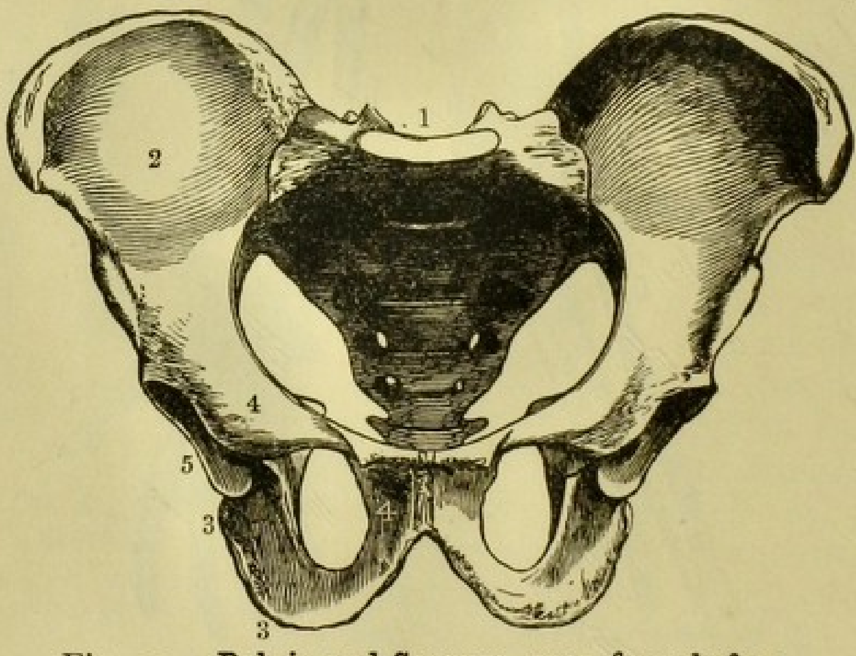


Fig. 33.—**Pelvis and Sacrum, seen from before.**
1, sacrum ; 2, ilium ; 3, ischium ; 4, pubis ; 5, acetabulum.

examine these in the skeleton of a young child, we find that each *os innominatum* is composed of three distinct parts, which meet at a deep cup-like depression called the **acetabulum** (Lat., a cup for holding vinegar). The broad upper portion is called the **ilium** (Gr. *eileo*, I twist) ; the lower part, the **ischium** (Gr. *ischion*, the hip) ; and that portion which is joined to the other innominate bone, the **pubis.**

The **acetabulum** receives the rounded head of the thigh bone. The bones of the pelvis are supported like a bridge on the legs as pillars, and serve in turn as a support for the internal organs of the *abdomen* or lower part of the trunk.

The **femur** or **thigh-bone** corresponds with the humerus of the arm. In general form it resembles that bone, but is much larger and stronger, having to bear the weight of the body. Its upper extremity is provided with a rounded head which articulates with the acetabulum of the hip-bone, forming a *ball-and-socket joint*, somewhat similar to that of the upper arm, but differing in one important respect. The rounded head of the femur is much more prominent than that of the humerus, and the acetabulum is much deeper than the glenoid cavity of the scapula. Thus the thigh has not the freedom of motion of the humerus, but is less easily dislocated.

The **calf-bones**, like those of the fore-arm, are two in number—the **tibia** or **shin-bone**, and the **fibula** (Lat. a clasp or buckle) or **splint-bone**. These bones correspond with the ulna and the radius, but the fibula does not rotate round the tibia as does the radius round the ulna ; it is slender throughout its length, and is firmly fixed to the tibia at both ends. The

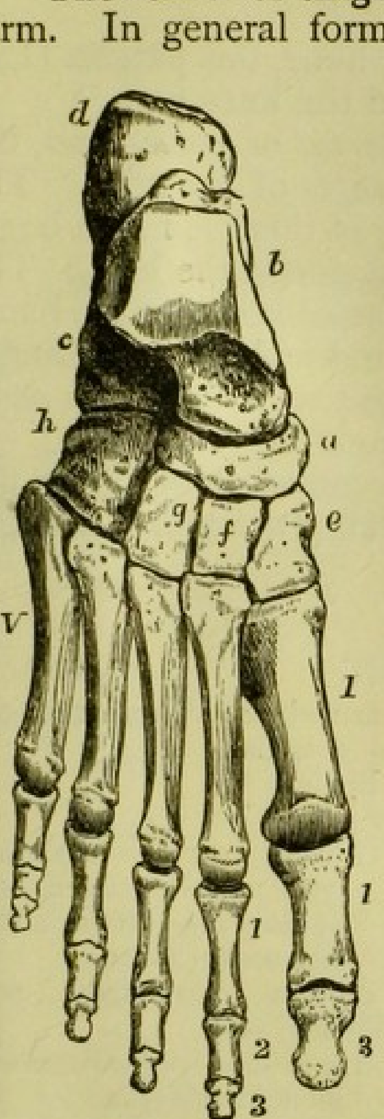


Fig. 34.—**Right foot, viewed from above.**

a, *b*, *cd*, *e*, *f*, *g*, and *h*, the tarsal bones ; I to V, metatarsal bones ; 1 and 3, phalanges of great toe ; 1, 2, and 3, phalanges of second toe.

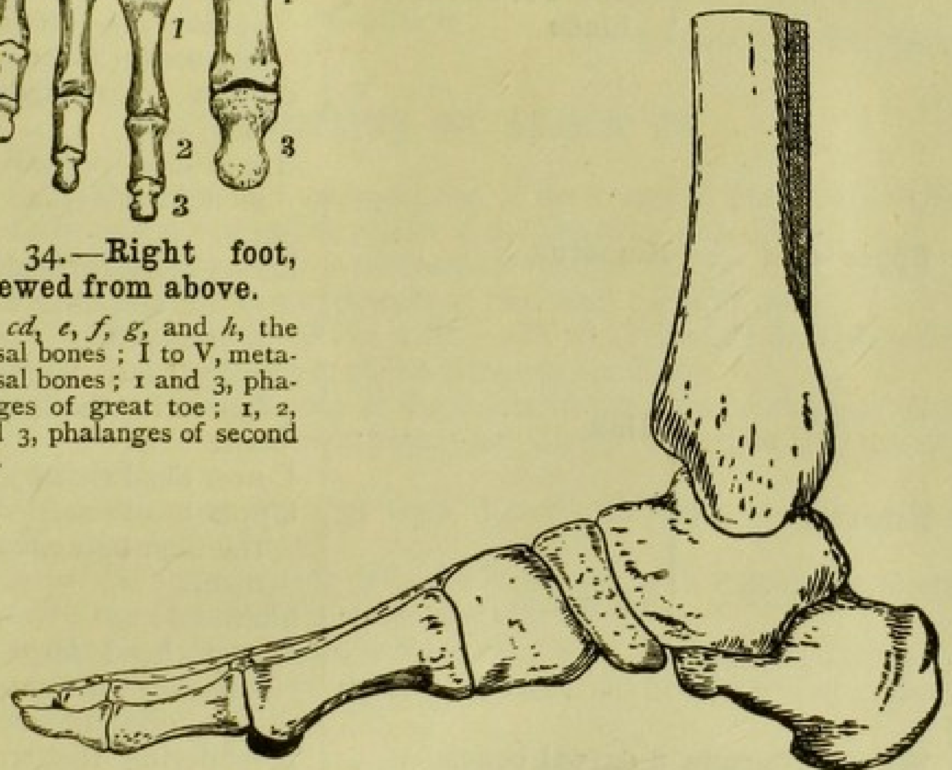


Fig. 35.—**The Bones of the Foot, viewed from the side, showing the arched form.**

tibia forms, with the femur, the hinge **knee-joint** which corresponds with the similar joint of the elbow.

The **knee-joint** is protected by a small bone, the **patella** (Lat. a little plate), called also the **knee-cap** and the **knee-pan.**

The **bones of the foot** consist of the *tarsal* or *ankle-bones*, the *metatarsal* or *instep-bones*, and the *phalanges* of the toes. The **tarsal bones** are seven in number. One of them is much larger than the others, and, projecting backward, forms the **heel.** The **metatarsal bones** are similar to the metacarpal bones of the hand. They are five in number, and are connected with the **phalanges** of the toes. The number of bones in the toes is the same as in the fingers and thumb, the great toe representing the thumb.

The **foot** is arched in form, and is prevented from falling flat by powerful ligaments. This arched form gives great strength combined with elasticity.

SUMMARY.

UPPER LIMB.	**Shoulder-girdle**	**Clavicle** or **Collar-bone**	articulates with sternum and scapula.
		Scapula or **Shoulder-blade**	Blade. Spine. Glenoid cavity—articulates with upper rounded head of humerus, forming a ball-and-socket joint. Process — articulates with clavicle.
	Upper arm	**Humerus**	Upper head—articulates with glenoid cavity. Shaft. Lower head—articulates with radius and ulna, forming a hinge joint.
	Forearm	**Ulna**	Upper head large—articulates with the humerus. Shaft. Lower head small.
		Radius	Upper head small—bound to the ulna by a circular ligament. Shaft. Lower head large—articulates with the carpus.
	Wrist or **Carpus**	**8 Carpal bones**	Slight gliding movement, rendering the wrist flexible.
	Hand	**5 Metacarpal bones**	Connecting the fingers and thumb with the wrist.
	Fingers	**14 Phalanges**	2 in the thumb. 3 in each finger.

LOWER LIMB.

Hip	**2 Ossa innominata**	Ilium. Ischium. Pubis. Acetabulum—a cavity which articulates with the rounded head of the femur—ball and socket.
Thigh	**Femur**	Upper head—articulates with the acetabulum. Shaft. Lower head—forms a hinge joint with the head of the tibia.
Knee	**Patella**	Protects the knee-joint.
Leg	**Tibia**	Upper head—articulates with the femur. Shaft. Lower head—articulates with the ankle.
	Fibula	Slender throughout its length. Fixed to the tibia at both ends.
Ankle	**7 Tarsal bones**	
Instep	**5 Metatarsal bones**	Connect the bones of the toes with those of the ankle.
Toes	**14 Phalanges**	2 in the great toe. 3 in each of the others.

QUESTIONS ON LESSON IV.

1. Describe the form and arrangement of the bones of the *shoulder-girdle*.
2. Describe and compare the joints of the shoulder and elbow.
3. In what way is the motion of the forearm limited ?
4. How are the various movements of the hand brought about ?
5. Describe the structure of the wrist. On what does its flexibility depend ?
6. Describe the arrangement of the bones in the hand.
7. Describe the arrangement of the bones in the thigh and leg. How does this arrangement differ from that in the corresponding parts of the upper limb ?
8. Compare the shoulder-joint with that of the hip ; and the elbow-joint with that of the knee.
9. Compare the arrangement of bones in the leg with that in the forearm.
10. Describe the bones of the ankle and the foot.
11. Write out, in tabular form, a complete list of the bones in both upper and lower limbs ; and in such a manner as to show the parts which correspond.

LESSON V.

LIGAMENTS. CARTILAGE. JOINTS.

THE **ligaments** are strong, white, fibrous bands which bind the bones together. Being more or less elastic, they allow of the necessary freedom of motion to the bones, and at the same time protect the joints from external injury and tend to prevent dislocation.

These ligamentous bands may easily be observed by carefully

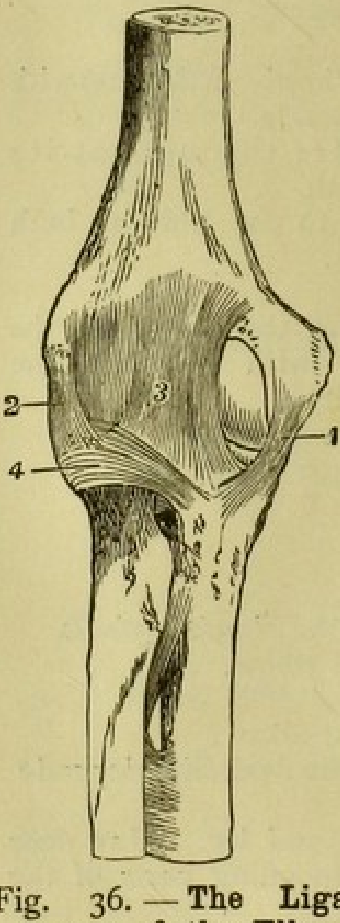


Fig. 36. — **The Ligaments of the Elbow-Joint, from the Front.**

1, 2, 3, and 4, the ligaments.

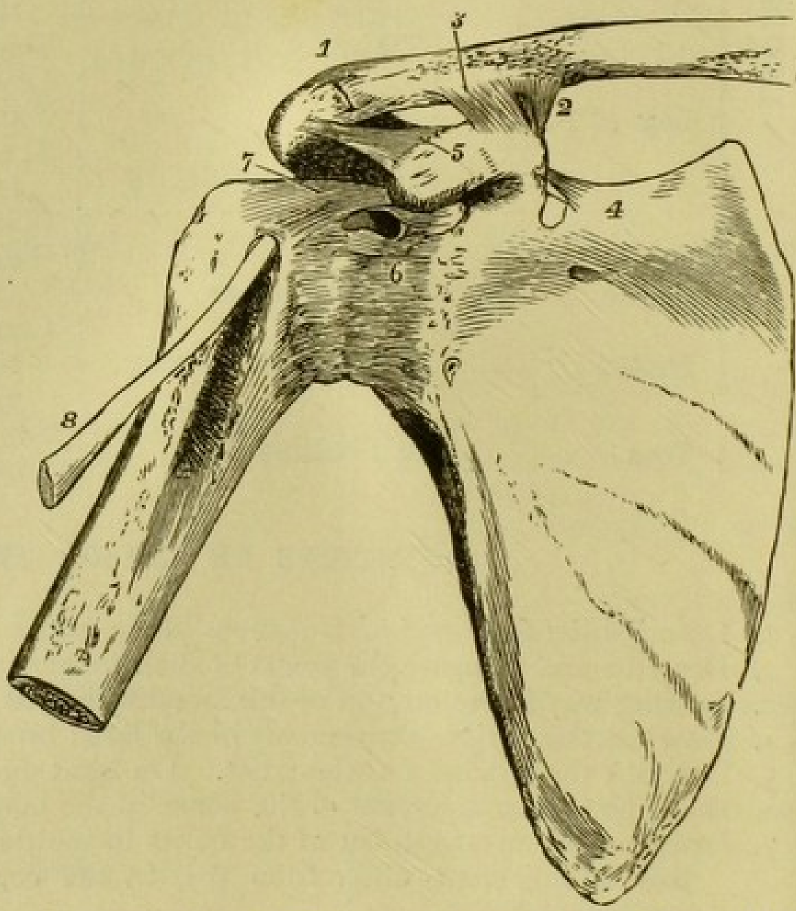


Fig. 37.—**The Shoulder-Joint, showing Ligaments and Tendon**

1 to 7, ligaments of the shoulder ; 8, a tendon.

removing the flesh from a cooked rabbit or fowl or joint of meat. It may be noticed at the same time that the masses of flesh (muscles) are united to the bones by other white bands. These are called **tendons**, and they must not be confused with ligaments, which always bind bone to bone.

Cartilage or **gristle** is a firm, tough, and flexible substance. Bone is produced by the gradual hardening of cartilage. The skeleton of a very young animal consists entirely of cartilage, and as the animal develops into maturity, the bones become gradually harder by the slow absorption of mineral matter derived from its food substances, till at last the skeleton consists almost entirely of bone.

Cartilage is not supplied with blood, hence it is white or semitransparent. When boiled for some time with water, it yields a substance called **chondrine** (Gr. *chondros*, cartilage), which closely resembles gelatine, being soluble in hot water and forming a 'jelly' on cooling.

Those cartilages which are converted into bone during growth are called **temporary cartilages**; whilst those which remain unchanged are termed **permanent cartilages.**

The **uses of cartilage** are various. It is *tough*, *flexible*, and *elastic*; and will be found in all parts of the body where these properties are essential. Sometimes it helps to form a flexible framework, as in the **costal cartilages** of the walls of the chest. The **intervertebral cartilages** of the backbone are flexible pads which bind the vertebræ together, at the same time allowing a certain degree of movement, enabling us to bend the back. In aged persons these cartilages become hardened by the absorption of lime, hence the stiffness of the vertebral column. They also act as *buffers* in deadening the effect of a blow or shock. Another use of cartilage is to

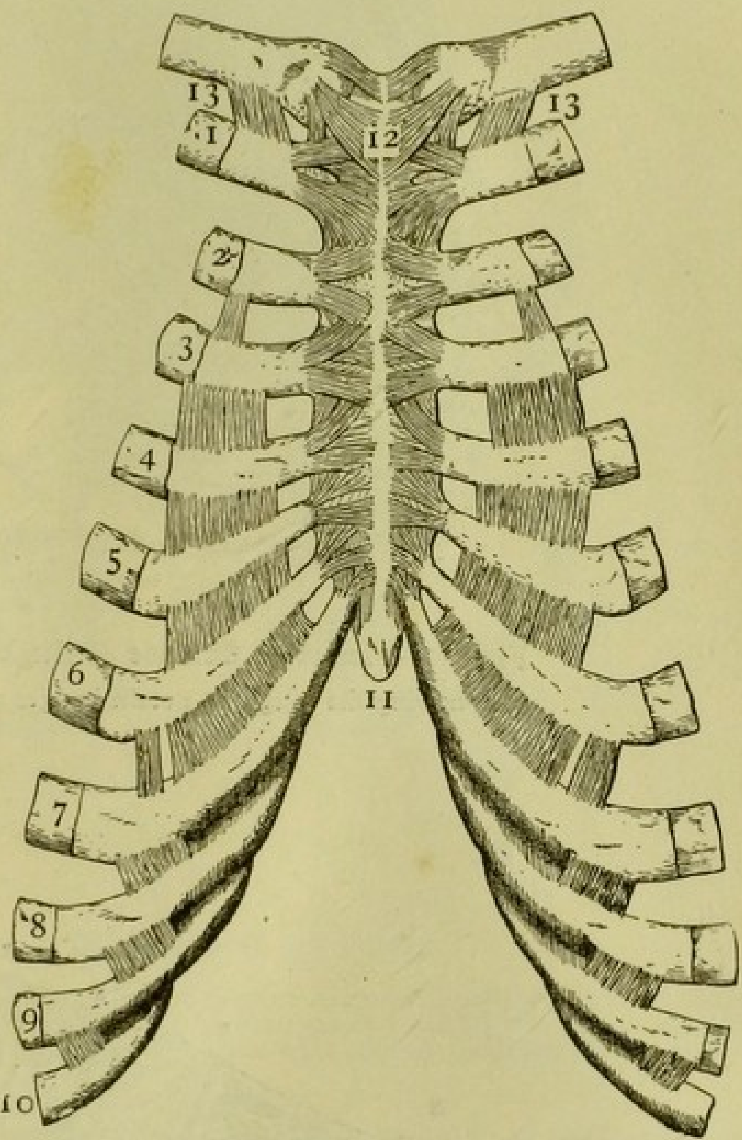


Fig. 38.—**The Ligaments and Cartilages of the Breast.**

1 to 10, the ends of the ribs, with their costal cartilages, and the ligaments uniting these cartilages; 11, cartilaginous end of the sternum; 12, ligaments uniting the clavicle with the sternum; 13, ligaments binding the clavicle to the first rib.

deepen the bony sockets of various joints by surrounding them at their edges in the form of a ring. The sockets thus deepened are better enabled to hold the rounded heads of the bones which

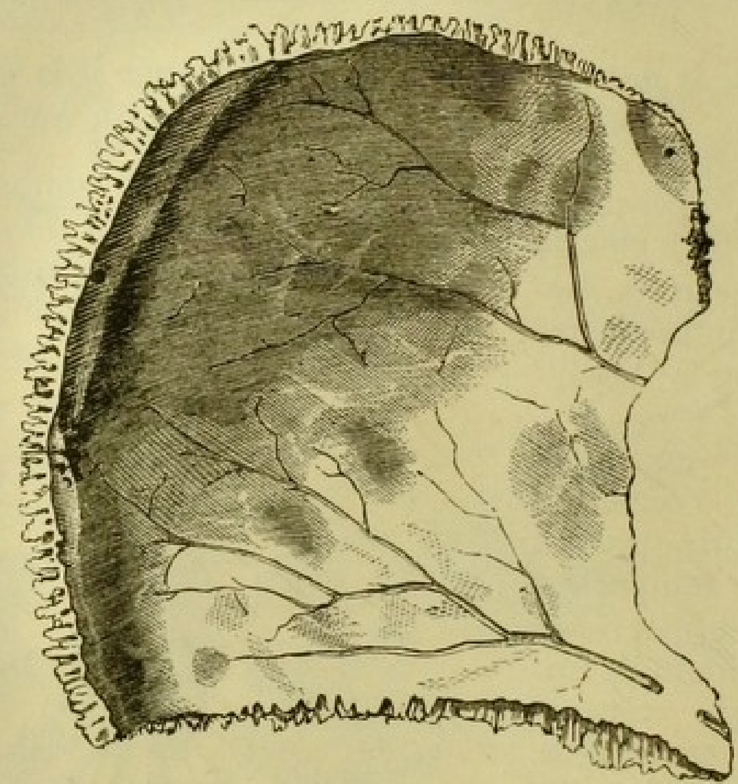


Fig. 39.—**Interior Surface of the Parietal Bone,**
Showing the irregular, notched edges of the suture.

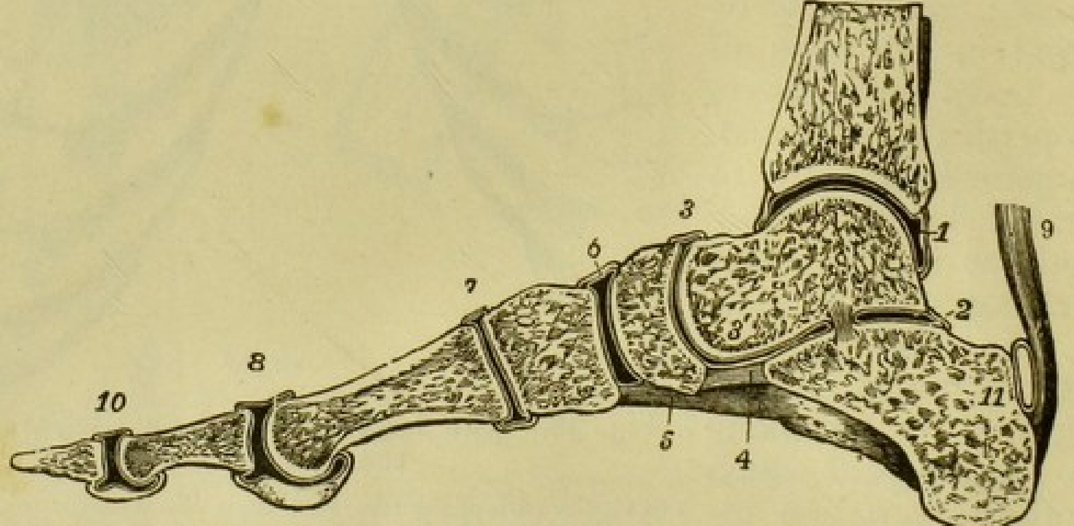


Fig. 40.—**Section of the Right Foot,**
Showing the nature of a sliding or gliding joint, synovial membranes, and synovial cavities; also ligament and tendon. Showing also the arched form of the foot.
1, 2, 3, 6, 7, 8, and 10, synovial cavities, surrounded by synovial membrane; 4 and 5, ligaments; 9, tendon.

move in them, and, the cartilage being flexible and elastic, the motion is not restricted. Cartilage also lines the surfaces of bones which glide over each other. In such cases the cartilaginous surfaces are smooth, thus making the motion easier. The cartilage which serves this purpose is called **articular cartilage**.

Joints are distinguished as *immovable* and *movable*.

Immovable joints are those in which the bones are in actual contact, *i.e.* without any intervening cartilage; and are incapable of motion on each other. In some such joints, as in the skull,

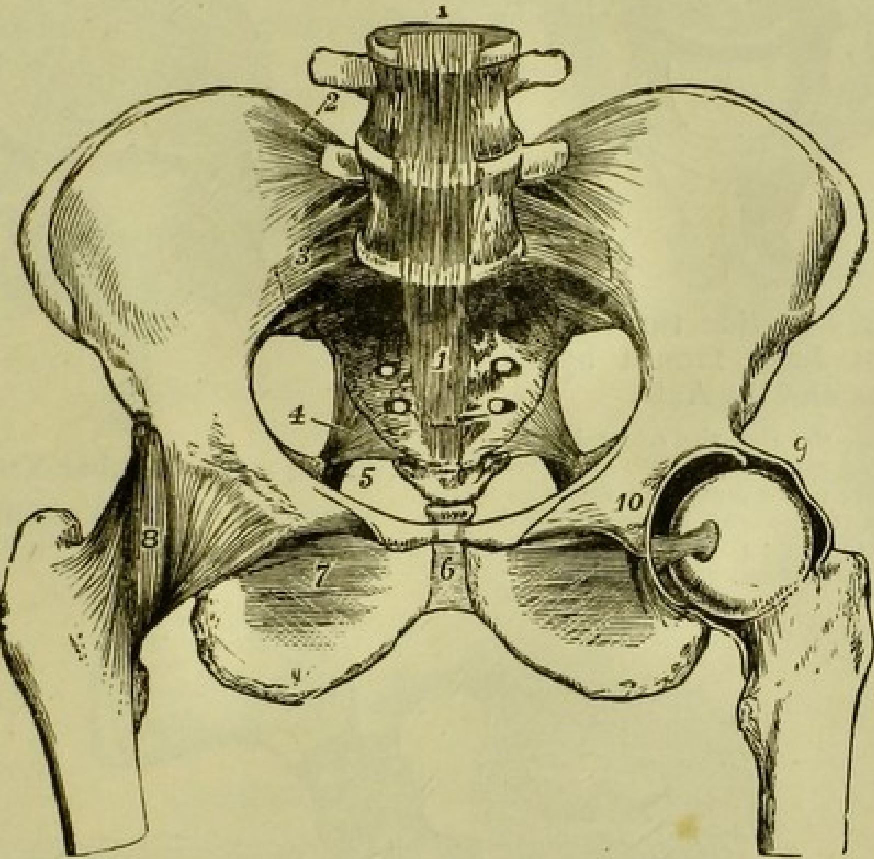


Fig. 41.—**The Joints of the Pelvis.**

1, ligament of the vertebræ; 2, 3, 4, 5, 6, 7, and 8, other ligaments; 9 and 10, ball and socket joint of the hip in part dissected, to show the synovial cavity; and also the ligament (*ligamentum teres*) which connects the ball of the femur with the interior of the acetabulum.

each bone has a very irregular sawlike edge, and the teeth or projections of the opposite edges are firmly dovetailed together. Immovable joints are often called **sutures** (Lat. *sutura*, a seam).

Movable joints are those in which the bones forming them are capable of motion against each other. These joints are subdivided into *perfect* or *complete*, and *imperfect* or *incomplete*.

The **perfect joints** are of four kinds, viz:—(1) **gliding joints**, consisting of bones which slide over each other, as those of the ankle and wrist; (2) **ball and socket joints**, consisting of a rounded head which rotates in a hollow socket, as the hip-joint and shoulder-joint; (3) **hinge joints**, like those of the elbow and the knee ; and (4) **pivot joints**, in which a projection of one bone serves as a pivot for the rotation of the other, as the joint formed by the atlas and the axis.

In each of these joints the articulating surfaces of the bones are covered with a thin layer of articular cartilage, and this

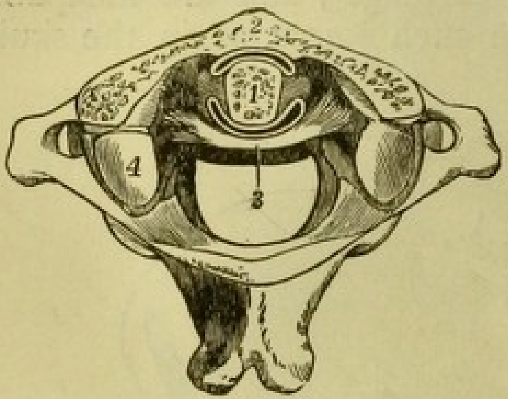


Fig. 42.—**Section through the Pivot Joint formed by the Atlas and the Axis.**

1, section through the odontoid peg, showing synovial cavities before and behind ; 2, cut portion of the atlas ; 3, the transverse ligament which holds the peg ; 4, surface of the atlas which articulates with the skull.

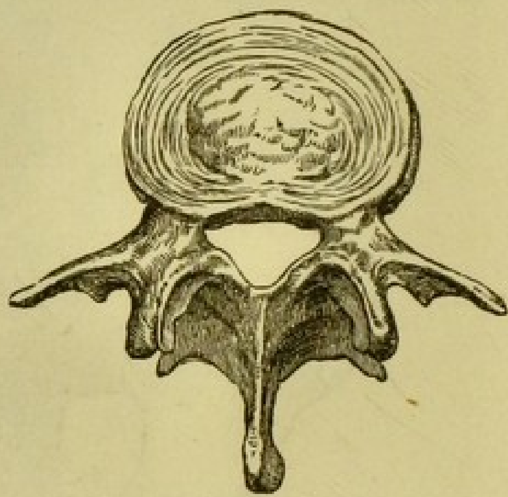


Fig. 43.—**A Lumbar Vertebra,**

Viewed from above, showing the intervertebral disc of cartilage.

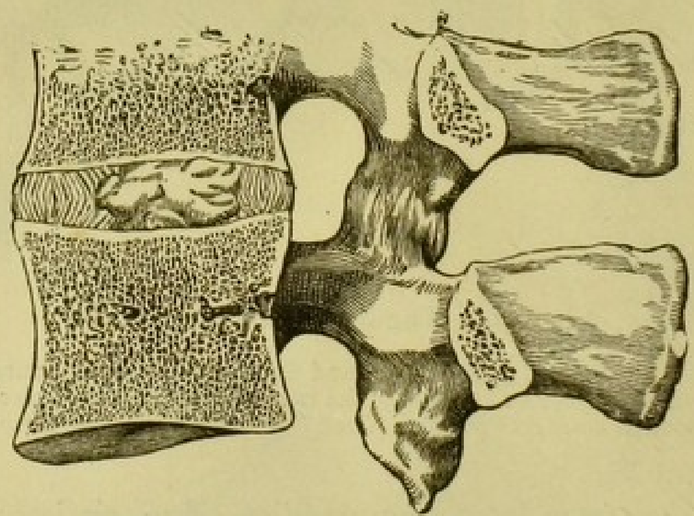


Fig. 44.—**Section through Lumbar Vertebræ,**

Showing an intervertebral disc of cartilage.

cartilage is again covered with a membrane called the **synovial membrane** (Gr. *syn*, together ; and *oon*, an egg), from which exudes a fluid (*synovia*) resembling the white of egg, the use of which is to lubricate or moisten the joints. The synovial membrane forms a closed sac or cavity, called the **synovial cavity**, which receives and contains the synovia.

An **imperfect movable joint** is one in which the bones are separated from each other by a layer of cartilage. The bones, therefore, do not move on each other, but all motion is due to the flexibility of the layer of cartilage between them. The vertebræ with the intervertebral cartilages form such joints.

SUMMARY.

1. **Ligaments** bind bones together.

2. **Tendons** connect muscles with bones.

3. **Cartilage** is tough, flexible, and elastic. When boiled it yields *chondrine*, which resembles gelatine. Chondrine is insoluble in cold water, but dissolves in hot water, forming a jelly on cooling.

5. **Kinds of Cartilage** :—
   - (*a*) *Temporary*—becomes converted into bone in adults.
   - (*b*) *Permanent*—not converted into bone.

6. **Uses of Cartilage** :—
   - (*a*) Forms strong yet flexible frameworks.
   - (*b*) Acts as buffers in deadening shocks and blows.
   - (*c*) Deepens the sockets of joints ; example—the hip-joint.
   - (*d*) Covers the articulating surfaces of bones, thus reducing the friction.

7. **JOINTS**
   - **Immovable** . . . . . . Sutures—skull.
   - **Movable**
     - **Perfect** . . .
       - Gliding joints—ankle and wrist.
       - Ball-and-socket joints—shoulder and hip.
       - Hinge joints—elbow and knee.
       - Pivot joints—joint of atlas and axis.
     - **Imperfect** . . Vertebral joints.

QUESTIONS ON LESSON V.

1. What are *ligaments* ? Where are they to be found ?
2. What is the difference between *ligament* and *tendon* ?
3. What is *cartilage* ? Describe its chief characteristics.
4. Describe the chief uses of *cartilage*. Illustrate your description by reference to various parts of the body.
5. Describe briefly the various kinds of *joints*, giving examples of each kind.
6. Describe the manner in which the bones of the skull are united to each other.
7. By what means are the bones enabled to move smoothly over each other ?
8. Describe the ankle and wrist joints.
9. Give a full description of the shoulder-joint. Illustrate your answer by a sketch.
10. Draw a sketch and give a description of the hip-joint. Show how the bones forming this joint are held together.
11. Give an example and explain the action of a *pivot joint*.
12. Describe the manner in which the bones of the vertebral column are connected together.
13. Write out, in tabular form, a list of all the various kinds of joints, giving examples of each kind.
14. Why in old age is the back generally stiff ?

LESSON VI.

THE COMPOSITION AND STRUCTURE OF BONE.

WEIGH a bone of a rabbit, sheep, or other animal, and then put it into a hot and clear fire. Let it remain till it is at a red heat throughout. Now remove it carefully from the fire, let it cool, and weigh again. It will be noticed that the bone has lost about one-third of its original weight, and that what remains is a white and brittle substance. That which has been burnt away by the fire is the **organic** or **animal matter** of the bone; while that which remains is the **earthy** or **mineral substance**, sometimes called the **ash**. From this we learn that bone consists of about thirty-three per cent. of animal matter, and about sixty-seven per cent. of mineral matter.

The proportion of animal to mineral substance is not the same in all bones. The *sternum* and the *scapula* contain a smaller proportion of mineral matter than other bones. The flexible bones of a young child also contain little mineral substance, while the brittle bones of aged persons contain a much larger proportion.

In the above experiment we completely destroyed the animal matter, and obtained the pure mineral substance or *bone ash*. By the following experiment we shall be able to dissolve out all the mineral substance, and thus obtain the **animal matter** :—

Place a bone taken from a recently killed animal in a vessel of weak *hydrochloric* (*muriatic*) *acid* (one part of the strong acid to about six of water), and let it remain for a day or two completely covered by the acid. Now pour off the liquid, and cover the bone with fresh acid, setting it aside again for some time. It will be noticed that the bone gradually becomes softer under this treatment, till at last it is flexible and elastic, like a piece of india-rubber. This is due to the gradual removal of the mineral substance it contained. This experiment teaches us that the **hardness of bone is due to its mineral matter**, and that **the animal substance resembles cartilage or gristle.**

In this experiment we notice also that the mass of animal matter retains the form of the bone from which it was obtained. In our first experiment, too, we found that the mass of mineral substance was also of the same form as the bone. Hence we conclude that **both animal and mineral substances are well blended together** in the bones.

The animal matter of bone may be converted into gelatine in the following manner :—

Take some bones that have been recently removed from the body of an animal, break them in pieces, and boil them in water for a considerable time. After this pour off the liquid and let it cool. As it does so it will form a *jelly*. The animal matter of the bone has been partially separated by prolonged boiling, and has been converted into **gelatine.**

While studying the skeleton the student will have noticed that the different bones of the body vary considerably in shape. They are generally classified as—

1. Long bones, as the femur and humerus.
2. Short bones, as those of the wrist and ankle.
3. Flat bones, as those of the top of the skull.
4. Irregular bones, as the vertebræ.

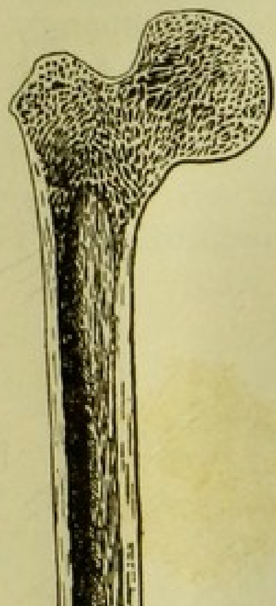


Fig. 45.—**Longitudinal Section of the Femur, showing the Compact and Cancellous Tissues, and the Medullary Cavity.**

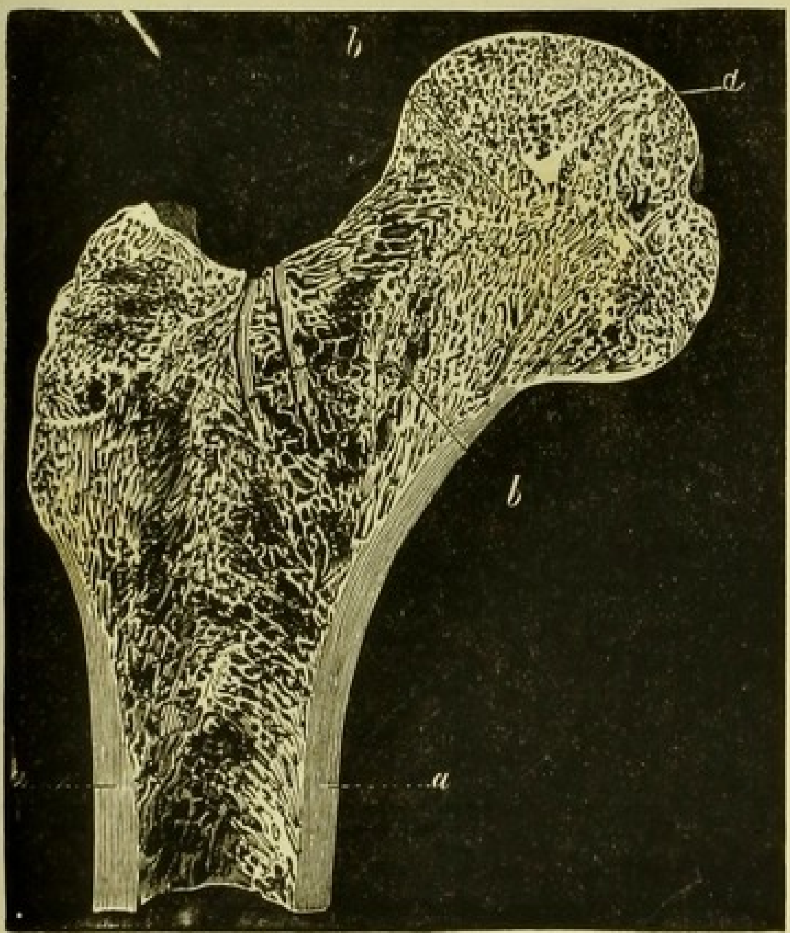


Fig. 46.—**Section of the head of the Femur.**
a, compact tissue ; *b*, cancellous tissue.

The long bones, like the femur, tibia, &c., consist of a long *shaft*, terminating at each end in a *head.*

Take a long bone, such as the femur (which should be from an animal recently killed), and saw it longitudinally into halves. Now look at the section and examine the structure of the bone, comparing it with the accompanying diagrams. It will be seen that the bone consists of two distinct kinds of substance. Its outer portion is composed of a very hard and compact substance, somewhat resembling ivory. This is called the **compact** or **dense tissue.** It is thickest along the shaft, and is very thin around the heads. The heads of the bone are filled with a less compact mass, which is so porous and light that it is called the **spongy** or **cancellous** (Lat. *cancelli*, a grating) **tissue.** In addition to these two kinds of tissue, the central cavity of the bone contains a soft pulpy substance, called the *marrow* ; the cavity itself is called the **medullary cavity.** The **marrow** consists of *fat cells* and *blood-vessels* supported by a very delicate connecting membrane. The

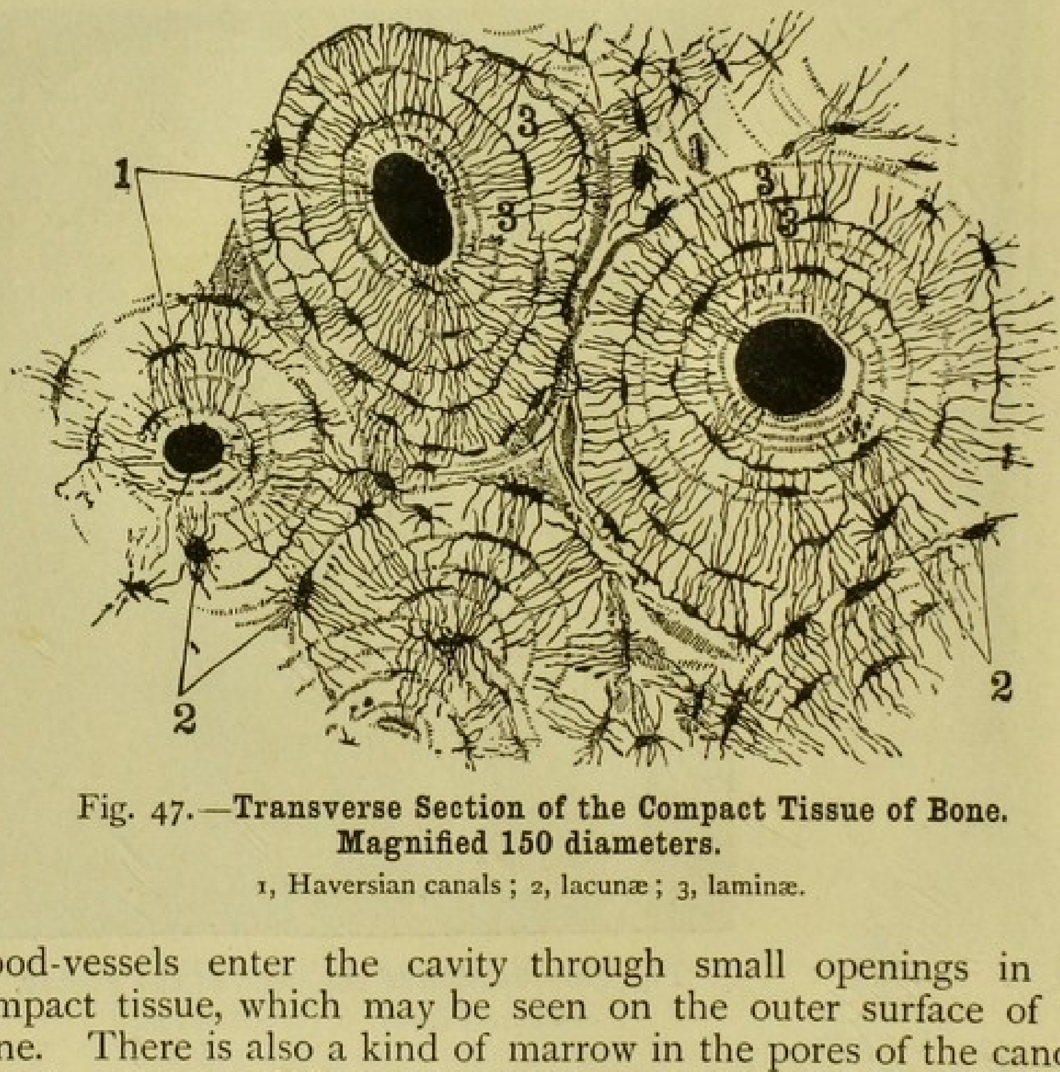


Fig. 47.—**Transverse Section of the Compact Tissue of Bone. Magnified 150 diameters.**

1, Haversian canals ; 2, lacunæ ; 3, laminæ.

blood-vessels enter the cavity through small openings in the compact tissue, which may be seen on the outer surface of the bone. There is also a kind of marrow in the pores of the cancellous tissue, but it differs from that of the medullary cavity, in that it is reddish in colour, more fluid, and contains much less fat.

The **short** and the **irregular bones** have no medullary cavity, but consist of a thin outer layer of compact tissue, filled in with cancellous tissue. The **flat bones** consist of a layer of cancellous tissue between two layers of the compact tissue.

That part of a bone which assists in forming a joint is covered with a smooth layer of articular cartilage. The remainder of the surface is covered with a tough and fibrous membrane, called **periosteum** (Gr. *peri*, around, and *osteon*, a bone).

Blood is supplied to the bone by small vessels from this periosteum, which pierce the bone underneath it. Other small vessels pierce the articular extremities, and pass to the cancellous tissue.

The circulation of blood *within* the substance of the bone is brought about by means of a number of minute canals, which are to be found in all parts of the bone.

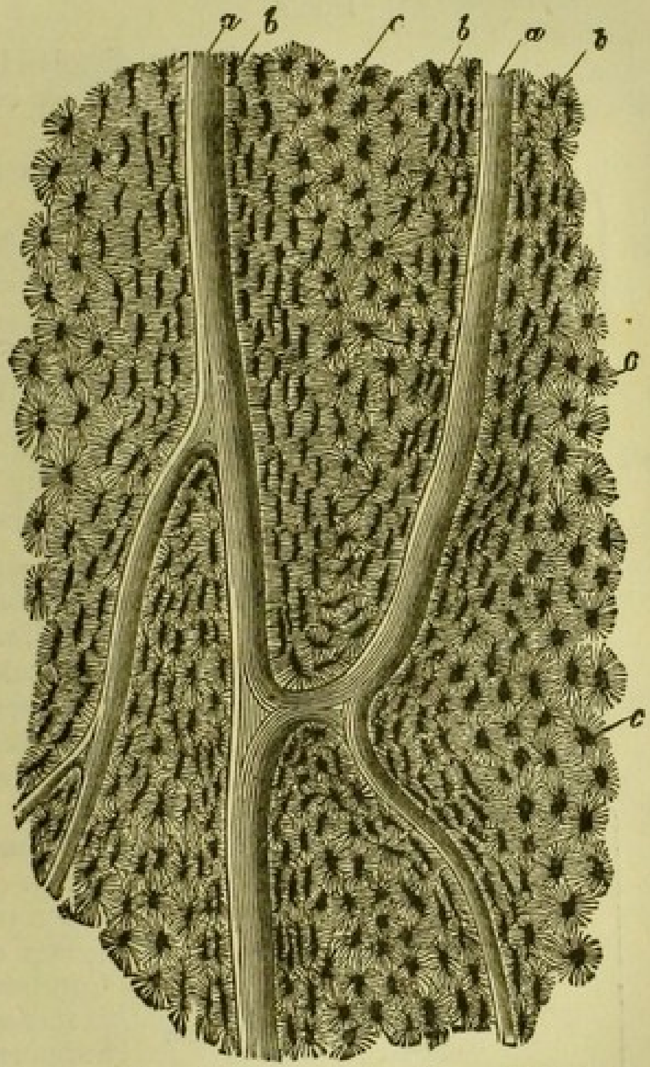


Fig. 48.—**Section parallel to the surface from the Shaft of the Femur. Magnified 100 diameters.**

a, Haversian canals ; *b*, *c*, lacunæ.

In order to study the minute structure of bone it will be necessary to cut a very thin slice from the compact tissue, and grind this down till it is semi-transparent. If the cutting be made transversely, it will show, under the microscope, cross sections of minute canals, called **Haversian canals** from Havers, who first discovered them. These canals vary in size, the average diameter being about $\frac{1}{500}$ of an inch. The Haversian canals are surrounded by small, irregular spaces called **lacunæ** (Lat. cavities), arranged in concentric circles, and so giving the bone a laminated appearance. The lacunæ communicate with each other, and with the Haversian canals, by means of very minute **canaliculi** which radiate from them in all directions.

If the section of bone be made longitudinally instead of transversely, then the Haversian canals will be opened along their length, as they run in the direction of the long axis of the bone. They will then be seen to branch and communicate with one another.

The Haversian canals are well supplied with blood-vessels. The canaliculi and lacunæ take up the nutrient matter from the blood, and distribute it throughout the bone.

SUMMARY.

Bone.

- **COMPOSITION.**
  - **Mineral Matter.**
    - May be dissolved out by acid.
    - Forms the *bone ash* when a bone is burnt.
    - Forms about two-thirds the weight of bone.
    - Least in the flexible bones of a child.
    - Most in the brittle bones of aged persons.
    - Less in the *sternum* and *scapula*.
  - **Animal Matter.**
    - Resembles *cartilage*—is flexible and elastic.
    - Yields *gelatine* on boiling.
    - Forms generally about one-third the weight of bone.
- **STRUCTURE.**
  - **Long bones.**
    - **Examples**: *Humerus*, *Radius*, *Ulna*, *Femur*, *Tibia*, *Fibula*.
    - **Heads.**
      - Articulating portion, covered with smooth *cartilage*.
      - Thin *compact tissue*.
      - Filled with *cancellous tissue*.
    - **Shaft.**
      - Thick *compact tissue*.
      - Often contains a *medullary cavity*.
    - **Marrow.**
      - Composed of blood-vessels and fat.
      - Supported by delicate connective tissue.
  - **Short bones.**
    - **Examples**—Bones of *wrist* and *ankle*.
    - Thin *compact tissue*.
    - Filled with *cancellous tissue*.
  - **Flat bones.**
    - **Examples.** *Frontal*, *Parietal*, *Occipital*.
    - **Composed of**
      - Layer of *cancellous tissue*.
      - Two layers of *compact tissue*.
  - **Irregular bones.**
    - **Examples**—*Vertebræ*.
    - **Structure**—Similar to short bones.

INVESTMENT	**Articular Cartilage.**	Covers articulating surfaces. Smooth. Covered with *synovial membrane.*
	Periosteum	Strong fibrous membrane. Covers the bone with the exception of articulating surfaces.
MINUTE STRUCTURE.	**Haversian Canals**	About $\frac{1}{500}$ in. in diameter. Run lengthwise through the *compact tissue.* Branched. Contain blood-vessels. Communicate with *lacunæ* by means of *canaliculi.*
	Lacunæ	Surround *Haversian canals* in rings. Give off *canaliculi* in all directions. Absorb and distribute nutriment.

QUESTIONS ON LESSON VI.

1. How would you remove the animal matter from bone, so as to obtain the mineral substance it contains?
2. How would you obtain *gelatine* from bone?
3. What is bone ash? How would you obtain it?
4. How would you remove the whole of the mineral or earthy substance from a bone, in order to get the animal matter?
5. Describe the composition of bone. Do bones vary at all in composition? If so, give illustrations.
6. What are the differences between the bones of a young child, the bones of a middle-aged adult, and the bones of persons of extreme age?
7. Describe the different kinds of bones, pointing out their variations in structure.
8. What is *marrow*? What is its use?
9. Compare the structure of the *parietal bone* with that of the *femur*.
10. With what kinds of covering are bones invested?
11. How are bones supplied with blood?
12. Describe the *minute* structure of bone, as revealed by the microscope. Illustrate your description by sketches.

LESSON VII.

THE MUSCULAR SYSTEM.

By removing the skin which forms the exterior covering of the body, we expose to view masses of **flesh** or **muscle** (see fig. 3), similar in appearance and structure to what we call *lean meat*, which is really the muscle of the various animals used for food.

The **general character of muscle** may well be studied by examining a piece of beef. It is reddish in colour, but this is due to the presence of blood, which circulates through every part of it.

If we steep a piece of beef for a very long time in cold water, a large proportion of the blood oozes out and tinges the water, leaving the flesh or muscle of a pale whitish colour. We notice also that it is composed of *fibres*. A large number of these muscular fibres, arranged side by side, and bound together by a skin or membrane, form a **muscle**; and the various muscles of the body make up the **muscular system.**

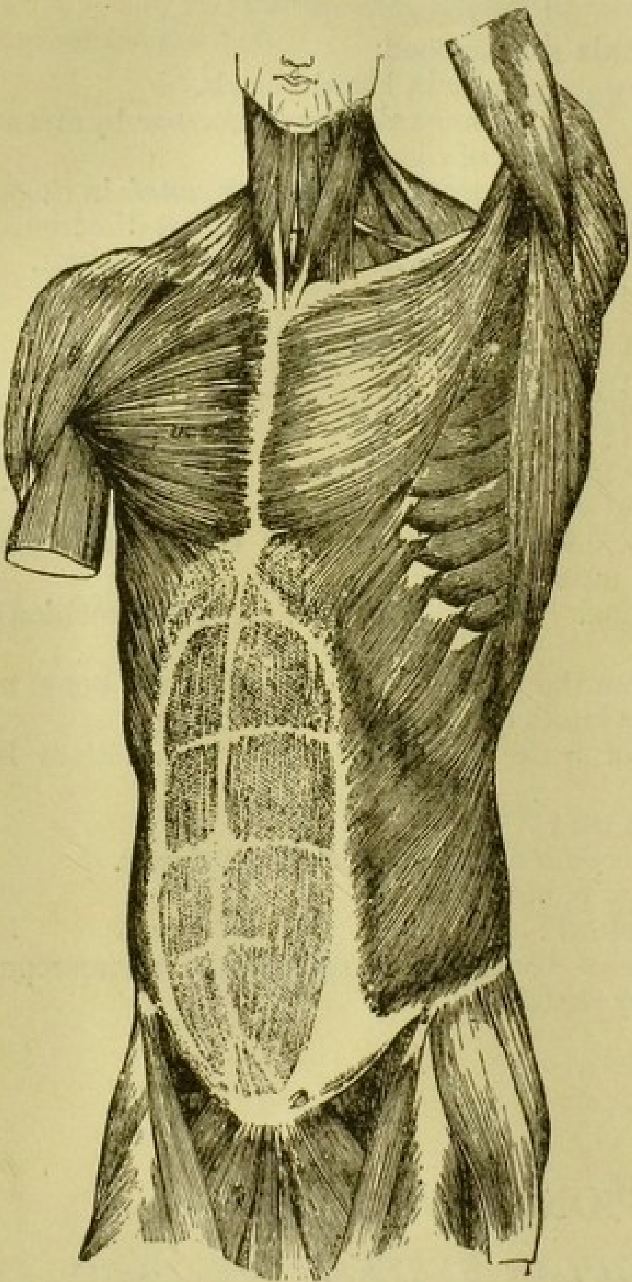


Fig. 49.—**Front View of the Muscles of the Trunk.**

There are **two kinds of muscles, voluntary** and **involuntary**. The former, being under the control of the will, are those which give us the power of voluntary motion and of locomotion; and these form the great bulk of the muscular system. The latter kind are to be found distributed in the substance of various internal organs, and in the walls of blood-vessels; and are concerned in producing those movements over which the will has no control, such as the beating of the heart, and the motions of the stomach and intestines. Both voluntary and involuntary muscles are composed of fibres, but there is a distinct difference in the form of the fibres, as will be shown presently.

Most of the **voluntary muscles** are connected with bones at one or both ends, and every fibre composing them has the power, under the influence of the will, of contracting in length. One end of such a muscle is generally fastened by means of a **tendon** to a fixed bone, and the other end to the bone to be moved; so that when the muscular fibres contract, the whole muscle shortens, becoming consequently thicker in the middle, and causing one of the bones to be moved.

As an illustration of this, lay the left forearm on a table before you, and grasp the mass of flesh which forms the front of the upper arm with the right hand. Now gradually raise the left forearm, still keeping the elbow on the table, and notice how the muscle thickens as the hand rises. The chief muscle engaged in this motion is one called the **biceps muscle** (Lat. *bi*, two; and *caput*, a head), because at its upper extremity it has two heads with separate tendons. These tendons are united to the scapula at the shoulder-joint, while the lower tendon is fastened to the radius, very near the elbow-joint. The points of union with the fixed bone (the scapula) are called the *points of origin* of the muscle; the point at which the muscle is attached to the bone to be moved (the radius) is called its point of *insertion*; and the thick, fleshy, middle part of the muscle is known as its *body*. Some few of the muscles have no tendons, the muscular fibres being connected directly with the bone; while others, instead of being of the form just described, are broad and flat muscular sheets. Some muscles are not connected in any way with bones. These often enclose cavities, in which case they are called *hollow muscles*, and are generally of the involuntary kind. Examples are to be seen in the heart and stomach.

Fig. 50.—**Side View of the Muscles of the Face and Neck.**

After a bone has been moved by a muscle, it is brought back to its former position by the contraction of a second muscle on its opposite side. Hence we find that muscles are generally arranged in pairs, each muscle of a pair being antagonistic in its action to the other.

Those muscles which are used to bend the limbs are called **flexors**; while those which straighten the limbs are called **extensors.**

Muscles may be made to contract by the application of some kind of **stimulus** or **irritant.** The stimulus is generally conveyed to the muscular fibres by means of the nerve which distributes its branches among them. But muscular contraction may also be produced by *mechanical irritation*, such as pinching or cutting; or by *electrical irritation*, such as is produced by the electric shock; or by *chemical stimuli*, such as irritant poisons.

Muscles may be made to respond to stimuli not only during life, but also shortly after death has occurred. Thus, the limbs of a recently killed frog may be made to jump violently by sending an electric current through them.

Just after death, the muscles of an animal are soft and pliant as during life; but after a short time they become so stiff and

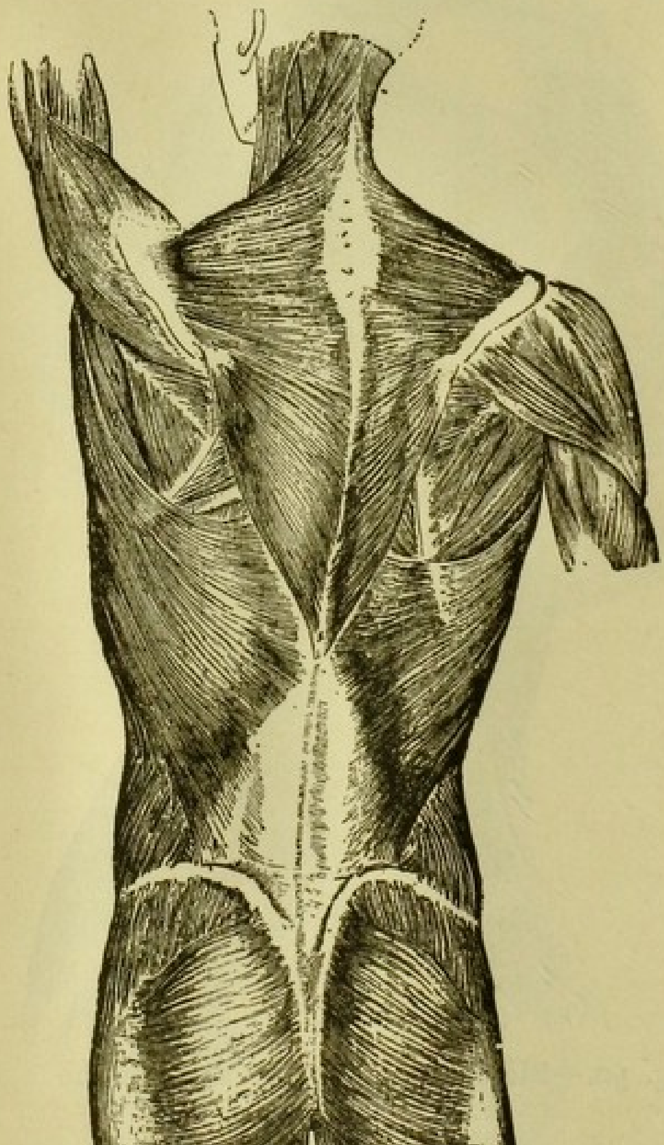


Fig. 51.—**Back View of the Muscles of the Trunk.**

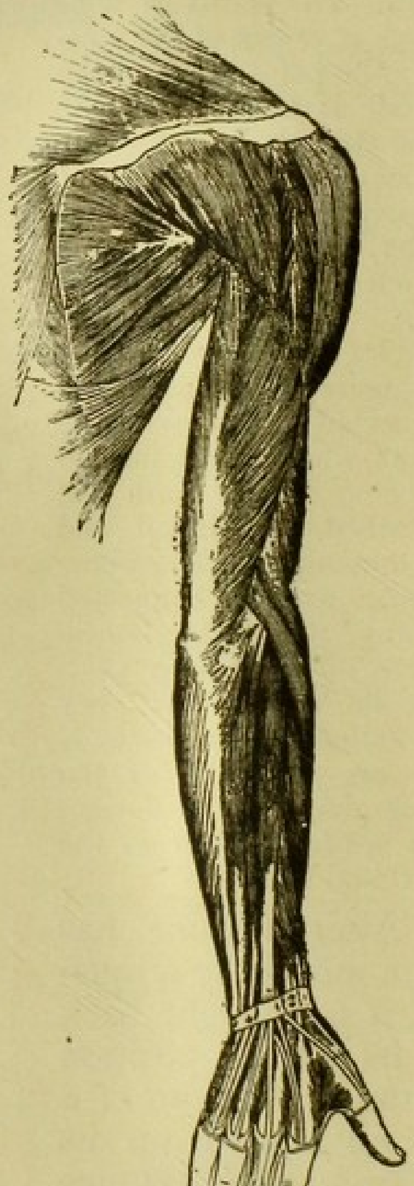


Fig. 52.—**Back View of the Muscles of the Arm.**

The large central muscle of the upper arm is the *biceps muscle*.

hard that it is impossible to bend the limbs without a danger of injuring the bones or joints. This **death-stiffening**, or **rigor mortis**, is due to the coagulation (Lat. *co*, together, and *ago*, I drive) of a fluid substance in the muscle, called **myosin**. In the human body this coagulation usually sets in at from four to six hours after death, and continues for one, two, or three days.

The **erect position of the human body** is maintained by the combined influence of a large number of muscles acting at the same time. The whole weight of the body rests on the arches of the feet; and the body may be supported in any position providing its centre of gravity is situated vertically over any point in the space enclosed by the feet. On account of the large number and suppleness of the joints, the centre of gravity cannot be maintained in such a position as described above without the contraction of certain muscles which give a degree of rigidity to the body. (Fig. 54.)

The muscles of the calf prevent the body from falling forward, but the contraction of these alone would pull the body backward, as they act on the thigh-bone, just above and behind the knee-joint. These muscles are therefore opposed by another set in front of the thigh, which connect the hip-bone above with the bones of the leg below the knee, and which, by their contraction, pull the leg straight. Then, again, these muscles tend to pull the trunk of the body forward, but they are balanced by the powerful muscles of the buttocks and back. Further, the contraction of the muscles of the back of the neck would pull the head backward, were it not for the contraction of antagonistic muscles which connect the lower part of the face with the sternum and collar-bone.

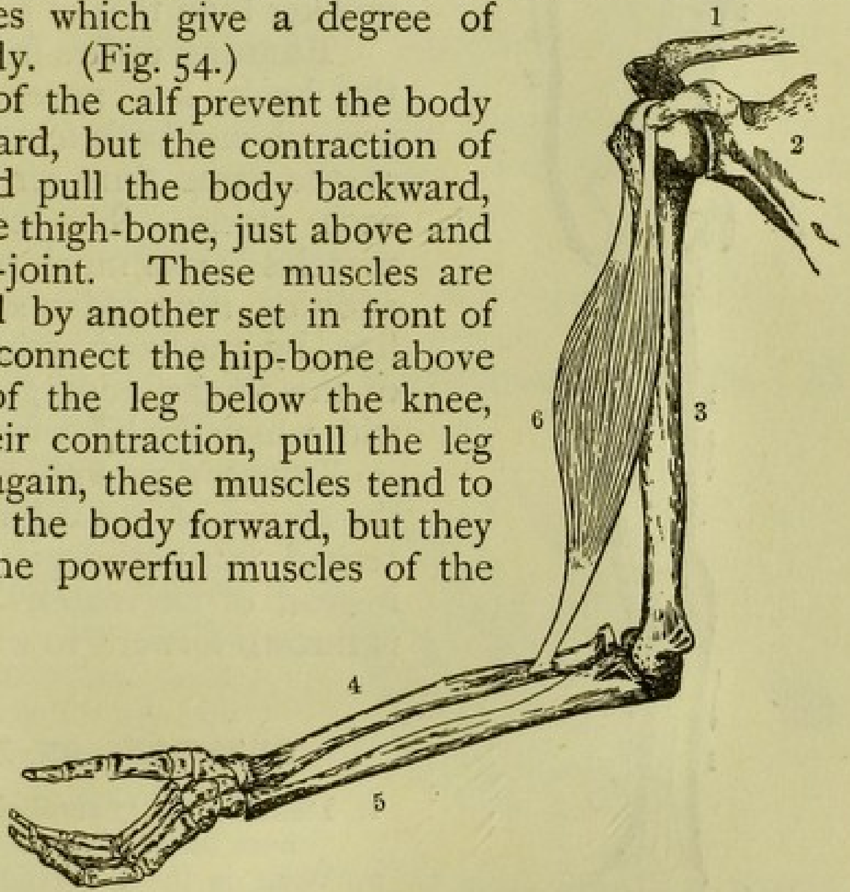


Fig. 53.—**The Biceps Muscle.**

1, clavicle; 2, scapula; 3, humerus; 4, radius; 5, ulna; 6, the biceps muscle.

When a person begins to **walk**, he first inclines the body forward, then raises one foot, swings the leg forward one step, and puts the foot to ground again. Now, just for a moment, the legs form with the ground an isosceles triangle, and consequently the trunk of the body is a little lower. But, before the foot reaches the ground, the contraction of the calf of the other leg raises the heel, and propels the body forward. The weight of the body is thrown on the first foot, and the one behind swings forward and passes in front of the other. A forward motion is thus given to the body, which is maintained without the expenditure of much muscular force. It will be observed that both feet are never off the ground at the same time in walking; also that, as the forward motion of each leg is a *swinging* motion, it follows the law of pendulum motion—the longer the pendulum the more slowly it swings. Hence the natural step of a child is quicker than that of a tall man.

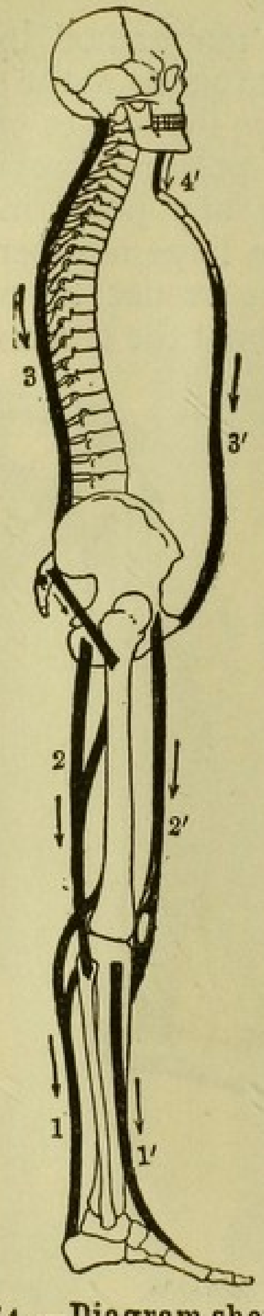


Fig. 54.—**Diagram showing the Action of the chief Muscles which keep the Body erect.**

Muscles which tend to keep the body from falling forward.

1, muscles of the calf; 2, of the back of the thigh; 3, of the spinal column.

Muscles which tend to keep the body from falling backward.

1′, muscles of the front of the leg; 2′, of the front of the thigh; 3′, of the front of the abdomen; 4′, of the front of the neck.

The arrows indicate the direction in which these muscles act.

Running differs from walking in that the heels are never brought to the ground, and both feet are off the ground at the same time for a brief period at each stride. The contraction of the muscles is also much more rapid, and, in addition, the sudden straightening of the legs, by the contraction of the muscles of the thighs, adds greatly to the force with which the body is propelled forward.

Jumping resembles running, as far as the action of individual muscles is concerned, but both legs act simultaneously instead of alternately, so that the body is thrown forward to a greater distance.

QUESTIONS ON LESSON VII.

1. Describe the general character and appearance of muscle.
2. What is the difference between *voluntary* and *involuntary* muscles? Give examples of each.
3. Describe the manner in which muscles are connected with bones.
4. Describe the action of any one voluntary muscle, showing how its form changes during this action.
5. What is a *tendon*? Where are tendons to be found?
6. Define the terms *origin* and *insertion* as applied to muscles.
7. Why are voluntary muscles generally arranged in pairs which act in opposition to each other?
8. How is the erect posture of the body maintained?

9. Describe the action of the muscles concerned during *walking*, *running*, and *jumping*.
10. Mention the different ways in which a muscle may be made to contract.
11. What are *flexor* muscles and *extensor* muscles ?
12. What is *rigor mortis* ? How is it caused ?

LESSON VIII.

THE STRUCTURE OF MUSCLE.

THERE is a distinct difference between the structure of voluntary muscles and that of involuntary muscles. But the two kinds resemble each other in that—

(1) They are both composed of fibres.
(2) The fibres of both have the power of contraction.
(3) Both produce motion by this contraction.

We will first study the structure of **voluntary muscles.** As already stated, we include under this term all those muscles which may be set in motion by an effort of the will. If we remove the skin from the leg of a rabbit, we at once expose several of these voluntary muscles, each of which is connected with two separate bones. Then if we trace one of these muscles to one of its ends —its origin or its insertion—we notice that it is connected with the bone by means of a tendon. Again, we may see that each of the muscles of the leg is surrounded by a sheath, composed of a very thin and transparent skin or membrane.

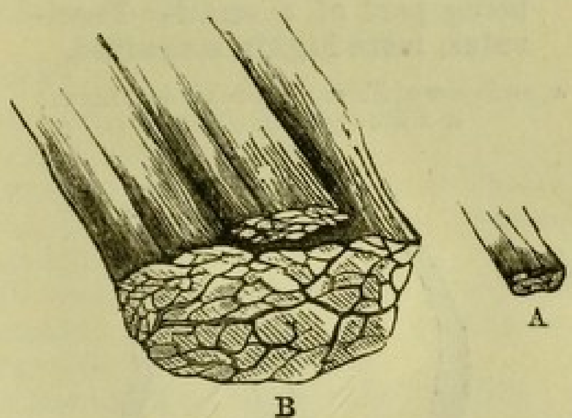


Fig. 55.—**A small Portion of Muscle, consisting of larger and smaller Fasciculi.**

A, natural size ; B, magnified five diameters.

Now let the leg of the rabbit be boiled till the flesh is easily torn asunder ; and, by means of needle points, we may then 'tease out' the flesh in such a manner as to show that each muscle is composed of **bundles of fibres.**

As a further, and, perhaps, a better illustration of this last point, take a small portion of a very large muscle, such as one of those which form the fleshy portion of a 'leg of beef.' Let this also be boiled till its fibres may easily be separated by needle points. We shall now see distinctly that not only is the muscle composed of bundles of fibres, but that each *bundle* is made up of still **smaller bundles**, each of which is distinctly visible to the naked eye. These *smaller bundles* are called **fasciculi** (Lat. *fasciculus*, a little bundle); and the fineness or coarseness of a muscle depends on the relative sizes of these small bundles of fibres. Thus, in the powerful muscles of the leg, the fasciculi are much larger than in the softer muscles of the cheeks.

If it is desired to study the structure more minutely, it will be necessary to take

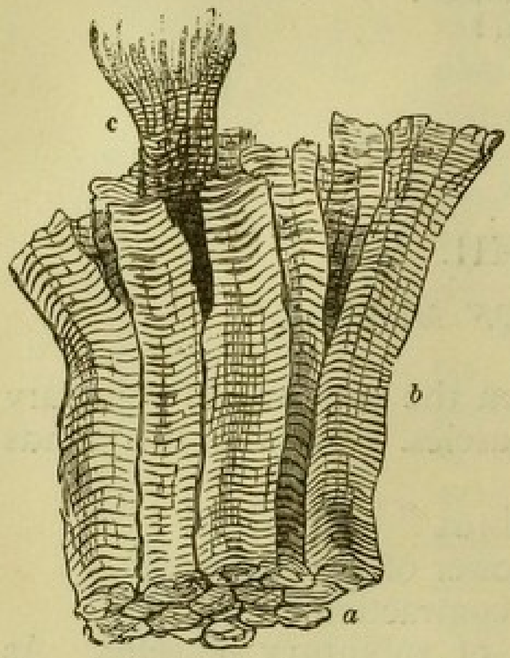


Fig. 56.—**A few Muscular Fibres, being part of a smaller Fasciculus, more highly magnified.**

a, end view of fibres; *b*, side view of fibres; *c*. a fibre split into fibrils.

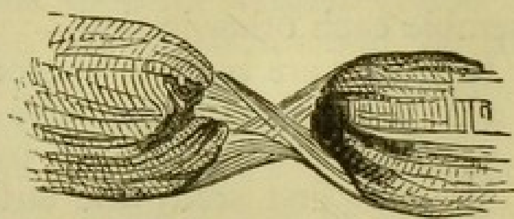


Fig. 57.—**A muscular Fibre ruptured, so as to exhibit the Sarcolemma.**

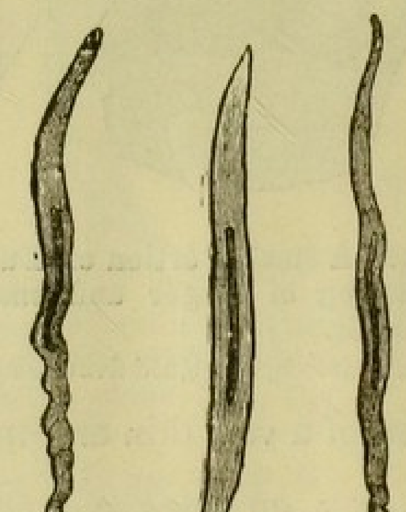


Fig. 58.—**Involuntary Muscular Fibre-cells from Human Blood-vessels.**

Magnified 350 diameters.

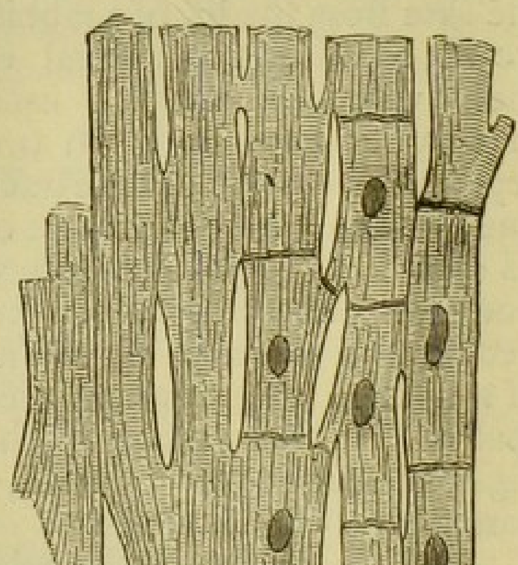


Fig. 59.—**Muscular Fibres from the Heart, showing the Striations and the Junctions of the Cells.**

Highly magnified.

a very small portion of muscle, and, after teasing it out till it is so fine as to be almost invisible to the naked eye, examine it with the help of a good microscope.

In this way we may learn that the fasciculi are composed of **fibres**, each of which is not more than $\frac{1}{500}$th of an inch in diameter on an average ; and that these fibres are composed of still smaller fibres called **fibrillæ** (Lat. *fibrilla*, a little fibre).

When the fibrillæ are examined under a high magnifying power, they are seen to consist of little disc-shaped bodies, united in such a manner as to produce transverse markings. It is on this account that voluntary muscle is often called **striped or striated muscle.**

Every fibre in a voluntary muscle is enclosed in a sheath of connective tissue called **sarcolemma** (Gr. *sarx*, flesh ; and *lemma*, a husk). This is a very thin, transparent, and comparatively tough membrane, which will sometimes remain entire after the enclosed fibrils have been ruptured by stretching or twisting, as represented in fig. 57.

Involuntary muscle is also called **non-striated**, or **unstriped muscle,** because it does not present transverse markings when examined under the miscroscope, as does voluntary muscle. Involuntary muscle is often made up of bundles of fibres ; but the fibres, instead of being of uniform diameter throughout, are composed of elongated cells which are generally pointed at their ends. These fibres have no sarcolemma.

The **muscular fibres of the heart** differ remarkably from those of involuntary muscles in general, as they are striated transversely, like those of the voluntary muscles. They are composed of quadrangular and branched cells, which exhibit longitudinal as well as transverse striæ.

SUMMARY.

VOLUNTARY MUSCLE. **(Striated or Striped.)**	Under the control of the *will.* Composed of **bundles of fibres.** These **bundles** composed of *smaller bundles* (*fasciculi*), visible to the unaided eye, and surrounded by sheaths. **Fasciculi** composed of *fibres*, each of which is surrounded by a sheath of *sarcolemma.* Average diameter about $\frac{1}{500}$ in. **Fibres** made up of minute *fibrillæ* (*fibrils*). **Fibrillæ** composed of *disc-like bodies*, and are consequently *striated transversely.*
INVOLUNTARY MUSCLE. **(Non-striated or Unstriped.)**	Not under the control of the *will.* Found chiefly in the *muscular walls* of the *internal organs and vessels.* **Fibres** composed of elongated cells with pointed ends, not marked transversely.
MUSCLES OF THE HEART.	*Involuntary*, yet *striped* or *striated.* *Striated longitudinally* as well as *transversely.* **Fibres** composed of *oblong and branched cells.*

QUESTIONS ON LESSON VIII.

1. Describe the structure of *voluntary muscle.*
2. What is *sarcolemma* ? What is its use ?
3. Describe the manner in which voluntary muscles are connected with bones.
4. What are *voluntary* and *involuntary* muscles ? Give examples of each.
5. Describe the structure of *involuntary muscles.* In what respects do they differ from voluntary muscles ?
6. Describe the structure of the muscular fibres of the heart.

LESSON IX.

THE LEVERS OF THE BODY.

A **lever** is a rigid bar which is capable of turning freely about a fixed point called the **fulcrum.** In fig. 60, the bar WP is free to swing or turn on the fulcrum F. If we apply a downward pulling force at the point, P, that end of the lever will move downward;

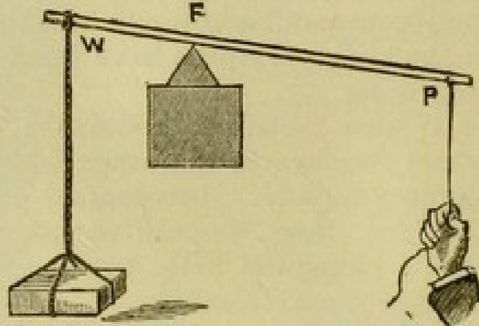


Fig. 60.—**Illustrating the Lever (First Order).**

W, a weight suspended at one end; F, the fulcrum; P, the point at which the power is applied.

but this pulling force may be resisted by suspending a weight at the other end of the lever. Thus we have two forces acting on the bar—one applied at the point P, and the other, the downward tendency of the weight suspended, acting at the point W.

Levers are classified under **three orders** according to the relative positions of the fulcrum, the point at which a power is applied, and the point at which this power is counteracted by a

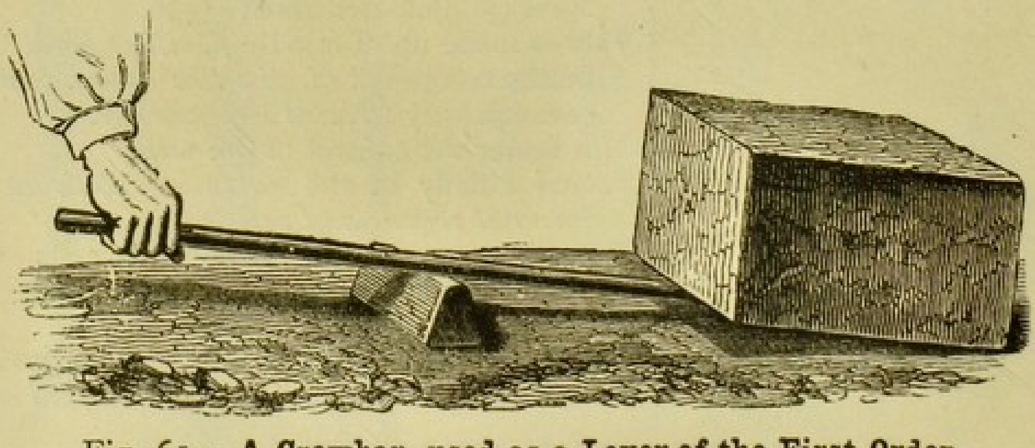


Fig. 61.—**A Crowbar, used as a Lever of the First Order.**

weight or any resisting body. The three orders are known as the *first*, *second*, and *third.*

Levers of the first order are those in which the *fulcrum is between the power and the weight.* The following are a few familiar examples :—

(1) The **crowbar**, when used to lift a weight at one end by the application of power at the other. In this case a block of wood usually forms the fulcrum. (Fig. 61.)

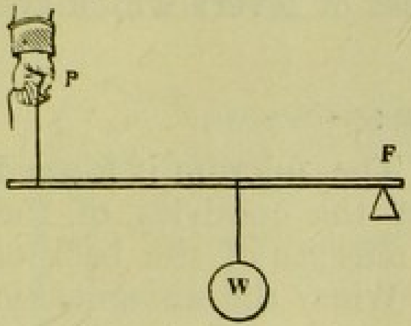


Fig. 62.—**A Lever of the Second Order.**
P, power; W, weight; F, fulcrum.

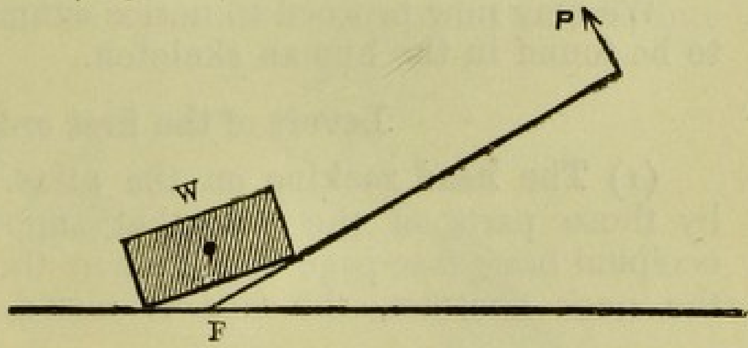


Fig. 63.—**A Crowbar, used as a Lever of the Second Order.**

(2) The **see-saw.**

(3) The beam of a **pair of scales.**

(4) The **poker,** when resting on a bar of the grate, and used to lift the coals in the fire.

Levers of the second order are those in which the *weight is between the fulcrum and the power.* The following are examples :—

(1) The **crowbar,** when used for lifting a weight, while one of its ends rests on the ground. (Fig. 63.)

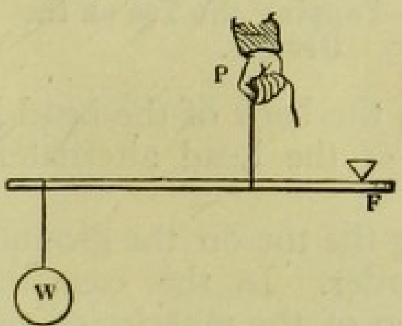


Fig. 64.—**A Lever of the Third Order.**
W, weight; P, power; F, fulcrum.

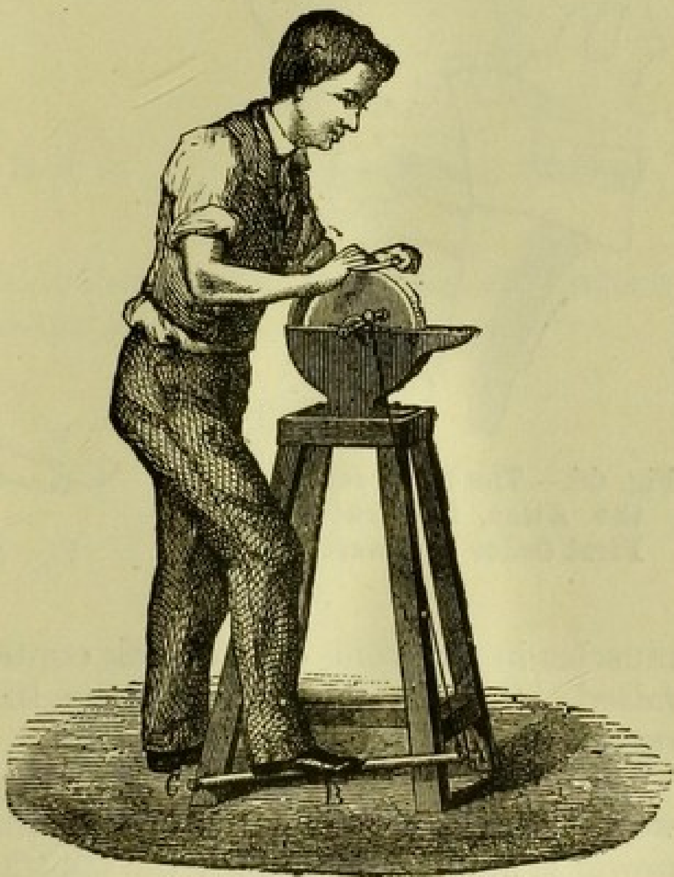


Fig. 65.—**The Treadle, illustrating a Lever of the Third Order.**

(2) The **wheelbarrow.** In this case the fulcrum is the point where the wheel rests on the ground.

Levers of the third order are those in which the *power is* *applied at a point between the fulcrum and the weight.* As an example we may mention—

The **treadle of a machine.**

We may now proceed to notice **examples of levers which are to be found in the human skeleton.**

Levers of the first order :—

(1) **The head rocking on the atlas.** The fulcrum is formed by those parts of the atlas that support the condyles of the occipital bone (see page 19). When the muscles of the back of the neck contract, the face is raised. When the antagonistic

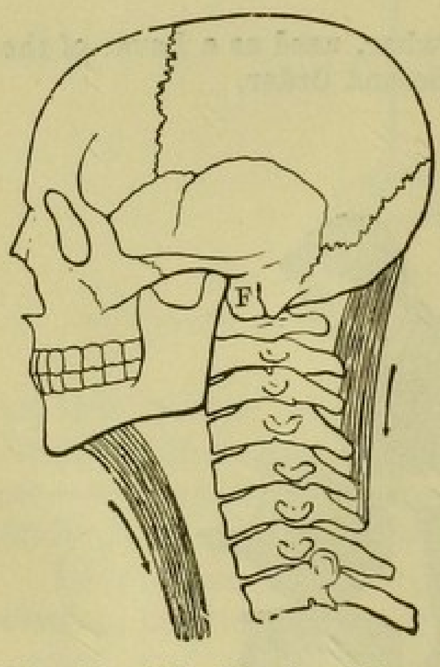


Fig. 66.—**The Head rocking on the Atlas, illustrating the First Order of Levers.**

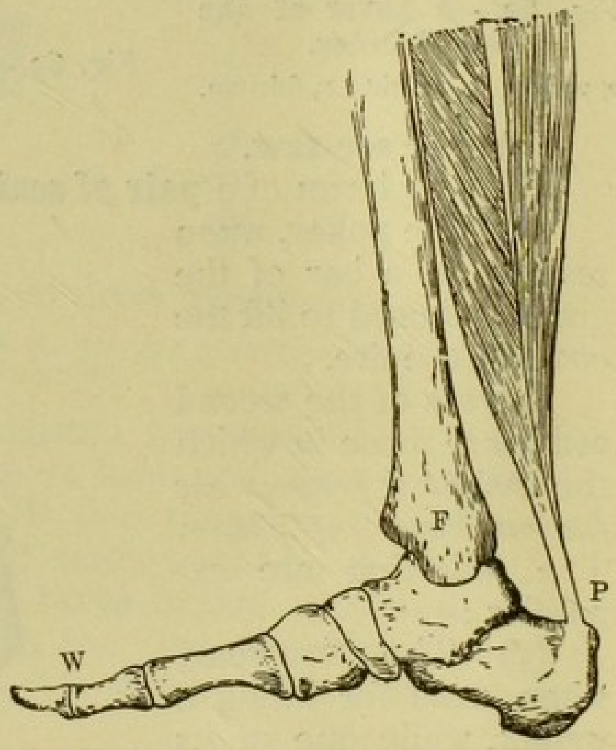


Fig. 67.—**Tapping the Toe on the Ground.**

muscles in the front of the neck contract, the back of the head is raised. So that the face and the back of the head alternately represent the power and the weight.

(2) Lift one **foot**, and then, by tapping the toe on the ground, we use the foot as a lever of the first order. In this case the power is applied behind by the contraction of the muscles of the calf, the fulcrum is at the ankle, and the ground offers the resistance.

(3) The **motion of the body on the hip** is another illustration. The hip-joints form the fulcrum ; and the contraction of the muscles connecting the pelvis with the bones of the leg provide the power. In this case the power (and the weight) may be alternately in front and behind.

Levers of the second order :—

(1) Illustrated by **lifting one leg off the ground.** In this case the hip-joint is the fulcrum, the leg is the weight to be moved, and

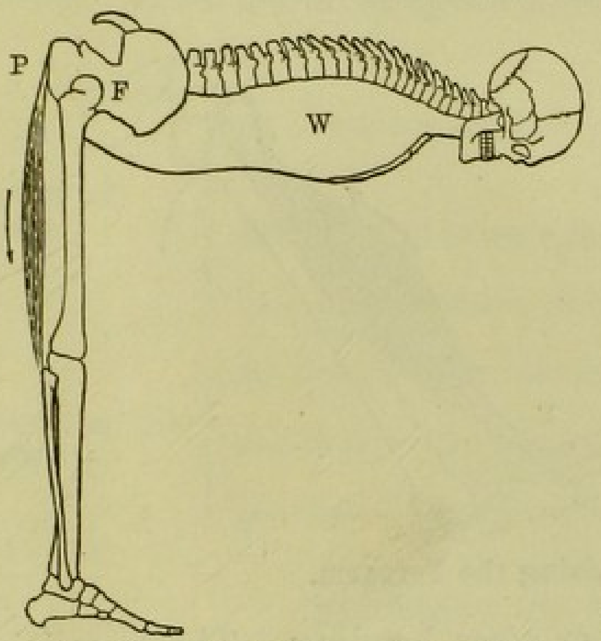


Fig. 68.—**The Motion of the Body on the Hip.**

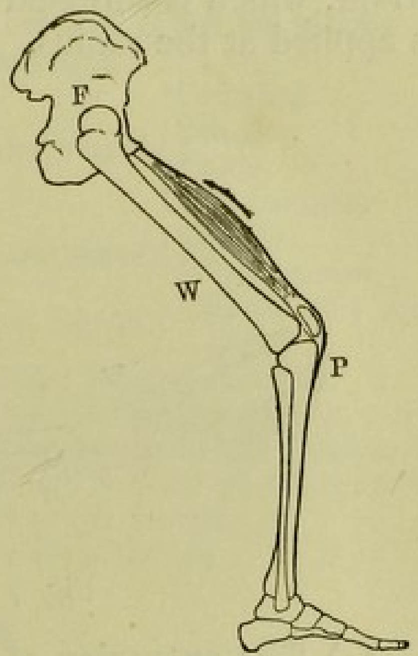


Fig. 69.—**Lifting the Leg.**

the lifting power is produced by the contraction of a muscle which extends from the hip-bone to the knee-cap. (Fig. 69).

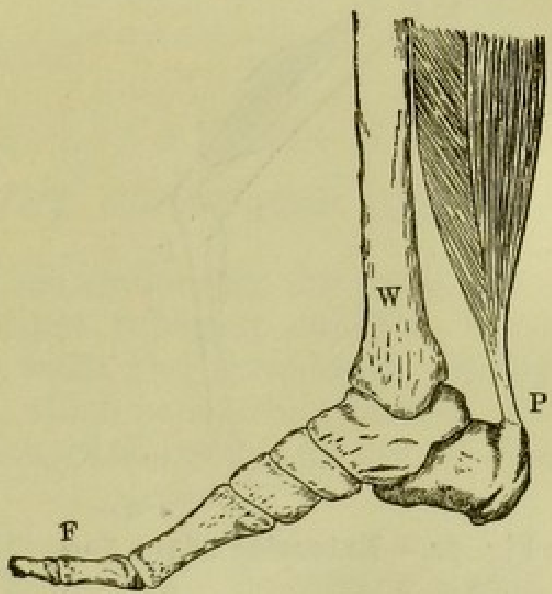


Fig. 70.—**Raising the Body on the Toe.**

(2) **Raising the body on the toe.**—The toe rests on the ground, thus forming the fulcrum. The weight is that of the body supported at the ankle, and the power is supplied by the contraction of the muscles of the calf, which are connected with the heel.

Levers of the third order :—

(1) **Raising the forearm.**—Here the elbow-joint forms the fulcrum, the forearm and hand the weight to be raised, and the power, which is supplied by the contraction of the biceps muscle, is applied at the radius.

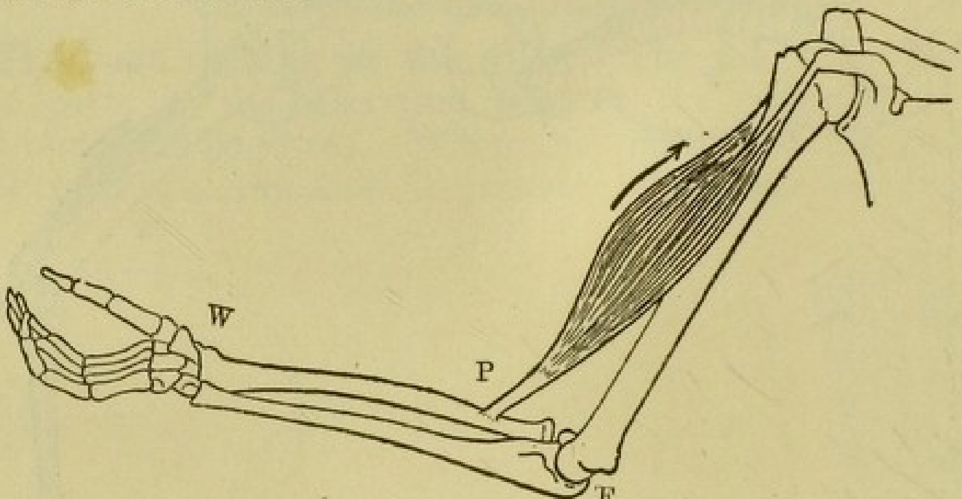


Fig. 71.—**Raising the Forearm.**

(2) **The extension of the leg after bending.**—The knee-joint is the fulcrum, the lower leg and the foot the weight to be moved,

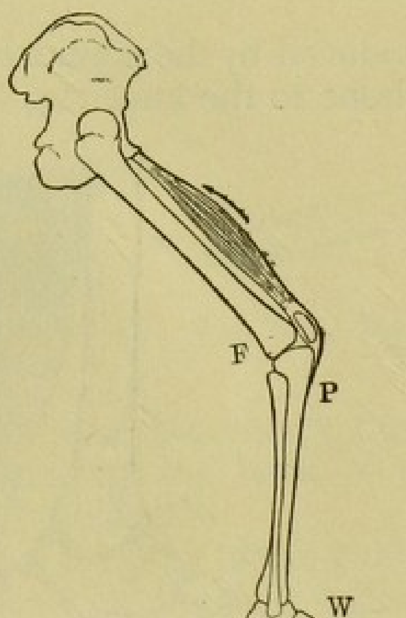


Fig. 72.—**Extension of the Leg.**

and the power is applied at the tibia in front of the leg, by means of muscles passing from it, over the knee-cap, to the hip.

The student should now endeavour to find for himself other examples of the three orders. To this end he may with advantage consider the motions of the lower jaw, the ribs, and other motions of the limbs.

SUMMARY.

A Lever	A rigid bar.	
	Movable round a fixed point (fulcrum).	
	If acted on by two forces	One is called the power.
		The other is called the weight or resistance.
Orders of Levers.	1st—*Fulcrum betweeen power and weight*	Crowbar. See-saw. Poker. The balance.
	2nd—*Weight between fulcrum and power*	Crowbar. Wheelbarrow.
	3rd—*Power between fulcrum and weight*	Treadle of a machine.
Levers of the Body.	*1st Order*—Illustrated by	Rocking of head on atlas. Motion of body on the hip.
	2nd Order—Illustrated by	Lifting the leg off the ground. Raising the body on the toes.
	3rd Order—Illustrated by	Raising the forearm. Extending the leg.

QUESTIONS ON LESSON IX.

1. What is a *lever*? Illustrate your answer by an example.
2. Give common examples of the three orders of levers.
3. Give an example of each of the three orders of levers as exemplified in the human body.
4. Show how the three orders of levers may be illustrated by the foot.

LESSON X.

THE CHEST AND ABDOMEN.

THE student will remember that the body of a vertebrate animal contains **two distinct tubes or cavities.** One of these is surrounded by bony walls, and includes the **cavity of the skull** and the **spinal canal**, which communicates with it. The other is the **great cavity** which contains the organs of digestion, circulation, &c.

We will now proceed to notice the form of the **great body cavity**; and here we strongly recommend the dissection of a small animal. In this instance an animal no larger than a rat will answer the purpose. Lay the dead animal on its back, stretch out its limbs, and pin them firmly to a flat board. Now take a sharp-pointed knife, and cut the skin from the throat in a straight line down to the tail, *taking care that the knife does not enter into the flesh at any point.* Now loosen the skin from the flesh, and pin it also to the board, spreading it out, right and left, to the greatest possible extent. The arrrangement of the **ribs** may now be seen, with the thin walls of muscle or flesh (**intercostal muscles**) which unite them. These, together with the back-bone behind, and the breast-bone in front, form the walls of the upper portion of the great cavity. The lower portion has no such firm framework. It is supported by the vertebral column behind; but, round the sides and front, the walls consist of flesh and fibrous connective tissue only. The flesh constitutes the **muscles of the abdomen**, abdomen being the name of the lower portion of the great body cavity.

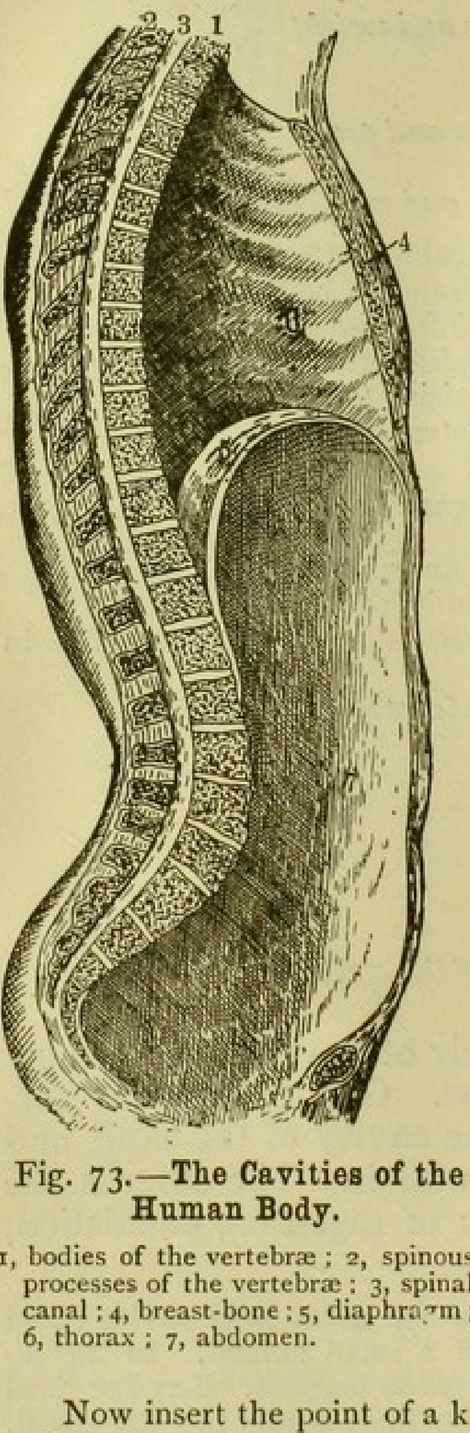


Fig. 73.—**The Cavities of the Human Body.**

1, bodies of the vertebræ; 2, spinous processes of the vertebræ; 3, spinal canal; 4, breast-bone; 5, diaphragm; 6, thorax; 7, abdomen.

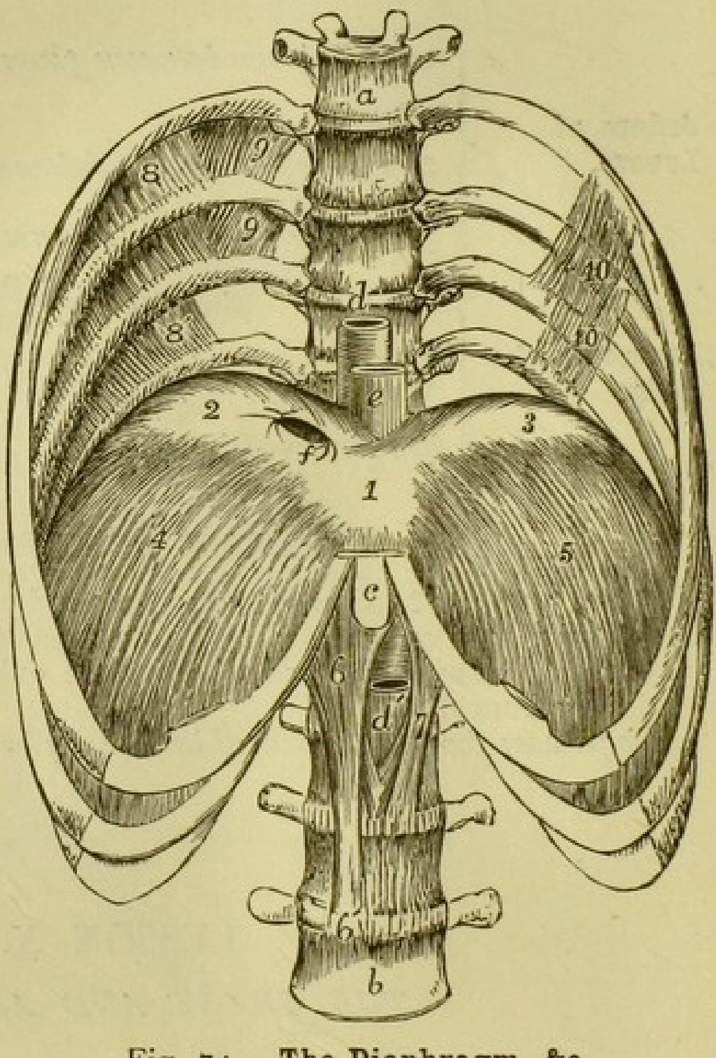


Fig. 74.—**The Diaphragm, &c.**

a, sixth dorsal vertebra; *b*, fourth lumbar vertebra; *c*, lower cartilaginous extremity of the breast-bone (ensiform cartilage); *d d'*, a great blood-vessel (aorta) passing through the diaphragm; *e*, œsophagus; *f*, opening through which a great vein (inferior vena cava) passes; 1, 2, and 3, tendinous portion of the diaphragm; 4 and 5, muscular portion of the diaphragm; 6 and 7, the pillars of the diaphragm. These are powerful muscles which connect the tendinous portion of the diaphragm with the spinal column. 8, 9, and 10, intercostal muscles.

Now insert the point of a knife just at the lower extremity of the sternum, and cut through that bone toward the throat, thrusting the knife no deeper than is absolutely necessary. The front walls of the cavity, consisting of the ribs and the intercostal muscles, may now be carefully cut away, so as to expose the interior. If we now carefully remove the organs which are contained in this portion of the body cavity (the heart and the lungs) we shall find that it is completely separated from the lower portion by a partition which is partly fleshy or muscular, and partly tendinous. In a small rabbit, for instance, the central portion is tendinous, and so thin that it is transparent ; while round its edges it is muscular.

Thus we see that **the great body cavity is divided into two distinct parts by a muscular and tendinous partition.** The upper part of this cavity is called the **thorax or chest** ; the lower portion is called the **abdomen or belly** ; and the arched partition which separates these is called the **diaphragm** (Gr. *dia*, across ; and *phragma*, a fence), also known as the **midriff.** The thick and fleshy portion of the diaphragm or midriff of the ox is sold by the butcher under the name of *skirt steak*, or *beef skirt.*

The **abdomen** (Lat. *abdo*, I hide) or lower portion of the great cavity may now be opened in a similar manner to that described above, without injuring the diaphragm. It will be noticed that certain vessels pass *through* this partition, and these are attached so firmly to it that the organs with which they are connected cannot be removed without injury to it unless the vessels are cut above and below.

After removing the organs of the abdomen we notice that its walls have no bony support excepting at the back, as they consist of the abdominal muscles and fibrous tissue only. The arrangement of these muscles is illustrated in fig. 49. We leave the study of the *organs* of the great cavity for future lessons.

SUMMARY.

- **THE GREAT CAVITY**
  - **Thorax or Chest**
    - **Shape** — Conical, with the diaphragm as its base.
    - **Walls**
      - Back—Vertebral column.
      - Sides—Ribs. Intercostal muscles
      - Front—Sternum. Costal cartilages.
      - Floor—Diaphragm.
  - **Diaphragm** — A muscular partition, dividing the thorax from the abdomen. Convex above and concave below.
  - **Abdomen**
    - **Walls**
      - Roof—Diaphragm
      - Back—Vertebral column.
      - Sides and Front—Abdominal muscles.

QUESTIONS ON LESSON X.

1. Describe the general structure of the body of a vertebrate animal.
2. Where is the *thorax*? What are the structures which surround it?
3. How would you proceed in order to examine the diaphragm of a small animal?

4. What is the abdomen? Describe the nature of its walls.
5. Give a short description of the *diaphragm*.
6. Describe briefly each of the following:—*intercostal muscle*, *thorax*, *midriff*, and *abdomen*.

LESSON XI.

THE ANATOMY OF THE FACE AND NECK.

It will be advisable to study the anatomy of the face and neck before learning the nature of the organs contained in the thorax and abdomen, as by adopting this plan we shall be able to understand better the connection between the organs of the face and those of the two divisions of the great body cavity.

The accompanying diagram exhibits a medial section of the face and neck, that is, a section carried from the tip of the nose backward, thus cutting through the middle of the cervical portion of the vertebral column.

We first proceed to note the positions of the **chief bones of the face**, &c., as exposed in this section; and we again remind the student of the advantage to be gained by comparing the structure of the human face and neck with that exhibited in a similar section of the head of some small animal.

The **sphenoid bone** separates the upper and back portion of the cavity of the nose from the cavity of the skull.

The **ethmoid bone** separates the same two cavities more toward the front.

The **nasal bones** form the upper and hard portion of the ridge of the nose, the lower portion of which is constructed of cartilage, and is therefore flexible.

The cavity of the nose is limited below by the **superior maxillary bones**, and the **palatal bones** behind them; these forming together the **hard palate.**

It will thus be seen that the **nasal cavity** occupies a very large proportion of the face. It is divided centrally from front to back by the thin bony plate called the **vomer**, and its outer or right and left walls are formed by the **superior, middle, and inferior turbinated or scroll-like bones**, the upper two of which form part of the ethmoid bone, while the lower or *inferior* are distinct bones.

Below the nasal cavities, and separated from them by the hard palate, is the **cavity of the mouth.** The roof of the mouth is continued backward from the hard palate by the **soft palate,** which is composed of fleshy substance, without any kind of hard support; and behind this the cavities of the mouth and nose both lead into a cavity called the **pharynx.**

The lower part of the pharynx is continuous with a fleshy tube which leads downward from it, passing completely through the thorax and the diaphragm, and then entering the *stomach.* This tube is called the **œsophagus, gullet,** or **food-passage.** Thus, after food or drink has passed through the mouth, between the tongue and the palate, it enters the pharynx, and is then conveyed to the stomach by means of the œsophagus.

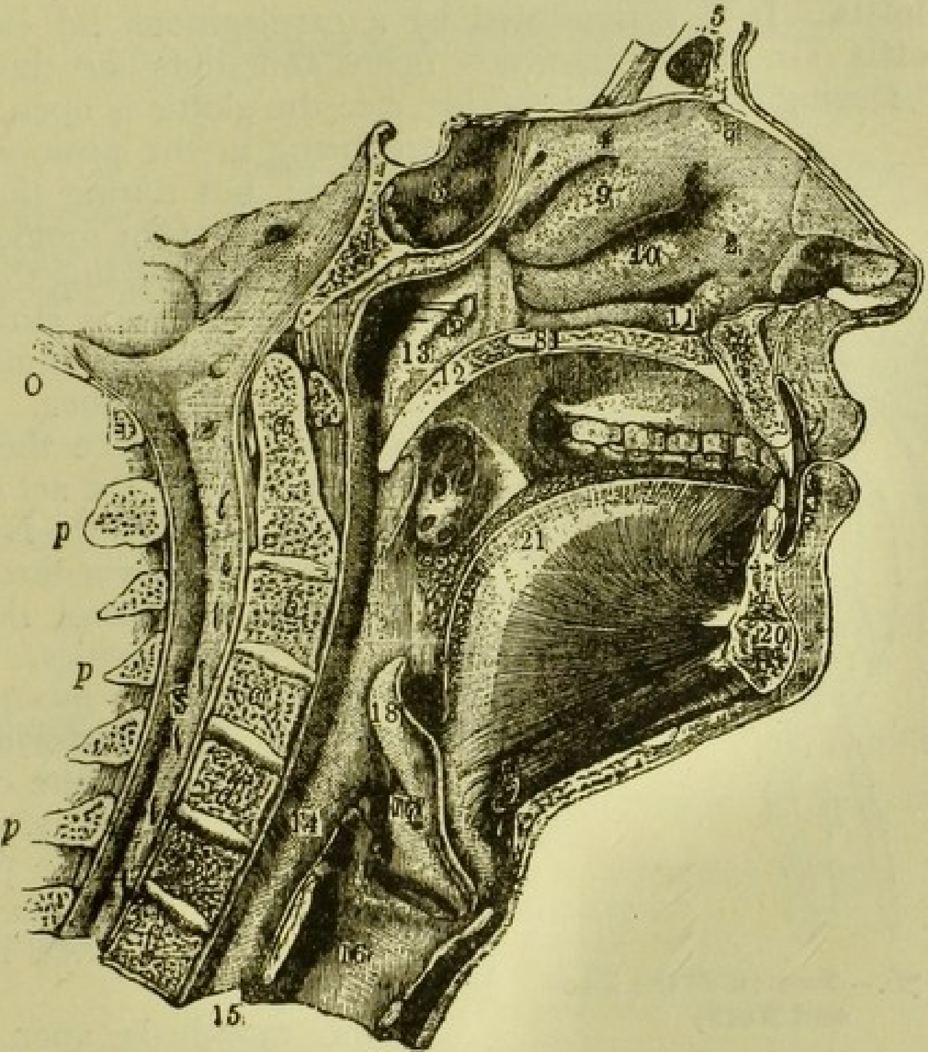


Fig. 75.—**Medial Section of the Face and Neck.**

1, sphenoid bone; 2, nasal cavity; 3, brain cavity; 4, ethmoid bone; 5, frontal bone; 6, nasal bone; 7, superior maxillary bone; 8, palatal bone; 9, superior turbinated bone; 10, middle turbinated bone; 11, inferior turbinated bone; 12, soft palate; 13, upper part of pharynx; 14, lower part of pharynx; 15, œsophagus; 16, larynx; 17, glottis; 18, epiglottis; 19, opening of Eustachian tube; 20, inferior maxillary bone; 21, tongue; 22, tonsil; *a* to *f*, bodies of cervical vertebræ; *s*, spinal cord; *p*, processes of cervical vertebræ; *o*, portion of occipital bone.

There is another tube that leads downward from the pharynx. It is situated just in front of the œsophagus, and is that hard tube which may be felt in the front part of the throat. This is called the **trachea** (Gr. *trachus*, rough) or **windpipe.** The upper part of the trachea is larger than the rest, and forms that prominence in the front of the throat which is sometimes called Adam's apple. It is the **larynx** or **voice-box**, so called because it contains the *vocal cords* by the vibration of which the voice is produced. The trachea, including the larynx, is composed of rings of *cartilage or gristle*, connected by means of soft *fibrous tissue*; and this will account for the irregularity or *roughness* experienced by pressing the fingers down the front of the throat.

The opening leading from the pharynx into the larynx is called the **glottis**. It is surmounted by a cartilaginous lid called the **epiglottis** (Gr. *epi*, upon) which opens and shuts like the lid of a box. During breathing, speaking, &c., the glottis is open, the epiglottis being in the position shown in fig. 75; but during the act of swallowing, just at the moment when food or drink is passing the top of the larynx, the glottis is closed, thus preventing any solid or liquid matter from entering the trachea.

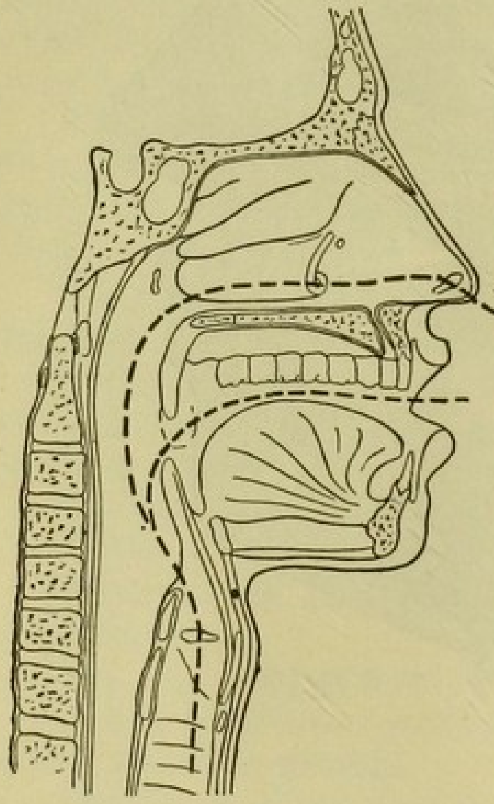


Fig. 76.—**Section of the Face and Neck,**

Showing the direction taken by the air during breathing, &c.

We may now trace the course taken by air during the act of inspiration. If the mouth is closed, the air inspired passes through the nostrils and then along the lower part of the nasal cavities. It next enters the pharynx by means of two openings called the **posterior nares** or **posterior nostrils**, one of which leads from each nasal cavity. The air then passes down the pharynx, through the glottis, to the larynx and trachea, and thence into the lungs.

If the mouth is open during ordinary breathing, some of the air still passes through the nose, taking the course just described. That which enters the mouth takes a shorter course, passing direct from the mouth into the pharynx; and then, joining the former current, goes with it through the glottis, the larynx, and the trachea.

The **pharynx has seven passages** communicating with it. Five of these have already been mentioned. They are—

(*a*) The passages (**posterior nares**), leading from the nasal cavities.

(*b*) One communicating with the mouth.

(*c*) The **œsophagus.**

(*d*) The **larynx.**

The other two are the **Eustachian tubes**, which form communications between the upper part of the pharynx and the cavities of the middle portions of the ears. (See fig. 205.)

SUMMARY.

- **STRUCTURES SURROUNDING THE NASAL CAVITIES**
  - **Ethmoid bone**
    - Including
      - Superior turbinated bone.
      - Middle turbinated bone.
    - Partly separates cranial and nasal cavities.
    - Partly forms outer side walls of nasal cavity.
  - **Vomer**—Separates right and left nasal cavities.
  - **Nasal bone**—Forms upper part of the ridge of the nose.
  - **Nasal cartilages**—Form the flexible framework of the nose.
  - **Sphenoid** bone—Lies between the posterior portion of the nasal cavity and the brain.
  - **Superior maxillary** bones, **Palatal bones** — Form the hard palate of the mouth.
- **THE PHARYNX Communicates with**
  - **Nasal cavities**, by the **posterior nares.**
  - **Mouth.**
  - **Middle ear**, by the **Eustachian tubes.**
  - **Trachea**, by the **glottis.**
  - **Œsophagus**, by which it is connected with the **stomach.**
- **THE PALATE**
  - **Hard palate**
    - Superior maxillary bones.
    - Palatal bones.
  - **Soft palate**
    - Fleshy. Forms the back portion of the roof of the mouth.
    - Between the upper pharynx and the mouth.
- **THE TRACHEA**
  - **Composed of**
    - Rings of **cartilage**, connected by
    - Soft **fibrous tissue.**
  - **Upper portion**
    - Called the **larynx.**
    - Contains the **vocal cords.**
- **FOOD PASSAGE**
  - Mouth.
  - Pharynx.
  - Œsophagus.
  - Stomach, &c.
- **COURSES OF THE AIR**
  - 1.
    - **Nostrils.**
    - Posterior nares.
    - Pharynx.
    - Glottis.
    - Trachea.
    - Lungs.
  - 2.
    - **Mouth.**
    - Pharynx.
    - Glottis.
    - Trachea.
    - Lungs.

QUESTIONS ON LESSON XI.

1. Describe the structures which surround the cavities of the nose.
2. In what way is the cavity of the nose separated from that of the brain?
3. Describe the structure of the *palate*.
4. Give a brief description of the *pharynx*. What are the openings leading into it?
5. Describe the positions, and compare the structures of the *trachea* and of the *œsophagus*.
6. Describe the course taken by food and drink after leaving the mouth.
7. What is the course taken by the air during ordinary breathing (1) When the mouth is closed, and (2) When the mouth is open?
8. Describe the position and use of the *epiglottis*.
9. What do we mean when we say that a particle of food has 'gone the wrong way'?

LESSON XII.

THE ORGANS OF THE THORAX.

THE **thorax or chest** contains—

The **trachea and its branches.**
The **lungs.**
The **heart and its great vessels.**
The **œsophagus.**

The **trachea** or **wind-pipe** passes downward from the throat into the thorax; and in the upper part of this cavity it divides into two branches called **bronchi.** One of these (the **right bronchus**) leads into the right lung, and the other (the **left bronchus**) into the left lung. These bronchi divide and sub-divide in the substance of the lungs till their branches (**bronchial tubes**) penetrate every part of those organs.

The **lungs or lights** are two large spongy organs which occupy the greater portion of the thorax. They are quite distinct from each other, although at some parts their adjacent surfaces are in contact. A large portion of the volume of the lungs is occupied by the *air-tubes* (branches of the trachea) and the little *air-cells* in which they terminate; hence the extreme lightness of these organs. To show this lightness a lung or a part of one may be floated on water. The general character and appearance of these organs may be learnt by examining the lights of a sheep or smaller animal, but it must be remembered that during life the organs are much larger, being inflated with air.

The **heart** is a hollow muscular organ situated nearly in the middle of the front and lower part of the chest, just above the

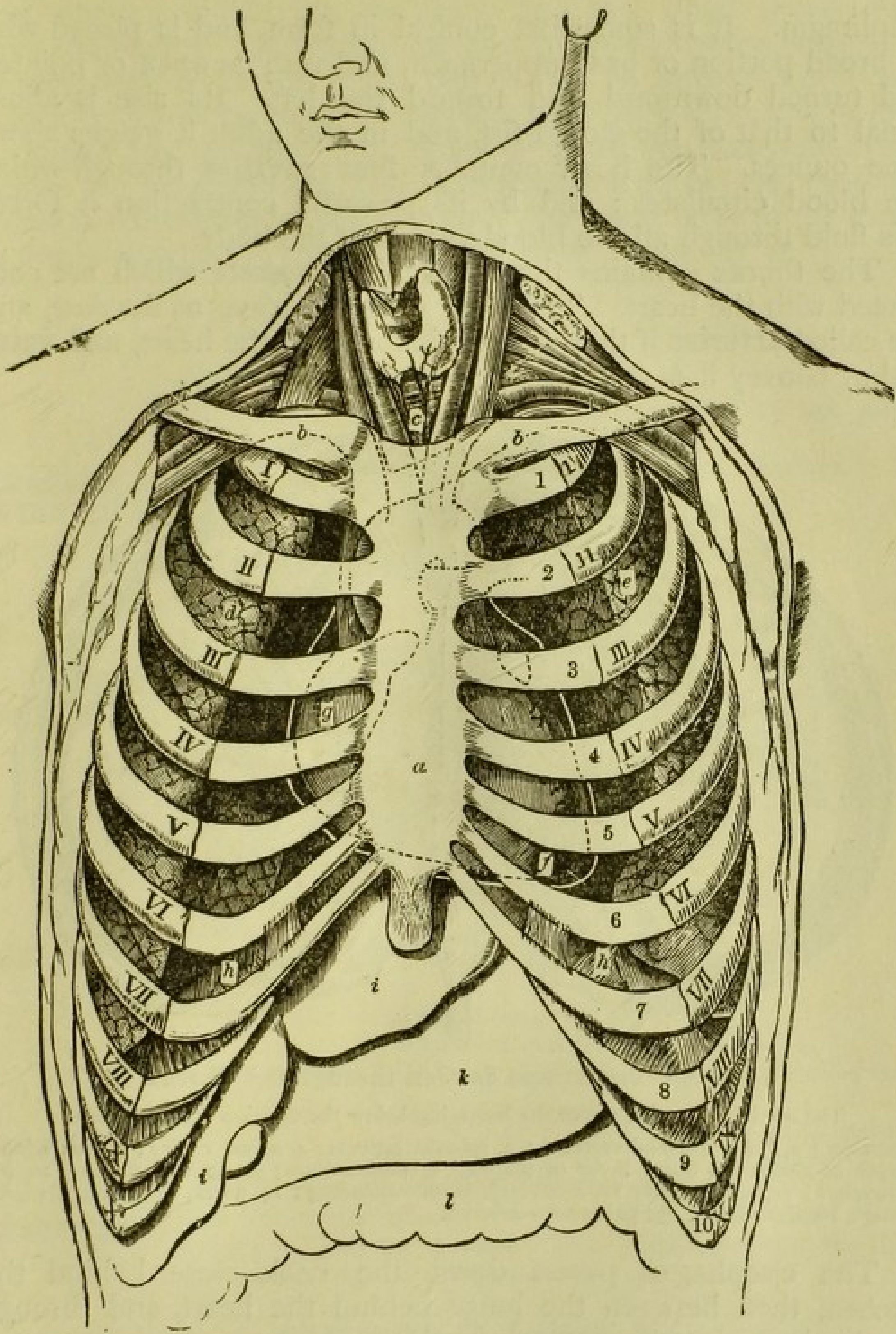


Fig. 77.—**The Organs of the Thorax.**

I to X, ribs; 1 to 10, costal cartilages on the left; *a*, sternum; *b*, clavicle; (the intercostal muscles are left out in order to show the organs inside the thorax); *c*, trachea; *d*, right lung; *e*, left lung; *f*, apex of the heart; *g*, base of the heart (the white line round the heart represents the pericardium); *h*, upper surface of the diaphragm; *i*, liver; *k*, stomach; *l*, intestine. The last three organs are beneath the diaphragm, and therefore belong to the abdomen.

diaphragm. It is somewhat conical in form, and is placed with its broad portion or **base** uppermost, and with its **apex** or pointed end turned downward and toward the left. Its size is about equal to that of the closed fist, and in the adult it weighs about nine ounces. The heart contains **four cavities** through which the blood circulates; and by its powerful contraction it forces this fluid through all the blood-vessels of the body.

The thorax contains the **great blood-vessels** which are connected with the heart. These all enter or leave at the *base*, and are called **arteries** if they convey blood *from* the heart, and **veins** if they convey it *to* the heart.

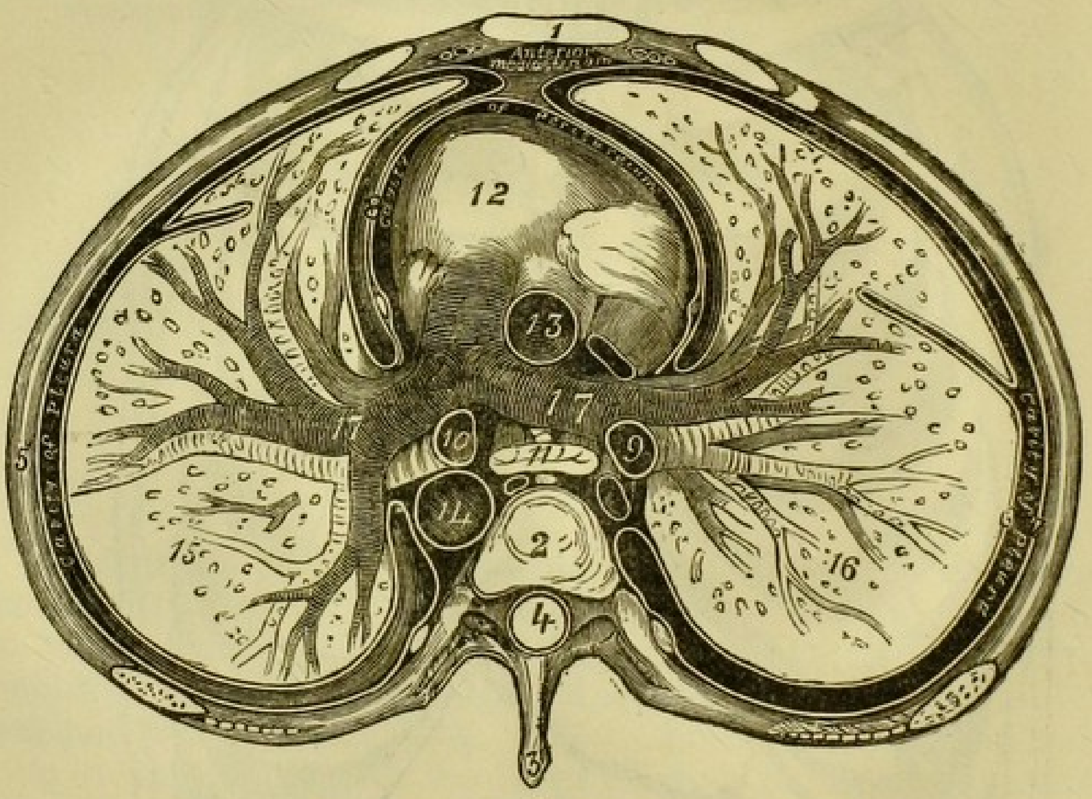


Fig. 78.—**Transverse Section through the Thorax.**

The section is carried above the heart, but below the division of the trachea.

1, sternum; 2, body of dorsal vertebra; 3, spinous process; 4, spinal cavity; 5, rib; 6, inner layer of pleura; 7, outer layer of pleura; 8, pericardium; 9, right bronchus; 10, left bronchus; 11, œsophagus; 12, heart; 13, aorta, ascending; 14, aorta, descending; 15, left lung; 16, right lung; 17, pulmonary arteries.

The **œsophagus** passes down the neck close behind the trachea, then between the lungs behind the heart, and through the diaphragm to the stomach beneath.

The organs just mentioned completely fill the thorax during life; but, when the chest of an animal is cut open, the lungs collapse, even if they are uninjured. If, however, a suitable tube be inserted in the trachea, the lungs may again be inflated by blowing into them.

Both heart and lungs are invested by double membranes.

That which surrounds the heart is called the **pericardium** (Gr. *peri*, about ; and *kardia*, the heart), and that which invests each lung the **pleura**. In both cases one layer of the membrane is so closely attached to the organ that it can be separated only with difficulty, while the other is reflected back from this so as to form a double bag or sac. The outer layer of the pericardium envelops the heart loosely, and is generally torn or cut when that organ is removed from the thorax. The outer layer of the pleura is firmly attached to the walls of the chest. (See fig. 78.)

SUMMARY.

TRACHEA or WIND-PIPE
- Leads from the mouth to the lungs.
- Composed of *rings of cartilage* connected by *soft fibrous tissue.*
- **Larynx**
  - The upper, enlarged portion of the trachea.
  - Sometimes called the *voice-box.*
  - Contains the vocal cords.
- **Bronchi**
  - The two great divisions of the trachea.
  - One enters each lung.
- **Bronchial tubes**—the subdivisions of the bronchi.

LUNGS or LIGHTS.
- Light, spongy bags.
- Contain *air-cells*—at the terminations of the bronchial tubes.
- Almost fill the thorax.
- **Pleuræ**
  - A *membrane* surrounding the lungs.
  - Composed of *two layers*
    - One covers the lungs.
    - The other lines the chest walls.

HEART . . .
- A *hollow muscle* (involuntary).
- Weighs about 9 ozs.
- Occupies lower, front, middle portion of the chest.
- Rests on the *diaphragm.*
- Its *apex* or point turns downward towards the left.
- Has four cavities.
- Forces the blood to all parts of the body.
- **Pericardium**
  - A *membrane* surrounding the heart.
  - Composed of *two layers*
    - One attached to the heart.
    - The other envelops it loosely.

ŒSOPHAGUS
- Leads from the mouth to the stomach.
- A soft, fleshy tube.
- Lies behind the trachea. Then passes between the lungs, and through the diaphragm.

QUESTIONS ON LESSON XII.

1. Give the names of the chief organs of the *thorax*, and describe briefly the position of each.
2. Where is the *trachea*? Where does it begin, and where does it end?
3. What are the *bronchi* and the *bronchial tubes*? Where are they to be found?

4. Give a brief description of the lungs. In what part of the body are they situated ?
5. Name the organs which touch the upper surface of the diaphragm.
6. Give a brief description of the heart. Say exactly where it is situated, and name the organs adjacent to it.
7. Describe exactly the position of the *œsophagus*. Where does it begin, and where does it end ?
8. Describe the *pericardium* and the *pleuræ*.

LESSON XIII.

THE ORGANS OF THE ABDOMEN.

THE **organs of the abdomen** include—

The **œsophagus** (lower portion).
The **stomach.**
The **intestines.**
The **liver.**
The **pancreas.**
The **spleen.**
The **kidneys.**
The **bladder.**

The **œsophagus** passes through the diaphragm, and immediately widens out into the *stomach*.

The **stomach** is a membranous and muscular bag, about ten inches in length from right to left, situated in part against the front wall of the abdomen, just beneath the diaphragm. It lies in part under the left portion of the liver. The stomach is somewhat pear-shaped, its larger end, called the *cardiac extremity*, being on the left, and the narrower end, called the *pyloric extremity*, on the right. The œsophagus enters the stomach at about two or three inches from the cardiac end, the opening being called the **cardiac orifice** ; and the narrow end of the stomach communicates with the intestines by an opening which is called the **pylorus** (Gr. *pulouros*, a gate-keeper). The upper surface of the stomach is short and concave, while the lower is long and convex. The former is called the *lesser curvature*, and the latter the *greater curvature*. The right upper surface of the stomach is covered by the liver, which lies between it and the diaphragm. Food-substances enter the stomach by means of the cardiac orifice, and, after being thoroughly mixed with the digestive fluid of the stomach, pass through the pylorus into the intestines.

The **intestines** consist of two distinct portions, the *small intestine*, and the *large intestine*, both together occupying a large portion of the abdominal cavity. The **small intestine** is a convoluted (twisted) tube, about twenty feet in length. For about ten inches, commencing at the pylorus, it is called the **duodenum** (Lat.

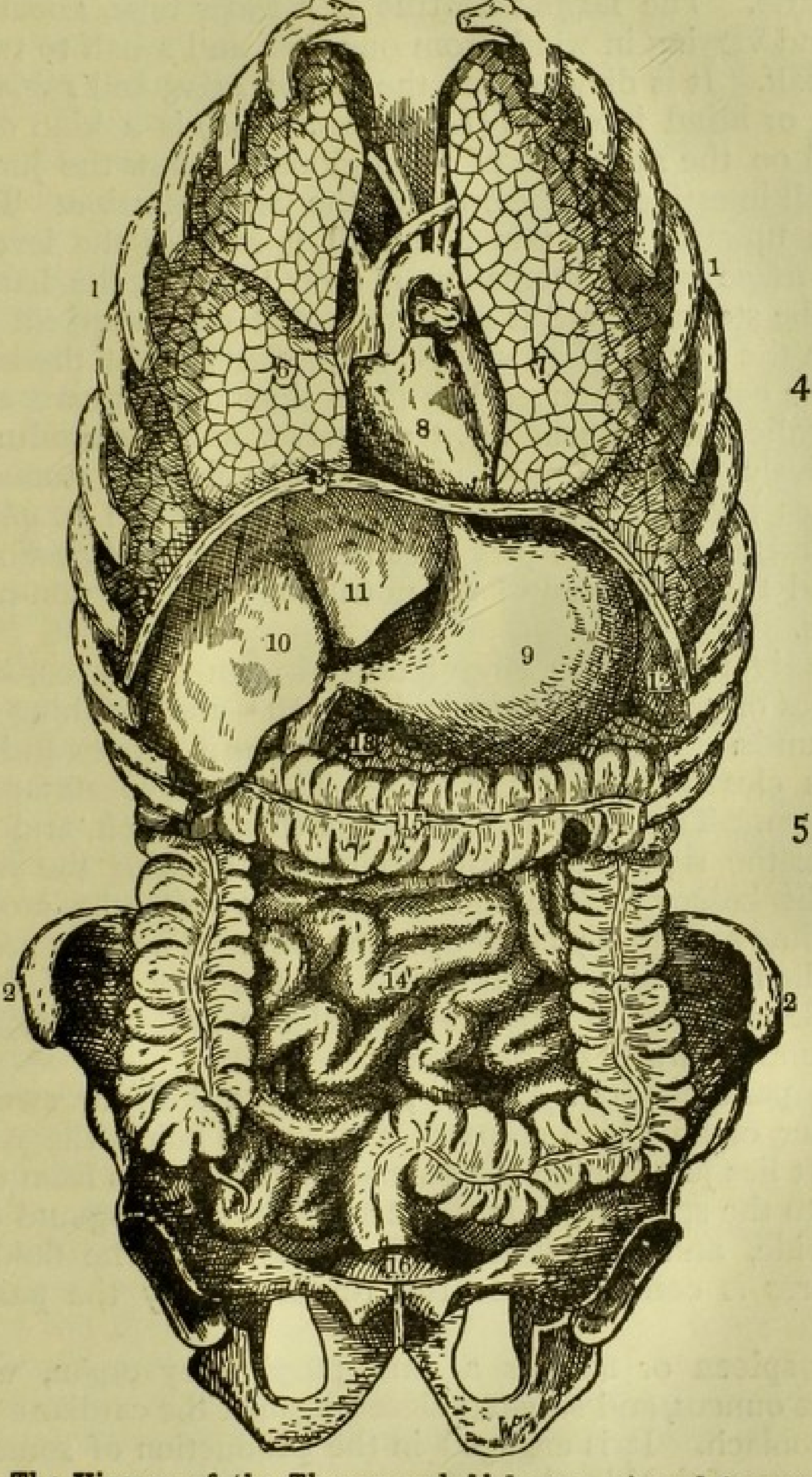


Fig. 79.—**The Viscera of the Thorax and Abdomen, viewed from the Front.**

1, ribs, the front portions of which, together with the sternum, have been removed ; 2, bones of the pelvis ; 3, diaphragm ; 4, thorax ; 5, abdomen ; 6, right lung ; 7, left lung ; 8, heart ; 9, stomach ; 10, right lobe of the liver ; 11, left lobe of the liver ; 12, spleen ; 13, pancreas ; 14, small intestine ; 15, large intestine 16, bladder.

duodeni, twelve), being considered to be about twelve finger-breadths long. The upper two-fifths of the remainder is called the **jejunum**, and the lower three-fifths the **ileum** (Gr. *illo*, I twist). There are, however, no distinct lines of separation between these three parts. The **large intestine** is a wider tube, about six feet long, and varying in width from one inch and a-half to two inches and a-half. It is divided into the *cæcum*, *colon*, and *rectum*. The **cæcum** or **blind intestine** (Lat. *cæcus*, blind) is a kind of pouch, situated on the right side of the abdomen, below the junction of the small intestine (the ileum) with the large intestine. The **colon** extends upwards from this point, till it reaches the level of the lower surface of the stomach ; it then turns to the left, passing under the stomach, and is again deflected downward till it terminates in the rectum (Lat. straight)—the last part of the intestines. Thus the colon is arranged like three sides of a square, the parts being called the **ascending, transverse, and descending colon** respectively. The mouth, pharynx, œsophagus, stomach, and intestines together form the **alimentary canal** (Lat. *alimentum*, nourishment), and each part does its share in the digestion of the food and the separation of the nutritious from the non-nutritious portions.

The **liver** is a very large reddish-brown organ, consisting of two lobes or parts—the right and the left—and weighing three or four pounds. The upper surface of the liver is convex and smooth, and fits closely against the under and concave surface of the diaphragm. The right lobe is larger than the left, and extends well over the right side of the abdomen, touching the intestines and right kidney ; while the smaller and left lobe crosses the middle line and partly covers the stomach. The liver prepares a fluid called the **bile**, which assists in the process of digestion. This bile is stored in a bladder called the **gall-bladder**, situated on the under surface of this organ.

The **pancreas** (Gr. *pan*, all ; and *kreas*, flesh) or **sweetbread** is another organ which prepares a digestive fluid—the *pancreatic juice*. It lies just behind the stomach and extends from the duodenum to the spleen. It is about seven inches long and one and a-half wide, and weighs about three ounces. The fluid which it prepares is conveyed into the duodenum by the **pancreatic duct.**

The **spleen** or **milt** is a dark purple-grey organ, weighing about six ounces, and situated closely against the cardiac extremity of the stomach. It is engaged in the production of some of the constituents of the blood.

The **kidneys** are two bean-shaped organs, measuring about four inches long and two and a-half broad, and weighing about four ounces each. They are situated at the back of the abdomen, one on each side of the vertebral column, deeply seated in the flesh of the loins on a level with the upper lumbar vertebræ. These are the organs which we find imbedded in the flesh and fat of the 'loin of mutton.' The use of the kidneys is to separate certain poisonous substances which have accumulated in the blood during its circulation throughout the body. These impurities are conveyed away from the kidneys by two tubes called **ureters**, which communicate with the bladder.

The **bladder** is a very strong membranous and muscular bag which lies in the cavity of the pelvis. This organ serves to contain the fluid (the urine) which is being constantly excreted by the kidneys, thus enabling it to be discharged at intervals.

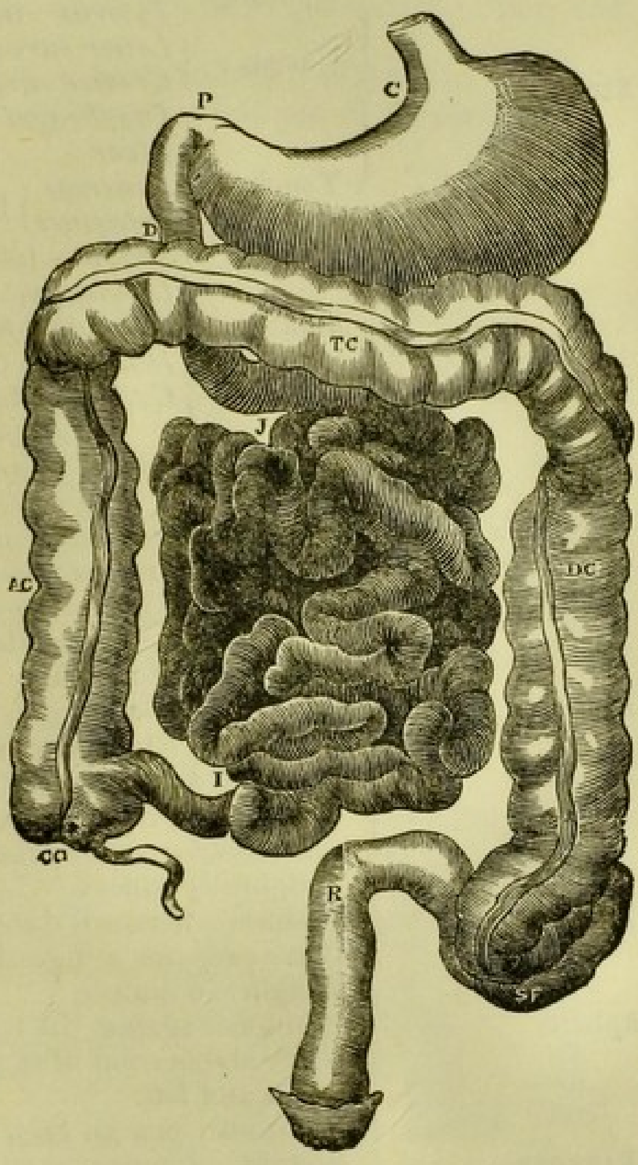


Fig. 80.—**The Abdominal Portion of the Alimentary Canal.**

C, cardiac opening of the stomach; P, pylorus; D, duodenum; J, jejunum; I, ileum; CC, cæcum; AC, ascending colon; TC, transverse colon; DC, descending colon; R, rectum.

Most of the organs of the abdomen are surrounded and supported by a membrane called the **peritoneum** (Gr. *peri*, about; and *teino*, I stretch). This is a double membrane forming a *shut sac*, resembling the corresponding membranes (the pleuræ and pericardium) of the thorax. Its outer layer lines the inner surface of the abdomen, and the other layer is reflected round the various organs, forming their exterior coverings. Some of the folds of the peritoneum connect portions of the intestines with the posterior walls of the abdomen. These are called the **mesenteries** (Gr. *mesos*, middle; and *enteron*, the intestine).

SUMMARY.

ORGANS OF THE ABDOMEN.

- **Œsophagus** . . Lower portion only.
- **Stomach** . .
  - Openings
    - *Cardiac*—left side.
    - *Pylorus*—right side.
  - Curves .
    - *Lesser curvature*—upper surface.
    - *Greater curvature*—lower surface.
  - Touches
    - *Diaphragm*, *Liver* } above.
    - *Pancreas*, *Intestines* } below.
    - *Spleen*— left side.
- **Intestines** . .
  - **Small** .
    - *Duodenum*—10 inches.
    - *Jejunum*—8 feet.
    - *Ileum*—12 feet.
  - **Large** . } Together about 6 feet.
    - *Cæcum* or blind intestine.
    - *Colon*
      - *Ascending*
      - *Transverse*
      - *Descending*
    - *Rectum or straight gut*
- **Liver** . . .
  - Weight—Three or four lbs.
  - Lobes .
    - Right—large.
    - Left—smaller—covers part of stomach.
  - Touches
    - Stomach.
    - Diaphragm.
    - Right abdominal wall.
    - Intestines.
  - Use . . Prepares the bile—a digestive fluid.
  - *Gall-bladder*—stores the bile.
- **Pancreas** . .
  - Weight—3 ounces.
  - Position—between duodenum and spleen.
  - Use—prepares a digestive fluid (pancreatic juice).
- **Spleen** . . .
  - Weight—6 ounces.
  - Position—against the cardiac end of the stomach.
  - Use—elaboration of the blood.
- **Kidneys** . . .
  - Right and left.
  - Positions—one on each side of upper lumbar vertebræ.
  - Weight—4 ounces each.
  - Use—Separates poisonous matters from the blood.
  - Ureters—convey these excretions to the bladder.
- **Bladder** . . .
  - Position—in the cavity of the pelvis.
  - Use—to contain the excretions of the kidneys.
- **Peritoneum** . Layers
  1. Lines interior of abdomen.
  2. Surrounds abdominal organs.

QUESTIONS ON LESSON XIII.

1. Name the chief organs of the abdomen, and state briefly the position of each.
2. What are the organs which touch the under surface of the diaphragm?
3. Give a brief description of the stomach. What organs surround it? What is its use?
4. Describe the form and arrangement of the *intestines*. With what organs are they connected?

5. Name the various parts of the *alimentary canal*, taking them in order; and say which parts belong to the thorax, and which to the abdomen.
6. Give a brief description of the liver. With what organs is it in contact?
7. Describe the forms, sizes, and positions of the *pancreas* and the *spleen*. Of what uses are these organs?
8. Where are the kidneys situated? Describe their general form, size, and use.
9. What part of the body is occupied by the bladder? What is its use?
10. Give a general description of the arrangement and use of the *peritoneum*.

LESSON XIV.

THE CHEMISTRY OF THE BODY.

All substances are either **elementary** or **compound.**

An **elementary substance** or **element** is a substance which consists of only one kind of matter, and therefore cannot be divided into two or more simpler substances.

A **compound substance** is one which consists of two or more elements chemically combined, and may be analysed or split up into these elements.

The following simple experiment illustrates these definitions:—

Put a little red oxide of mercury (red precipitate) into a test-tube, and heat it in the flame of a spirit lamp. After a short time a greyish deposit will be formed on the cool part of the tube, which deposit consists of a number of minute globules of the liquid metal called quicksilver or mercury. While this deposit is being formed, pass into the tube a smouldering taper or chip of wood, and it will immediately burst into flame. Thus we have separated the oxide of mercury into two distinct substances:—one is the metal *mercury*, and the other is a gas which supports combustion much better than air. This gas is called *oxygen*. Hence the oxide of mercury is a *compound substance*; and, since the two substances oxygen and mercury cannot be further simplified, they are called *elements*.

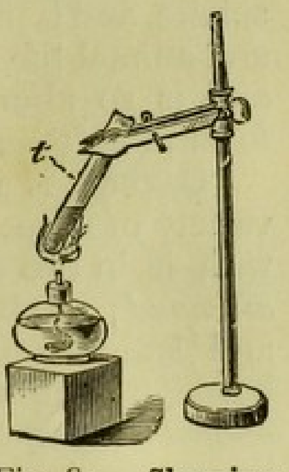


Fig. 81.— **Showing how to decompose the Red Oxide of Mercury.**

Over sixty **elementary substances** are known to chemists. Four of these are *gases* at ordinary temperatures, two only are *liquids*, and the others are *solids*.

About fifteen of these elements have been found in the human body. The chief of these are—

Oxygen, forming about 72 per cent. of the weight.
Carbon „ „ 13·5 „ „
Hydrogen „ „ 9 „ „

Nitrogen,	forming about	2·5	per cent. of the	weight.
Calcium	,, ,,	1·3	,,	,,
Phosphorus	,,	1·2	,,	,,
Sulphur	,, ,,	·15	,,	,,

Sodium, *chlorine*, *fluorine*, *potassium*, *iron*, *magnesium*, and *silicon* are also present in small quantities.

Each of these is present in combination with others, thus giving rise to a variety of chemical compounds; but oxygen, nitrogen, and hydrogen also exist in small proportions in the elementary form as gases.

Thus we see that the body is made up of a number of chemical compounds, each compound being formed by the union of two or more elements. These compounds are the *proximate principles* which enter into the formation of the various tissues of the body.

Before proceeding to describe the chief compounds of the body, we will study the general characters of its **four chief elements,** viz. *oxygen*, *carbon*, *hydrogen*, and *nitrogen*.

The simple experiment described above is sufficient to illustrate the **chief characteristics of oxygen.** It is an invisible gas, which powerfully supports combustion or burning, but is not itself combustible. Oxygen forms about one-fifth of the volume of the atmosphere, and is that constituent of the air which supports combustion and animal life. It also forms eight-ninths of the weight of water, and is so abundant in the earth's crust that it is calculated to form more than one-third the weight of the whole globe.

Carbon is a *solid* element which is capable of existing in a variety of forms. As a natural mineral substance we are familiar with it in two forms—*black lead* (*plumbago or graphite*) and the *diamond*; the latter being its purest and crystalline form. Charcoal and lamp-black are artificial varieties of carbon. When carbon burns, it combines with the oxygen of the air, forming an invisible *compound* gas, called **carbonic acid gas.** This gas is also produced by the combustion of any compound substance which contains the element carbon, such as coal, coal gas, wood, oils, spirits, &c. (See page 78.)

In order to ascertain the **chief properties of hydrogen gas,** it will be advisable to resort to a few simple experiments:—

(*a*). Fit any kind of bottle with a good cork, through which passes a straight glass tube; and see that the apparatus is air-tight with the exception of the tube through which the gas has to pass. Put into the bottle a few scraps of zinc, and cover these with diluted sulphuric acid (about eight parts of water to one of the strong acid). Hydrogen gas immediately begins to come off, and, being lighter than air, may be collected in an *inverted* bottle.

(*b*). Collect some of the gas in a *dry* bottle as above described, and then hold the mouth of the bottle near a flame, *taking great care that no flame is brought near the apparatus in which the gas is being generated.* The hydrogen gas will burn with a pale blue flame, and form a *deposit of water* on the sides of the bottle. *Hydrogen combines with oxygen (from the air) when it burns, hence* **water is a compound consisting of hydrogen and oxygen.**

(*c*). Fill another jar with hydrogen, and pass into it a lighted taper. The taper is extinguished as soon as it enters the gas, but the gas itself burns. Thus we learn that *hydrogen is not a supporter of combustion.* (Fig. 83.)

If water contains oxygen, how is it that water will not support combustion? We answer this by saying that the oxygen in the water is not *free*, but is in combination with hydrogen. Air supports combustion because the oxygen it contains *is* free, the air being a *simple mixture* of two gases, and not a chemical compound.

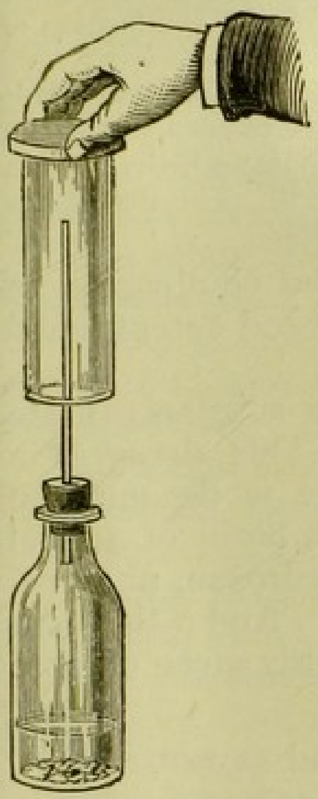


Fig. 82. — **Showing how to prepare and collect Hydrogen gas.**

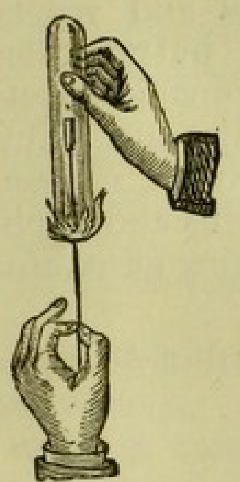


Fig. 83.

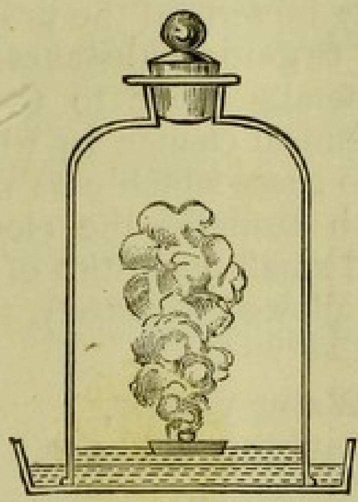


Fig. 84. — **Showing how to prepare Nitrogen from the Atmosphere.**

Nitrogen is the other gas of the atmosphere, and it may be separated from the oxygen with which it is mixed by the following simple process :—

Place a small piece of dried phosphorus on a cork floating in a dish of water. Ignite the phosphorus and then cover it quickly with a bell jar or wide-mouthed bottle. As the phosphorus burns, the volume of the air becomes less, and the water rises to take the place of the gas consumed. The oxygen of the air has combined with the phosphorus, and nitrogen only remains, this nitrogen occupying about four-fifths of the original air. After the nitrogen has stood till it is quite free from the white fumes formed by the combustion of the phosphorus, the bottle or jar may be turned over without losing any of the gas, which may then be tested with a lighted taper, and it will be found that **nitrogen does not support combustion.** Nitrogen is a very inactive gas, and its use in the atmosphere is to modify the violent action of the oxygen, and so render the air fit for the support of animal life.

We have already learnt that water is formed by the combustion of hydrogen; and that carbonic acid gas is produced by the combustion of carbon; the element burnt in each case combining with the oxygen of the air. Nearly all combustible substances contain both carbon and hydrogen; hence, when these substances burn, they produce both carbonic acid gas and water. We may illustrate this in the following way:—

Hold a dry tumbler over the flame of a candle, and the inside of the glass will be quickly covered with a deposit of water formed by the combustion of the hydrogen in the candle.

Repeat the above experiment, and then remove the tumbler, closing it quickly with a glass plate or a piece of cardboard, so as to retain some of the gas produced by the burning of the candle. Now open it just a little, pour in a little clear lime-water, close again quickly, and shake it. The lime-water turns milky, which proves the presence of carbonic acid gas.

The heat of the candle-flame is due to the combustion of carbon and hydrogen; and the carbonic acid gas and water formed may be termed the **products of combustion.**

Organic substances (animal and vegetable substances) are generally prone to **decay** and **putrefaction.** This decay is a chemical change by which the organic substance is decomposed into gases which pass off into the air. Thus, a piece of animal flesh contains the elements oxygen, carbon, hydrogen, nitrogen, and small quantities of phosphorus and sulphur. And if this flesh be allowed to putrefy, the following gases are slowly given off into the air:—

Water vapour,	composed of	*hydrogen* and *oxygen*,
Carbonic acid gas,	,,	*carbon* and *oxygen*,
Ammonia,	,,	*nitrogen* and *hydrogen*,
Carburetted hydrogen,	,,	*carbon* and *hydrogen*,
Sulphuretted hydrogen,	,,	*sulphur* and *hydrogen*.

A certain proportion of **mineral matter** enters into the composition of all parts of the body, but the proportion varies considerably in the various organs and tissues. The amount of mineral substance in any part may be determined by completely burning that part, till nothing but a white **ash** remains. This ash is the mineral or inorganic substance, all the animal or organic matter having been changed into gases during the combustion.

Every tissue and fluid of the body is composed of a number of organic and inorganic compounds.

The **organic compounds of the body** may be classified into—

(1) **Non-nitrogenous,** containing *carbon*, *hydrogen*, and *oxygen* only.

(2) **Nitrogenous,** containing *nitrogen*, as well as *carbon*, *hydrogen*, and *oxygen*.

The **non-nitrogenous compounds** include *fats* and *oils*, *amyloids*, and certain *organic acids*.

The **fats** and **oils** are sometimes called hydro-carbons. They consist of *carbon*, *hydrogen*, and *oxygen*, but the proportion of oxygen is small.

The **amyloids** (Gr. *amulon*, starch, and *eidos*, form) include those compounds which resemble starch in chemical composition. They contain the same three elements that form fats and oils, but the proportion of oxygen is larger. In these compounds hydrogen and oxygen are present in the same proportion in which they combine to form water. The chief amyloids in the body are **glycogen, glucose** or **grape-sugar,** and **lactose** or **milk-sugar.**

The **nitrogenous compounds** are generally classified into *proteids* or *albuminoids* and *gelatinoids.*

The **albuminoids** include all those compounds which resemble *albumen* or white of egg in composition. They are found in all the living tissues of the body, and consist of *carbon*, *hydrogen*, *oxygen*, and *nitrogen*, together with a small proportion of *sulphur* or *phosphorus.* The chief albuminoids of the body are—

Albumen, found in the *blood* and *most tissues.*

Globulin, found in the *blood* and *many of the tissues.*

Myosin, found principally in *muscles.*

Fibrin, formed in *blood* as it coagulates or clots.

Casein, found in the *milk.*

The **gelatinoids** are those compounds which resemble **gelatine**. The chief are :—

Gelatine, formed by boiling bone.

Chondrin, found in *cartilage.*

The **inorganic or mineral compounds** found in the body are derived from our food and drink. Many of these pass through the body without undergoing any change, but others form a necessary part of the structure of certain tissues. Thus, the bones are rendered firm and hard by the presence of certain mineral compounds. The chief inorganic compounds are *water*, *calcium carbonate*, *calcium phosphate*, and *common salt.*

Although **water** is present largely in all living animal and vegetable substances, yet it is regarded as an inorganic or mineral compound *More than two-thirds of the weight of the body is water.* This is derived chiefly from our food and drink, but a small quantity is formed in the body. The **uses of water** in the body are—

1. To render the tissues soft, elastic, and flexible. This may be easily illustrated by heating a tissue till all the water has been driven off, when it will become hard, horny, and brittle.

2. To dissolve nutrient matter, and convey it to all parts of the body in a fluid form.

3. To assist the various processes of absorption, secretion, and excretion.

Calcium carbonate (carbonate of lime) is composed of the metal *calcium* together with *carbon* and *oxygen.* It exists largely in the *bones* and *teeth.* *Chalk* is a variety of this compound.

Calcium phosphate (phosphate of lime) consists of *calcium*, *phosphorus*, and *oxygen.* It forms more than fifty per cent. of the weight of *bone.* **Bone ash** (see page 40) consists chiefly of this compound and calcium carbonate.

Sodium chloride or **common salt** consists of the metal *sodium* and a yellowish-green gas called *chlorine.* It is present in small quantities in nearly *all parts of the body.*

Many other inorganic substances exist in the body; and the most important of these will be mentioned in connection with the special functions in which they are concerned.

SUMMARY.

THE FOUR CHIEF ELEMENTS OF THE BODY.	**Oxygen**	A gas. Powerful supporter of combustion. Not combustible. Forms one-fifth of the volume of the air. Forms eight-ninths of the weight of water.
	Carbon	A combustible solid. Varieties—charcoal, lampblack, black-lead, and the diamond. Forms carbonic acid gas when it burns. Contained in most combustible substances.
	Hydrogen	A very light gas. Combustible. Forms water when it burns. Does not support combustion. Forms one-ninth of the weight of water.
	Nitrogen	An inactive gas. Does not support combustion. Forms four-fifths the volume of the air.

CHIEF ORGANIC SUBSTANCES OF THE BODY.	**Non-nitrogenous**	**Fatty**	Fats and oils—not much oxygen.	
		Amyloids	Glycogen Glucose (grape sugar) Lactose (milk sugar)	Hydrogen and oxygen as in water.
	Nitrogenous	**Albuminoids or Proteids**	Albumen—blood and most tissues. Globulin—blood and many tissues. Myosin—muscles. Fibrin—blood. Casein—milk.	
		Gelatinoids	Gelatine—bone. Chondrin—cartilage.	

INORGANIC SUBSTANCES FOUND IN THE BODY	**Water**—Forms more than two-thirds the weight of the body.	
	Calcium carbonate—Calcium, carbon, and oxygen.	In bones and teeth.
	Calcium phosphate—Calcium, phosphorus, oxygen.	In bones and teeth.
	Common salt—Sodium and chlorine—in nearly all parts.	

QUESTIONS ON LESSON XIV.

1. Define *element* and *compound*. Illustrate your answer by an experiment.
2. Describe the general characters of the four chief elements found in the body. What other elementary bodies exist in the body?
3. Describe the chemical composition of water and air.
4. What is meant by *decay*? What are the chief products of the decay of organic matter? Give the chemical composition of each.
5. What is the difference between a nitrogenous and a non-nitrogenous organic compound? Give examples of each class.
6. Name the chief nitrogenous constituents of the body, and say where each may be found.
7. Compare the chemical composition of fat, sugar, and albumen.
8. What is the proportion of water in the body? What is the use of this water?
9. Name the chief mineral substances of the body. Give the chemical composition of each, and say where each may be found.

LESSON XV.

WASTE AND REPAIR—FOODS.

THAT the body is continually wasting away may be proved as follows:—

(1) Let the expired air from the lungs strike the surface of a cold object, such as a looking-glass, and a deposit of water is formed. Again, place the palm of the hand on the surface of a very cold slate or plate of glass, and let it remain for a few seconds. On removing it a similar deposit of water will be seen. Thus we learn that water is continually passing off from the lungs, and through the pores of the skin. Water, we remember, is composed of the elements hydrogen and oxygen; hence we are made acquainted with two sources of loss of these elements.

(2) Now blow air from the lungs through a glass tube, and let it bubble through clear lime-water. In a very short time the lime-water assumes a milky appearance, thus proving the presence of carbonic acid gas (see page 78). The lungs, therefore, are a source of loss of carbon and oxygen.

In order to ascertain the *amount* of loss in a given time, let a person weigh himself accurately, and then, after a few hours, during which time no food or drink should be taken, let him weigh himself again.

The chief **sources of loss** to the body are—

(1) The **lungs**. (2) The **skin**. (3) The **kidneys**.

By means of the **lungs** we lose both *water* (in the form of vapour) and *carbonic acid gas*.

By means of the **skin** we part with *water*, a small quantity of *mineral salts*, and a little *carbonic acid gas*.

The **kidneys** are the source of a considerable loss of *water*, and a very large quantity of *urea*.

The **loss by the skin** varies very considerably. The exudation through its pores is commonly known as **perspiration** or **sweat.** In hot weather, or during violent exercise, we perspire very freely; so much so that the skin becomes covered with globules of water, containing carbonic acid gas and urea in solution. But in cool weather, and during rest or the taking of gentle exercise, the liquid exuded evaporates into the air as fast as it reaches the surface, and consequently the perspiration is *insensible*.

From the above we learn how the four chief elements of the body—oxygen, carbon, hydrogen, and nitrogen, are lost. The loss of hydrogen and oxygen in the form of water is very variable, and is replaced largely by the water contained in our foods and drinks. The loss of carbon and nitrogen is repaired by the use of organic food-substances, and amounts to an average of 4,500 grains of carbon and 300 grains of nitrogen daily in an adult person, taking moderate exercise.

The **high temperature of the body** (about 99° F.) is produced and maintained by chemical action. This action is chiefly *oxidation*, very closely resembling that which takes place when a candle burns (see page 78). The materials to be oxidised are supplied through our foods. A constant supply of oxygen gas is also obtained by the blood as it circulates through the lungs; and we may regard the carbonic acid gas given off as the product of the continuous oxidation of carbon in the body.

If we cease to take food for any considerable time the body gradually wastes away, and in a few days a marked change is produced in the general appearance. The discharge of waste matter by means of the lungs, skin, and kidneys still continues, and every muscular exercise adds to it. As no food is being taken, the temperature of the body is maintained by the oxidation and consequent wasting away of the *tissues*. After a few days the temperature decreases, till, at about the ninth or tenth day, the body has lost about forty per cent. of its weight, and is reduced to a temperature of about 70° F, when **death from starvation** puts an end to the painful existence.

Before considering the manner in which the waste of the body may be most advantageously repaired, it will be necessary to learn the nature of the various food-substances of which we make use.

Food-substances may be divided into *organic* and *inorganic*.

Organic foods may be subdivided into *animal* and *vegetable foods*; and each of these again into *nitrogenous* and *non-nitrogenous*.

Among the **animal nitrogenous foods** may be mentioned—

(1) **Albumen.** This substance may be obtained from white of egg, of which it forms about 20 per cent. It is a clear and transparent liquid when fresh, but coagulates, when heated, into a white opaque solid.

(2) **Casein** (Lat. *caseus*, cheese). This compound exists largely in milk, from which it may be separated in a solid form by the addition of an acid. This is illustrated in the making of cheese;—the milk is separated into *curds* and *whey* by the addition of *rennet*, and the curd from which the cheese is made contains the casein.

(3) **Fibrin** (Lat. *fibra*, a fibre). Fibrin exists in blood.

(4) **Myosin** (Gr. *mus*, a muscle). This is an important constituent of the juice of muscles. It is converted into **syntonin** by the addition of an acid.

The above four nitrogenous substances all closely resemble each other in chemical composition, and are all termed *albuminoids*.

(5) **Gelatine.** This may be obtained from bones by boiling. It swells considerably in cold water, but does not dissolve. It is soluble in hot water, and when the solution cools it forms a 'jelly.' The different kinds of glue are varieties of gelatine.

The chief **vegetable nitrogenous foods** are:—

(1) **Gluten.** This substance exists in all cereal grains. It forms about 10 per cent. of wheat flour, from which it may be obtained as follows:—Tie a little wheat flour in a calico bag, and well knead it in a vessel of water. A substance passes through the interstices of the calico which gives a milky appearance to the water. This substance is *starch*. After removing as much as possible of the starch in this manner, the contents of the bag will consist of a very sticky substance, which may be drawn out into threads. This is *gluten*. Gluten so closely resembles fibrin that it is sometimes termed *vegetable fibrin*.

(2) **Legumen.** Legumen exists largely in all kinds of peas and beans, and other seeds.

The principal **non-nitrogenous foods** are:—

(1) **Starch.** This is a vegetable substance which exists largely in various parts of plants. A method of separating it from flour has just been described; it may also be obtained in large quantities from potatoes, rice, arrowroot, &c. It is insoluble in cold water, but dissolves slightly in hot water, forming a kind of jelly on cooling.

(2) **Sugar.** There are several varieties of sugar derived from both plants and animals. *Cane sugar*, *beet sugar*, *grape sugar*, and *milk sugar* are the chief. The solid part of *honey* also consists largely of *grape sugar*. These varieties of sugar are all more or less soluble in water.

(3) **Gums.** These are also vegetable products, obtained from various parts of plants.

(4) **Fats and Oils.** These are obtained from both animal and vegetable sources. Fats are solid, derived chiefly from animals; oils are liquid, and are obtained chiefly from fruits. They resemble each other in chemical composition, and are insoluble in water.

The **inorganic or mineral foods** consist chiefly of water, *common salt*, *calcium carbonate*, and the *phosphates of calcium*, *magnesium*, *potassium*, *and sodium*; also certain *salts of iron*, &c. These foods are not, with the exception of water and common salt, generally taken separately; but they all exist in the animal and vegetable substances we eat.

Life cannot be sustained on mineral foods alone, although these may contain all the elements required to make good the waste. Neither can life be permanently sustained by any one class alone of the organic foods. Hence it follows that our food must consist of mixtures of these. But the various food-substances we employ do generally consist of such mixtures; for instance, wheat flour contains the nitrogenous substance gluten, the non-nitrogenous substance starch, and also various mineral salts derived by the wheat plant from the soil in which it grew. Again, butcher's meat contains the nitrogenous myosin, the non-nitrogenous fat, together with mineral salts obtained indirectly from the soil.

We may now study the manner in which life may be best sustained by ordinary food-substances with the greatest economy as regards the work thrown on the various organs concerned. We have seen that the **daily waste** of carbon and nitrogen from the system amounts to

Carbon	4,500 grs.—about 10 ozs.
Nitrogen	300 grs.—about ¾ oz.

Now let us suppose a person to feed on **bread only.** In order to obtain the necessary quantity of *nitrogen* to repair this waste, he would have to eat nearly 4¼ lbs. daily. This weight of bread contains

Carbon	9,000 grs.
Nitrogen	300 grs.

Hence he would be compelled to take about double the quantity of carbon required in order to obtain the necessary weight of nitrogen. This not only implies a waste of food substance, but also that a great deal of extra work is thrown on certain organs.

Next, let us suppose that he feeds on **lean meat only**. Then, in order to obtain the necessary quantity of *carbon*, he must eat no less than 6½ lbs. daily, as this weight of lean meat contains

Carbon	4,500 grs.
Nitrogen	1,350 grs.

In this case we notice a similar waste of *nitrogen*, the removal of which would also give an undue amount of work to the organs concerned.

But it is possible to take such a **mixed diet** of bread and meat as will supply all the requirements of the system, and at the same time yield but little waste material. In doing this we also reduce the total amount of food taken. Thus :

2 lbs. of **bread** contain . .	**carbon** 4,500 grs.,	and **nitrogen**	150 grs.
¾ lb. of **lean meat** contains .	**carbon** 500 grs.,	and **nitrogen**	150 grs.
Total	5,000 grs.		300 grs.

So that by eating no more than 2¾ lbs. of solid food daily we should be enabled to repair all the waste of the body, taking an excess of 500 grains of carbon only. This clearly shows the advantage that may be gained by a mixed diet which is selected with due regard to the requirements of the body.

A **model food** is one which contains nitrogenous, non-nitrogenous, and mineral food substances in the proportions in which they are required to make good the waste of the body. Among such foods may be mentioned (1) **milk**, on which young animals entirely subsist ; and (2) **eggs**, which provide all the nourishment to young birds till they are hatched. The following tables give the exact composition of these :

1. The Composition of Milk.

		Human	Cow's
Water	. . . . . .	890	858
Solids	*Casein* (nitrogenous) .	35	68
	Butter (non-nitrogenous).	25	38
	Sugar (non-nitrogenous) .	48	30
	Salts	2	6
		1000	1000

2. The Composition of Fowl's Eggs.

	White	Yelk
Water	78	52
Nitrogenous matter . . .	20·4	16
Fatty (non-nitrogenous) **matter** .	—	30·7
Salts	1·6	1·3
	100·0	100·0

Nitrogenous foods are frequently termed **tissue-forming foods**; and **non-nitrogenous, heat producers.** But this method of classification is very misleading, since both nitrogenous and non-nitrogenous are oxidised in the body, and, therefore, both help to maintain the high temperature. It is known, however, that none but nitrogenous food-substances are capable of forming tissues.

SUMMARY.

1. **Sources of loss to the body**:—
   - (*a*) **Lungs**: much *water* and *carbonic acid gas*.
   - (*b*) **Skin**: much *water* and a little *carbonic acid gas*.
   - (*c*) **Kidneys**: much *water* and *urea*.

   (The amount of loss increases with muscular activity.)

2. **FOODS**:
   - **ANIMAL**
     - **Nitrogenous**
       - **Albumen**—*white of egg.*
       - **Casein**—*milk* and *cheese.*
       - **Fibrin**—*blood.*
       - **Myosin**—*muscle.*
       - **Gelatine**—*bone.*
     - **Non-nitrogenous**
       - **Fats** and **sugar.**
   - **VEGETABLE**
     - **Nitrogenous**
       - **Gluten**—*cereal grains.*
       - **Legumen**—*pulse.*
     - **Non-nitrogenous**
       - **Starch**—*all parts of plants.*
       - **Sugars**—*all parts of plants.*
       - **Gums**—*all parts of plants.*
       - **Oils**—*fruits.*
   - **MINERAL**: *Water*, *common salt*, *calcium carbonate*, *calcium phosphate*, *&c.*

3. Life cannot be sustained by nitrogenous, non-nitrogenous, or mineral foods alone; all three kinds must be used.

4. | | |
   |---|---|
   | **Daily loss** | Carbon : Nitrogen :: 15 : 1. |
   | **In bread** | Carbon : Nitrogen :: 30 : 1. |
   | **In lean meat** | Carbon : Nitrogen :: $3\frac{1}{2}$: 1. |
   | **In mixed diet** { **Bread**—2 lbs. **Meat**—$\frac{3}{4}$ lb. } | Carbon : Nitrogen :: 16 : 1 (about). |

   Hence the advantage of the **mixed diet** in making good the daily loss with but little waste.

5. **A model food** is one which will supply the necessary elements in about the same proportions as they are given off from the system.

QUESTIONS ON LESSON XV.

1. What proofs can you give to show that the body is continually wasting away?
2. What are the chief sources of loss to the body?
3. What is the nature of the waste materials thrown off by the lungs, the skin, and the kidneys respectively?
4. How would you prove that carbon is oxidised in the body?
5. What is the cause of the high temperature of the human body?
6. Why does an animal die when it ceases to take food?

7. Give a list of animal and vegetable food-substances, and classify them according to their chemical composition.
8. How would you obtain starch and gluten from wheat flour?
9. Compare the chemical composition of starch and fat.
10. What are the chief mineral constituents of our foods? Describe the composition of each.
11. What would be the disadvantage of feeding on bread or meat alone?
12. Explain clearly why it is better to make use of a mixed diet of bread and meat.
13. What is a *model* food? Describe the composition of one such food.
14. Why are nitrogenous foods called *tissue-formers*, and non-nitrogenous foods *heat-producers*? State any objections you may have to this method of classification.

LESSON XVI.

THE TEETH AND MASTICATION.

Each **tooth** has a *crown*, a *neck*, and a *root* consisting of one or more *fangs*. The **crown** is the part which protrudes beyond the gum into the mouth. The **neck** is that slightly constricted portion which is embraced by the gum; and the **fang** or **fangs** include all that part of the tooth which penetrates into the jaw-bone.

If we examine our teeth we shall notice that they vary much in general form. Those in the front of each jaw are provided with sharp, chisel-like edges, and are consequently well adapted for biting or cutting: these are called the **incisors** (Lat. *incido*, I cut). Next to these, on each side, is a single tooth of about the same size, which has a somewhat pointed crown. This is called the **canine** or **dog tooth** (Lat. *canis*, a dog), because its position in the human skull corresponds with that of the long, conical, tearing tooth in the skull of the dog and other carnivorous (Lat. *caro*, flesh; and *voro*, I devour) or flesh-eating animals. The human canine tooth may also be said to slightly resemble that of a carnivorous animal in general form, inasmuch as its summit is more or less conical. Beyond these canine teeth on either side is a pair of **premolars** or **bicuspids** (Lat. *bis*, twice; and *cuspis*, a pointed extremity), so called because each has two cusps or ridges on the top of the crown, separated by a furrow. Beyond these again are larger teeth, each possessing two or more fangs, and having a very broad and irregular surface well adapted for the grinding of foods; hence these teeth are called the **molars** (Lat. *mola*, a mill).

A child of about six years possesses twenty teeth, called the **temporary** or **milk teeth**. These consist of four *incisors* in the front of each jaw, a single *canine* tooth on each side of these incisors, and a pair of *molars* on each side beyond the canines. At the age of about seven years these milk teeth begin to be cast off, their places being taken by the **permanent teeth** which grow beneath them ; and, at about the age of twelve, all have in this way given place to the permanent set.

The **permanent teeth** of the adult number thirty-two. They consist, in each jaw, of four *incisors*, two *canines*, four *bicuspid*, and

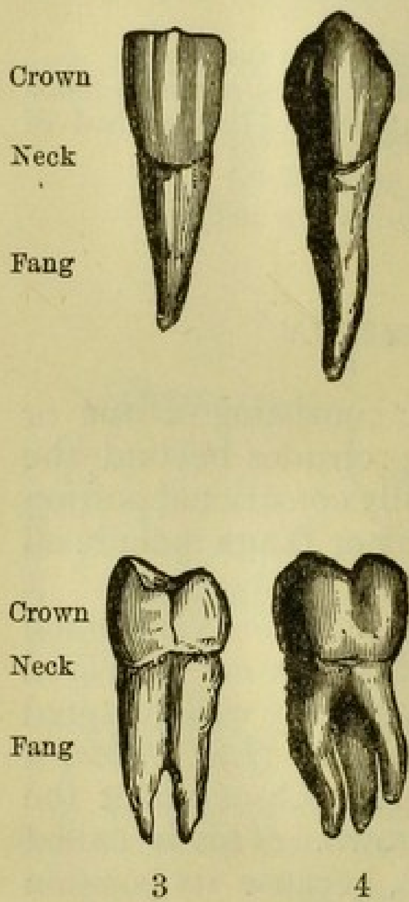


Fig. 85. — **Showing the four kinds of Human Teeth.**

1, incisor tooth (exterior view) ; 2, canine tooth (exterior view) ; 3, bicuspid tooth (side view showing the two cusps) ; 4, molar tooth (exterior view).

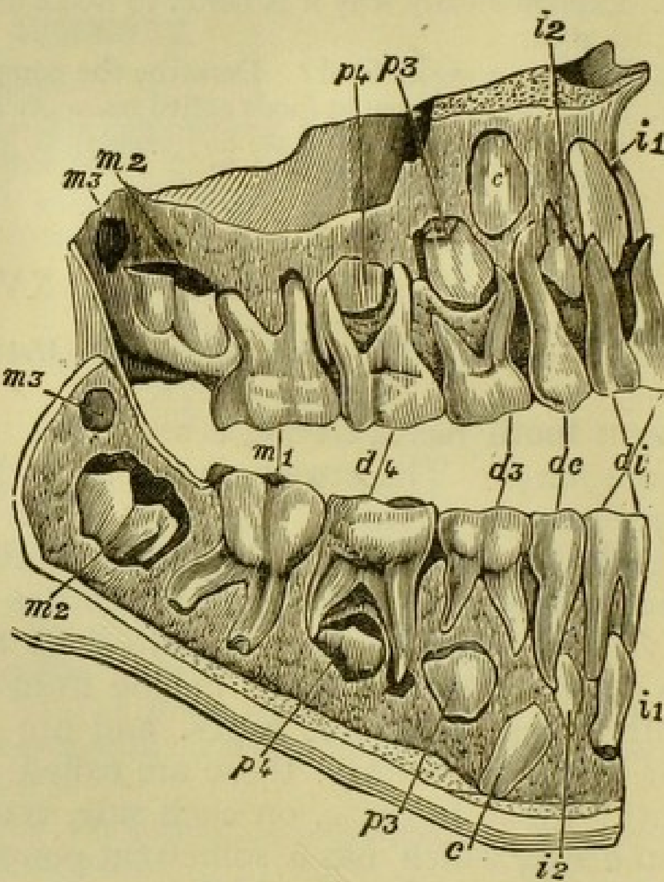


Fig. 86.—**Section of the Jaws of a Child of $6\frac{1}{2}$ Years, showing the Milk or Deciduous Teeth, also the Permanent Teeth in Process of Formation.**

di, the milk incisors ; *dc*, the milk canines ; *d*3, and *d*4, the milk molars ; *i*1 and *i*2, the permanent incisors ; *c*, the permanent canines ; *p*3 and *p*4, the permanent bicuspids ; *m*1, the first permanent molars, which have already made their appearance ; *m*2 and *m*3, the second and third permanent molars.

six *molars*. The last of the molars are called the **wisdom teeth**; they do not appear till between the seventeenth and twenty-fifth years.

The mass of a tooth consists chiefly of a hard substance called **dentine or ivory** (Lat. *dens*, a tooth). It resembles in composition the compact tissue of bone, but contains a much larger proportion of mineral matter (seventy-two per cent.), and is consequently harder. The mineral matter, like that in bone, consists chiefly of calcium phosphate and calcium carbonate ; and the animal matter may also be made to yield gelatine by boiling. In structure dentine differs from bone, as it contains no Haversian canals, lacunæ, &c.,

but is penetrated by a multitude of very delicate tubes which communicate with the cavity of the tooth.

This cavity is called the **pulp-cavity**. It contains a very soft substance—the **pulp**. This consists of a mass of minute blood-vessels and nerves which enter through an opening at the point of each fang.

The dentine which forms the crown of the tooth is covered with a substance called the **enamel**. It is the hardest substance in the body, and contains only two or three per cent. of animal

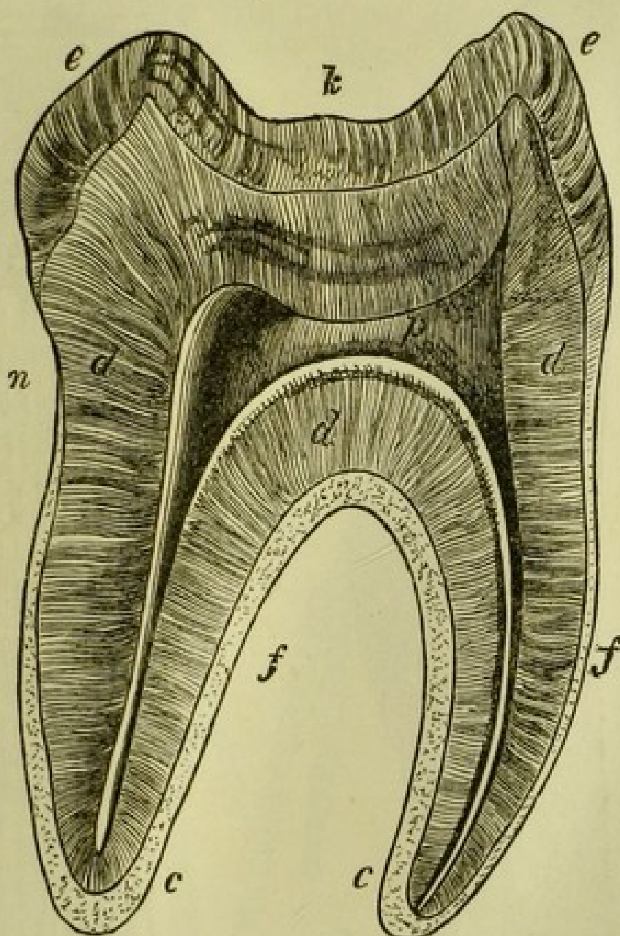


Fig. 87.—**Longitudinal Section of a Molar Tooth.**

k, crown; *n*, neck; *f*, fangs; *e*, enamel; *d*, dentine; *c*, cement; *p*, pulp cavity.

matter. When examined under a high magnifying power, the enamel is seen to consist of exceedingly fine hexagonal fibres.

The root of each tooth is surrounded by a substance called the **cement**. This substance is softer than the dentine, and in structure resembles bone—it contains *lacunæ* and *canaliculi*, but no Haversian canals.

The **use of the teeth** is to **masticate** the food, that is, to reduce it to such a finely divided state that it may be readily acted on by the various digestive fluids. It has already been noticed that the different kinds of teeth are adapted for different modes of action;

and we may now observe how this variety of action is still further increased by the complex movement of the lower jaw. When we

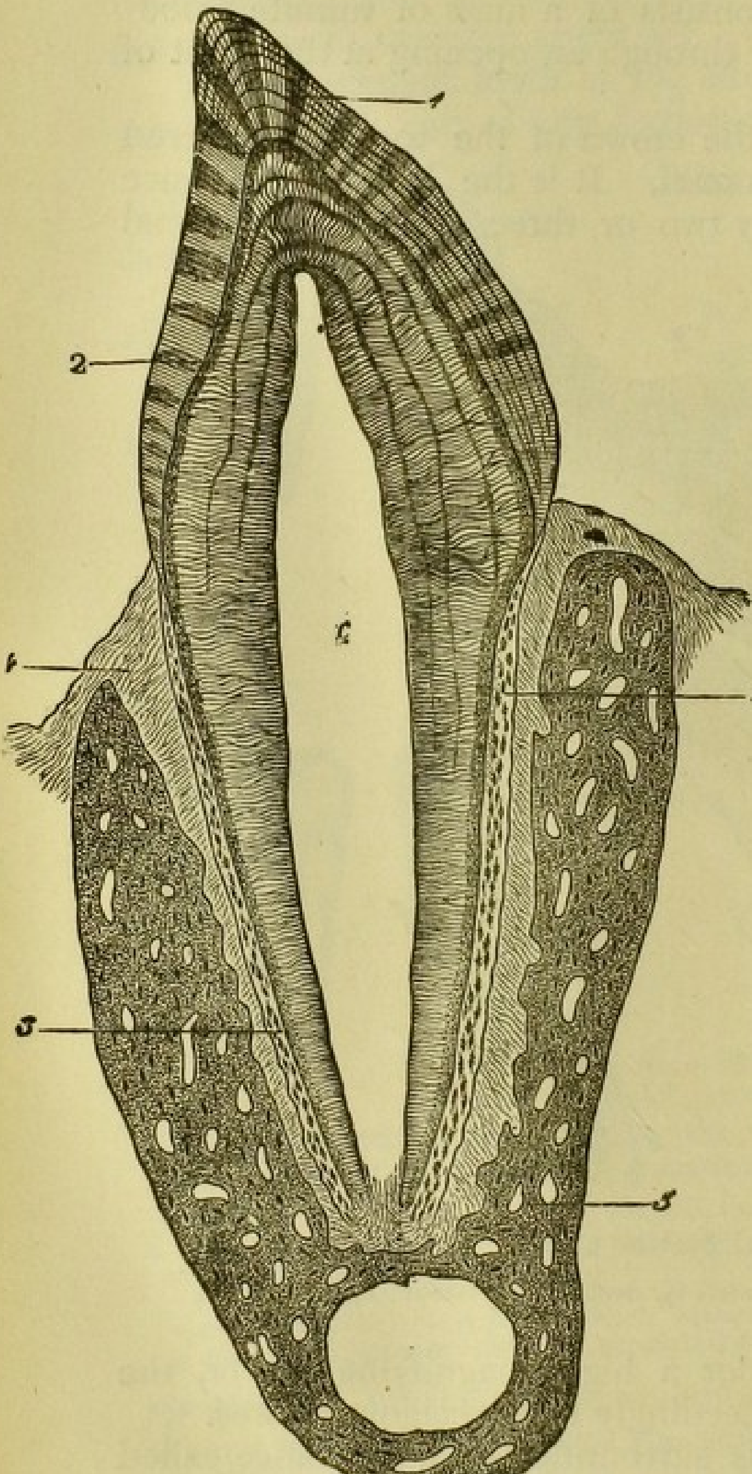


Fig. 88.—**Vertical Section of Premolar of Cat.**

c, pulp-cavity ; 1, enamel ; 2, dentine ; 3, cement ; 4, periosteum ; 5, bone of the lower jaw.

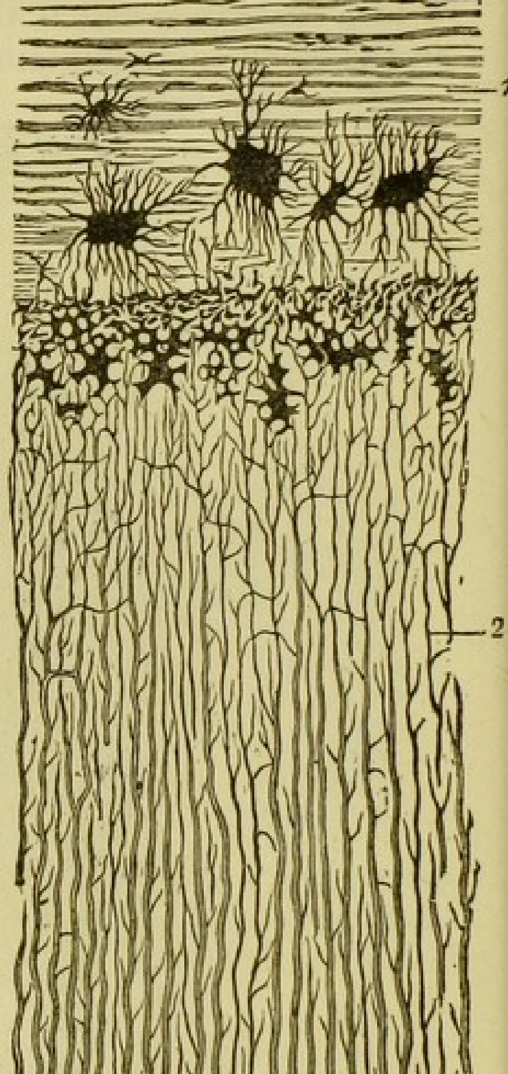


Fig. 89.—**Section of the Fang of a Human Tooth. Magnified 300 diameters.**

1, cement, with lacunæ ; 2, tubes of the dentine.

bite our food we move the jaw perpendicularly, and make use of the front or incisor teeth. After this, it is passed over, to the molars which thoroughly crush and grind it. Now this grinding could not be carried on effectually if the lower jaw were capable of a vertical motion only. But if we observe the motion of the jaw during the grinding of the food, we shall find that it moves a little to the right and left, and also forward and backward. The broad and rough surfaces of the molar teeth are consequently caused to slide over each other, thus thoroughly grinding the food which may be between them. The *carnivorous animals* have not broad molars like ours. They bite and tear the flesh on which they feed, generally giving the jaw an up and down motion only. The *herbivorous animals*, on the other hand, have very large and perfect molars, and they give to the lower jaw a much greater variety of motion than we do. This may be readily observed in the cow, sheep, goat, and horse.

During mastication the food must be continually moved about so that every portion of it may be brought between the molar teeth. This is effected by the muscles of the tongue, cheeks, and lips.

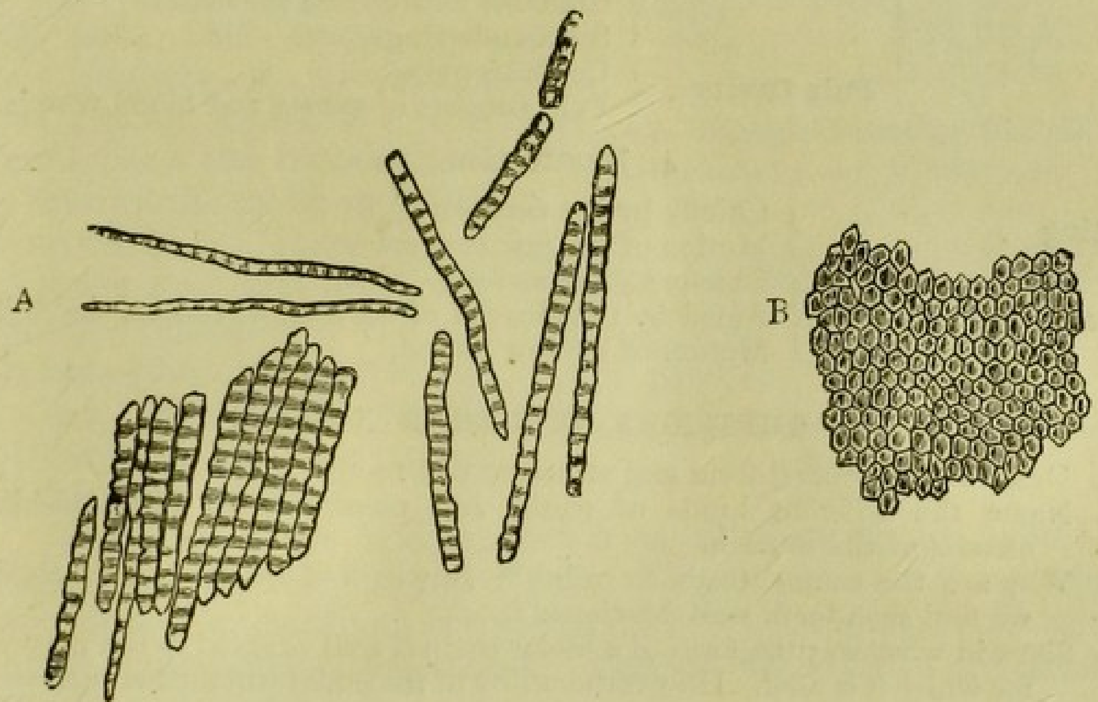


Fig. 90.—**Enamel Fibres. Magnified 350 diameters.**
A, the sides, and B, the ends of the fibres.

The **action of the muscles** concerned in mastication would generally be regarded as a *voluntary* action; but it is often partly or wholly an *involuntary* act, since it not unfrequently continues for some time while we give no thought whatever to it, as for example, when we are eating and engaged in reading at the same time. In this case the reading may absorb the attention to such an extent that we become unconscious of the continued action of the lower jaw.

SUMMARY.

1. The Milk Teeth.

	M	C	I	C	M	
Upper jaw . .	2	1	4	1	2	20
Lower jaw . .	2	1	4	1	2	

2. The Permanent Teeth.

	M	B	C	I	C	B	M	
Upper jaw	3	2	1	4	1	2	3	32
Lower jaw	3	2	1	4	1	2	3	

3. Structure of a Tooth.

TOOTH . .

- **Dentine or Ivory**
  - Forms the greater portion of the tooth.
  - Harder than bone.
  - Contains 72 per cent of mineral matter.
- **Enamel** . .
  - Hardest substance in the body.
  - Composed of very delicate fibres.
  - Contains only 2 or 3 per cent. of animal matter.
- **Cement** . .
  - Softer than dentine.
  - True bone.
  - Contains lacunæ and canaliculi.
  - Surrounds fangs.
- **Pulp Cavity** .
  - Contains pulp.
  - Pulp consists of nerves and blood vessels.

4. Mastication.

- **Biting** . . . .
  - Chiefly by the *incisors.*
  - Motion of the jaw *vertical.*
- **Chewing** . . .
  - Chiefly by the *molars.*
  - Aided by the muscles of the tongue, cheeks, and lips.
  - Motion of the jaw varied.

QUESTIONS ON LESSON XVI.

1. Describe the general form and structure of a tooth.
2. Name the different kinds of teeth, and point out the distinguishing characteristics of each.
3. Why are the canine teeth so called? In which of the lower animals do we find such teeth well developed?
4. Show in what way the form of a molar tooth is well adapted to the purpose for which it is used. How is the utility of the molar still further increased by the movements of the lower jaw?
5. Describe the arrangement of the teeth in a child of about six years.
6. Describe the arrangement of the different kinds of teeth in the jaws of an adult, giving also the number of each kind.
7. Describe fully the structure of a tooth as shown in a section; and give the general characters of the different materials of which it is composed.
8. What do you suppose to be the usual cause of toothache?
9. How does the motion of the lower jaw of a dog, when feeding, differ from that of the cow?
10. Why do we masticate our food?
11. Is the motion of the jaw in eating a voluntary or an involuntary act? Give reasons for your answer.

LESSON XVII.

GLANDS—THE SALIVARY GLANDS AND INSALIVATION.

A **gland** is an organ which has the power of separating certain materials from the blood which flows through it. Glands are of two kinds; *secreting* and *excreting*.

A **secreting gland** (Lat. *se*, aside; and *cerno*, I separate) is one which *prepares* a substance from the materials of the blood; in other words, it manufactures a material which did not pre-exist in the blood; this substance being set apart for some future use in the body. Each secreting gland is provided with a system of *blood-vessels*, and generally a *duct* or *tube* which conveys away the material prepared.

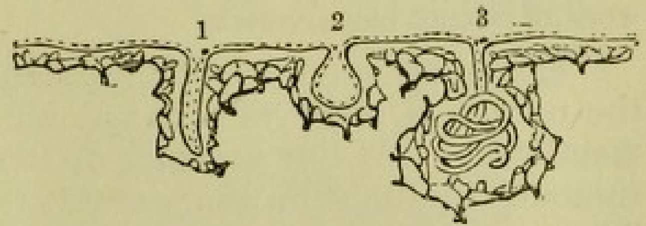


Fig. 91.—**Simple Secreting Glands.**
1, straight tube; 2, sac; 3, coiled tube.

An **excreting gland** (Lat. *ex*, out; and *cerno*) does not *prepare* a substance, but simply separates a material from the blood which is afterwards to be expelled from the body. These glands also are provided with *ducts* for the removal of the *excretion*—the substance excreted. The **sweat glands** of the skin are an example of this kind of gland.

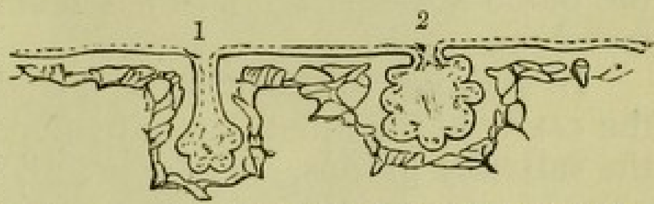


Fig. 92.—**Simple Glands, with pouched sides.**

There are other bodies known as **ductless glands**, which, as their name implies, have no ducts. The functions of these organs are not well understood, but they generally appear to be concerned in the elaboration of the blood. The **spleen** is one of the ductless glands.

Many of the membranes which line the cavities of the body and its organs also have the power of secretion, hence they are called **secreting membranes.** The amount of substance secreted obviously depends on the extent of the secreting surface. Hence we sometimes find the membrane drawn up into folds in order that its surface may be increased. On the other hand, we often find the secreting membrane dipping down into the substance beneath in such a manner as to form a multitude of minute tubes, each one having an opening at the general surface. This forms the simplest kind of gland, called the **simple tubular gland.** In many cases the tubular gland is developed into a coil or convolution, thus adding still more to the secreting surface. The tubular gland is also sometimes enlarged till its shape is somewhat globular;

and again, it often enlarges still more, till its outline consists of a number of little pouches, all communicating with one common cavity. This last form of gland is generally known as the **lobulated gland.**

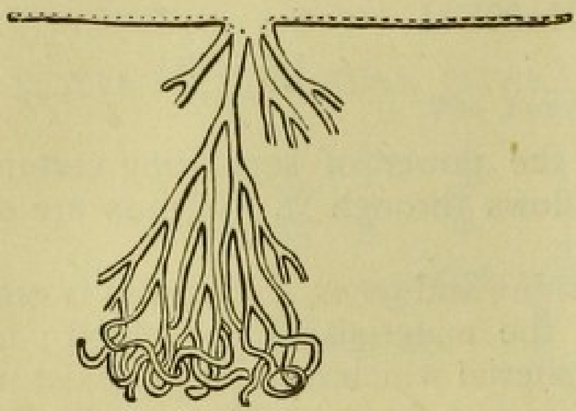


Fig. 93.—**Compound Tubular Gland.**

Some glands develop to such an extent that they consist of a number of bodies resembling the simple glands just described, but all communicating with one common duct. These are called **compound glands.** If they consist of a number of branching tubes they are called **compound tubular glands**; but if composed of a group of sacs or lobules with one common outlet they are termed **racemose** or **compound lobulated glands.** But although the glands vary so considerably in form, yet they are all constructed on one general principle —all consist of a secreting membrane which is closely surrounded by a network of minute blood-vessels.

The whole interior of the **alimentary canal**, from the *mouth* to the *rectum*, is lined with a soft kind of skin called the **mucous membrane.** At the margins of the lips this membrane is continuous with the skin which covers the exterior surface of the body. The mucous membrane is richly supplied with minute simple or compound glands called the **mucous glands.** These separate from the blood a watery fluid called **mucus** which serves to keep the membrane moist.

In addition to the mucous glands the structures surrounding the cavity of the mouth are provided with numerous others called the **salivary glands.** These are all compound lobulated glands,

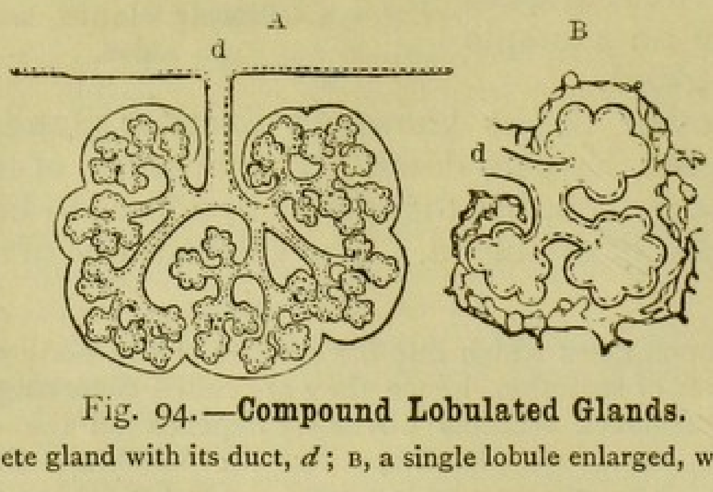


Fig. 94.—**Compound Lobulated Glands.**

A, a complete gland with its duct, *d*; B, a single lobule enlarged, with *d*, its duct.

and secrete a fluid called the **saliva** which aids considerably in the process of digestion, as will be presently shown.

The most important of the **salivary glands** are the *three pairs* known as the *parotid*, the *submaxillary*, and the *sublingual.*

The **parotid glands** (Gr. *para*, near: and *ous*, the ear) are situated below and in front of the ear. They are the largest of the salivary glands. Their ducts, which are about one eighth of an inch in diameter, open into the mouth through the cheek, just opposite the second molar teeth of the upper jaw.

The **submaxillary glands** (Lat. *sub*, under ; and *maxilla*, a jaw) are about the size of plums. They are situated beneath the lower jaw, one on each side. The ducts of these glands open into the mouth under the tip of the tongue, and may be easily seen by means of a looking-glass.

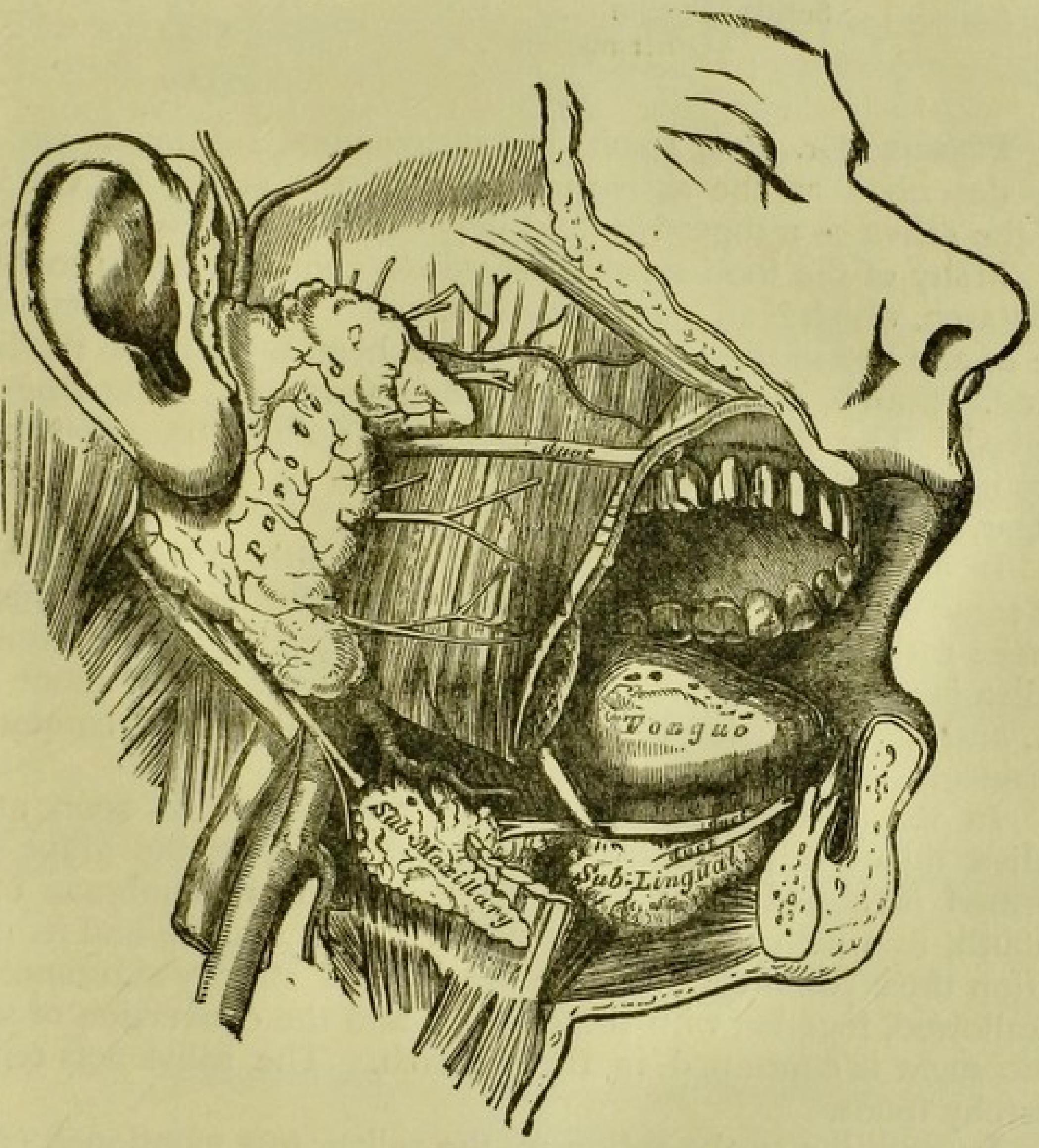


Fig. 95.—**The Salivary Glands.**

One side of the lower jaw has been removed, and the face dissected, in order to show the salivary glands of the right side.

The outlines of the **sublingual glands** (Lat. *sub*, under ; and *lingua*, the tongue) may also be seen by means of a looking-glass. They are no larger than almonds, are situated on each side of the bridle, forming ridges between the tongue and the gums of the lower jaw, and are covered only by mucous membrane. Each of these glands has several ducts, some of which open into the duct of the corresponding submaxillary gland.

The fluid secreted by the salivary glands—**the saliva**—is a transparent, watery fluid, slightly alkaline [1] in its action. In the mouth it is always mixed with the secretion of the mucous glands, but if obtained direct from the duct of a salivary gland its **composition** is as follows :—

Water	. . . . .	9,941
Solids	Mineral salts . . .	23
	Ptyalin	14
	Other matters . . .	22
		10,000

Ptyalin (Gr. *ptuo*, I spit) is a nitrogenous substance, and may be described as the active principle of the saliva, for the value of the saliva as a digestive fluid depends on its presence.

Many of the food-substances we eat contain a large proportion of starch, which is an insoluble substance. No food-substance can be of any use in the body until it has been brought to the liquid state. Starch, therefore, is useless as a food until it has been dissolved. The **ptyalin** has the power of doing this. It converts the insoluble starch into a soluble variety of sugar called grape-sugar.

In order to illustrate this action, put a little of the solid ptyalin or some saliva, or even a portion of a dried salivary gland, into a vessel with some starch, adding also some water unless the liquid saliva is used. Keep the mixture at a temperature of about 100° F., and the conversion of starch into the soluble sugar commences at once.

In the mouth also this change commences as soon as the saliva mixes with starchy foods, and some of the grape-sugar formed is absorbed at once by the mucous membrane of the mouth, by which means it enters the blood system, and its circulation thus commences. The unchanged starchy substances are swallowed, together with some saliva, and the conversion of starch into sugar is continued in the stomach. The saliva acts only on starchy foods.

In addition to the action of the saliva just mentioned (which may be termed a chemical action) it is useful also as a *mechanical agent* and a *general solvent*. With the mucus it moistens the mouth, thus facilitating speaking and assisting mastication. It dissolves savoury substances, thus enabling us to taste them. It

[1] An *alkali* is a substance which has a soapy taste and feel, and has the power of neutralising acids. Acids are distinguished by their sharp, sour taste. Acids turn vegetable blue colours red ; alkalies turn vegetable reds blue.

also assists in forming the food into a soft mass previous to swallowing.

The **rate of the secretion of the saliva** is from one to two pounds daily. The secretion is probably continuous, but is always increased by the introduction of a substance into the mouth. This substance need not necessarily be digestible or even tasty, for the saliva may be readily produced by the sucking of a glass bead or a pebble ; and even the *odour* of a savoury dish will 'make the mouth water.'

The **salivary glands of children** do not act till about the fourth or the sixth month. It would seem, therefore, that children should not be fed with foods containing much starch before that age. We shall, however, learn that the saliva is not the only fluid which is capable of digesting starch.

SUMMARY.

- **GLANDS (Function)**
  - **Secreting** . . Prepare and separate a fluid from the blood. Example—*salivary glands.*
  - **Excreting** . . Separate waste materials from blood. Example—*sweat glands.*
  - **Ductless** . . Have no duct. Example—the *spleen.* Probably engaged in the elaboration of the blood.
- **GLANDS (Forms)**
  - **Simple** . . *Tubular.* *Lobulated.*
  - **Compound** . . *Tubular.* *Lobulated.*
- **SALIVARY GLANDS**
  - **Parotid** . .
    - Situated under and in front of the ear.
    - Largest.
    - Duct opens opposite the second molar.
  - **Submaxillary**
    - Under the lower jaw.
    - Size of a large plum.
    - Duct opens at the bridle of the tongue.
  - **Sublingual** .
    - Under the tongue.
    - Size of an almond.
    - Several ducts.
- **SALIVA** . .
  - **Composition** .
    - *Water.*
    - *Salts.*
    - *Ptyalin*—the active principle.
    - Other matters.
  - **Uses** . . .
    - **Chemical**—changes starch into grape-sugar.
    - **Mechanical**
      - Moistens mouth—facilitates speaking.
      - Dissolves savoury substances—thus aiding taste.
      - Assists in swallowing by forming a soft bolus.
  - **Rate of Secretion**
    - From one to two pounds daily.
    - Probably continuous.
    - Accelerated on taking food.
    - None in children till four or six months.

QUESTIONS ON LESSON XVII.

1. What is a gland? Give examples of the different kinds of glands.
2. Describe some of the various forms of glands.
3. Describe the general character and use of *mucous membrane*. Mention any part of the body where this membrane may be found.
4. Describe the form, size, and position of each of the chief salivary glands. Where are the openings of the ducts of these glands?
5. What is the saliva? Describe its composition. What is its use?
6. What quantity of saliva is secreted daily? Is it always secreted at the same rate? If not, state the circumstances which accelerate or retard its flow?
7. What is *ptyalin*? How would you illustrate the action of ptyalin on certain food-substances?

LESSON XVIII.

THE ŒSOPHAGUS AND DEGLUTITION. THE STOMACH AND GASTRIC DIGESTION.

THE **œsophagus** is the narrowest portion of the alimentary canal, and, although generally described as muscular, it consists of three distinct coats.—The **outer coat** is thick and *muscular*, and consists of two distinct sets of muscular fibres, some running longitudinally, *i.e.* lengthwise down the tube, and the others passing in a circular direction round it. The **inner coat** is a *mucous membrane*, which, as its name implies, contains mucous glands; it is drawn up into longitudinal folds, thus increasing the amount of secreting surface. The **middle coat** consists of a loose filamentous membrane called *connective*, *areolar*, or *fibrous tissue*, which unites the outer and inner coats of the tube.

After the food has been masticated and thoroughly mixed with the saliva, it is collected into a bolus by the tongue and the muscles of the cheeks, and then passed between the tongue and the palate till it reaches the back of the mouth. This muscular action may be voluntary, but is usually performed unconsciously.

The food must now pass into the pharynx without touching the posterior nares or entering the glottis. This is accomplished as follows:—The *larynx* and *pharynx* are both raised together and carried forward under the tongue. The *glottis* is closed by the *epiglottis*; and the *posterior nares* are shut off by the sides of the soft palate. The contraction of the muscles at the back of the mouth forces the food over the epiglottis into the pharynx. The pharynx now contracts above it, and the bolus is forced into the *œsophagus.* The student should observe the motion of the larynx in swallowing by pressing the fingers lightly on the front of the throat during the act.

As soon as the food enters the upper portion of the œsophagus, the circular muscles in the walls of that tube contract just above it, thus forcing it a little downward. This action is repeated by all the circular muscular fibres throughout the tube, each set contracting *just above the food only* till it passes into the stomach. It must not be understood, however, that the food is forced down the œsophagus by a series of distinct movements or jerks ; but that the successive muscular contractions produce a regular wave-like motion throughout the tube. The longitudinal muscular fibres also contract at the sides, thus helping the œsophagus to grasp the food more effectually.

It will have been observed that the act of swallowing is purely a muscular action—that the food does not *fall* into the stomach by its own weight, but is *forced* downward. This being the case, the act of swallowing may be performed with the body in any position. Thus jugglers sometimes eat, and even drink while standing on their heads, drink being conveyed into the stomach in exactly the same manner as solid food.

After the food has passed to the back of the mouth, the remainder of the act of *swallowing* or *deglutition* (Lat. *de*, down ; and *glutio*, I swallow) is purely involuntary, and consequently we cannot then stop the bolus in its passage to the stomach. The *mucus* secreted by the internal mucous membrane of the œsophagus, acts as a *lubricant*, and thus facilitates the passage of the food.

When the œsophagus is not engaged in swallowing, it is flattened, its front and back walls being in contact. In order that the act of deglutition may take place with regularity and ease, the bolus of food must be sufficiently large to be within the grasp of the contracting muscles. It is on this account that some persons experience a considerable difficulty in swallowing a pill, especially if it be a small one, unless food or drink be taken at the same time.

The general form, size, and position of the **stomach** have already been described in Lesson XIII. ; we have now to notice the structure of its walls, and its action on the food.

The **walls of the stomach** consist of **four distinct coats.** The **outer coat** is a layer of the **peritoneum** which is reflected round most of the organs of the abdomen. It is a **serous membrane**, that is, one which secretes a watery fluid called **serum.** The use of the serum is to moisten or lubricate the surfaces of organs which glide more or less over each other.

The other three coats of the stomach correspond exactly with those of the œsophagus, and are, in fact, continuations of them. The outer of these, which, of course, lies next the peritoneal coat, is **muscular**; the next is composed of **areolar tissue**, and the inner coat is a **mucous membrane.**

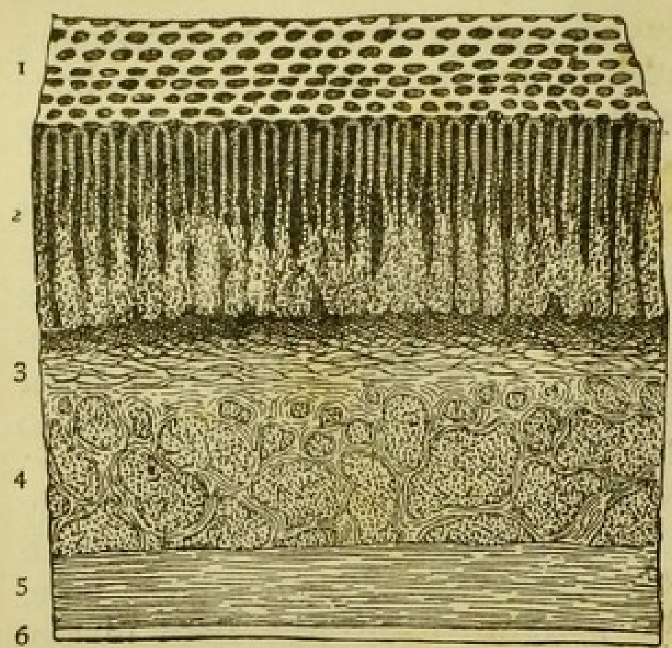


Fig. 96.—**A Section through the Walls of the Stomach. Magnified 15 diameters.**

1, surface of the mucous membrane, showing the openings of the peptic glands; 2, mucous membrane, composed almost entirely of glands; 3, submucous or areolar tissue; 4, transverse muscular fibres; 5, longitudinal muscular fibres; 6, peritoneal coat.

The **muscular coat of the stomach** consists of **three sets of involuntary muscular fibres. The outer set** run **longitudinally** from the cardiac orifice to the pylorus, and are continuous with the longitudinal fibres of the œsophagus. The **middle set** of fibres **encircle all parts of the stomach,** and are especially numerous at the pyloric end. The **inner set** consist of **oblique fibres.** They are continuous with the circular fibres of the œsophagus, and exist chiefly at the cardiac end of the stomach.

By means of these muscles the **contents of the stomach are kept in a continuous circular motion,** passing from the cardiac end to the pylorus along the greater curvature, and back to the cardiac end along the lesser curvature: and, as with the œsophagus, these motions are best maintained when the stomach is moderately distended with food-substances, so that the muscles can grasp them on all sides.

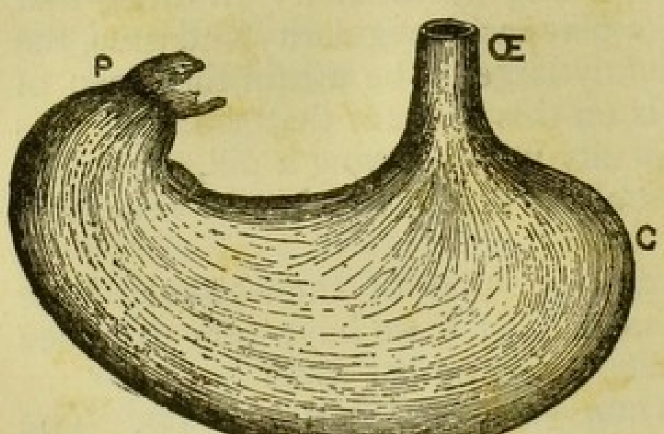


Fig. 97.—**Muscular Coat of the Stomach.**
External layer of longitudinal fibres.
P, pylorus; C, cardiac end; Œ, œsophagus.

The **walls of the stomach** are capable of great distension; consequently it can adapt itself to the quantity of food it contains, and, at the same time, be always in contact with the food so as to act on it.

The **circular muscular fibres** at the intestinal end of the stomach form a strong band which serves to keep the pylorus closed. Such circular muscles are called **sphincters** (Gr. a tight band). This sphincter remains at first firmly closed during digestion; but, as the process continues, it slowly relaxes, thus allowing the digested portions to pass through into the intestines; and, towards the termination, it allows *all* the contents of the stomach to pass.

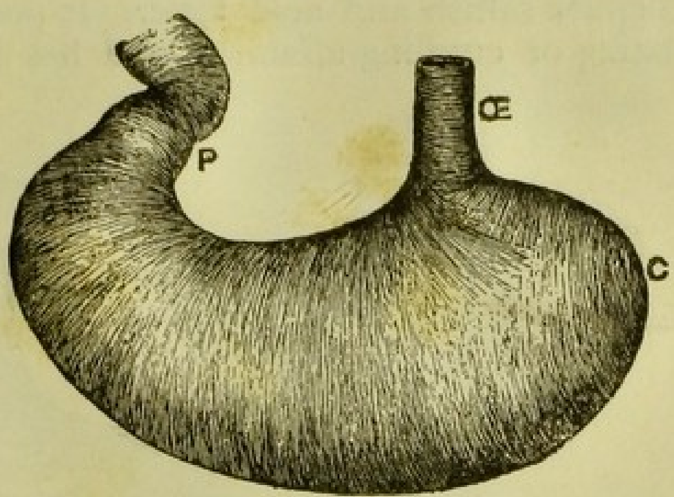


Fig. 98.—**Muscular Coat of the Stomach.** Middle layer of circular fibres.

The time during which substances remain in the stomach varies considerably with the nature of the food and the method of cooking. Usually it is not less than one hour, and seldom more than five hours.

The **mucous membrane of the stomach** is smooth, level, and soft, when the organ is moderately distended ; but is drawn up into longitudinal folds when the stomach is empty. It consists almost entirely of minute glands, which secrete **mucus** to keep the surface moist, and, during digestion, a powerful fluid known as the **gastric juice** or **gastric fluid.**

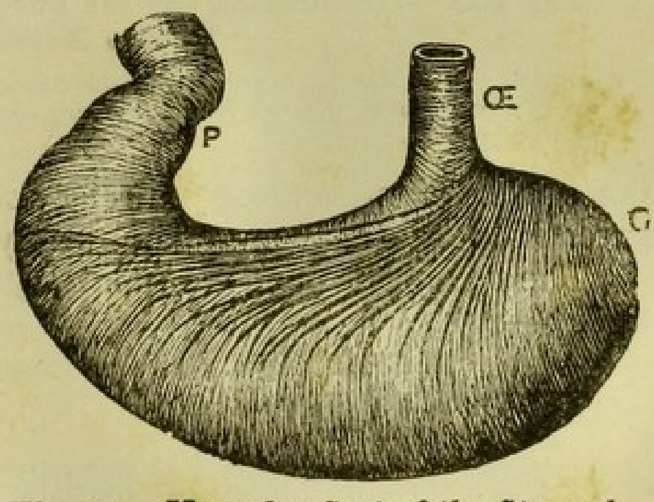


Fig. 99.—**Muscular Coat of the Stomach.** Inner layer of oblique fibres.

These **glands** are called **gastric glands** or **peptic glands** (Gr. *pepto*, I cook, or digest). They are tubular glands, the openings of which may be seen on the surface of the mucous membrane by the aid of a lens.

When the stomach contains no food, the mucous membrane is very pale in colour, and is moistened by mucus only ; but as soon as food is introduced, or even a non-digestible substance, the supply of blood increases, the mucous membrane becomes of a bright pink colour, and the secretion of the gastric fluid immediately commences.

It is difficult to ascertain accurately the **quantity of gastric**

fluid secreted in a given time, but after careful experiments and observations it has been estimated that from ten to twenty pints of this fluid are poured into the stomach every twenty-four hours.

The **gastric fluid** is a clear and colourless liquid, having a slightly saltish and acid taste. It possesses the power of coagulating or curdling albumen, and has antiseptic properties, that is,

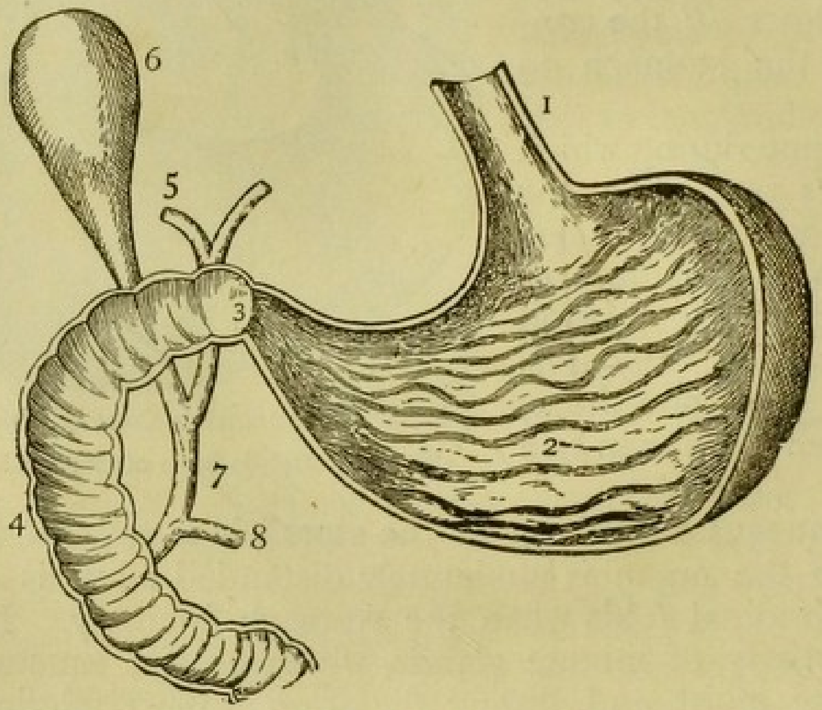


Fig. 100.—**The Stomach and the Duodenum, laid open to show the Mucous Membrane.**

1, œsophagus ; 2, mucous membrane of the stomach ; 3, pylorus ; 4, duodenum ; 5, the ducts which convey the bile from the liver ; 6, gall-bladder ; 7, common duct ; 8, the pancreatic duct.

the power of preventing putrefaction. It is on account of this latter property that 'high game' may be eaten with impunity.

The **composition of the gastric juice** is shown in the following table :—

Water		994·4
Solids	Pepsin	3·2
	Common salt	1·5
	Hydrochloric acid (muriatic acid)	·2
	Potassium chloride	·5
	Calcium chloride	·1
	Phosphates of calcium, magnesium, and iron	·1
		1000·0

Pepsin is the active principle of the gastric fluid. It is a nitrogenous substance which has the power, in the presence of an acid, of dissolving nitrogenous foods. Pepsin may be obtained in a dissolved form by thoroughly washing the mucous membrane of the stomach of any animal with water ; or it may be procured in the solid form from the chemist. The power of pepsin as a digestive fluid may be illustrated by the following experiment :—

Cut up a little lean meat into very small pieces, thus imitating mastication. Put them into a vessel with some water, a little pepsin, and a drop or two of hydrochloric acid. Heat this mixture up to a temperature of 100° F. (the temperature of the body), and keep it at this for a few hours, stirring frequently with a glass rod to imitate the motions in the stomach. The meat thus treated will be reduced to a pulp as in the stomach.

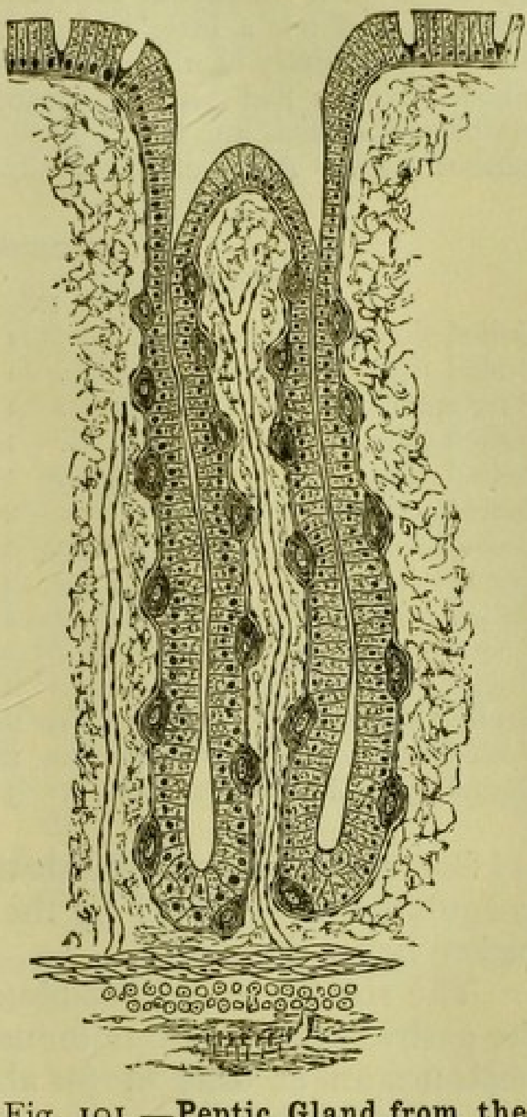


Fig. 101.—**Peptic Gland from the Mucous Membrane of the Stomach. Highly magnified.**

The **gastric fluid** has no action on starchy foods, neither does it act on fats. The former, however, are dissolved in the stomach by the swallowed saliva, but the acidity of the gastric juice somewhat retards this action. Fatty tissue consists of fat cells united together by areolar tissue, and each cell consists of a particle of fat surrounded by a cell-wall of albuminous (nitrogenous) substance. Consequently, when fatty tissue passes into the stomach, the areolar tissue and the albuminous cell-walls are dissolved, and the fat itself is set free in the form of minute globules, giving the whole contents of the stomach a milky appearance.

This milky fluid is called **chyme** (Gr. *cheo*, I pour) because it is *poured* into the intestine. It consists of—

(*a*) Saliva and partially dissolved starchy foods.
(*b*) Gastric fluid and partially dissolved nitrogenous foods.
(*c*) Undigested fat in the form of minute globules.
(*d*) Mucus from the mucous glands.
(*e*) Indigestible substances.

The character of the chyme varies considerably according to the nature of the food taken ; but it is generally a thick, milky, acid fluid, possessing a disagreeable odour.

The changing of the food into chyme by the gastric fluid is called **chymification.** The average time occupied in producing this change is from three to four hours.

The information we possess concerning these changes in the stomach is the result of a number of experiments made on living and on recently-killed animals ; and not a little is due to the investigations of Dr. Beaumont, who had an opportunity of witnessing the action of the gastric fluid in a Canadian whose stomach had been perforated by a bullet. Dr. Beaumont introduced various substances into his stomach, and noted the time required to chymify various foods. A few of the results obtained are as follows :—

Time occupied in Chymification.

	Hours		Hours
Boiled rice	1	Roasted beef	3
Boiled tripe	1	Boiled mutton	3
Raw apples	1½	Boiled carrots	3¼
Boiled salmon	1½	Roasted mutton	3¼
Boiled sago	1¾	Bread	3½
Boiled, cured cod-fish	2	Boiled potatoes	3½
Boiled beans	2½	Boiled turnips	3½
Sponge cake	2½	Cheese	3½
Baked potatoes	2½	Boiled eggs (hard)	3½
Roasted goose	2½	Fried eggs	3½
Boiled gelatine	2½	Boiled cabbage	4
Broiled lamb	2½	Boiled or roasted fowl	4
Boiled beef	2¾	Roasted pork	5¼
Boiled apple dumplings	3	Boiled gristle	5½

Some **albuminous substances,** such as casein (of milk), are coagulated or curdled by the gastric fluid, thus becoming solid before being digested.

The soluble and diffusible substances formed by the action of the gastric fluid on albuminous foods are called **peptones.** These peptones are at once fit for absorption, and are to a certain extent taken up by the mucous membrane of the stomach, and pass into the blood circulation.

SUMMARY.

ŒSOPHAGUS . .
- Narrowest portion of alimentary canal.
- Length about 9 inches.
- Communicates between *pharynx* and *stomach*. Passing through the *diaphragm*.
- **Coats** .
  1. **Outer muscular** { Longitudinal fibres. Circular fibres.
  2. **Middle areolar** (filamentous).
  3. **Inner mucous.**

DEGLUTITION

- 1.
  - Food collected into a bolus by tongue and cheeks.
  - Glided between tongue and palate to back of mouth.
  - Voluntary. Or may be performed unconsciously.
- 2.
  - Muscles contract at back of the mouth.
  - *Larynx* and *pharynx* raised and carried forward.
  - *Glottis* closed by the *epiglottis.*
  - *Posterior nares* shut off.
  - *Pharynx* receives food and contracts above it, forcing it down into the *œsophagus.*
  - Involuntary.
- 3.
  - Food forced down the *œsophagus* by the wave-like contraction of the muscular fibres just above it.
  - Thus carried into the *stomach.*
  - Involuntary.

STOMACH

- **Coats**
  - 1. **Outer Peritoneal** — A *serous* membrane.
  - 2. **Muscular**
    - Outer *longitudinal* fibres.
    - Middle *circular* fibres.
    - Inner *oblique* fibres.
  - 3. **Areolar** — Composed of loosely-woven filaments.
  - 4. **Mucous**
    - Smooth, soft, and level.
    - Drawn up into folds when not distended.
    - Composed almost entirely of tubular *peptic* or *gastric glands.*
    - Very pale when inactive.
    - Turns bright pink on introducing a substance into the stomach.
- **Motions** — **Cause food to revolve**
  - From *cardiac orifice* to *pylorus* along the *greater curvature.*
  - From *pylorus* to *cardiac orifice* along the *lesser curvature.*
- **Glands**
  - *Tubular.*
  - Open at the surface of the mucous membrane.
  - Secrete *mucus* and *gastric juice.*

GASTRIC FLUID

- **General properties**—Clear, liquid, saltish, acid.
- **Quantity secreted daily**—10 to 20 pints.
- **Contains**
  - Water.
  - Pepsin.
  - Common salt and other salts.
  - Hydrochloric acid.
- **Action**
  - Dissolves *nitrogenous foods.*
  - No action on *starchy foods.*
  - No action on *fats*; but
  - Dissolves the albuminous walls of the fat cells, also the tissue which binds the cells together, thus liberating minute globules of fat.
  - Converts *albuminoids* into diffusible *peptones.*
  - Converts foods into *chyme.*
  - Coagulates certain albuminous foods before digesting them.
  - Acts as an *antiseptic.*

QUESTIONS ON LESSON XVIII.

1. Describe the form, size, position, and structure of the *œsophagus.*
2. Describe the action of the parts concerned in the act of swallowing. To what extent is this a voluntary action ?
3. Describe carefully the action of the muscular fibres of the œsophagus during deglutition.
4. What is the cause of the difficulty sometimes experienced in swallowing a pill ?
5. Describe the structure of the walls of the stomach.
6. By what means is the food kept in motion during gastric digestion ? Describe this motion. What purpose is served by this motion ?
7. Describe the general appearance of the mucous membrane of the stomach (1) When the organ is empty, and (2) When food is introduced.
8. Describe the general characters and composition of the *gastric fluid.*
9. What is the action of the gastric fluid on (1) starchy fluids, (2) nitrogenous foods, and (3) fats ?
10. What is *pepsin* ? What is its use ? How may it be obtained ?
11. What is chyme ? Of what does it consist ?
12. Describe fully the various changes which take place in the food while in the stomach.
13. Explain the term *chymification.*
14. What are peptones ? Where and how are they formed ? How do they differ from the materials from which they are produced ?

LESSON XIX.

THE INTESTINES AND INTESTINAL DIGESTION.

THE general form and arrangement of the intestines have been described in Lesson XIII.

Both **large and small intestines,** like the stomach, consist of **four coats.** These coats also correspond with those of the stomach, being arranged as follows ;—

1. **Outer serous coat,** formed by the peritoneum.
2. **Muscular coat,** composed of
   (*a*) *External longitudinal fibres* and
   (*b*) *Internal circular fibres.*
3. **Areolar layer.**
4. **Mucous membrane,** forming the interior surface.

The **mucous membrane of the small intestine** is in part drawn up into folds, like that of the stomach, but to such an extent that they do not disappear when the tube is distended. These folds are called the **valvulæ conniventes.** They serve to increase the area of the secreting surface, to prevent the food from passing too rapidly through the intestine, and to assist the mixing of the food with the digestive fluids which are poured into the intestines.

The mucous coat of both large and small intestines also resembles that of the stomach in that it consists chiefly of **glands.**

But the glands are of various kinds; some are tubular, and arranged parallel with each other. Others (*Peyer's glands*) are somewhat globular or ovoid in form, and are distributed singly (*solitary*) or in groups (*Peyer's patches*). Others, again, are minutely lobulated (*Brunner's glands*), and are so large as to be visible to the naked eye.

The ducts of all these glands (excepting the *Peyer's glands*, which have no ducts) open on the internal surface of the intestines and thus pour their secretions into the alimentary canal.

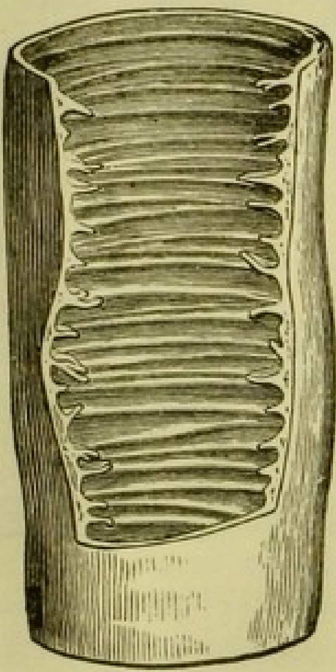


Fig. 102.—**A Portion of the Small Intestine laid open to show the Folds of the Mucous Membrane (Valvulæ Conniventes).**

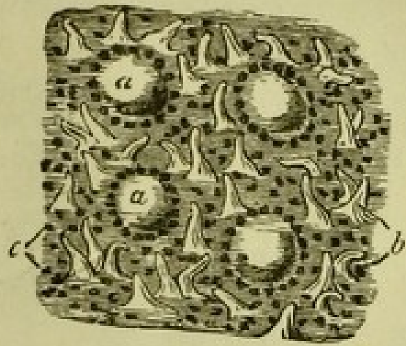


Fig. 103.—**A Small Portion of the Mucous Membrane of the Small Intestine. Magnified 12 diameters.**

a, Peyer's glands, surrounded by tubular glands; *b*, villi; *c*, openings of the tubular glands.

The nature of the **secretions** of these glands is not well understood. Some of them probably secrete mucus only; others are supposed to resemble the salivary glands and the pancreas in function.

The interior surface of the *small* intestine is covered also with a multitude of minute projections called **villi** (Lat. shaggy hair) which give the surface a fine velvety appearance. These, however, will be described in our next lesson, as they are engaged in the *absorption* of nutritious matter rather than in the digestion of food.

When the partially digested food passes from the stomach, through the pylorus, it almost immediately mingles with two very important digestive fluids, called the **bile** and the **pancreatic fluid** respectively. The former is prepared by the liver, and the latter by the pancreas. Both these fluids enter the duodenum at or near the same point, one being conveyed from the liver by means of the **bile-duct** and the other from the pancreas by the **pancreatic duct.**

The **pancreas** is a lobulated gland, situated within the curve of the duodenum, as already described in Lesson XIII. In structure it closely resembles the salivary glands. The **liver** will be fully described in Lesson XXVII.

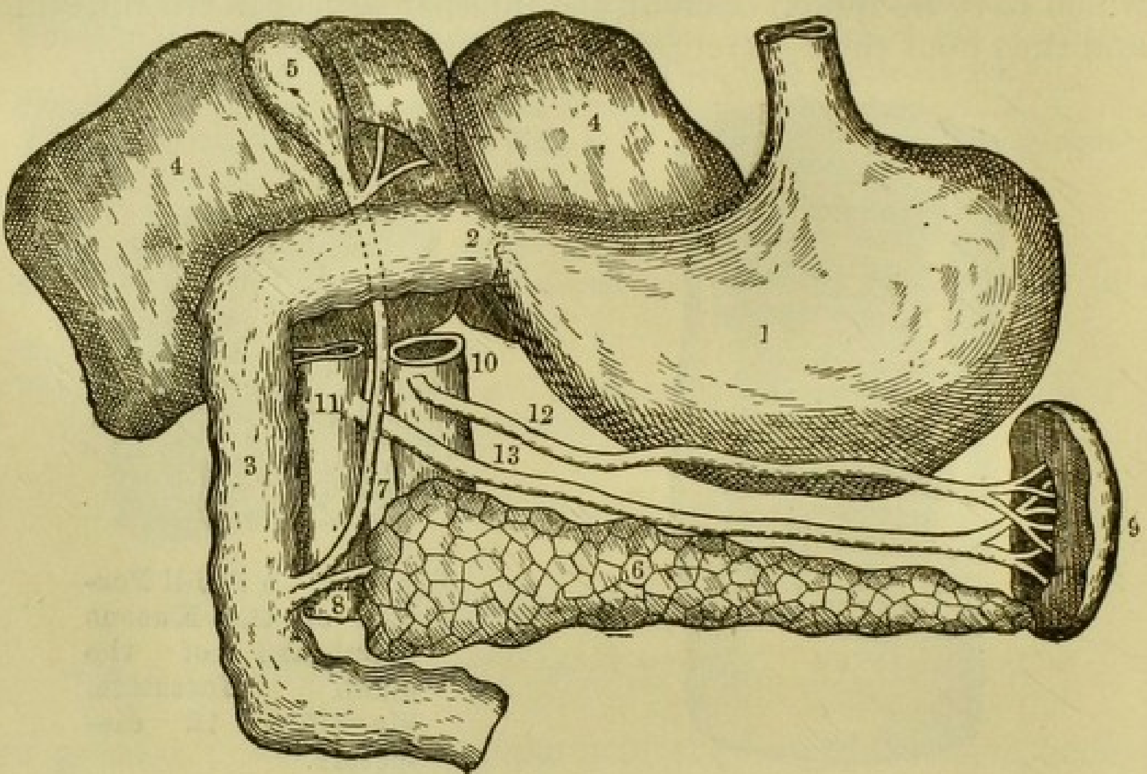


Fig. 104.—**The Stomach, Duodenum, Liver, Spleen, and Pancreas.**

1, stomach; 2, pylorus; 3, duodenum; 4, liver (under surface); 5, gall-bladder; 6, pancreas; 7, bile duct; 8, pancreatic duct; 9, spleen; 10, aorta; 11, portal vein; 12, splenic artery; 13, splenic vein.

The **pancreatic juice** is a colourless and transparent fluid; which is slightly alkaline and viscid, and of which twelve to sixteen ounces are secreted daily. It contains—

Water	. . . . . .	980·5 parts
Solids	Pancreatin	12·7 ,,
	Inorganic salts, &c. .	6·8 ,,
		1000·0 ,,

The **function** of this fluid resembles that of the saliva, but is more varied in its action. Thus, it converts starchy foods into soluble grape-sugar; but like the gastric fluid it dissolves albuminous and gelatinous foods, converting them into peptones; it also *emulsifies* fats, rendering them fit for absorption.

A simple experiment will enable us to understand the meaning of the term *emulsifies*. Pour into a glass vessel about an ounce of water, and then a little oil or melted fat (if the latter, the water should be hot). The two liquids remain quite distinct, the oil or fat floating on the water. Now shake the mixture vigorously, and the oil or fat is separated into globules which are distributed throughout the water ; but, on allowing the mixture to rest for a short time, the liquids separate again. Hence we say that oil is *insoluble* in water. Next, add a little alkali (potash or soda) to the mixture and shake it again. At once a milky fluid is formed, which is termed an *emulsion*. The fat or oil has been separated by the alkali into extremely minute particles which remain diffused throughout the liquid.

The **bile** is a yellow or greenish-yellow fluid, also slightly alkaline, having the following **composition** :—

Water		859·2 parts
Solids	Bilin	91·5 ,,
	Fat	9·2 ,,
	Cholesterin	2·6 ,,
	Mucus and colouring matter	29·8 ,,
	Salts	7·7 ,,
		1000·0

The bile is **secreted continuously**, at the rate of from thirty to forty ounces daily. If not needed at once for digestion, it passes into the gall-bladder, where it is stored until required. If digestion is going on, it passes direct from the liver, where it is secreted, to the duodenum.

The chief **uses of the bile** as a digestive fluid are (1) to assist in emulsifying fats, (2) to moisten the mucous membrane of the intestine, and (3) to act as a natural purgative by assisting the muscular motions and the secretion of the intestines.

When the *chyme* passes into the small intestine, it is soon mingled with the pancreatic fluid, the bile, and the secretions of the intestinal glands ; and these fluids, together with the saliva and the gastric fluid which form part of the chyme, complete the process of digestion. All kinds of foods are now being dissolved, and by the worm-like motions kept up by the muscular fibres of the intestines, the whole is urged slowly on. The dissolved portions are rapidly absorbed by the mucous mem-

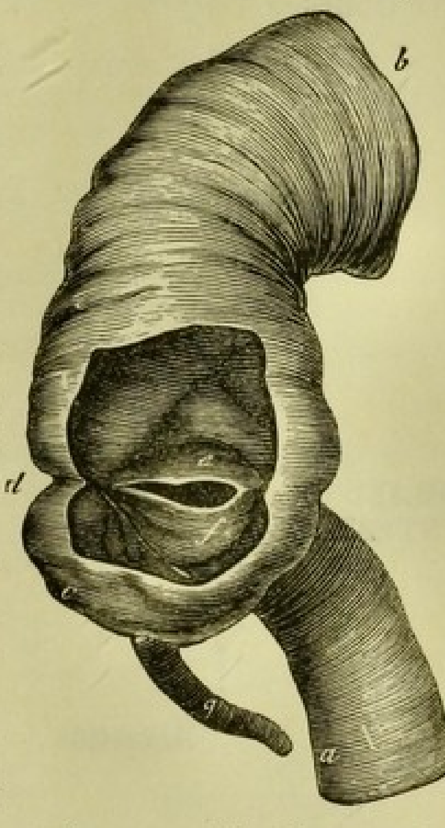


Fig. 105.—**The Ileo-cæcal Valve.**

a, ileum ; *b*, ascending colon ; *c*, cæcum ; *d*, junction of the cæcum and colon ; *e* and *f*, loose folds of the mucous membrane, forming the ileo-cæcal valve ; *g*, vermiform appendage.

brane, while the undigested and indigestible portions pass onward towards the rectum.

As soon as the chyme is subjected to the influence of the bile and pancreatic fluid, its appearance is changed, the emulsified fats giving it the appearance of milk. The term **chyle** is applied to the emulsified contents of the small intestine.

After the chyle has passed through the whole length of the small intestine, it enters the large intestine through an opening which is guarded by two folds of the mucous membrane. These folds project into the large tube, and so prevent the reflux of the contents into the small intestine. Thus they form a valve between the *ileum* and the *cæcum*, which is known as the **ileo-cæcal valve**.

Digestion continues in the large intestine ; the dissolved portions are gradually absorbed, leaving a residue which becomes more and more solid.

The time occupied by the food in passing through the intestines varies considerably. Perhaps the average for the small intestine is twelve hours ; and, for the large, from twenty-four to thirty-six hours.

SUMMARY.

SMALL INTESTINE

- **Coats** . . .
  - **Serous**—a continuation of the *peritoneum*.
  - **Muscular**
    - *External longitudinal fibres.*
    - *Internal circular fibres.*
  - **Areolar.**
  - **Mucous**
    - **Valvulæ conniventes**—folds of membrane.
    - **Glands**
      - *Tubular.*
      - *Globular.*
      - *Lobulated.*
    - **Secretions**
      - *Mucus.*
      - A secretion resembling the *pancreatic fluid.*
    - **Villi**—engaged in *absorption.*
- **Digestion** . .
  - Continued action of *saliva* and *gastric fluid.*
  - **Bile**—Emulsifies fats.
  - **Pancreatic fluid**
    - Converts starch into sugar.
    - Dissolves nitrogenous foods.
    - Emulsifies fats.

LARGE INTESTINE . .
- Digestion completed.
- Fluid portions absorbed, leaving a solid residue.

SUMMARY OF THE PROCESS OF DIGESTION.

Starchy foods . .	Solution commenced in the *mouth* by the *saliva*. Continued in the *stomach* by the swallowed *saliva*. Completed in the *intestines* by the *intestinal juices*.
Nitrogenous foods .	Solution commenced in the *stomach* by the *gastric fluid*. Continued in the *intestines* by the *gastric fluid* which has passed through the pylorus, by the *pancreatic fluid*, and also (probably) by the *intestinal secretions*.
Fats	*Fat globules loosened* from their nitrogenous cell-walls and membranes by the *gastric fluid*. Digested in the *intestines* by the *bile* and the *pancreatic fluid*.
Mineral salts . .	Dissolved by the various digestive fluids.

QUESTIONS ON LESSON XIX.

1. Describe the structure of the *intestines*.
2. In what respects does the mucous membrane of the intestines differ from that of the stomach?
3. What are the *valvulæ conniventes*? What are their uses?
4. Describe the general form and position of the *pancreas*. What is the nature of the fluid which it secretes?
5. Describe the action of the *pancreatic fluid* on various kinds of foods.
6. What are the general properties of the *bile*? Where is it prepared? Where does it enter the alimentary canal?
7. What are the uses of the bile?
8. What is *chyme*? Of what does it consist? Describe the changes which take place during its formation.
9. In what part of the abdomen does the small intestine communicate with the large intestine? How do they join? What is the condition of the contents of the small intestine just before passing into the large intestine?
10. What changes does the food undergo in the large intestine?
11. Describe the nature of the food materials in a beef-steak pudding. Where are these materials digested? Name the fluid or fluids concerned in the digestion of each.
12. Describe the action of the gastric fluid, the pancreatic fluid, and the bile, respectively, on fatty tissue.

LESSON XX.

ABSORPTION.

THE **object of the present lesson** is to show how the nutritious matter derived from the food during the process of digestion enters into the blood system.

Food is taken in order to repair the waste which is continually going on in the various tissues of the body, and also, during youth, to allow of the growth and development of the system as a whole.

In the alimentary canal the various food-substances are simply *digested*, that is, either converted into a soluble form, or else separated into such minute particles that they are capable of being transmitted through moist membranous structures. But now it is necessary that the materials so digested enter the blood system. They are then conveyed to the various tissues and added to their structures, while the blood at the same time removes from these tissues those materials which have performed their office, and which are termed the waste products. The passage of the nutritious substances from the digestive canal to the blood system constitutes the process called **absorption.**

We have noticed that the process of digestion commences in the mouth, and is continued more or less throughout the alimentary canal. We have also learnt that the whole of the canal is lined with a soft mucous membrane which is richly supplied with blood-vessels, and that as soon as the digestion of a food-substance commences, the dissolved portions begin to penetrate the soft membrane and pass through the thin walls of the minute blood capillaries. Thus we become acquainted with one process by which nutritious matter enters the blood—a process which we may term the **absorption by blood-vessels.** We shall presently learn, however, that there is another and distinct process of absorption, carried on by a complicated system of vessels especially adapted for the purpose.

The **blood-vessels** seem to exercise no choice in the materials absorbed. Every kind of food is readily imbibed provided it is dissolved or reduced to such a finely-divided state that it is capable of permeating their walls. It must be remembered that this absorption is carried on almost exclusively by the minutest blood-vessels (the capillaries), the walls of which are exceedingly thin.

The other portion of the process of absorption referred to above is carried on by a system of vessels called the **lymphatic system** (see fig. 6), and the function performed by the vessels of this system is of such an important character that they are often said to constitute the **absorptive system.**

The **lymphatic system** (Lat. *lympha*, clear water) is so called because its vessels usually contain a watery fluid. It consists of *lymphatic capillaries*, *lymphatic vessels*, *glands*, and two vessels called *lymphatic trunks*, the larger of which is situated at the back of the thorax and is called the *thoracic duct.*

The **lymphatic capillaries** are very minute vessels (Lat

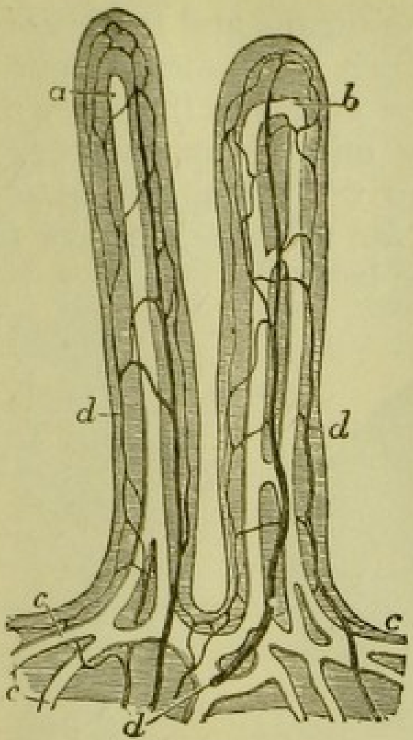


Fig. 106.—**Two Intestinal Villi. Magnified 100 diameters.**

a, *b*, and *c*, lacteals ; *d*, blood-vessels.

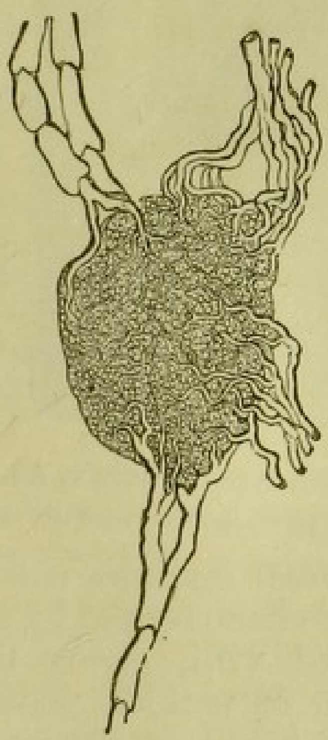


Fig. 107. —**A Lymphatic Gland with its Vessels.**

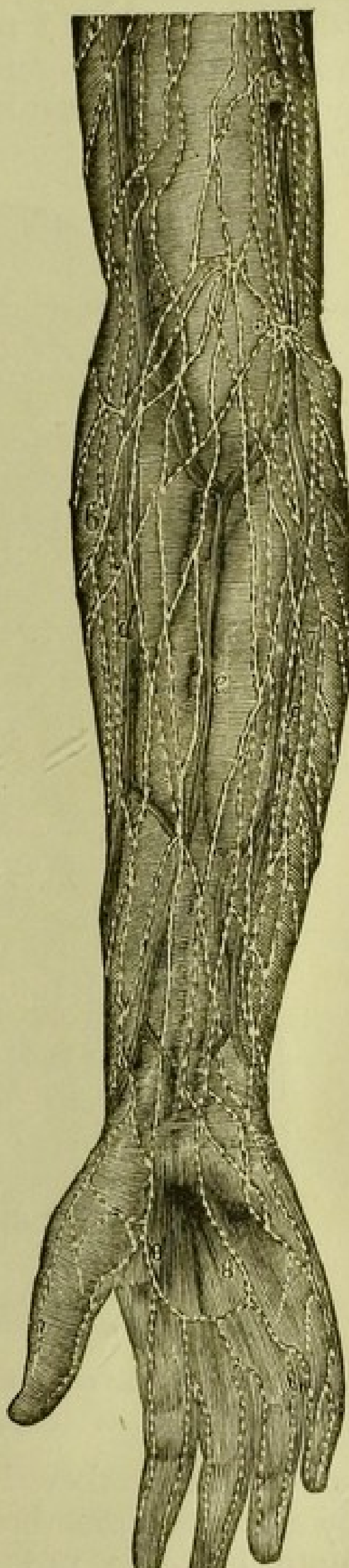


Fig. 108.—**The Superficial Lymphatics of the Arm and Hand.**

capillus, a hair) which originate in the organs and tissues of nearly every part of the body. Those which have their origin in the walls of the intestines differ from the others in that they contain, during digestion, a fluid resembling milk in appearance. They are consequently distinguished from the other lymphatic capillaries by the name **lacteals.** (Lat. *lac*, milk.) We now proceed to study the nature and uses of these lacteals.

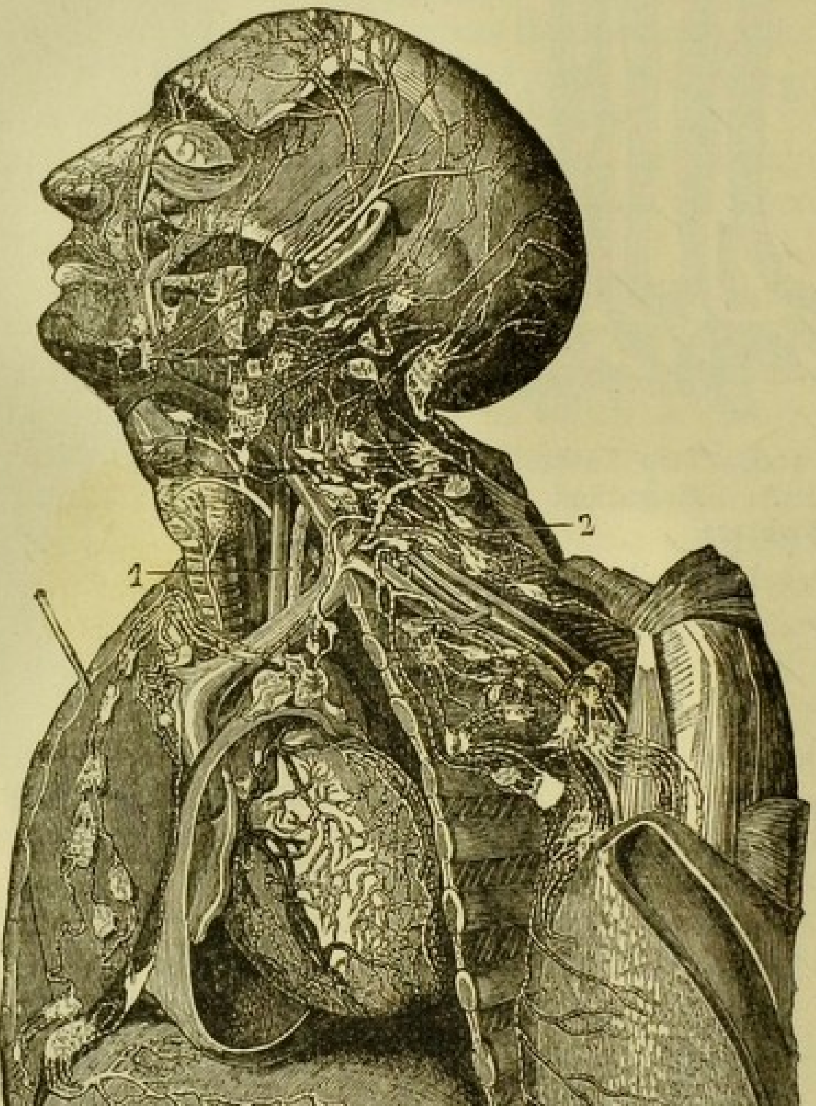


Fig. 109.—**Lymphatics of the Head, Neck, Thorax, &c.**

1 and 2, the upper portion of the thoracic duct, showing its junction with the venous system.

It will be remembered that the small intestine is lined internally by a mucous membrane which is characterised by a number of minute hair-like projections called **villi,** giving the membrane the appearance of a yellowish or pinkish velvet. Each *villus* is supplied with a network of blood capillaries, and also one or more *lacteals.* These vessels are very advantageously situated for absorption, as they are surrounded on all sides by

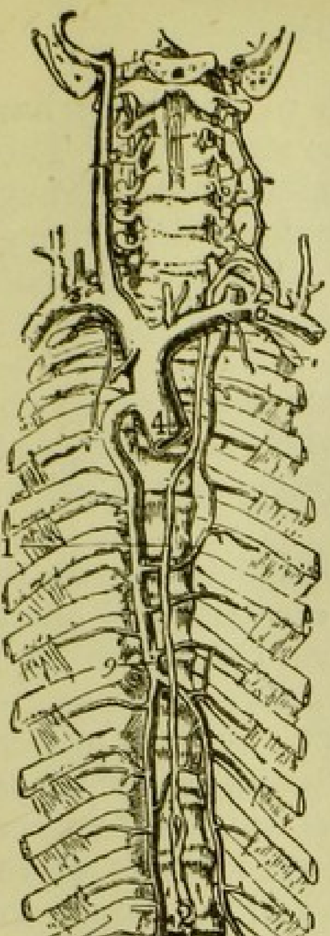


Fig. 110.—**The Thoracic Duct.**

1, the thoracic duct, in front of the vertebral column; its upper extremity communicating with the venous system at the junction of the left jugular and left subclavian veins (compare with fig. 6); 2, receptaculum chyli; 3, inferior vena cava, lower portion; 4, superior vena cava.

digested food-substances, only an extremely thin layer of tissue separating. Hence in the villi absorption goes on very rapidly, both by the blood-vessels and the lacteals. This is also supplemented by means of other blood-vessels and lacteals which lie in the mucous membrane *between* the villi, and also in the corresponding membrane of the large intestine where there are no villi.

The absorption as carried on by the lacteals differs in one important respect from that by the blood-vessels, since the former have the power to select the fatty constituents from the various products of digestion, while the latter possess no power of selection.

During fasting the lacteals contain a clear, transparent fluid, closely resembling that which fills the other lymphatic capillaries; but during digestion they contain a milky fluid called **chyle** (Gr. *chulos*, juice), the change in appearance being due to the innumerable particles of fatty matter absorbed from the intestine.

The chyle is collected by **lymphatic vessels,** which resemble thin-walled veins (see page 131). Like veins, they are also provided with **valves** which allow of the passage of fluid in one direction only, viz. towards the *thoracic duct*; and the valves are arranged at such short distances from each other, that, when full, the lymph-vessels have a knotted or beaded appearance.

As the chyle moves onward, and especially as it passes through the **lymphatic glands,** the number of oily particles diminishes, corpuscles resembling the white corpuscles of the blood (see page 117), and a nitrogenous substance called fibrin are formed: in fact, as it approaches the blood system which it is ultimately to enter, it becomes more and more like blood, excepting in the matter of red corpuscles which give the colour. We may therefore regard the lymphatic glands as being concerned in the elaboration of the blood.

The **lymphatic capillaries** in other parts of the body have their origin in the spaces between the various structures. Their office is to collect the fluid part of the blood which exudes through the walls of the blood-vessels, and substances which, though having once formed part of a tissue, are not yet waste materials, but are capable of reorganisation, and may therefore be adapted for nutrition.

The **lymph** thus absorbed by the *lymphatic capillaries* is collected by the *lymphatic vessels*, and transmitted through *lymphatic glands*, becoming more and more like blood (excepting in colour) as it proceeds.

All the **lymphatic vessels**, including those which convey the chyle from the intestines, finally empty their contents into one of the two **lymphatic ducts**. The smaller of these, called the **right lymphatic duct**, enters a large vein at the right side of the root of the neck. The larger duct—**the thoracic duct**—lies just in front of the vertebral column. Its lower end, situated in the upper portion of the abdomen, is four or five times as wide as the upper part, and is called the **receptaculum chyli** or **receptacle of the chyle.** The remainder of the duct lies at the back of the thorax, and its upper end leads into a larger vein at the root of the neck on the *left* side. Thus we have been able to trace the passage of food materials from the mouth, till they finally enter the blood system.

SUMMARY.

Absorption by Blood-vessels		From the mucous membrane in all parts of the alimentary canal. No power of selection— Every kind of food absorbed if dissolved, or if so finely divided that it can permeate the walls of the blood capillaries.
LYMPHATIC SYSTEM	**Lacteals**	The lymphatics of the *intestines*. Many originate in the *villi* of the small intestine. Contain { *During digestion*—a milky fluid (*chyle*). *During fasting*—a watery fluid. } Absorb *fatty* substances.
	Other Lymphatics	Absorb the fluid portion of blood (lymph) which has exuded through the blood-vessels. Also other substances for reorganisation.
	Glands	Engaged in *elaborating blood* from the lymph and chyle.
	Thoracic duct	In front of backbone, chiefly in thorax. *Receptaculum chyli*—lower portion—situated in the abdomen. Receives lymph and chyle, and pours them into the blood system.

QUESTIONS ON LESSON XX.

1. What is meant by absorption? What are the organs concerned in the absorption of nutriment?
2. Where does the absorption of nutritious matter commence? In what parts is it continued?
3. How does the absorption by blood-vessels differ from that by the lacteals?
4. What are *lacteals* and *lymphatics*?
5. Describe the structure of a villus. In what way is it particularly adapted for absorption?
6. What are the organs and vessels which make up the *lymphatic system*?
7. What is the difference between *lymph* and *chyle*?
8. How is the food conveyed from the alimentary canal into the blood?
9. What is the *thoracic duct*? Where is it situated? What does it contain during fasting, and what shortly after a meal?
10. What are *lymphatic glands*? What is their use?

LESSON XXI.

THE BLOOD.

THE **blood** consists of a colourless alkaline fluid called the *liquor sanguinis*, and myriads of minute floating bodies called *corpuscles.*

The **liquor sanguinis** (Lat. *sanguis*, blood), called also the **plasma**, consists of water in which is dissolved certain *mineral salts* and *albumen* and other *nitrogenous matter.*

The **blood corpuscles** are of two kinds, usually termed the *red* and the *white* or *colourless*

The **red corpuscles** are minute circular discs, concave on both sides, having a diameter of about $\frac{1}{3200}$ inch, and a thickness of about $\frac{1}{12000}$ inch. If placed flat, edge to edge, ten millions of them would be required to cover a square inch. They are so numerous in the blood that they make it a thickish liquid, and probably form about forty per cent. of the total weight of the blood. When examined singly under a powerful microscope they are not red, but of a pale yellowish colour; yet these are the bodies which, when seen *en masse*, give to the blood its uniform red colour. These corpuscles seem to be supported by a firm elastic framework, so that they readily change their shape in passing through narrow apertures, and regain it immediately after.

The **white or colourless corpuscles** are a little larger than the red, being about $\frac{1}{2500}$ inch in diameter. Being composed of a very soft, jelly-like substance (*protoplasm*) they readily change their form. They much resemble a minute animal organism, found abundantly in stagnant water, called the *amœba*. They also, like the amœba, are constantly shooting out irregular processes, and are therefore said to be capable of *amœboid movements*. The colourless corpuscles are not nearly so numerous as the red, the proportion being about one to five hundred. The proportion, however, varies considerably, being dependent on the kind and amount of food taken, age, &c.

When freshly-drawn blood is allowed to remain at rest for a few minutes it becomes semi-solid and jelly-like by the formation of what is called a **clot**. At first the clot thus formed constitutes the whole mass of the blood, and is of the same uniform colour. But after a short time a very pale yellowish liquid begins to ooze out and collect on the surface. The clot becomes gradually smaller as this liquid exudes, till, at the end of a few hours, it is much firmer, and floats in the yellowish fluid.

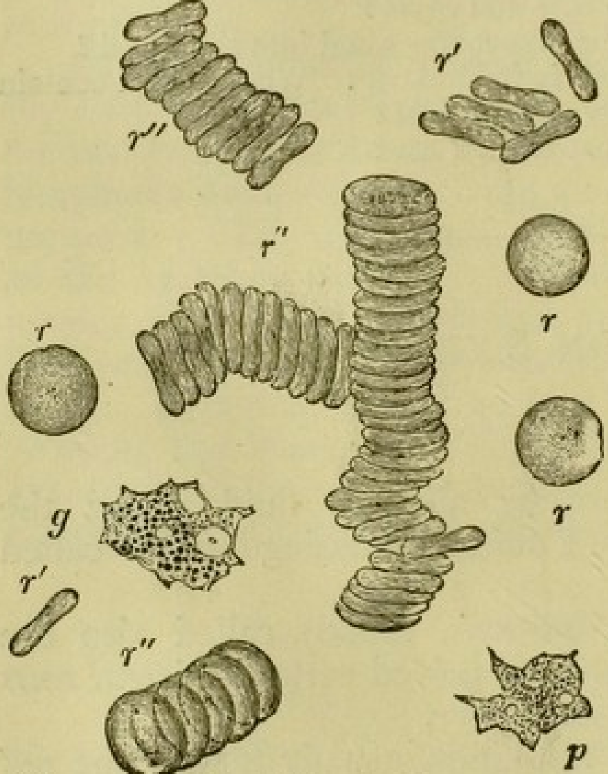


Fig. 111.—**Blood Corpuscles, as seen under a powerful Microscope.**

r, red corpuscles lying flat; *r'*, red corpuscles on edge and viewed in profile; *r''*, red corpuscles arranged in rouleaux; *p* and *g*, colourless corpuscles.

The clot is due to the formation of **fibrin**—a substance which is not present in living blood, but is formed spontaneously, after the blood has been drawn, from materials in solution. This change in the blood is termed **coagulation**; and the liquid which separates from the clot is called **serum** (*whey*). The serum is almost entirely free from corpuscles, these being entangled with the fibrin.

The following tables will assist in making this change clear :—

Blood (before coagulation)	**Liquor sanguinis** .	Water. Salts. Albumen. The elements of fibrin.
	Corpuscles . . .	Red. Colourless.

Coagulated blood . .	Water Salts Albumen	**Serum.**
	Fibrin Corpuscles	**Clot.**

If fresh blood be stirred briskly with a bunch of twigs, the fibrin is formed very rapidly, and collects on the twigs, leaving behind a red fluid called **defibrinated blood** (blood deprived of its fibrin) which will not coagulate. Thus :—

Blood	**Liquor sanguinis.**	Elements of fibrin		**Fibrin.**
		Albumen, Salts, Water	**Serum**	**Defibrinated blood.**
	Corpuscles			

The **coagulation of blood** may be **retarded**, and even prevented, by keeping it at a temperature below 40° F., or at a higher temperature than 120° F. The addition of common salt, or contact with living tissues, will also prevent this change. On the other hand, coagulation may be **hastened** by free access to the air (as by exposure in a shallow vessel), by allowing the blood to remain at perfect rest, or by bringing it in contact with foreign (non-living) matter. In the last case, the coagulation is rapid in proportion to the surface which is in contact with the blood ; hence the reason for whipping with a bunch of twigs.

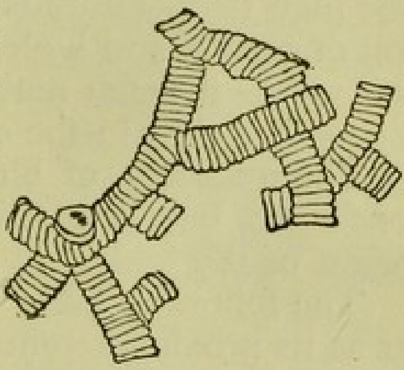


Fig. 112.—**Red Corpuscles arranged in Rouleaux.**

Under ordinary circumstances the coagulation sets in before the corpuscles have time to subside or settle to the bottom of the vessel ; but the red corpuscles have a tendency to adhere to each other when the blood is at rest, forming rolls or columns resembling piles of coins, the piles being connected with each other at their ends so as to form a kind of network which sinks more quickly than would single corpuscles. When this change takes place rapidly, the red corpuscles subside before the fibrin is formed. In this case a red clot is formed by fibrin and red corpuscles at the bottom of the vessel, over which is a yellowish clot produced by fibrin and colourless corpuscles, together with a few of the red variety, sufficient to impart a buff-yellow tint. This upper layer is commonly known as the **buffy coat**, and is often cup-shaped in form, owing to the great shrinking of the fibrin on account of the absence of the network of red corpuscles.

The **colour of the blood** is due to the presence of a nitrogenous substance, called **hæmoglobin**, in the red corpuscles. This substance contains a considerable proportion of iron oxide, and has the power of combining with oxygen gas. As the blood flows through the capillaries surrounding the air-cells of the lungs, the hæmoglobin combines with oxygen from the air, becoming of a bright scarlet colour. The blood thus changed in colour returns to the heart, by which it is forced throughout the body. Then, on passing through the tissues of various organs, and especially the muscles, the hæmoglobin gives up some of its oxygen, which seems to be held by only a feeble chemical affinity, to the carbon and hydrogen of these tissues, forming respectively carbonic acid gas and water. The hæmoglobin then changes to a dark purple or purple-black colour, and the blood again returns to the lungs with the carbonic acid gas in solution. In the lungs this gas is given off into the air and expired, while the hæmoglobin receives a fresh supply of oxygen from the inspired air. From the above description it will be readily understood why the hæmoglobin has been termed the *oxygen carrier* of the blood.

In the body the bright scarlet blood is *usually* found in the **arteries** (vessels which convey blood *from* the heart), while the dark purple blood *usually* flows through the **veins** (vessels which convey blood *to* the heart). Hence the bright blood is often termed **arterial**, and the dark blood **venous**.

When a drop of dark blood from a vein is left exposed to air, it absorbs oxygen from the air, and soon becomes bright. This change may also be illustrated as follows :—

Half fill a test-tube with dark venous blood, and shake it up with the air contained in the tube. It will speedily turn to a bright scarlet ; but, if set aside for some time, will gradually turn dark again. This experiment may be varied by causing air or oxygen to bubble through a vessel containing venous blood.

The **temperature of the blood** is about 99° F. in health, but is not exactly the same in all parts of the body at the same time. The high temperature is due to chemical action, chiefly the oxidation of carbon and hydrogen of the tissues. The blood is warmed as it passes through muscles, glands, and other active organs ; but is cooled slightly in the capillaries of the skin.

The **quantity of blood in the body** also varies with certain conditions, but is usually estimated at about one-tenth the total weight of the body.

The following table shows the **composition of human blood** as far as its proximate principles are concerned :—

Water	785·0
Red corpuscles (dry)	130·0
Albumen (dissolved in the serum)	70·0
Fibrin (elements of)	2·2
Fatty matter	1·4
Common salt	3·6
Other salts	1·8
Colouring matter, waste, and accidental matters, &c.	6·0
	1000·0

When blood has been dried by the evaporation of all its water, its ultimate or elementary chemical composition is almost identical with that of dried flesh. Under these circumstances the **composition of blood** is

Carbon	58·0
Oxygen	19·0
Nitrogen	17·5
Hydrogen	7·0
Ash (mineral matter)	4·5

Some of the **uses of the blood** have already been pointed out in connection with certain organs, and others have yet to be mentioned. The chief uses, however, may be summarized as follows :—

1. It serves as a storehouse for nutrient matter absorbed

from the foods, and conveys the nutriment to all parts of the body.

2. It conveys the materials from which the secretions are formed to the various glands which prepare them.

3. It carries the oxygen gas to all the tissues where the process of oxidation goes on, thus being essential for the maintenance of the high temperature of the body.

4. It collects up waste materials, and conveys them to the excreting organs for separation and removal.

5. It serves to distribute heat throughout the body.

6. It moistens the various tissues.

SUMMARY.

- **Composition of the BLOOD**
  - **Liquor Sanguinis**
    - The liquid of the blood.
    - *Contains*
      - *Water.*
      - Dissolved *albumen.*
      - Mineral *salts.*
      - The *elements of fibrin.*
  - **Corpuscles** . .
    - **Red** . . .
      - *Discs*, round, with *concave sides.*
      - *Diameter*, $\frac{1}{3200}$ inch.
      - *Thickness*, $\frac{1}{12000}$ inch.
      - *Yellowish* when viewed singly.
      - Have a tendency to *adhere* and form *piles* when the blood is drawn.
      - Hæmo-globin
        - Contains iron oxide.
        - The oxygen carrier.
    - **Colourless**
      - Shape constantly varying.
      - *Diameter*, $\frac{1}{2500}$ inch.
      - *Transparent*, *jelly-like.*
      - Resemble the *amœba.*
      - One to every 500 red.

- **CLOTTED BLOOD** .
  - **Serum** . . .
    - *Water.*
    - Dissolved mineral *salts.*
    - Dissolved *albumen.*
  - **Fibrin** . . . Formed during coagulation.
  - **Corpuscles** . Red and white.
  - (Fibrin and Corpuscles:) **Clot**—floats in the serum.

- **BLOOD** . .
  - **Arterial** . .
    - *Bright red.*
    - *Rich in oxygen.*
    - *Usually* contained in *arteries.*
  - **Venous** . .
    - Dark purple.
    - Usually found in veins.
    - Contains
      - Less oxygen than arterial blood.
      - More carbonic acid gas.
    - Converted into arterial blood by absorption of oxygen.
  - **Temperature** 99° F.
  - **Quantity** . . One-tenth the weight of the body.

QUESTIONS ON LESSON XXI.

1. Describe the appearance of the corpuscles of the blood as seen with the aid of a microscope. How do the red corpuscles differ from the white?
2. Describe the changes which take place when a vessel of freshly-drawn blood is left exposed to air.
3. What are the materials dissolved in the fluid part of the blood?
4. Describe an experiment by which you would deprive blood of its fibrin.
5. What is clot? Of what is it composed?
6. What is meant by defibrinated blood? Illustrate your answer by an experiment.
7. What is meant by the term 'buffy coat' as applied to blood? Under what circumstances is it formed?
8. How would you convert venous into arterial blood? Where does this change take place in the body?
9. What are the differences between arterial and venous blood?
10. Where and how, in the body, is arterial blood changed into venous?
11. What is the cause of the high temperature of the body? By what means is the temperature uniformly distributed?
12. Mention some of the chief uses of the blood.

LESSON XXII.

THE HEART AND ITS DISSECTION.

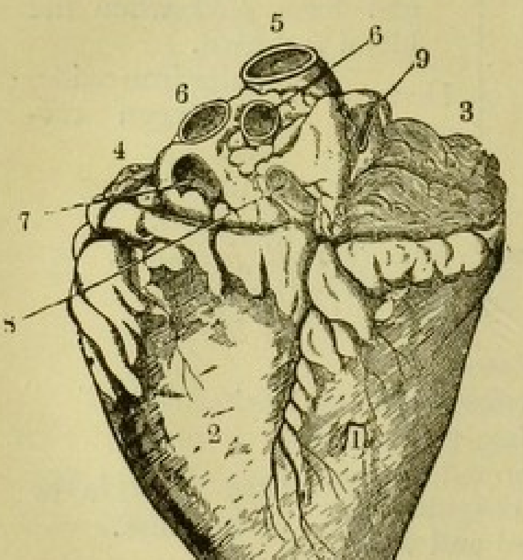


Fig. 113.—**The Sheep's Heart, viewed from behind.**

1, right ventricle; 2, left ventricle; 3, right auricle; 4, a small portion of the left auricle; 5, the aorta; 6, the pulmonary arteries; 7, pulmonary vein trunk; 8, vena cava inferior; 9, vena cava superior.

THE **heart** is a hollow muscular organ which, by its contraction, forces the blood through the whole system of blood-vessels. A general description of this organ has already been given in Lesson XII., and we shall now proceed to study its structure and action.

The student is strongly recommended to procure a sheep's heart from the butcher, and dissect it with the help of the simple instructions here given.

Many of the **sheep's hearts** sold have a deep cut on the front. This is made on opening the carcase of the animal, while carelessly chopping through the breast-bone. Select one which is free from this defect, and one in which the blood-vessels at the base (upper and broader portion) are not closely cut. If a superabundance of fat surrounds the base of the heart, remove the greater portion of it without cutting any of the vessels.

The student, having provided himself with a sharp knife with a pointed blade, a few wood skewers, and a jug of water, may now proceed with the **examination and dissection of the heart** as follows :—

Place the point of the knife just underneath the surface of the heart, so as to raise a portion of the very thin membrane or skin which closely invests it. This membrane is the inner layer of the **pericardium**, the outer layer of which, it will be remembered, surrounds the heart loosely, and is cut or torn away in removing the organ from the chest. A few remaining portions of this outer

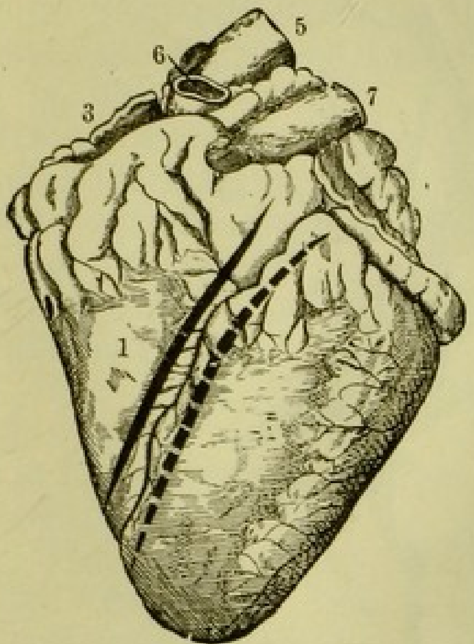


Fig. 114.—**The Sheep's Heart, viewed from before.**

1, right ventricle; 2, left ventricle; 3, right auricle; 4, left auricle; 5, the aorta; 6, a cut branch of the aorta; 7, pulmonary artery. To open the right ventricle, cut as shown by the thick unbroken line. To open the left ventricle, cut along the thick dotted line. Between these two lines is a groove containing a blood-vessel, marking the position of the septum which separates the ventricles.

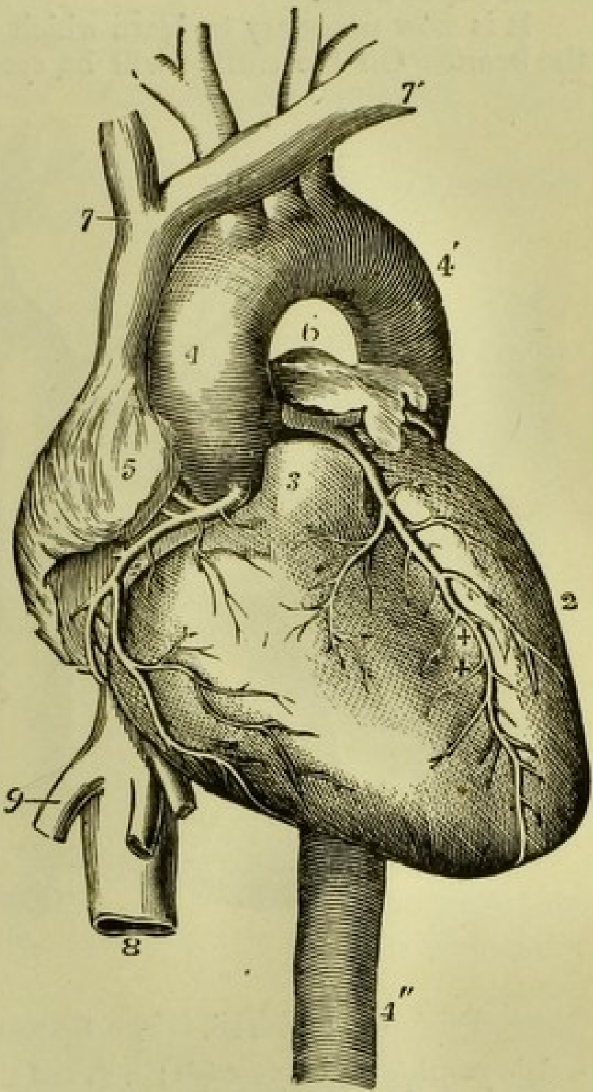


Fig. 115.—**The Human Heart and its Vessels, viewed from before.**

1, right ventricle; 2, left ventricle; 3, root of the pulmonary artery cut short; 4, 4′, and 4″, the aorta; 5, right auricle; 6, left auricle; 7, veins which unite to form the vena cava superior; 8, inferior vena cava; 9, hepatic vein; +, coronary arteries.

layer may still be seen attached to the great blood-vessels at the base of the heart, for it is here that the inner adherent layer is reflected back to form the outer and loose layer.

Now notice the two thin fleshy flaps which lie over the base of the heart like ears, one on each side. These are the **auricles** (Lat. *auricula*, a little ear). They are hollow, and, of course, when distended with blood, do not lie so flat. Notice also the general conical shape of the heart.

We may now examine the **blood-vessels** at the base of the heart. If some of them appear to be small, portions may be cut down till we arrive at the point where the smaller vessels unite to form a large one. In this way we may readily reduce the number of blood-vessels to about seven. Some of these have very thick, firm, and elastic walls, which retain their circular form, although the vessels are quite empty. These are the **arteries**, which convey the blood *from* the heart. The other vessels have thinner walls, which are comparatively inelastic and limp. These are the **veins**, which bring the blood *to* the heart.

It is now necessary to learn which is the right and which the left side of the heart. On the surface will be seen two grooves, on opposite sides, one

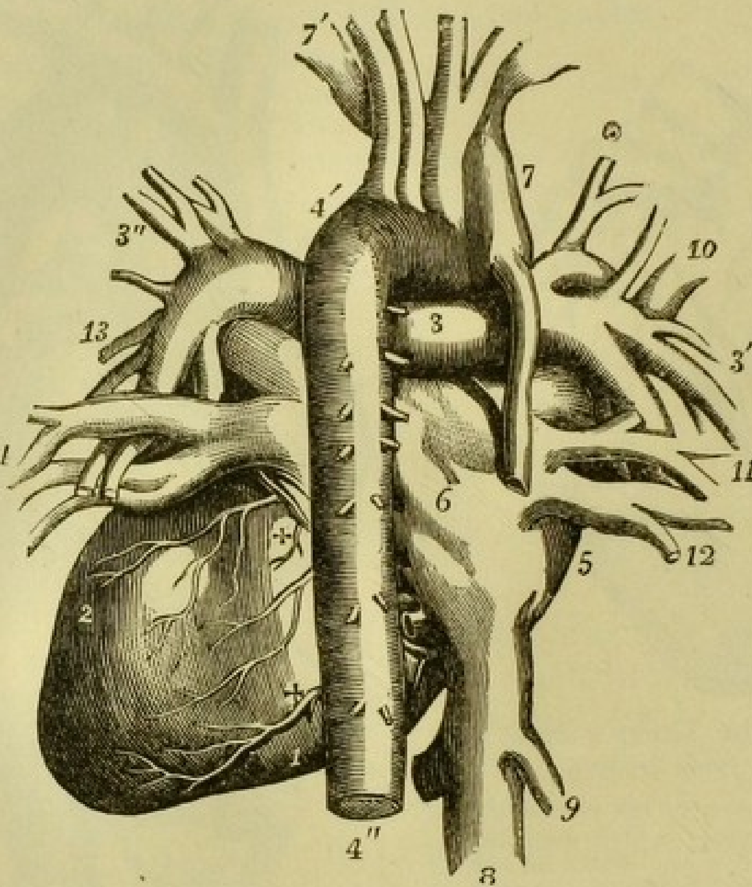


Fig. 116.—**The Human Heart from behind.**

1, right ventricle; 2, left ventricle; 3, 3′, and 3″, the pulmonary arteries and their branches; 4′ and 4″, the aorta; 5, right auricle; 6 is placed on the division between the right and left auricles; 7, superior vena cava; 8, inferior vena cava; 9, hepatic vein; 10, 11, and 12, right pulmonary veins; 13 and 14, left pulmonary veins; +, the coronary arteries.

situated in front and the other behind. Inside the heart, extending between these grooves, is a fleshy partition which separates two cavities called the **ventricles** (Lat. *ventriculus*, a little belly)—the right and the left. These ventricles constitute the greater part of the heart, and are much stronger and more muscular (fleshy) than the auricles. We may now readily distinguish between the right and the left ventricles by pressing their walls between the finger and thumb, the walls of the left ventricle being much thicker than those of the right.

Now hold the heart before you in the **position** it would occupy (see fig. **115**), supposing it to be the heart of a person facing you: that is, with its base uppermost and its apex inclined to the left (your right), the left ventricle being on your right, and *vice versâ*. From this stage it will be assumed that the student is able to distinguish between the **four cavities of the heart**, *viz.*—the right and left *auricles*, and the right and left *ventricles*.

By means of the wood skewers we may now learn the manner in which the various **vessels** communicate with these four cavities. The arteries will thus be seen to lead *direct* from one or other of the ventricles, while the veins communicate directly with the auricles, and indirectly through these with the ventricles. Care must be taken to avoid tearing or breaking any of the interior structures while applying these tests.

The **great blood-vessels** may now be named as follows :—

1. Largest *artery*, leading direct from the *left ventricle*, called the **Aorta**.

2. Two other *arteries*, leading direct from the *right ventricle*, called the **Right** and **Left Pulmonary Arteries.**

3. Two large *veins*, communicating with the *right auricle*, called the **Inferior** and the **Superior Venæ Cavæ**.

4. Two *veins*, communicating with the *left auricle*, called the **Pulmonary Veins**.

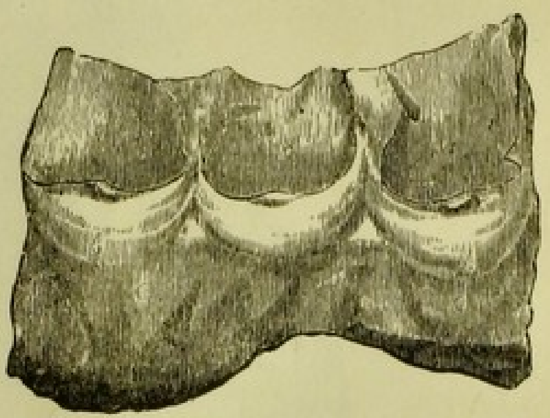


Fig. 117.—**The Semilunar Valves of the Trunk of the Pulmonary Arteries, the Vessel being cut and laid open.**

The **Aorta** (Gr. *airo*, I raise up) conveys blood from the *left* side of the heart to *all parts of the body*.

The **Pulmonary Arteries** (Lat. *pulmo*, a lung) convey blood from the *right* side of the heart to the *lungs*.

The **Venæ Cavæ** collect the blood *from all parts* (the **superior** from the *upper*, and the **inferior** from the *lower parts*), and carry it into the *right cavity*.

The **Pulmonary Veins** collect the blood which has circulated in the *lungs*, and convey it into the *left cavity*.

It will be noticed that the auricle and ventricle of each side of the heart communicate with each other, so that the blood which has entered the auricle can pass into the corresponding ventricle.

We must now examine the **interior of the heart**. For this purpose proceed as follows :—

Hold the heart with its *front* surface toward you (see fig. 114), and make a clean cut through the wall of the **right ventricle**, about half an inch from the groove before mentioned, and extending from the top of the ventricle to the apex of the heart. Now open the ventricle by pushing aside this cut wall, and observe the following points in connection with its structure :—

The wall of the **right ventricle** is almost entirely *muscular*, and numerous **columns of flesh (columnæ carneæ)** project from its surface. Some of these stand out like pyramids, and are called the **papillary muscles** (Lat. *papilla*, a nipple). To these *papillæ* are attached very fine **tendinous threads (chordæ tendineæ)**, which are again connected at their other and upper ends with thin membranous *flaps* or *cusps*. The cusps are three in number, and lie loosely against the walls of the ventricle, but it will be readily understood that a

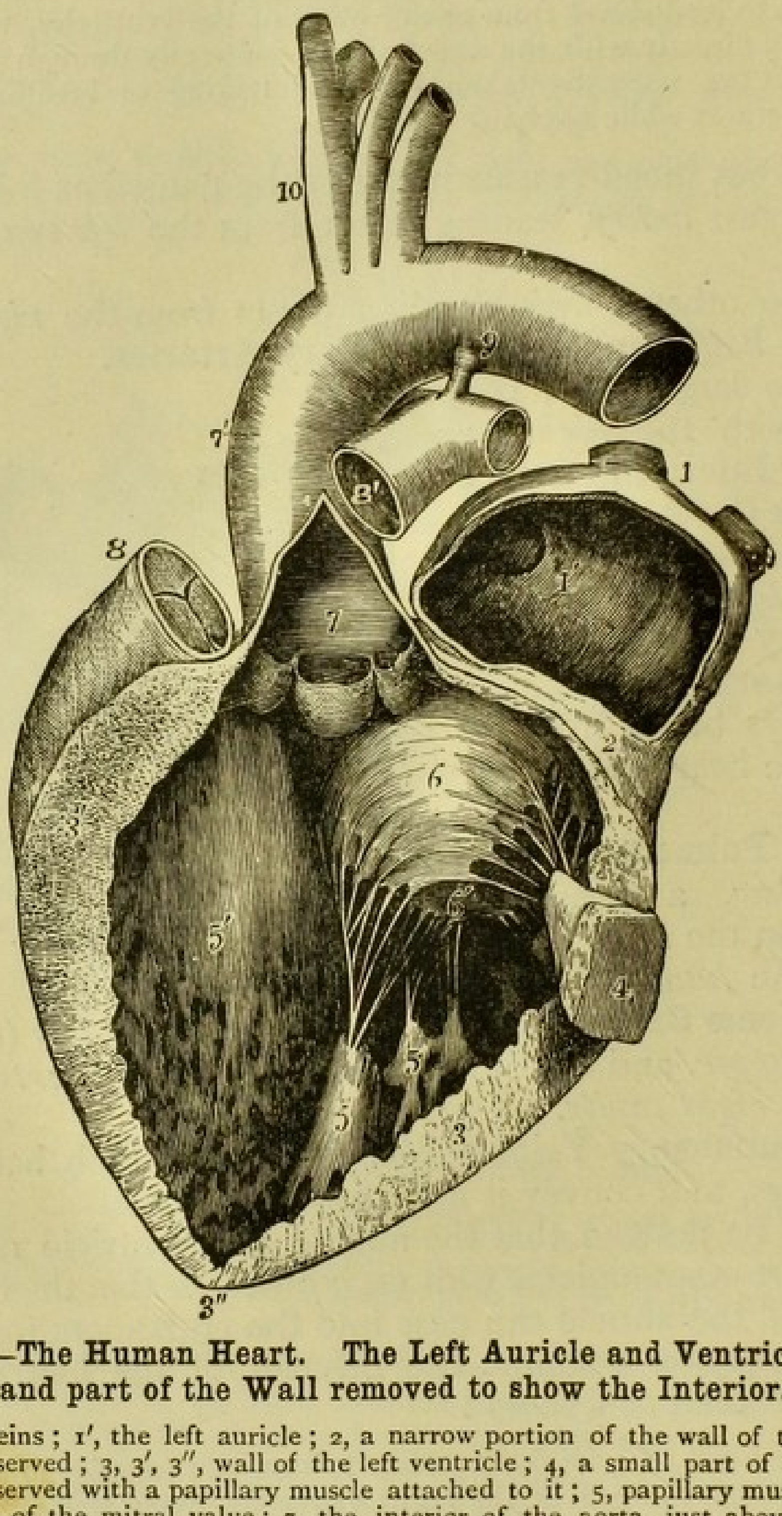


Fig. 118.—**The Human Heart. The Left Auricle and Ventricle opened, and part of the Wall removed to show the Interior.**

1, pulmonary veins ; 1′, the left auricle ; 2, a narrow portion of the wall of the auricle and ventricle preserved ; 3, 3′, 3″, wall of the left ventricle ; 4, a small part of the wall of the ventricle preserved with a papillary muscle attached to it ; 5, papillary muscles ; 6 and 6′, the segments of the mitral valve ; 7, the interior of the aorta, just above its semilunar valves ; 7′, the arch of the aorta ; 8, the root of the pulmonary artery with its semilunar valves ; 8′, a separated portion of the pulmonary artery, remaining attached to the aorta by a cord, 9 ; 10, branches of the aorta.

pressure of blood in the ventricle would act on the under surfaces of these cusps and cause them to rise. Under these circumstances the tendinous cords are stretched, and the edges of the cusps meet so as to stop the communication between the ventricle and the auricle above it. The three cusps thus form a valve called the **tricuspid valve**; and, from the arrangement we have just observed, it is clear that this valve will allow a free passage of blood *from auricle to ventricle*, but not in the opposite direction.

If we now prolong the cut towards the origin of the pulmonary arteries until we lay open the trunk which gives rise to these vessels, we shall find another set of valves called the **semilunar valves** (Lat. *semi*, half; and *luna*,

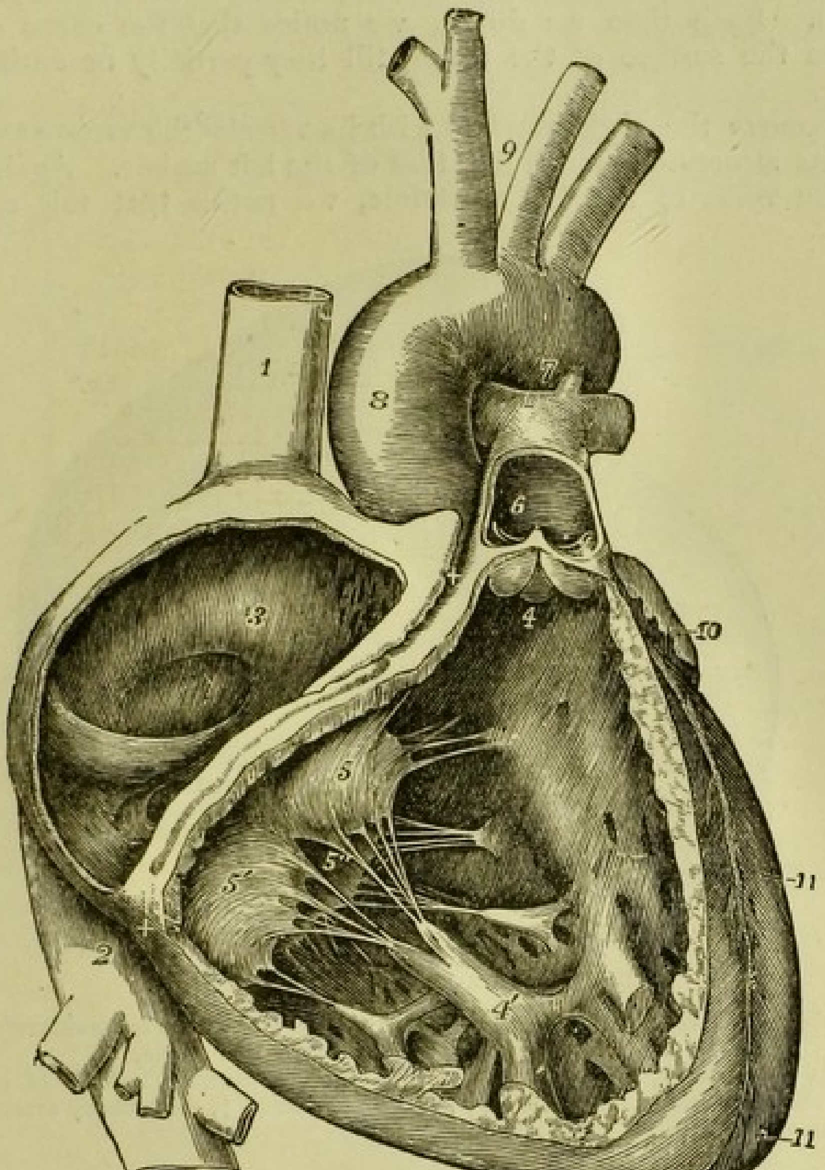


Fig. 119.—**Interior of the Right Side of the Human Heart.**

1, superior vena cava; 2, inferior vena cava; 3, interior of the right auricle; 4, semilunar valves of the pulmonary artery; 4′, papillary muscle; 5, 5′, and 5″, cusps of the tricuspid valve; 6, pulmonary artery; 7, 8, and 9, the aorta and its branches; 10, left auricle; 11, left ventricle.

the moon). These are three semi-circular membranous pouches, with their convex surfaces turned toward the ventricle. They therefore offer no obstruction to the blood as it passes *from* the ventricle, but a backward tendency of the blood would fill the pouches, causing their edges to meet, and thus closing the passage into the ventricle.

Now remove the **left auricle** completely, with its **pulmonary veins**, and notice the thinness and irregularity of its walls. We are now enabled to look down into the cavity of the **left ventricle**, which resembles the right in that a membranous valve lies between it and the auricle. This valve is called the **mitral valve** from its supposed resemblance to a bishop's mitre : it is also called the **bicuspid valve**, being composed of two cusps or flaps.

As the left ventricle is as yet uncut, we may easily study the **action of the valve** as follows :—Pour a little water into the ventricle, close the aorta which leads from it, and then squeeze the ventricle between the fingers and the thumb. Each time we do so, we notice that the cusps of the valve float up on the surface of the water, till they partially or entirely close the ventricle.

If we remove the **right auricle** with its vessels (the **venæ cavæ**), we shall find that its structure is much like that of the left auricle. Again, by cutting through the walls of the **left ventricle**, we notice that this cavity closely

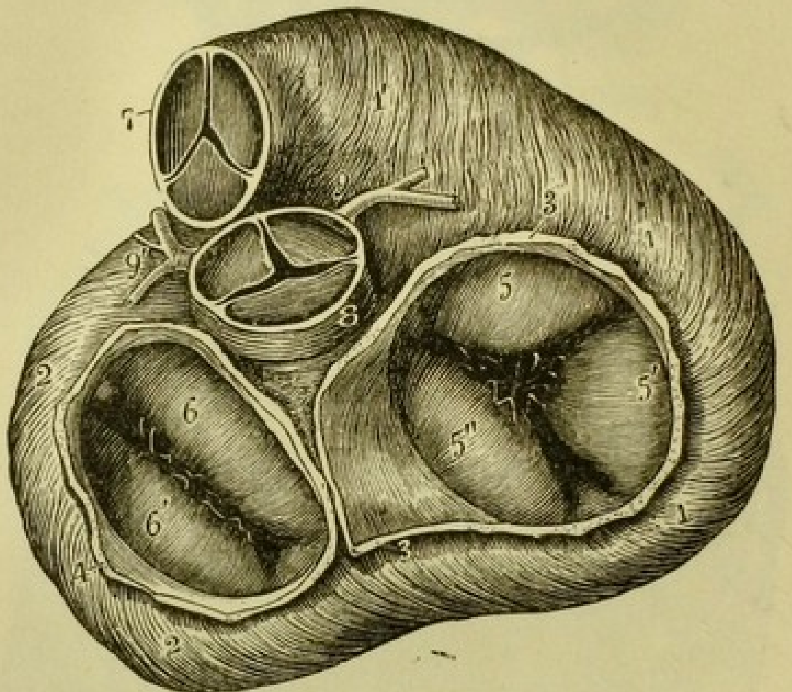


Fig. 120.—**The Base of the Heart.**

The auricles have been cut away. and the valves are closed. The pericardium has also been removed to expose the muscular fibres.

1 and 1, right ventricle ; 2, left ventricle ; 3, wall of right auricle ; 4, wall of left auricle ; 5, 5′, and 5″, the tricuspid valve ; 6 and 6′, the mitral valve ; 7, pulmonary artery ; 8, aorta ; 9 and 9′, coronary arteries.

resembles the ventricle already dissected, but that its walls are very much thicker.

Lastly, lay open the **aorta** as we did the pulmonary arteries, and here, at the origin of this great artery, we shall notice another set of **semilunar valves**, which are also arranged so as to prevent the blood from flowing back to the heart. If instead of laying open the aorta, we cut it short immediately above the semilunars, we may fill the three little pouches with water, thus illustrating their action, *i.e.* their tendency to close the passage from the aorta into the ventricle when acted on by a pressure from above. Just outside the semilunars of the aorta may be seen two small openings. These are the origins of the **coronary arteries**, by which the heart itself is supplied with blood for its nourishment. This blood is afterwards collected up by the **coronary veins** ; and branches of both the coronary arteries and the coronary veins may be seen on the outer surface of the heart, the main vessels lying in the grooves outside the edges of the middle partition, and in the grooves between the auricles and the ventricles. (See figs. 115 and 116.)

SUMMARY.

- **HEART**
  - **Right cavity**
    - Right *auricle*
    - Right *ventricle*
    - Between these the **tricuspid valve.**
  - **Left cavity**
    - Left *auricle*
    - Left *ventricle*
    - Between these the **bicuspid** or **mitral valve.**

- **CAVITIES** of the **HEART**
  - **Right auricle**
    - Thin irregular walls.
    - **Vessels**
      - *Vena cava superior*—from *upper parts.*
      - *Vena cava inferior*—from *lower parts.*
  - **Right ventricle**
    - Thick walls.
    - *Papillary muscles.*
    - *Chordæ tendineæ.*
    - *Three cusps*—form the **tricuspid valve.**
    - **Vessels**
      - *Right pulmonary artery*—to right lung.
      - *Left pulmonary artery*—to left lung.
      - **Semilunar valves** just below junction.
  - **Left auricle**
    - Thin irregular walls.
    - **Vessels**
      - *Right pulmonary vein*—from *right lung.*
      - *Left pulmonary vein*—from *left lung.*
  - **Left ventricle**
    - Very thick walls.
    - *Papillary muscles.*
    - *Chordæ tendineæ.*
    - *Two cusps*—form the **bicuspid** or **mitral valve.**
    - **Vessel**—The *aorta*—to *all parts.*
    - *Semilunar valves* at its origin.
    - *Coronary arteries* commence just outside the semilunar valves.

QUESTIONS ON LESSON XXII.

1. Describe the *pericardium*, and the manner in which it envelops the heart.
2. What are *arteries*, and what are *veins*? Name the great arteries and veins connected with the heart, and describe the direction in which the blood flows in each.
3. How would you distinguish between the arteries and the veins of the heart?
4. What are the *auricles*? Where are they situated, and what are they like?
5. In what respects do the auricles of the heart differ from the ventricles? In what do the ventricles differ from each other?
6. Describe the structures which are exposed on opening one of the ventricles.

7. Where is the *tricuspid valve*? What is its use? How would you illustrate its action?
8. Describe the structure of the *mitral valve.*
9. Where are the *semilunar* valves? Describe their structure and their mode of action.
10. Where and what are the *coronary arteries* and the *coronary veins*?
11. If you were shown a sheep's heart, how could you tell which was the right side and which was the left?
12. How do the semilunar valves differ from the other valves on the same side of the heart?

LESSON XXIII.

THE BLOOD-VESSELS AND CIRCULATION.

THE system of **blood-vessels** through which the blood circulates consists of *arteries*, *capillaries*, and *veins*.

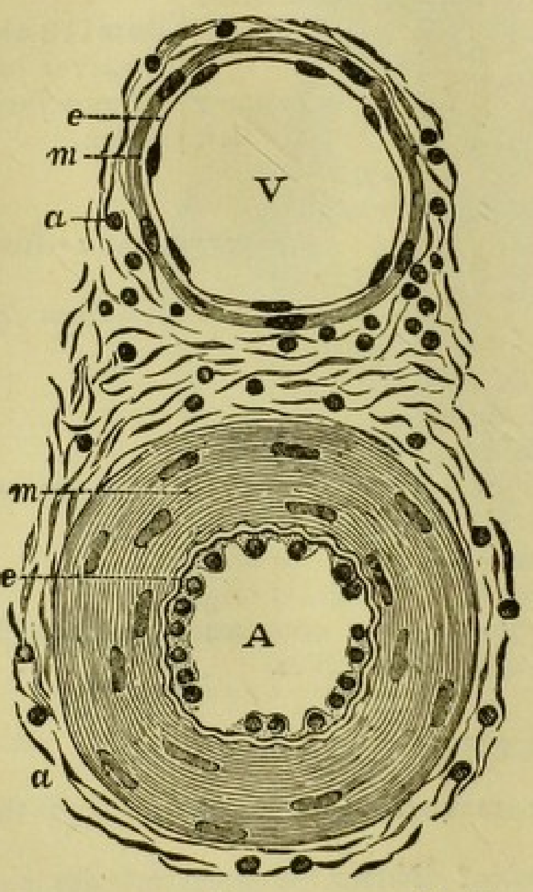


Fig. 121. — **Transverse Section through a small Artery and Vein.**

A, artery; V, vein; *e*, epithelial lining; *m*, middle muscular and elastic coat, thick in the artery, much thinner in the vein; *a*, outer coat of areolar tissue (magnified 350 diameters).

The **arteries**, as we have already learnt, have *strong*, *tough*, and *elastic walls*, and convey the blood stream *from the heart.*

These vessels have three distinct **coats**:—

1. The outer strong and tough layer of *areolar tissue*, containing *elastic fibres.*

2. The middle *muscular* and *elastic* coat. This layer is so thick in the large arteries that it forms the greater part of the wall. The muscular fibres encircle the vessels.

3. The internal coat formed of *layers of elastic tissue*, lined with a delicate layer of *epithelium.*

The **large arteries** divide into branches as they proceed from the heart, and these branches again divide and subdivide into smaller and smaller arteries, till at last they give rise to the smallest vessels — the *capillaries.*

The **capillaries** (Lat. *capillus*, a hair) are very minute vessels, having an average diameter of about $\frac{1}{3000}$ of an inch. They are generally arranged like the meshes of a network, though the form of this network varies considerably in different parts. The walls of capillaries are exceedingly thin, so that fluids very readily ooze through them, and, on this account, the changes which the blood undergoes during its circulation take place chiefly in these vessels.

After the blood has passed through the meshes of the capillaries, it is collected up by very small **veins.** These small veins unite, forming larger and larger veins, till at last they open into the great veins which take the blood direct into the auricles.

The **structure of veins** is very similar to that of arteries. Their walls are composed of the same three coats, but they are thinner, and the muscular and elastic fibres are not nearly so abundant. Hence the walls collapse when the veins are empty.

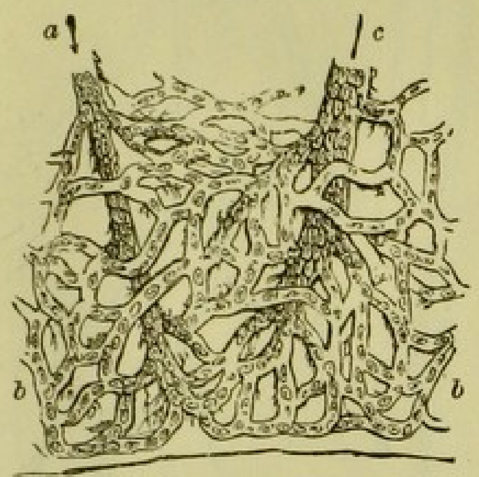


Fig. 122.—**Capillary Blood-vessels in the Web of a Frog's Foot, as seen with the microscope.**

a, small artery ; *b*, capillaries ; *c*, small vein. The arrows show the course of the blood.

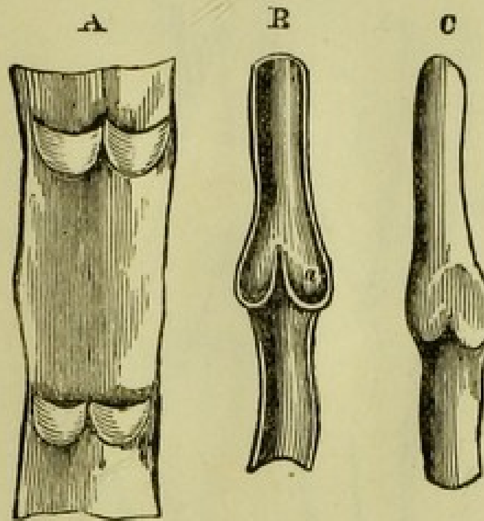


Fig. 123.—**Diagram showing the Valves of Veins.**

A, part of a vein laid open, with two pairs of valves.
B, longitudinal section of a vein, showing the valves closed.
C, portion of a distended vein, exhibiting a swelling at a pair of valves.

Most veins are also provided with **valves** like the semilunar valves of the heart, sometimes arranged at very short intervals. All these valves are situated with their free edges turned toward the heart. Hence they allow the blood to flow freely towards that organ ; but any backward tendency on the part of the blood would fill these pouch-like valves, causing them to extend across and to close the vein. In small veins the valves are sometimes single, but generally they are arranged in pairs.

Arteries are generally deeply set, while many of the larger veins are situated very near the surface of the body, so near that their direction, as shown by the bluish tint visible through the skin, may be easily traced. If we lay bare the arm, we notice several of these veins on the front surface, and by pressing the

K 2

finger along one of these in a direction opposite to the course of the blood we cause the blood to flow backward on the valves, thus filling them out, stopping the vein, causing it to swell out and present a knotted appearance.

If we thus prevent the blood from passing through one of the veins of the arm, we do not interfere with the general circulation, as the veins are connected with each other by numerous branches, and thus the blood can readily take another course ; and, the total capacity of the veins being much greater than that of the

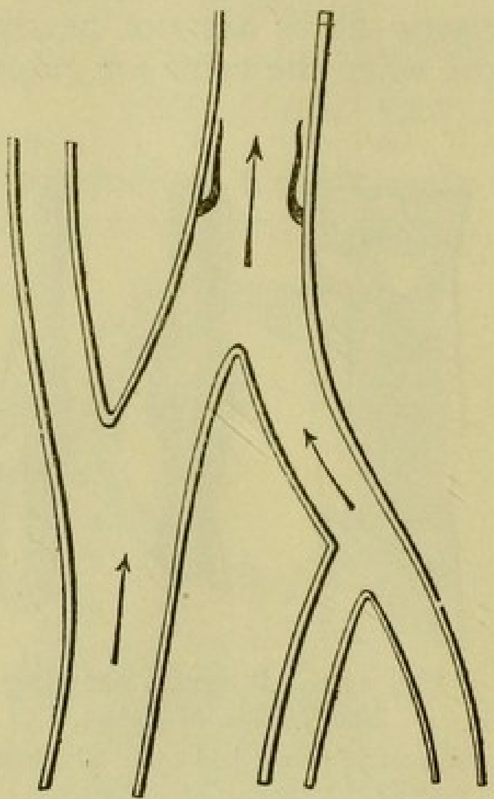


Fig. 124.—**Vein with Valves open.**

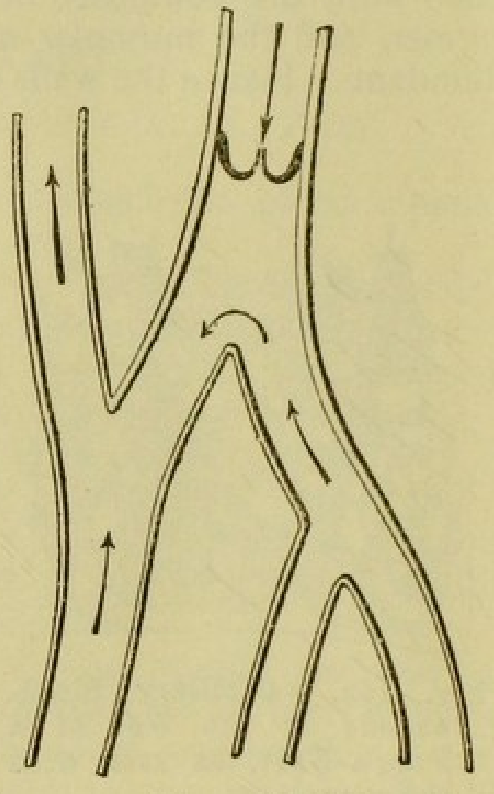


Fig. 125.—**Vein with Valves closed; the stream of blood passing off by a lateral branch.**

arteries, they are capable of conveying to the heart much more blood in a given time than they receive.

Some veins have no valves. Among these may be mentioned the *venæ cavæ*, the *pulmonary veins*, the *portal vein* which supplies the liver, the *hepatic vein* (Gr. *hepar*, the liver) which takes blood from the liver, and the *renal veins* (Lat. *renes*, kidneys) which lead from the kidneys to the vena cava inferior.

Having noticed the chief characters of the different blood-vessels, we now turn our attention to the **action of the heart**, commencing for convenience at that period immediately following the contraction of the ventricles, and during which the heart is passive. The cavities now dilate, and the blood flows freely from the *venæ cavæ* and the *pulmonary veins* into the right and left auricles respectively, and thence into the ventricles. But as the auricles receive more than passes at once into the ventricles, their walls become fully distended. They then contract simultaneously, each one forcing its contents into the ventricle below it, the force of this contraction not being sufficient to send the blood back into the great veins, where it would be resisted by the pressure of the fluid they already contain. As the ventricles fill, the cusps of the tricuspid and mitral valves float up on the surface of the blood. Now follows the simultaneous contraction of the ventricles, the effect of which is to close the valves between them and the auricles, and also to open the semilunars at the entrances of the

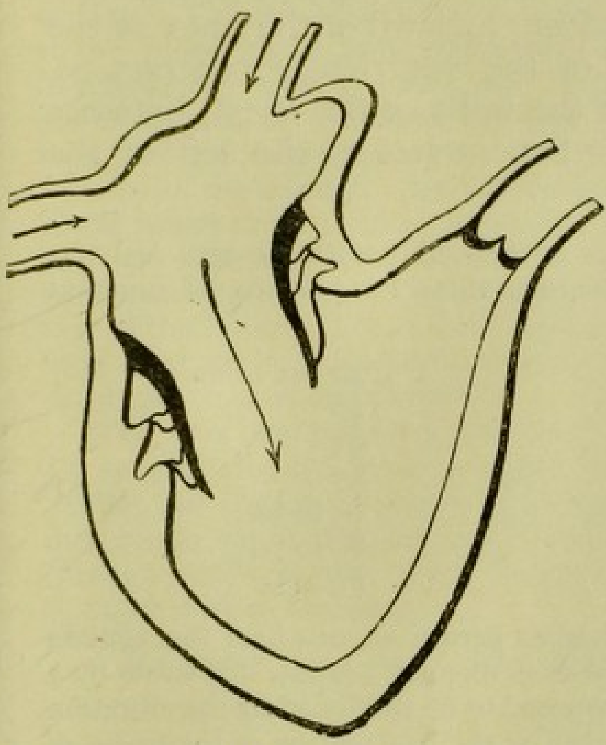


Fig. 126.—**Diagram showing the position of the Valves of the Heart while the walls are relaxed.**

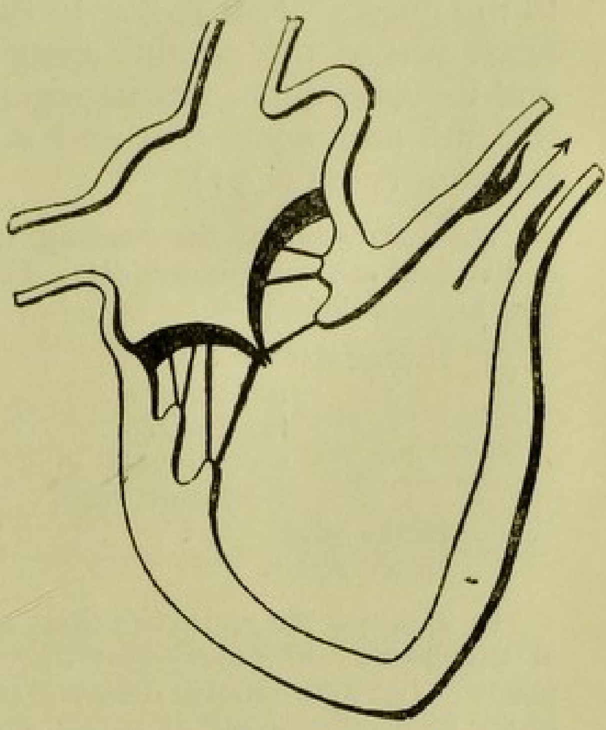


Fig. 127.—**Diagram showing the position of the Valves of the Heart during the contraction of the ventricles.**

great arteries. The cusps of the tricuspid and mitral valves are raised with such force that the chordæ tendineæ are tightly stretched, and the regurgitation of blood into the auricles is rendered impossible by the meeting of the edges of the cusps. The chief use of the tendinous cords is to prevent the valves from going too far into the auricles. It will thus be seen that when the ventricles contract there is but one course on each side open to the blood, namely, that furnished by the great arteries—the *pulmonary arteries* and the *aorta*, on the right and left respectively. These vessels are not only filled with blood, and that almost suddenly, but their walls are distended, since the blood is forced into them more rapidly than it can be received by their branches. The walls being elastic, they recoil on the blood, thus tending to force it both back into the heart, and also into the smaller arteries. But the backward pressure fills the pouches of the semilunar valves, with which the arteries on both sides are provided, thus preventing its motion in that direction ; hence we see that the elastic recoil of the arteries assists the action of the heart in propelling the blood through the system.

The whole of the action just described occupies less than one second, and at every contraction of the ventricles about three ounces of blood are forced into each of the two arterial systems.

We may feel the **beating of the heart** by applying the hand to the chest. This is due to the tilting forward of the apex of the heart just at the commencement of the ventricular contraction, and its consequent beating against the walls of the chest, between the fifth and sixth ribs, and about two inches to the left of the sternum (see fig. 77).

The **frequency of the beating** varies considerably with the age, activity, and various other circumstances. The average rates for persons of different ages are as follows :—

During the first year	120 per minute.
,, second year.	110 ,,
,, third year	95 ,,
,, seventh year	87 ,,
,, fourteenth year	85 to 80 ,,
In the adult	80 to 70 ,,
In old age	70 to 60 ,,

By applying the ear to the chest of another person we can hear the **sounds of the heart**. For every beat there are two distinct sounds, followed by a pause. The first sound is dull, and is supposed to be produced by the vibration of the tricuspid and mitral valves, and also by the contraction of the walls of the ventricles. The second sound is short and sharp, and is undoubtedly produced by the sudden closure of the semilunar valves.

The **pulse** in the arteries is due to the sudden distension of their walls immediately after each ventricular contraction. We have already noticed that the blood is forced into the aorta by a series of jerks, each corresponding with the contraction of the left ventricle. Thus a rush of blood is produced in this vessel by each contraction, and is transmitted by it into the smaller arteries. Hence, if we cut an artery, the blood always issues in jerks. But as the arterial walls are elastic, and are distended by the blood-pressure, the recoil tends to diminish the suddenness of each jerk, and, consequently, to convert the intermittent into a continuous stream. Thus, if we cut a very small artery, we notice that the jerks are prolonged considerably, so that the flow is almost continuous.

This action of the elastic walls of the arteries may be well illustrated by the following experiments:—Fasten one end of a long glass or metal tube to the stop-cock of a water pipe by means of an india-rubber tube as short as possible, and fix a small nozzle to its other end. Then turn the cock on and off alternately and rapidly, to imitate the intermittent discharges of the ventricles. The water will issue from the other end of the pipe in a series of jets, each jet ceasing the moment the water is turned off. Next, substitute a *long* india-rubber tube for the one just used, and repeat the experiment. It will now be found that a continuous stream issues from the tube. The pressure of water stretches the elastic tube, and, when the stream is turned off, the india-rubber recoils on the water, and the intermittent flow is changed into a continuous stream.

As the blood passes from the larger into the smaller arteries, and then into the capillaries, it comes in contact with a gradually increasing amount of surface. This multiplication of surface greatly increases the resistance offered to the blood by friction, which also tends to equalise the current as well as to reduce its velocity. Not only is the surface increased, but also the total sectional area of the small arteries or capillaries of any part is much greater than that of the large artery or arteries supplying that part, so much so that the velocity of the blood in the capillaries is only $\frac{1}{400}$ that in the aorta. As the blood passes onward into the veins, the velocity again increases, owing to the decrease of area, but the circulation in these vessels is less rapid than in the corresponding arteries, the capacity of the former being two or three times that of the latter. These facts explain how it is that, while the flow of blood from a cut artery is intermittent and rapid, the stream from a vein of the same size is continuous and slower.

The time required for a portion of the blood to make a complete circulation, *i.e.* to pass through arteries, capillaries, and veins, is less than one minute. Seeing that the blood passes so slowly through the capillaries this may appear incredible, but it must be remembered that each portion of the blood passes through only a very short distance of capillary tube, probably less than $\frac{1}{30}$ of an inch in any case.

We may now view the **circulation as a whole,** tracing the course of the blood from a certain point till it arrives at that same point again. The blood which has been collected from all parts by the **venæ cavæ** is poured into the **right auricle.** It then passes into the **right ventricle,** and is forced through the **pulmonary arteries** into the **lungs.** After circulating through the **capillaries of the lungs,** where it gives up carbonic acid gas and absorbs oxygen, it is collected by the **pulmonary veins,** and conveyed by them into the **left auricle,** and thence into the **left ventricle.** This ventricle contracts, forcing the blood through the **aorta** and its branches into **capillary networks in all the tissues,** excepting those few, such as the outer skin, the nails, hair, enamel of the teeth, &c., which are bloodless. It is then collected up by veins which convey it directly or indirectly into the **venæ cavæ,** thus completing a revolution.

It will thus be seen that there are two distinct circulations by which the blood can pass from one side of the heart to the other. One is called the **pulmonary circulation,** by which it passes from the right side to the left by means of the vessels of the lungs. The other is the **systemic circulation**, or the circulation generally through the whole system, commencing at the left ventricle, and terminating at the right auricle.

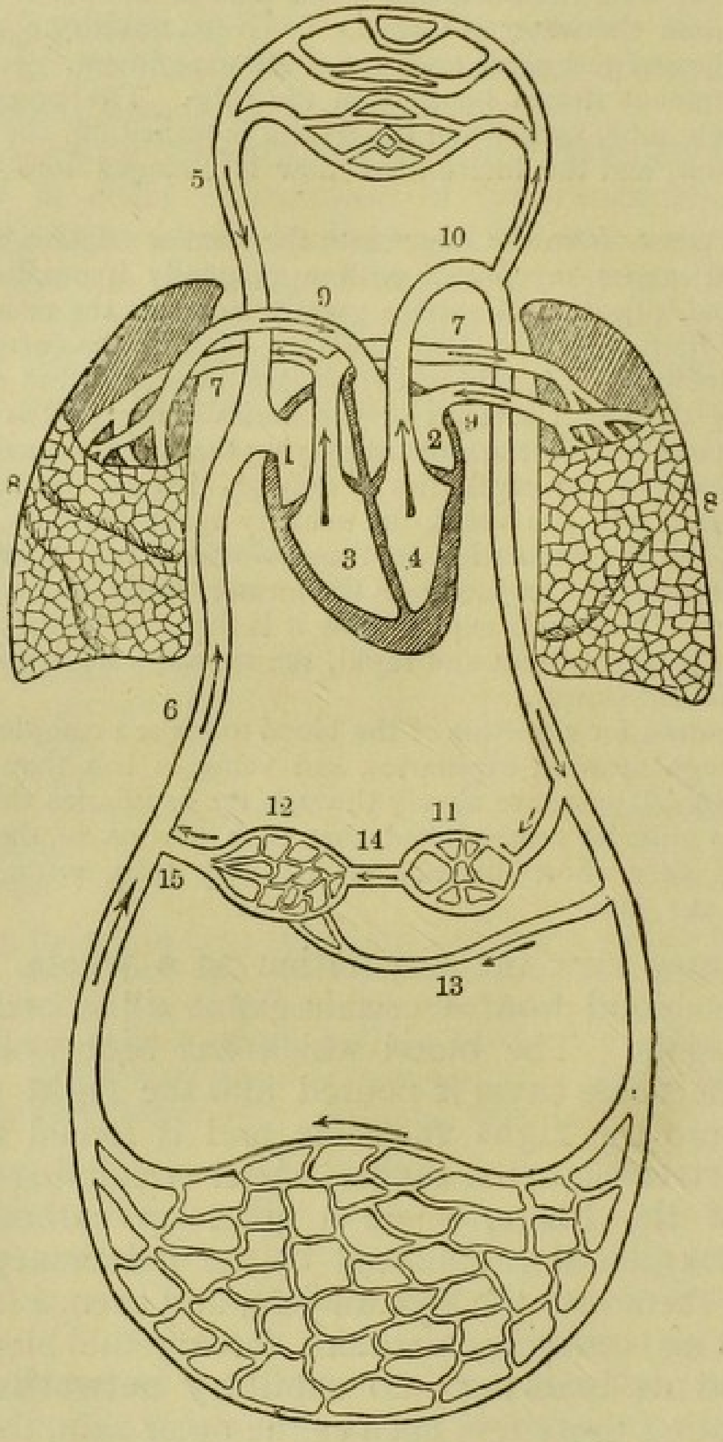


Fig. 128.—**Diagram illustrating the Circulation.**

1, right auricle; 2, left auricle; 3, right ventricle; 4, left ventricle; 5, vena cava superior; 6, vena cava inferior; 7, pulmonary arteries; 8, lungs; 9, pulmonary veins; 10, aorta; 11, alimentary canal; 12, liver; 13, hepatic artery; 14, portal vein; 15, hepatic vein.

The **pulmonary circulation** (Lat. *pulmo*, a lung) is not nearly so extensive as the systemic, and less force is therefore needed to

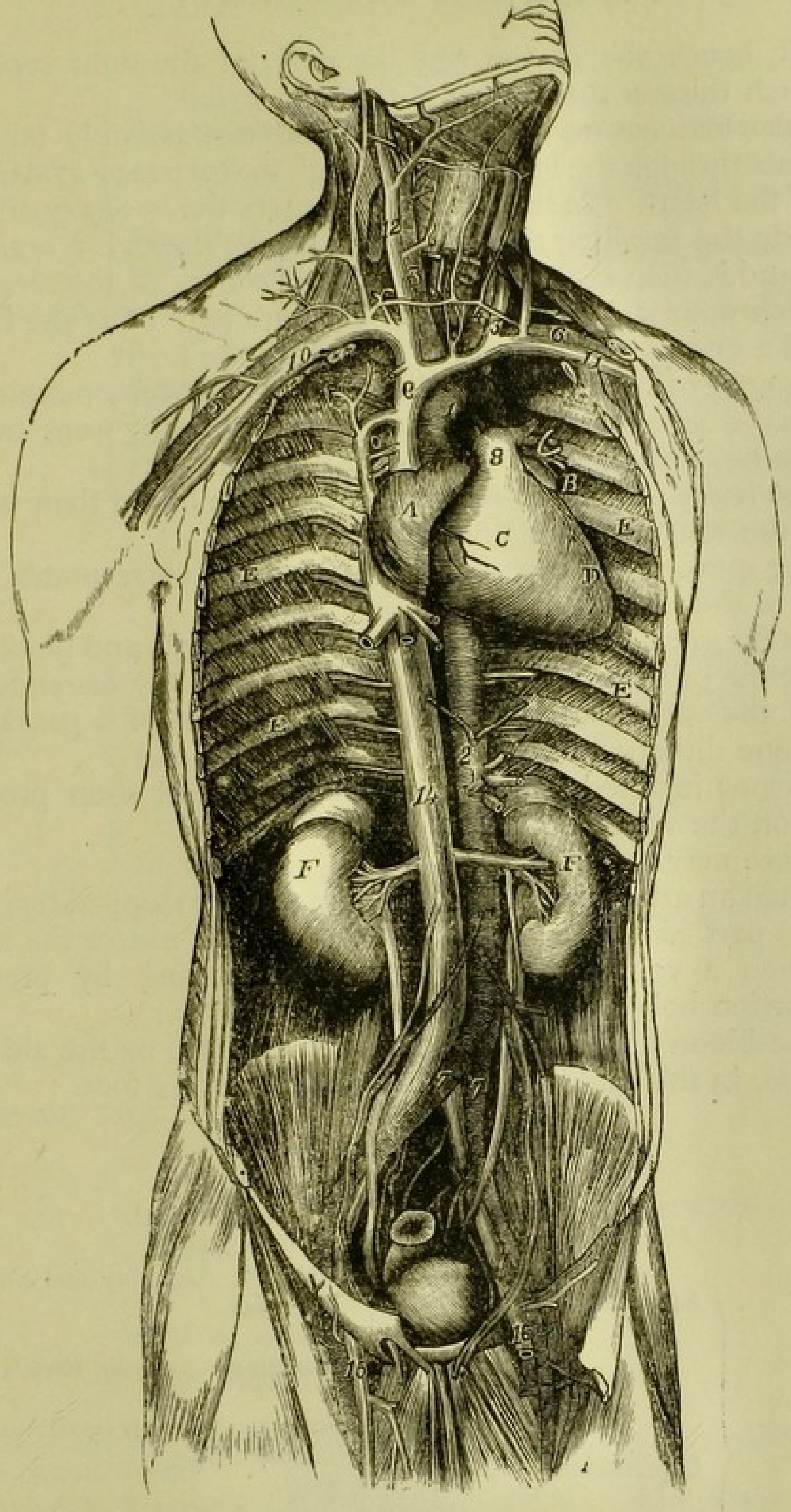


Fig. 129.—**General View of the Heart and Great Blood-vessels of the Trunk.**

A, right auricle; B, left auricle; C, right ventricle; D, left ventricle; E, ribs; F, kidneys; 1, arch of the aorta; 2, descending aorta; 3 and 4, right and left carotid arteries; 5 and 6, right and left subclavian arteries; 7, arteries supplying the lower extremities; 8, pulmonary artery; 9, vena cava superior; 10 and 11, right and left subclavian veins; 12 and 13, right and left jugular veins; 14, vena cava inferior; 15 and 16, veins which collect blood from the lower extremities.

produce it, hence the reason why the walls of the right ventricle are so much thinner than those of the left.

The **shortest course** which the blood can possibly take is, however, not through the lungs, but through the **coronary system,** or system of the heart. In this instance it enters the *coronary arteries* just outside the semilunars of the aorta, passes through a *capillary network*, and is then collected up by the branches of the *coronary veins*, which pour it direct into the right auricle. Thus the blood completes a circulation without ever leaving the heart.

The course of the blood in the body was first demonstrated by Harvey in the seventeenth century, and the following were among the **proofs** he gave as the results of his experiments :—

1. The heart propels in half an hour more blood than would make up the weight of the whole body.
2. The spurting of blood from the arteries corresponds with the beats of the heart.
3. Tie the great veins and the heart becomes pale and bloodless.
4. Tie the great arteries, and the heart is unduly distended.
5. All the valves are so arranged as to allow of a passage of blood in one direction only.
6. Poisons injected into a single blood-vessel soon produce an effect on the whole body.

To these may also be added—

7. When an artery is cut, the bleeding may be stopped by pressing on the part *above* the wound, *i.e.* on the side nearer the heart.
8. When a vein is cut, we stop the bleeding by pressing on the portion below the wound.
9. The blood may actually be seen in motion, by the aid of a microscope, in the capillaries of the web of a frog's foot.

SUMMARY.

BLOOD-VESSELS

- **Arteries**
  - Take blood *from* the heart.
  - *Coats*
    - 1. Outer *areolar*.
    - 2. Middle *muscular* and *elastic*—thick.
    - 3. Inner *epithelial*.
  - Assist in propelling blood by their elastic recoil.
- **Capillaries**
  - Connect small arteries with small veins.
  - Arranged like *networks*.
  - Very *thin walls*.
  - *Diameter* about $\frac{1}{3000}$ inch.
- **Veins**
  - Convey blood *to* the heart.
  - *Coats*—same as in arteries, but less muscular and elastic tissue.
  - Generally provided with *valves*—like the *semilunars*.

ACTION OF THE HEART	**Auricular Contraction**	Simultaneous. Blood forced into *ventricles*. Force not sufficient to cause regurgitation into the veins.
	Ventricular Contraction	Valves between the auricles and ventricles closed. *Chordæ tendineæ* tightly stretched. *Semilunars* forced open. Blood forced into the great arteries.
	Beating . .	Apex of heart tilted forward against the front wall of the chest. From 60 (old age) to 120 (young child) per minute.
	Sounds . .	*Dull sound*—closure of *tricuspid* and *mitral valves*, and contraction of *ventricles* (?). *Sharp sound*—sudden closure of *semilunars*. Followed by a *pause*.

CIRCULATION	**In arteries** .	In jerks (*pulsations*). Very rapid. Elastic recoil tends to produce a continuous stream in the smaller arteries.
	In capillaries	Very slow and uniform. Great resistance offered by the capillary walls.
	In veins . .	Much faster than in capillaries. Not so rapid as in arteries. Steady flow. Valves prevent backward flow.

COURSE OF THE BLOOD	Right auricle Right ventricle Pulmonary arteries Lungs (capillary system) Pulmonary veins Left auricle	**Pulmonary circulation.**
	Left ventricle Aorta Capillary networks in all parts Venæ cavæ. Right auricle.	**Systemic circulation.**

QUESTIONS ON LESSON XXIII.

1. How would you distinguish between arteries and veins? Describe the structure of each.
2. What are capillaries? Where are they found? What is the size of a capillary?
3. What is the use of valves in veins? How are these valves constructed?
4. Name arteries that have valves, and veins that have no valves.
5. How would you determine the positions of the valves in the veins of your own arm?
6. Describe fully the action of the heart and its valves.

7. Describe the condition of the heart and its valves (1) just before the contraction of the ventricles, and (2) just after this contraction.
8. What is the use of the *chordæ tendineæ*?
9. Describe fully the action of the *semilunar valves*. When are they shut, and when open? What shuts them?
10. What do you mean by the beating of the heart? At what rate does the heart beat?
11. Describe the sounds of the heart. How are they produced?
12. What is the pulse? What causes the pulsation of blood in the arteries? Why is there no pulsation in the capillaries and the veins?
13. How does the blood flow from (1) a cut artery, and (2) a cut vein?
14. Describe the course of the blood as it passes from the right to the left side of the heart; and also as it flows from the left to the right side.
15. What is the shortest course the blood can take?
16. Give proofs that the blood circulates.

LESSON XXIV.

THE TRACHEA AND LUNGS.

THE **trachea** consists of a series of cartilaginous hoops, shaped like the letter C, and arranged so as to be complete before and deficient behind. These rings are surrounded externally by fibrous connective tissue, which also joins their extremities, thus completing the tube behind; it also fills in the spaces between the rings. It will thus be seen that the trachea is a resistant and elastic tube, which, though always open for the passage of air, will yield with the bending of the neck, and will also allow of the distension of the œsophagus, which lies against its posterior portion where the cartilage is absent.

The two upper cartilaginous rings, which are much larger than the others, form the framework of the **larynx**. The first, called the **thyroid cartilage** (Gr. *thureos*, a shield; and *eidos*, form), is very wide in front, forming the prominence known as Adam's apple, but is open behind, and is connected by means of ligaments and muscles with a small U-shaped bone, the **hyoid bone** (Gr. letter *υ*; and *eidos*, form), situated just above it. The second cartilage is the only *complete ring* in the windpipe. It is called the **cricoid cartilage** (Gr. *krikos*, ring; and *eidos*, form). Its broadest portion is behind, while in front it is so narrow that a space is left between it and the first, this space being occupied by the fibrous tissue. Of course, this second ring will not so freely admit of the distension of the œsophagus behind it, and this will account for the sharp pain we experience in the upper part of the throat when we swallow a large and hard substance, such as a solid piece of food which has not been properly masticated.

The **bronchi** resemble the trachea in general structure, being composed of similar rings of cartilage and fibrous tissue. The cartilages, too, are incomplete behind.

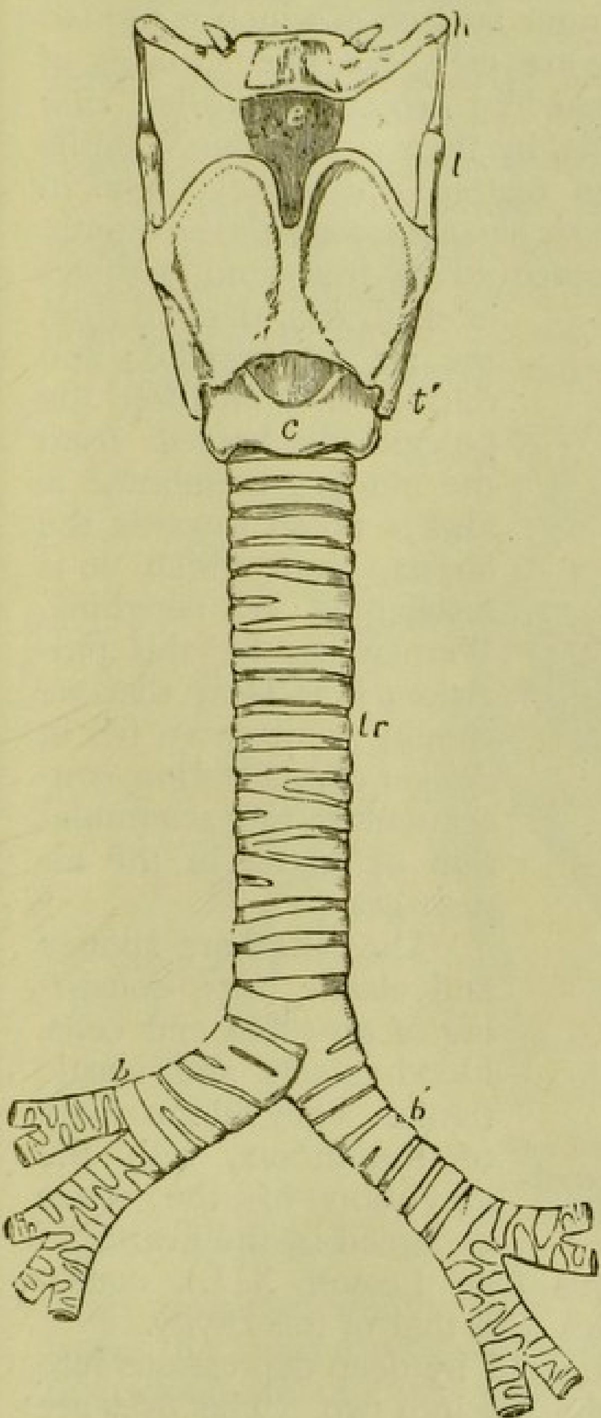


Fig. 130.—**The Trachea. Front.**

h, hyoid bone ; *tt′*, thyroid cartilage ; *c*, cricoid ; *e*, epiglottis ; *tr*, trachea ; *b* and *b′*, bronchi.

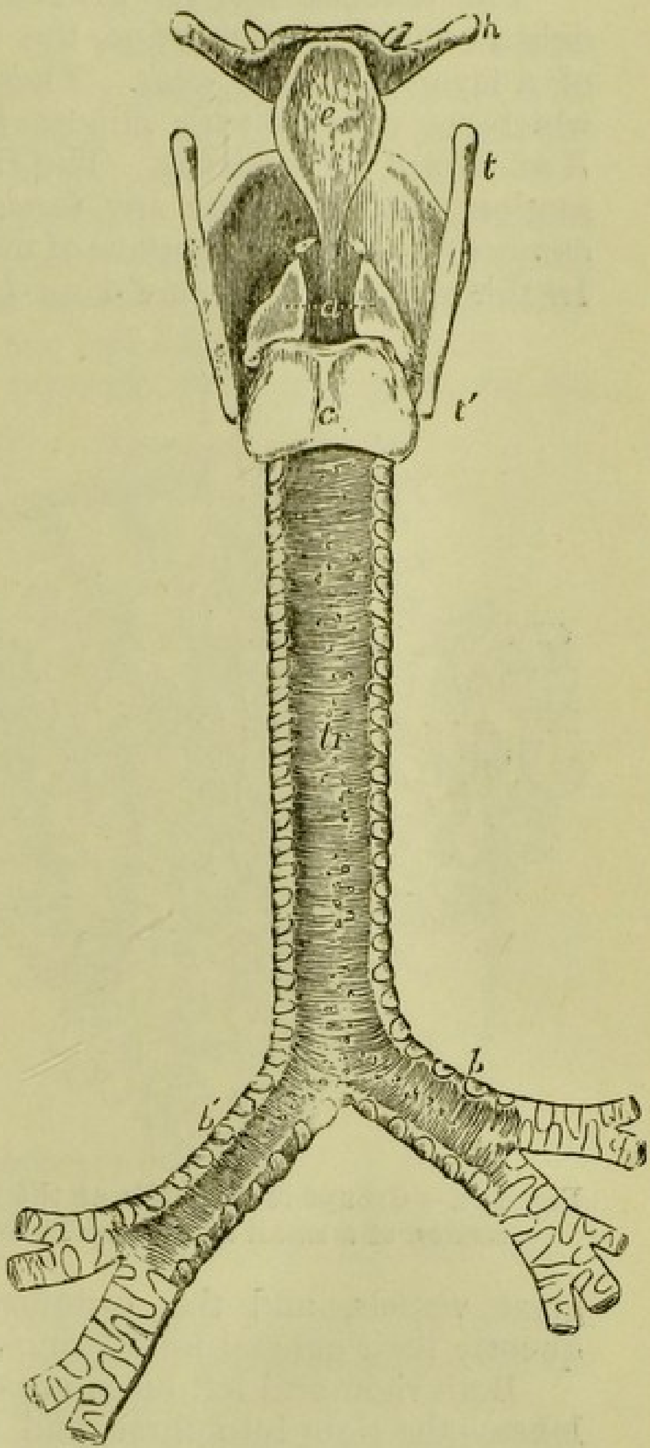


Fig. 131.—**The Trachea. Back.**

a, arytenoid cartilages ; *h*, hyoid bone ; *tt′*, thyroid cartilage ; *c*, cricoid ; *e*, epiglottis ; *tr*, trachea ; *b* and *b′*, bronchi.

The bronchi subdivide into smaller and smaller tubes, called the **bronchial tubes**, which penetrate every part of the lungs, and finally terminate in groups of **air-cells**. In the bronchial tubes the rings of cartilage are incomplete, and become more and more so as thet ubes subdivide into smaller branches, till in the smallest divisions they disappear altogether.

The **trachea and its branches** are all lined internally by a delicate **mucous membrane**, the inner surface of which is formed of a layer of *ciliated cells*. These are cells, the free surfaces of which are covered with minute hair-like projections called *cilia* (Lat. *cilium*, an eyelash). The cilia, by their continuous vibratile motion, tend to move any foreign matter, which may come in contact with the inner surface of the air passages, towards the mouth. In this way the lungs are kept comparatively free from particles of dust, &c., derived from the air we breathe; and during inflammation the phlegm discharged from the mucous membrane is always urged towards the larynx, from which it is discharged by coughing. Were it not for this provision, it is clear that we should constantly be in danger of suffocation, consequent on the accumulation of matter in the air passages.

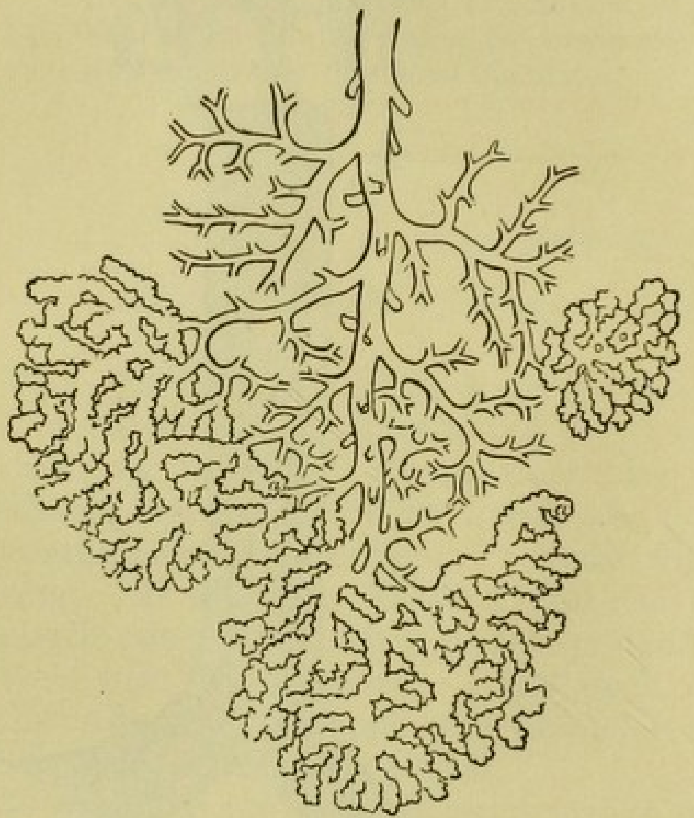


Fig. 132.—**Groups of Air-cells at the termination of a small Bronchial Tube.**

The **lungs** are spongy and elastic bags, consisting of air-tubes and cells, blood-vessels and elastic tissue. They fill the cavity of the thorax, with the exception of the space occupied by the heart, the great vessels, and the œsophagus (see Lesson XII.), consequently their general form coincides with that of this cavity.

Both right and left lungs are divided by deep depress ons into **lobes**—the right into three, and the left into two. The *lobes* are again divided by lesser depressions into **lobules** (see fig. 7). Each lobule is a miniature representation of the whole lung, being supplied with its own systems of air-tubes and blood-vessels.

The **lungs** are supplied with dark *venous* blood by means of the **pulmonary arteries** which proceed from the **right ventricle.** These arteries divide and subdivide into smaller and smaller branches, penetrating every portion of the organs, till at last they form **capillary networks** which surround and lie on the walls of the **air-cells.** These walls of the air-cells are extremely thin, as are also the walls of the capillary vessels, and thus the blood is brought almost in contact with the inspired air.

It is in these capillaries that the **venous blood becomes converted into bright arterial blood**, by exchanging carbonic acid gas collected in the tissues of all parts of the body for oxygen gas absorbed from the air contained in the air-cells.

The blood thus changed is collected by small veins, formed by the union of the capillaries ; and these veins unite, forming larger veins, ultimately giving rise to the **pulmonary veins**, which pour their contents directly into the **left auricle** of the heart.

Although we are continually expiring and inspiring air, yet the

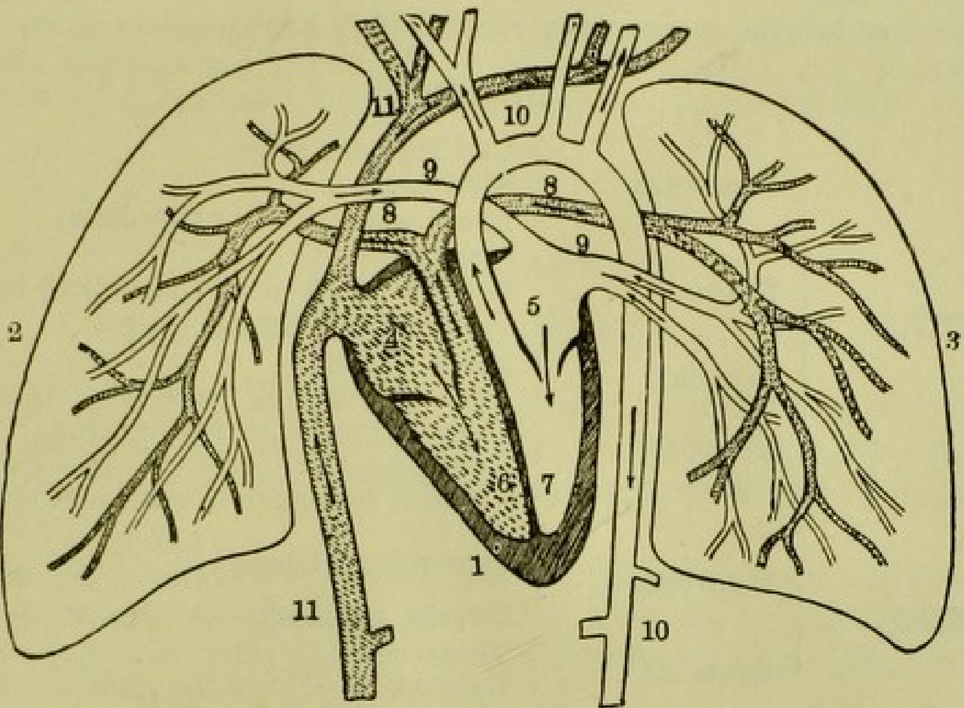


Fig. 133.—**The Pulmonary Circulation.**

1, heart ; 2, right lung ; 3, left lung ; 4, right auricle ; 5, left auricle ; 6, right ventricle ; 7, left ventricle ; 8, pulmonary arteries ; 9, pulmonary veins ; 10, aorta ; 11, venæ cavæ. The arrows indicate the direction of the blood-stream. The shading represents venous blood.

lungs are never empty—in fact, the amount of air which enters and leaves the lungs during ordinary breathing is small compared with that which remains after each expiration.

The air which passes in and out of the lungs in ordinary quiet breathing is called the **tidal air**, and amounts to from 20 to 30 cubic inches in an adult person. After each *expiration*, however, about 200 cubic inches still remain in the lungs, this being termed the **stationary air.** By making a very deep expiration we can expel about a half of this (the **supplemental air**), and the lungs then contain about 100 inches of **residual air** which cannot be expelled.

From the above statements we learn that the lungs contain about 230 cubic inches after an ordinary *inspiration*; that is, the 200 inches of stationary air, together with the 30 inches of tidal air. By taking a very deep inspiration we can add about 100 inches to this, bringing the total up to 330 cubic inches, thus inflating the lungs to their full capacity. The term **complemental air** has been applied to the 100 inches added by the deep inspiratory effort.

An adult person at rest breathes about fifteen times a minute; and, knowing this, we can easily calculate the total quantity of air inspired and expired in a given time. For example, in twenty-four hours this would amount to

$$30 \times 15 \times 60 \times 24 = 648,000 \text{ c. ins., or } 375 \text{ c. ft.}$$

This quantity, however, is largely increased, and may be more than doubled, by physical exertion.

Children breathe much more rapidly than adults—about thirty times a minute.

SUMMARY.

TRACHEA	**Structure**	Cartilaginous rings. Fibrous tissue. Lined with ciliated *epithelium.*
	Rings	C-shaped. Complete in front. Incomplete behind. Connected by fibrous tissue.
	Bronchi	Right and left. In structure similar to *trachea.*
	Bronchial tubes	Rings of cartilage very imperfect. Cartilage disappears in smallest tubes, which terminate in groups of air-cells.
LARYNX	**Two rings**	**Thyroid cartilage** — Large. Incomplete behind. **Cricoid cartilage**—A complete ring.
	Contains	**Vocal cords.** **Epiglottis**—Closes the *glottis.*
LUNGS	**Right**	Three *lobes.*
	Left	Two *lobes.*
	Vessels	**Air-vessels**— *Bronchial tubes* and *cells.* **Blood-vessels** — *Pulmonary arteries. Capillaries. Pulmonary veins.*

AIR IN LUNGS (cubic inches)

After ordinary expiration.	200 *stationary* — 100 *residual*—never expelled. 100 *supplemental.*	
After deep expiration	100 *residual.*	
After ordinary inspiration	100 *residual*, 100 *supplemental* } *stationary*; 30 *tidal* or *breathing air*	230.
After deep inspiration	100 *residual* 100 *supplemental* 30 *tidal* 100 *complemental*	330.

QUESTIONS ON LESSON XXIV.

1. Describe the general form, size, position, and structure of the *trachea*.
2. How does the structure of the trachea differ from that of the œsophagus?
3. Describe the general form and structure of the *larynx*.
4. How do the smallest branches of the trachea terminate in the lungs?
5. What provision is made for the discharge of any foreign matter that may find its way into the air-passages?
6. Describe the general form and position of the lungs. How does the right lung differ from the left?
7. Describe the manner in which the blood circulates in the lungs. Name the vessels concerned in this circulation?
8. Where does *arterial* blood become *venous*, and where does *venous* blood become *arterial*?
9. How does the blood which leaves the lungs differ from that which enters them?
10. How much air enters and leaves the lungs at each breath? To what extent may this quantity vary? What is the greatest, and what is the least quantity of air which the lungs may contain during life?

LESSON XXV.

WHY WE BREATHE—VENTILATION.

In Lesson XV. we learnt that all living tissues were constantly wasting away, and that not only was it necessary that they should be repaired, but also that the waste substances should be removed from the system.

Now, the lungs are included among those organs which remove waste matter, but we have to learn that they are at the same time sources of gain as well as of loss to the system, or at least to the blood.

We have noticed that arterial blood becomes venous in the capillaries of the tissues of most parts. This is due to the fact that some of its oxygen has united with carbon and hydrogen of the waste matters, forming carbonic acid gas and water. The oxygen supply was obtained from the air-cells of the lungs, and was conveyed to all parts by the blood stream.

Life could not be maintained for even a short time without this chemical combination, for not only is it a great source of heat, by which the high temperature (99° F.) of the body is maintained, but is also a means by which waste organic matter is converted into simpler compounds (*carbonic acid gas*, *water*, and *urea*) previous to removal.

Thus the lungs are a source of gain to the blood; and the oxygen imported by these organs is utilised in converting waste or dead animal matters into substances which can readily be taken up by the blood and transported by that fluid to those organs which are destined to remove them.

When the dark venous blood reaches the capillaries which surround the air-cells of the lungs, it is immediately changed in colour, becoming bright scarlet. Carbonic acid gas passes through the thin layer of membrane which separates the air from the blood, and oxygen gas passes from the air into the blood. We see, then, that the lungs do not *prepare* carbonic acid gas, but simply serve as a means by which this gas, brought by the blood, is separated from the system.

The readiness with which the diffusion of gases may take place through moist membranes may be illustrated as follows:—Fill a bladder with venous blood, and suspend it in a jar of oxygen. The oxygen will be absorbed, and the blood will soon acquire the properties of arterial blood. Again, suspend a bladder of arterial blood in a jar of carbonic acid gas, and the blood will soon become venous.

The extent to which these changes take place in the body may be judged by comparing expired with inspired air. The latter contains about 79 per cent. of nitrogen, 21 per cent. of oxygen, with only about ·04 per cent. of carbonic acid gas, and a variable proportion of water vapour; while the expired air contains about 5 per cent. *more* carbonic acid gas, 5 per cent. *less* oxygen, and an increased proportion of water vapour, the nitrogen remaining the same.

It follows from this, that if a person were to shut himself up in a room without any means of ventilation whatever, the air he breathed would gradually lose its oxygen, and gain a corresponding proportion of carbonic acid gas. When one or two per cent. of the oxygen had thus been removed, a feeling of general uneasiness would arise, accompanied by headache; and as the loss increased, there would not be sufficient oxygen in the inspired air to change the colour of the blood. This would certainly be the case when the loss of oxygen and the gain of carbonic acid gas rose to ten per cent. The blood would then be venous throughout the system. Carbonic acid gas, which is in itself slightly poisonous, would saturate the blood; and this, together with the oxygen starvation, would speedily cause death from **asphyxia** (Gr. *a*, without; and *sphuzo*, I throb—cessation of pulse, caused by suffocation).

It is probable that in this case death would be caused by the deprivation of oxygen rather than by the poisonous effects of carbonic acid gas, for it has been proved that air containing 10 or 15 per cent. of this gas produces no immediate effect on the animal system providing the supply of oxygen be proportionately increased.

When an animal is strangled, choked, or drowned, the same disease (asphyxia) ensues. In these cases no oxygen can enter the blood, while the carbonic acid gas is fast accumulating by the oxidation of the tissues, and soon saturates the blood, all of which rapidly becomes venous. The occurrence of death in a few minutes shows the importance of oxygen gas in the renewing of the blood.

We have now learnt the necessity of ventilating our rooms—that is, of allowing for the removal of the expired air, and for the access of pure air from the outside atmosphere to take its place.

QUESTIONS ON LESSON XXV.

1. What changes take place in blood as it passes (1) through the capillaries of the lungs, and (2) through the capillaries of the muscles?
2. What is the temperature of the blood? How is this temperature maintained?
3. What is the difference between inspired and expired air?
4. What is asphyxia? How is it caused?
5. What is the direct cause of death when an animal is strangled?
6. How is it that a person turns black in the face when he is choked?
7. If a number of people were shut up in a close room without any ventilation, what changes would the atmosphere undergo? What would be the probable condition of the atmosphere (1) when the people began to complain, and (2) when they began to die?
8. What is meant by oxidation? How do we know that oxidation is always going on in the body?

LESSON XXVI.

HOW WE BREATHE.

BEFORE we go on to describe the manner in which the air is caused to enter and leave the lungs, it will be desirable to recall a few particulars concerning the structure of the chest and the lungs.

The **walls of the chest** are formed by the *back bone* behind, the *breast bone* or *sternum* in front, the *ribs* with their *intercostal muscles* around the sides, and the membranous and muscular *diaphragm* below. The heads of the ribs form *movable joints* with the dorsal vertebræ, and the other ends of the ribs are connected in front with the sternum by the flexible *costal cartilages*. The lungs fill the greater part of the conical cavity of the thorax—all excepting the small portion occupied by the *lower trachea*, the *œsophagus*, and the *heart* with its *great vessels*. They are enclosed in a double membrane—the *pleura*—one layer of which is firmly attached to the outer surface of the organs, while the other lines the cavity of the chest, being closely adherent to its walls.

Thus the chest is an air-tight cavity, having no *direct* communication with the atmosphere ; while the lungs may be considered as bags filling this cavity, being themselves filled out with air which enters through the trachea.

Although in fig. 78 a space is represented between the two layers of the pleura, this is not actually the case, the space being inserted only for the sake of distinctness : the two layers of the pleura are practically in contact with each other, there being nothing between them save a very little watery fluid (*serum*) which is secreted by the membrane, and only sufficient of this to allow of a free gliding motion during the respiratory movements of the chest and lungs. Such a secreting closed sac is called a *serous membrane.*

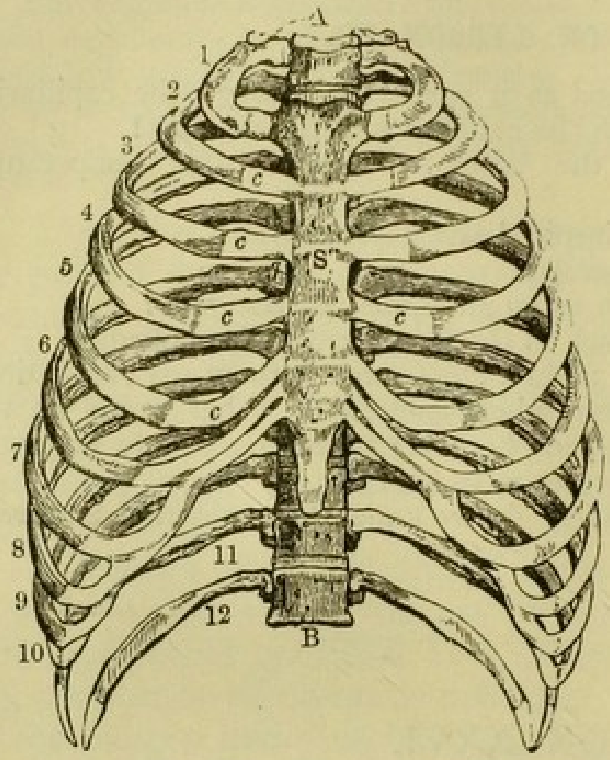


Fig. 134.—**The Framework of the Chest.**

A, first dorsal vertebra ; B, last (12th) dorsal vertebra ; 1 to 12, ribs ; S, sternum ; C, costal cartilages.

If a hole be made in the walls of the chest, the lungs immediately collapse, becoming considerably smaller; and while the chest is thus perforated breathing is very difficult, or, if the opening is large, quite impossible. It is the natural elasticity of the lungs which causes them to shrink away from the walls of the chest ; hence it must be that in their normal condition they are stretched by some force which is able to overcome this elasticity.

Respiration is the result of the alternate expansion and contraction of the walls of the chest. In **inspiration** (Lat. *in*, and *spiro*, I breathe) we enlarge the chest by means of certain muscles, and so tend to produce a vacuum (an empty space) between the lungs and the chest ; and, as a natural result, air rushes in through the trachea, thus causing the lungs to expand with the chest. When these muscles cease to contract, the elasticity of the lungs causes those organs to return to their former volume. The walls of the chest follow the lungs, and the air taken in is expelled again. This is the act of **respiration** (Lat. *re*, again ; and *spiro*, I breathe).

Fit up an apparatus as represented in fig. 135, in which A is a stout glass tube, provided with a sound cork, B, and also an airtight piston, C, resembling that of an ordinary syringe. A short tube, D, passing through the cork, has a small india-rubber bag tied to it. Fit the cork in the tube while the piston is near the top. Now, by lowering the piston we increase the capacity of the cavity containing the bag. The pressure outside the bag is thus lowered, and air rushes into it through the tube D till a balance is restored. The bag is thus stretched. As soon as we let go the piston, the elasticity of the bag, being free to act, drives out the air just taken in, and the piston returns to its former place. It will be noticed that in this experiment the elastic bag and its tube represent the lungs and trachea ; and the vessel enclosing it, the thorax. If while the bag is inflated a hole be made through the cork into the tube, air rushes in, and the bag collapses, thus illustrating the effect of piercing a hole in the walls of the chest.

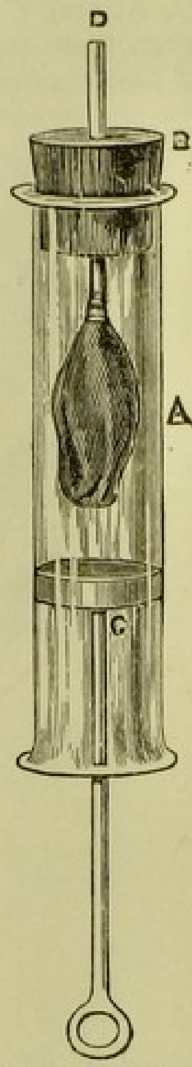


Fig. 135.—**Apparatus for illustrating the Movements of Respiration.**

We have now to study the mechanism by which the chest is made to contract and expand.

Inspiration is a muscular act by which the cavity of the chest is *widened* and *deepened*. The latter result is brought about by the contraction of the **diaphragm**, which causes it to become less arched. This contraction would also make the chest narrower by exerting a pulling force on its side walls to which the diaphragm is attached, but this is prevented by the action of the intercostal muscles.

The **intercostal muscles** connect the adjacent ribs throughout their length. They consist of two thin layers of oblique muscular fibres which occupy the spaces between the ribs. These layers are termed respectively the *internal* and *external*. The **internal intercostal muscles** pass obliquely *downwards* and *backwards* from the lower margin of one rib to the upper margin of the next. The **external intercostal muscles** incline *downwards* and *forwards*, and are much stronger than the internal. The ribs also are inclined considerably downwards and forwards ; and as the intercostal fibres are placed obliquely with regard to the ribs, when they contract they tend to arrange themselves at right angles with these bones, and in doing so the ribs are either raised or depressed. The **external intercostal muscles** *raise* the ribs, widening the cavity of the chest, and thus assisting *inspiration*.

The **internal intercostal muscles** *depress* the ribs, thus making the chest narrower and assisting *expiration*.

The student may construct for himself the simple apparatus illustrated in figs. 137, 138, and 139, which will at once make clear the action of the **intercostal muscles**. A B is an upright bar of wood which represents the *spine*. With this are jointed two parallel bars, C D and E F, which represent two of the *ribs*. Another bar, D F, represents the *sternum*. The joints at C, D, E, and F are all movable. An elastic band is now stretched obliquely between these parallel bars thus representing the intercostal muscles. If the band passes *downwards* and *backwards* (*i.e.* towards the spine) as in fig. 138,

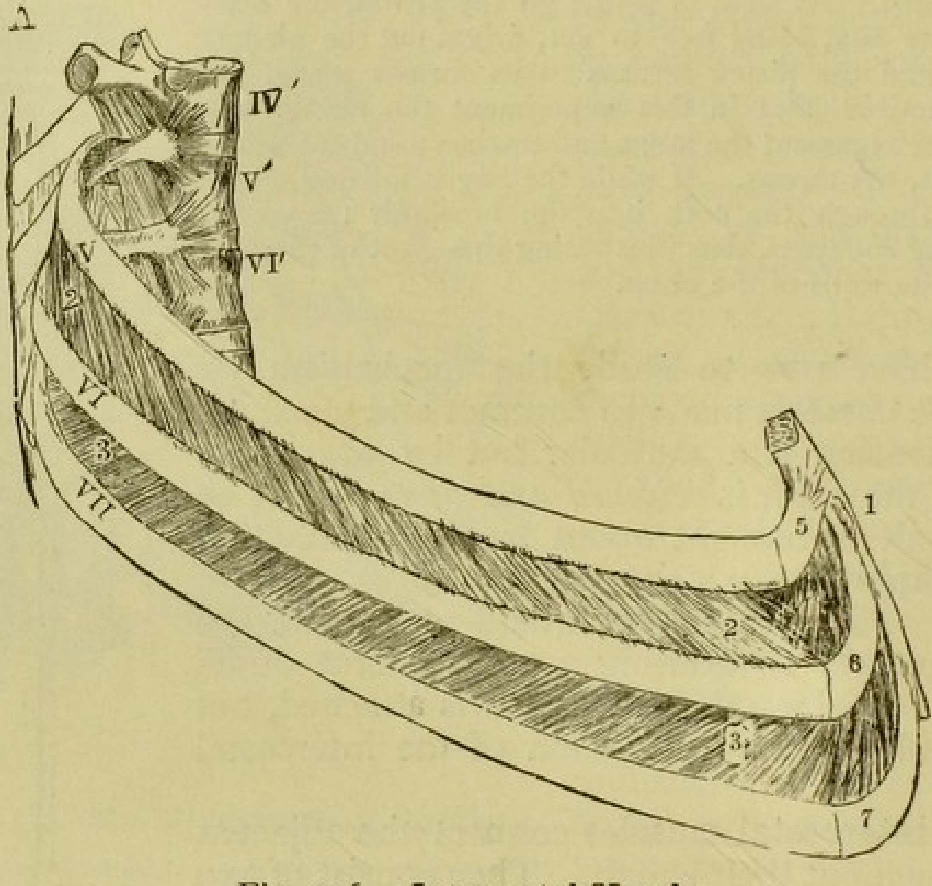


Fig. 136.—**Intercostal Muscles.**

IV′, V′, and VI′, 4th, 5th, and 6th dorsal vertebræ; V, VI, and VII, 5th, 6th, and 7th ribs; 5, 6, and 7, 5th, 6th, and 7th costal cartilages; 1, sternum; 2, external intercostal muscles; 3, internal intercostal muscles, the external layer having been removed.

it represents the *internal* intercostals. As it contracts it tends to bring its two ends as near together as possible, and in doing this it pulls down the bars representing the ribs. By stretching the band *downwards* and *forwards*, as in fig. 139, we illustrate the action of the *external* intercostals, which by their contraction raise the ribs.

We are now better able to understand the **respiratory movements**, which may be briefly described as follows :—

During **inspiration** the **diaphragm descends**, making the chest *deeper* ; and the **external intercostals contract**, thus raising the ribs and making the chest *wider*. The capacity of the chest being thus enlarged, the lungs are inflated as before described.

In **tranquil breathing** the *inspiration* of air is effected chiefly by the *diaphragm* in men, while in forced inspiration the intercostals play a very important part. In women the diaphragm does not play so important a part as the ribs.

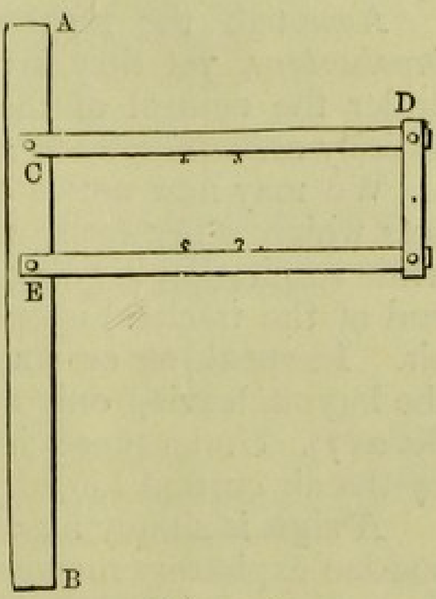


Fig. 137.

As the ribs are raised during inspiration, the sternum will of course rise with them. This movement may be noticed by laying the hand on the front of the chest while taking a deep inspiration. Again, when the diaphragm moves, the organs of the abdomen must follow its movements, and this causes a visible motion of the walls of the abdomen. Hence respiration which is effected chiefly by the diaphragm is often termed **abdominal respiration,** while that produced chiefly by movements of the side walls of the chest is called **costal** respiration.

After the lungs have been inflated by the inspired air they are stretched considerably, and their **elasticity** is sufficient in

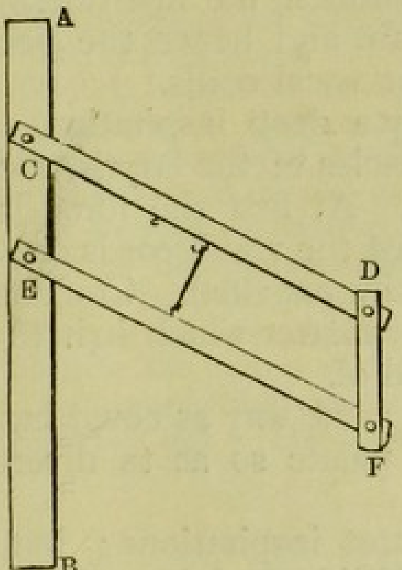


Fig. 138. — **Illustrating the Action of the Internal Intercostals.**

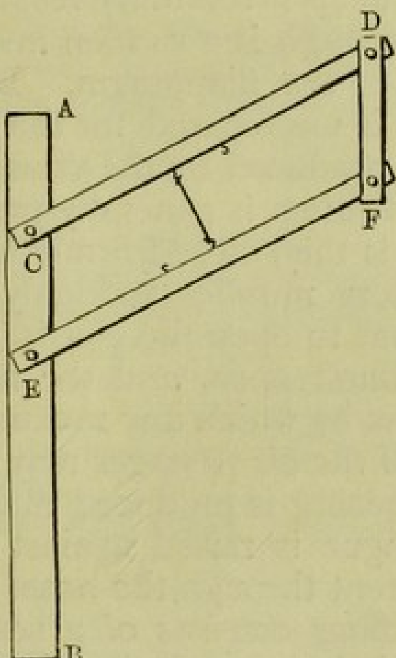


Fig. 139. — **Illustrating the Action of the External Intercostals.**

quiet breathing to expel the air without the aid of any muscles. But in a **forced expiration** the **internal intercostals** are brought into play, and also the **muscles of the abdomen**, which latter act on the organs of the abdomen, thus exerting indirectly an upward pressure on the diaphragm.

Although the **respiratory movements** are generally purely *involuntary*, yet they are brought about by muscles which are under the control of the *will* ; and are sometimes partially or entirely *voluntary*, as in speaking, singing, and blowing.

We may now notice some of the more important respiratory acts which differ from ordinary breathing. Generally speaking, while respiration is going on, the *glottis* (the aperture at the upper end of the trachea) is open so as to allow a free passage to the air. In **speaking** or **singing** the *vocal cords* are stretched across the larynx, leaving only a narrow space for the passage of air (see fig. 217). Under these circumstances the cords are made to vibrate by the air current forced between them, thus producing the voice.

A **sigh** is simply a prolonged inspiration, followed by a rather sudden expiratory movement. The former is produced chiefly by the action of the abdominal muscles, and the latter is due to the elastic recoil of the lungs and the walls of the chest. When the mind is intensely concentrated on some particular subject for a long time, the breathing becomes so quiet that the blood is imperfectly aërated ; and this feeble respiration is compensated for by deep involuntary respirations (sighs) at intervals.

Hiccough is a sudden inspiration, produced by the spasmodic action of the diaphragm. Being so sudden, the aperture of the glottis is unprepared for the rush of air, and hence the peculiar sound produced by the vibration of the vocal cords.

Coughing is generally preceded by a deep inspiration. The glottis is then closed firmly by the muscles of the larynx, and the expiratory muscles suddenly contract. At first the force is not sufficient to open the glottis, but at last the vocal cords are suddenly burst open, and the air is noisily expelled. Coughing is a means by which any mucus or other matter which irritates the walls of the air passages may be got rid of.

Sneezing is produced much in the same way as coughing, but the tongue is raised against the soft palate so as to divert the air current through the nose.

Sniffing consists of a series of short inspirations ; but, the mouth being closed, the whole of the air inspired is made to pass through the nostrils.

Sobbing is a series of convulsive inspirations, each taking place while the glottis is more or less closed.

Laughing consists of short and rapid expirations.

Yawning is a long inspiratory act, accompanied by a stretching of the muscles of the mouth and face.

SUMMARY.

- **INSPIRATION**
  - **Chest enlarged**
    - *External intercostals* contract.
      - Raise the ribs.
      - Make the chest *wider.*
    - *Diaphragm* depressed.
      - Chest made *deeper.*
  - **Lungs expand** with the chest.
  - **Air rushes in** through the trachea, filling the enlarged lungs.
- **EXPIRATION**
  - **Chest made smaller**
    - *Elastic walls* of the thorax recoil.
    - *Elastic lungs* recoil.
    - **Forced expiration.**
      - *Internal intercostals* contract.
        - Ribs depressed.
        - Chest becomes narrower.
      - *Diaphragm* raised.
        - Chest made shallower.
      - *Abdominal muscles* contract.
        - Abdominal organs press on under side of diaphragm.
  - **Air forced out** through the trachea.

QUESTIONS ON LESSON XXVI.

1. Describe the structure of the walls of the chest.
2. Describe the arrangement of the organs of the thorax, and the arrangement and nature of the membranes which surround the lungs.
3. What would be the effect of an opening through the wall of the chest? Explain the cause.
4. Would it be possible for a person to breathe while the wall of the chest is perforated? Give reasons for your answer.
5. How do the walls of the chest move during respiration?
6. In what way do the ribs move? By what mechanism are they moved?
7. How does the contraction of the diaphragm produce inspiration?
8. Through what passages does the air move in breathing?
9. Describe fully the manner in which the intercostal muscles move the ribs.
10. What are the forces which expel the air from the lungs in expiration?
11. Describe the course of the air and the movements which take place during *coughing*, *sneezing*, and *sniffing*.
12. What is a *sigh*? How does it differ from an ordinary inspiration?

LESSON XXVII.

THE LIVER.

The liver is the largest gland in the body. In the adult it weighs from 50 to 60 ounces, and forms about one-fortieth the weight of the entire body.

It is situated at the top of the abdomen, with its upper and convex surface fitting closely against the under and concave surface of the diaphragm.

The liver consists of two parts called **lobes**—the right and the left. Of these the right is much larger than the left. The former also extends well over the right upper portion of the abdomen, while the latter is not large enough to reach the left side of the body, although it lies over a considerable portion of the stomach.

The upper, convex surface of the liver is very smooth and regular; but the under surface is very irregular, and is broken

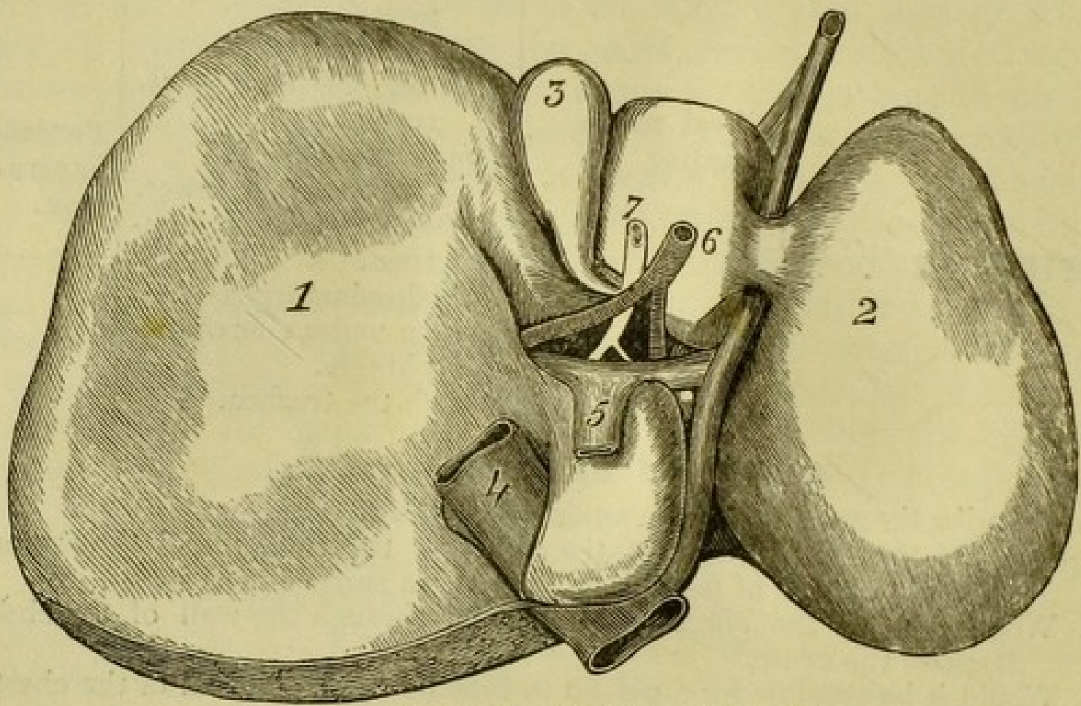


Fig. 140.—**The Under Surface of the Liver.**

1, right lobe; 2, left lobe; 3, gall-bladder; 4, vena cava inferior; 5, portal vein; 6, hepatic artery; 7, hepatic duct.

by the entrance and exit of the various vessels which belong to the organ.

The liver is extremely well supplied with blood vessels, and in it the blood is deprived of a large quantity of the impurities which it has gathered from various parts of the body.

It is almost entirely surrounded by the **peritoneum**, which invests it loosely.

The vessels of the liver are—

(1) The **portal vein.**
(2) The **hepatic artery.**
(3) The **hepatic vein.**
(4) The **hepatic duct.**

The first *three* of these are blood-vessels, and the last conveys away from the liver a fluid called the **bile**, which is prepared from the blood.

The first *two* convey their contents *to* the organ, and the last two *from* it.

The **portal vein** (Lat. *vena portæ*, or vein of the gate—the gate being the depression between the lobules of the liver) conveys to the liver a large volume of blood which it collects from the veins of the *stomach*, *intestines*, *pancreas*, and *spleen*. This blood has already circulated through the capillary systems of these organs, and is therefore of a dark purple colour, and at the same time is very rich in nutritious matter.

The **hepatic artery** (Gr. *hepar*, the liver) brings to the liver a supply of bright arterial blood direct from the descending branch of the aorta. The office of this blood is to nourish the structures of the liver.

The blood of *both* these vessels, after it has circulated through the capillaries of the liver, is collected by the branches of the **hepatic vein**, which vessel conveys it directly into the ascending or inferior vena cava (see fig. 128).

The **hepatic duct** conveys the bile into the gall-bladder or into the duodenum—to the former if digestion is not going on, and to the latter if the digestive organs are active.

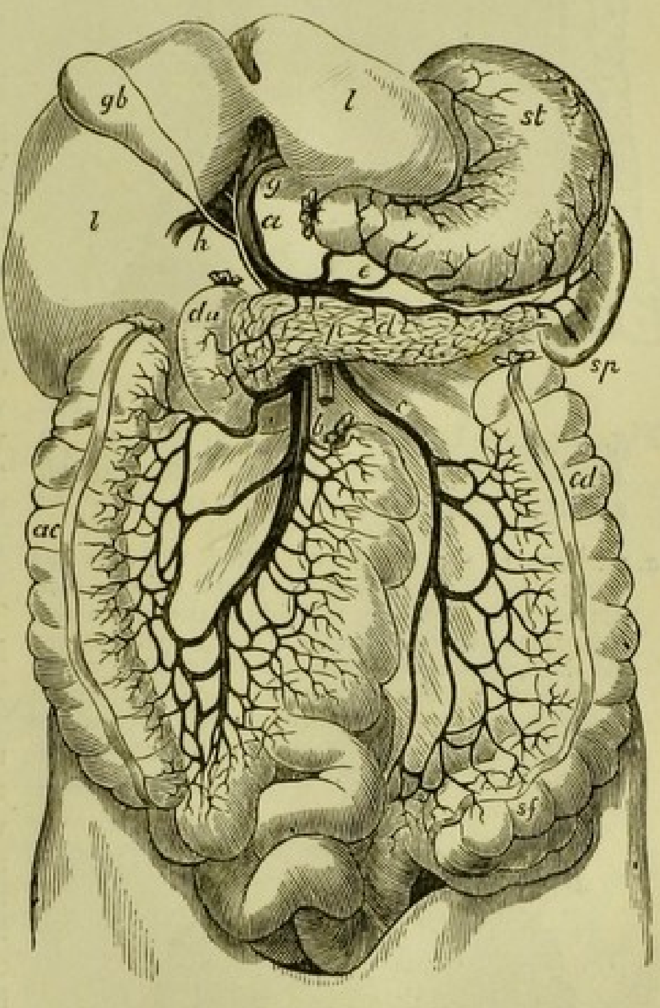


Fig. 141.—**The Portal Vein and its Branches.**

l, liver, under-surface; *gb*, gall-bladder; *st*, stomach; *sp*, spleen; *p*, pancreas; *du*, duodenum; *ac*, ascending colon; *cd*, descending colon; *a*, *b*, *c*, *d*, *e*, the portal vein and its branches. Portions of the duodenum and colon have been removed.

The branches of the **portal vein**, the **hepatic artery**, and the **hepatic duct** all run together, side by side, in canals which are called **portal canals.**

The substance of the liver is made up of small **lobules**, each about one-twentieth of an inch in diameter, and therefore distinctly visible to the naked eye. Each lobule is formed of a peculiar arrangement of the small branches and capillaries of the four vessels of the liver. It will now be convenient to trace the branches of these vessels separately, in order to learn their relations to each other.

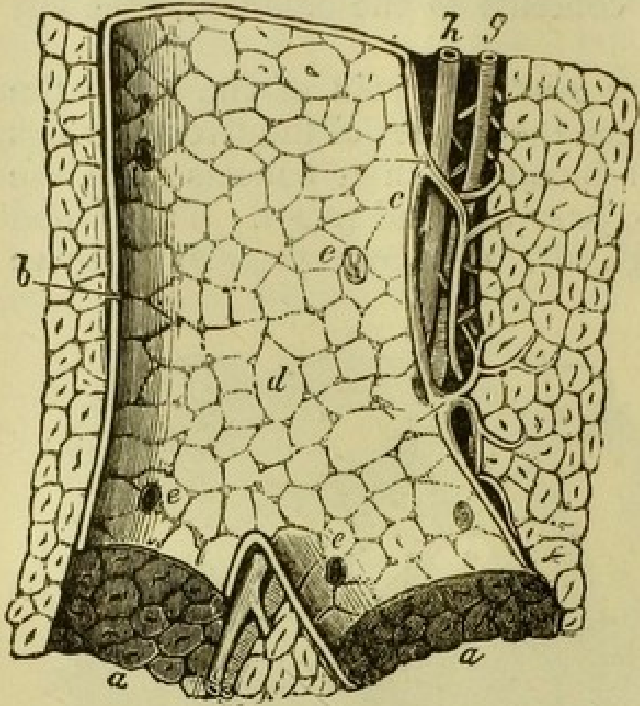


Fig. 142.—**Longitudinal Section of a Portal Vein and Canal. Magnified about 5 diameters.**

a, portions of the canal from which the vein has been removed; *b*, side of the portal vein in contact with the canal; *c*, the side of the vein which is separated from the canal by the hepatic artery and duct, with areolar tissue (Glisson's capsule); *d*, internal surface of the portal vein, through which are seen the outlines of the lobules and the openings, *e*, of the interlobular veins; *g*, hepatic artery; *h*, hepatic duct.

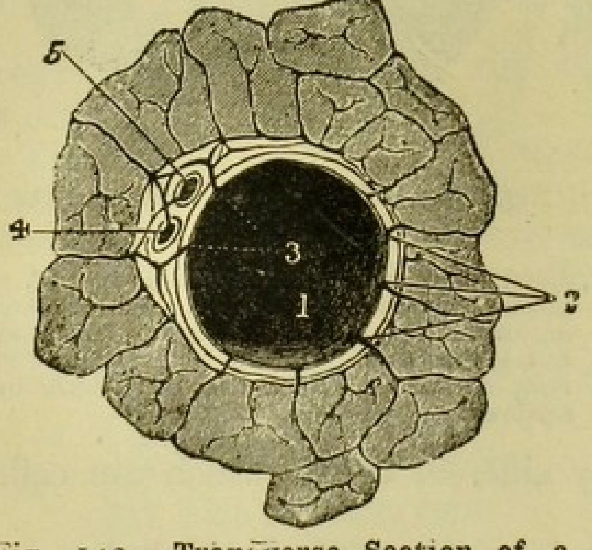


Fig. 143.—**Transverse Section of a small Portal Canal and its Vessels.**

1, portal vein; 2, interlobular branches; 3, other branches; 4, hepatic duct; 5, hepatic artery.

The branches of the **portal vein** give off small veins which *surround the lobules* and separate them from each other. These small veins are consequently called the **interlobular veins.** The interlobular veins give off still smaller branches, which run toward the centres of the lobules, and give rise to a close network of capillaries. These capillaries then unite to form other small veins which collect the blood and convey it into vessels which occupy the centres of the lobules, and which are called the **intralobular veins.** The intralobular veins then convey the blood to the bases of the lobules, and into the larger **sublobular veins,** around which the lobules are placed. The sublobular veins unite to form the **hepatic vein,** which vein carries the blood direct to the ascending vena cava. Thus the interlobular veins are the distributing branches of the portal vein; and the intralobular veins and the sublobular veins may be regarded as the collecting branches of the hepatic vein; the two sets of branches being united by the capillaries of the lobule.

The **hepatic artery,** as already stated, brings bright arterial blood to the various structures of the liver, for these structures, like all other parts of the body, need a supply of oxygen gas. The branches of this artery are distributed like those of the portal vein; and the blood brought by them is, after circulation through capillary systems, returned either into the subdivisions of the portal vein or into the capillary network of the lobules. Thus the bright arterial blood of the hepatic artery is eventually mingled with that of the portal vein, and the whole is conveyed away to the vena cava by a single vessel —the hepatic vein.

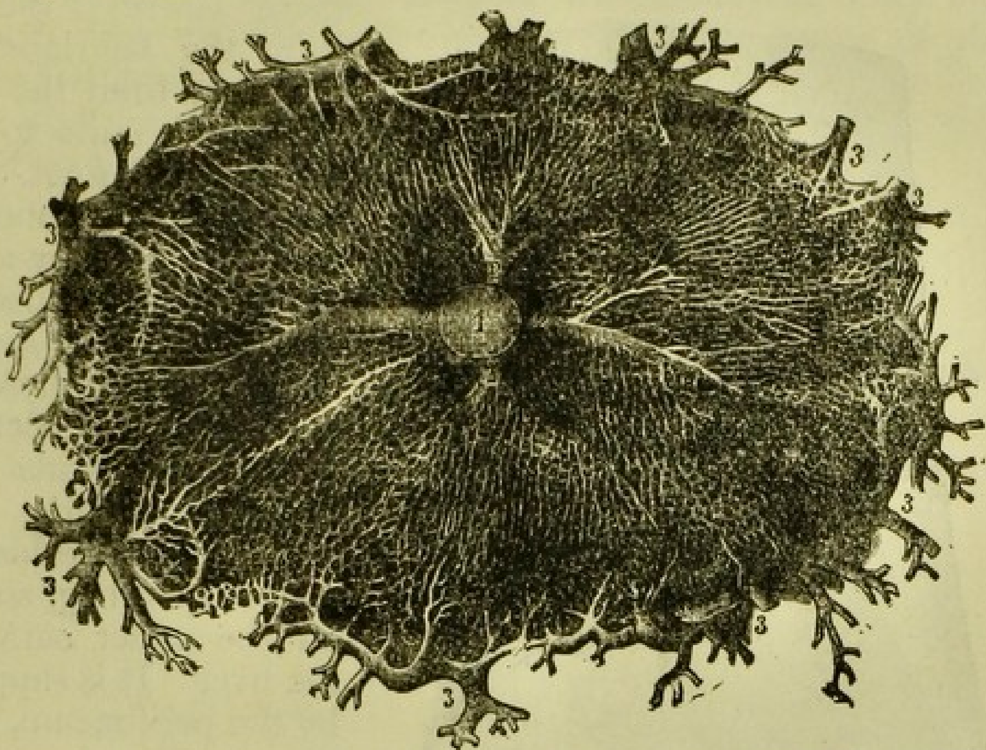


Fig. 144.—**Cross Section of a Lobule. Magnified about 60 diameters.**

1, intralobular vein; 2, its smaller branches, collecting blood from the capillary network; 3, interlobular branches of the portal vein, with their subdivisions passing inwards towards the capillary network in the substance of the lobule.

The spaces between the blood-vessels of the liver are filled with minute cells, about one-thousandth of an inch in diameter, called **hepatic cells** or **liver cells.** The blood capillaries run between these, and all changes which occur in the blood as it circulates through the liver are brought about by the action of the cells, which are separated from the blood only by the exceedingly thin walls of the capillaries.

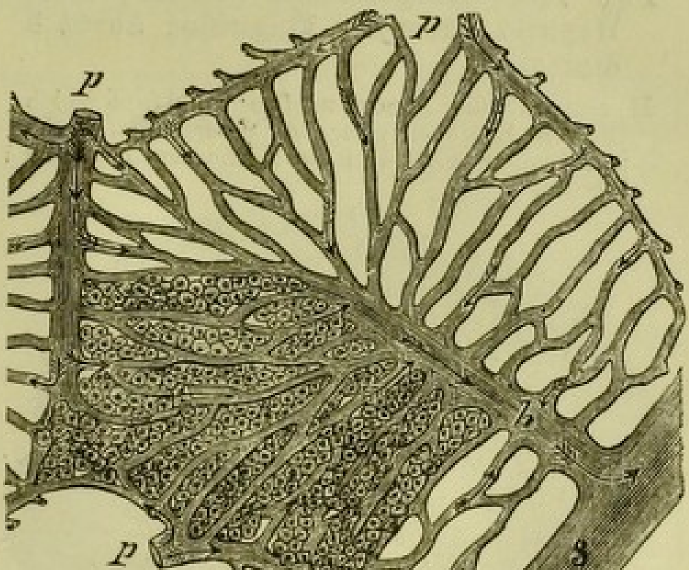


Fig. 145.—**Diagrammatic Representation of a Lobule in section. The section takes the course of the intralobular vein.**

p, interlobular branches of the portal vein; *h*, intralobular branches of the hepatic vein; *s*, sublobular vein. The arrows indicate the direction of the course of the blood. The liver cells are represented in part only.

The materials which are separated from the blood in the blood capillaries appear to pass through the liver cells to another set of capillaries which are called the **bile capillaries.** These unite to form small **biliary ducts**, which by their further union form the two larger ducts. One of these conveys the bile from the left lobe, and the other from the right, while both unite to form *the* **hepatic duct.** The gall-bladder is connected with this tube by a duct of its own, called the **cystic duct** (Gr. *kustis*, a bladder), and these two unite into the **common duct**, which leads direct to the duodenum.

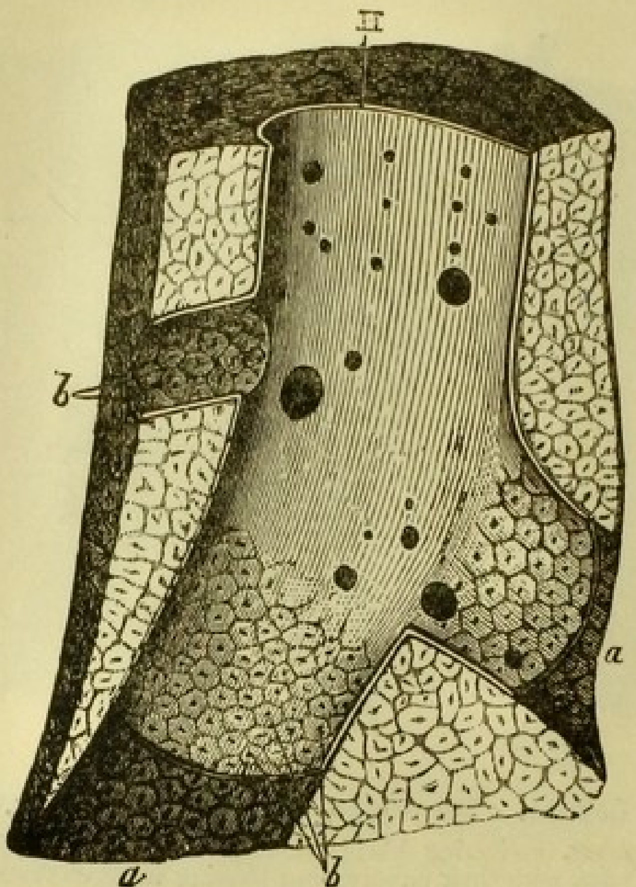


Fig. 146.—**Longitudinal Section of an Hepatic Artery. Magnified about 5 diameters.**

H, hepatic vein ; *a*, portion of the canal from which the vein has been removed ; *b*, openings of the intralobular veins, situated in the centres of the lobules.

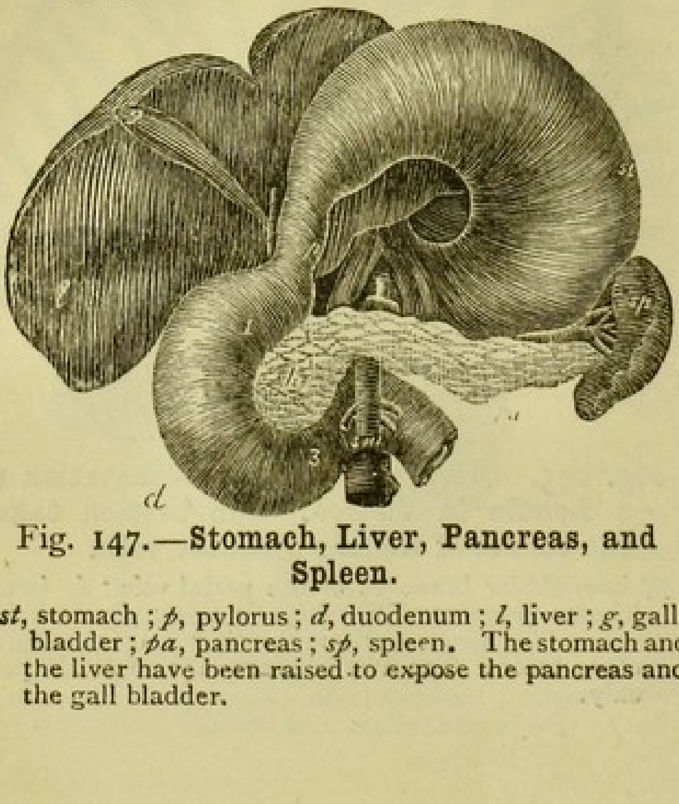


Fig. 147.—**Stomach, Liver, Pancreas, and Spleen.**

st, stomach ; *p*, pylorus ; *d*, duodenum ; *l*, liver ; *g*, gall-bladder ; *pa*, pancreas ; *sp*, spleen. The stomach and the liver have been raised to expose the pancreas and the gall bladder.

The **gall-bladder** is a pear-shaped bag, situated on the under surface of the liver. It is supported by the peritoneum, which passes below it ; and its broader end projects beyond the front margin of the liver. The cystic duct is connected with the narrow end.

The most important **function of the liver** is the **secretion of the bile.** And this single function serves a twofold purpose ; for, not only is the bile turned to account as a powerful digestive fluid, but its separation from the blood is a means of the removal of an excess of carbon and hydrogen which has accumulated in that fluid ; these elements being found largely in some of the compounds carried off by the bile.

The **secretion of the**

bile is continuous, but is retarded during fasting, and increased on taking food.

The **quantity** secreted daily is from thirty to forty ounces (about a pint and three-quarters). Sometimes some of this is reabsorbed into the blood, owing to an obstruction in the hepatic duct; and the result of this is a disease called *jaundice*, characterised by the yellow colour of the skin.

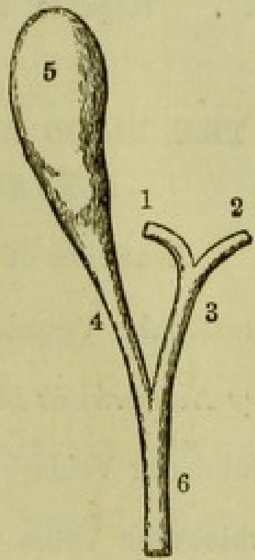


Fig. 148.—**The Gall-bladder and its Vessels.**

1, right hepatic vessel; 2, left hepatic vessel; 3, hepatic duct; 4, cystic duct; 5, gall-bladder; 6, common duct.

The liver prepares another substance called **glycogen**, which resembles starch and sugar in composition. That this substance is prepared by the liver may be proved by the analysis of the blood contained in the portal and hepatic artery before entering the liver, and that of the hepatic veins after it has left the liver. In the former case no glycogen can be detected, while in the latter it is abundant. The glycogen is afterwards converted into a kind of sugar, which is carried off from the liver by the hepatic vein, enters the vena cava, by which it is carried to the right side of the heart. It then goes to the lungs. But, if we examine the blood of the pulmonary veins which is just leaving the lungs we find no trace of sugar. It therefore appears that sugar is oxidised in the lungs—that is, converted into carbonic acid gas and water, thus helping to maintain the high temperature of the body.

The liver also seems to have the power of arresting various poisonous substances which have found their way into the blood. Thus, if any metallic poisons have been taken into the stomach, they reach the liver by the portal vein, and are there detained.

SUMMARY.

VESSELS OF THE LIVER.

- **Blood vessels**
  - **Portal vein**—from
    - Stomach.
    - Intestines.
    - Spleen.
    - Pancreas.
  - **Hepatic artery**—from aorta.
  - **Hepatic vein**—to vena cava inferior.
- **Bile vessels** . **Hepatic duct**—to
  - Cystic duct and gall-bladder, or
  - Common duct and duodenum.

COURSE OF THE BLOOD IN THE LIVER.

PORTAL VEIN.

↓

Branches of Portal Vein.

↓ ↓

Interlobular Vessels—between Lobules.

↓ ↓ ↓

HEPATIC ARTERY. → **Branches of Hepatic Artery.** ——→ *Capillary Networks in the substance of the Lobules.*

↓ ↓ ↓

Intralobular Veins—in centres of Lobules.

↓ ↓

Sublobular Veins—under the Lobules.

↓

HEPATIC VEIN.

COURSE OF THE BILE.

Bile Capillaries→Bile Ducts→HEPATIC DUCT
- **Cystic Duct** and **Gall-bladder.** (*Digestive organs inactive.*)
- **Common Duct** and **Duodenum.** (*Digestion going on.*)

BILE . . .

- **Purposes of secretion**
  - Digestive.
  - Removal of excess of carbon and hydrogen from blood.
- **Secretion** . .
  - 30 to 40 ozs. daily—continuous.
  - Retarded during fasting.
  - Accelerated on taking food.

Glycogen . .

- Resembles starch and sugar in composition.
- Prepared in the liver.
- Apparently oxidised in the lungs—thus producing heat.

QUESTIONS ON LESSON XXVII.

1. Describe the general form, position, and size of the liver, mentioning the various organs with which it is in contact.
2. Describe the membranes which surround and enter into the substance of the liver.
3. Name the various vessels connected with the liver. Give the origin of each, and describe the nature of the fluid contained in each one.

4. Describe the *gall-bladder*. Where is it situated? What is its use? What does it contain? Give the names of the vessels connected with it. In which direction does the fluid move in these vessels? Illustrate your answer by a sketch.
5. What is the nature of the fluid contained in the *portal vein*? Where does this fluid come from?
6. How is it that the liver discharges less blood than it receives? In what respects does the blood discharged differ from that received?
7. What is a *portal canal*? What does it contain?
8. What is the size of an *hepatic lobule*? Describe the arrangement of its constituent parts. How does the blood circulate through a lobule?
9. Where is the *bile* formed? Describe the course of its circulation (*a*) when the digestive organs are active, and (*b*) after fasting.
10. What are the chief functions of the liver?
11. What is the quantity of bile secreted daily? What becomes of all this?
12. What are the chief uses of the bile? (See Lesson XIX.)
13. What is *glycogen*? Where is it formed, what is its use, and what becomes of it?

LESSON XXVIII.

THE SKIN.

THE **skin** or **integument** forms a protective covering over the whole of the body. It consists of two layers, the *epidermis* and the *dermis.*

The **epidermis** (Gr. *epi*, upon; and *derma*, the skin) **cuticle**, or **scarf-skin**, covers every part of the *dermis* or *true skin.* It is hard and horny, and composed of minute scales which are being continually worn away from the surface. The thickness of the epidermis varies in different parts. In the palms of the hands and the soles of the feet—parts which are much exposed to great pressure—it is as much as $\frac{1}{20}$ of an inch, while in some parts the thickness is less than $\frac{1}{200}$ of an inch.

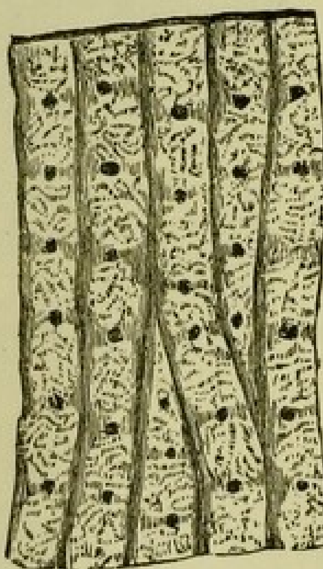


Fig. 149.—**Magnified View of the Epidermis, showing the Pores.**

The surface of the epidermis presents a multitude of minute openings when viewed with a magnifying glass. These are called the **pores** of the skin, and are really the openings of the ducts of little glands which secrete the **sweat** or **perspiration.**

The **epidermis** itself contains no blood-vessels and but few nerves, its office being simply to protect the deeper layer of the skin. If we thrust a needle through the epidermis without penetrating the dermis beneath, we feel no pain and shed no blood; but, as soon as the dermis or true skin is injured, we feel a sharp sensation of pain, and more or less blood flows.

The internal cavities of the body are all lined with a soft, pinkish membrane called the **mucous membrane**; and this is continuous with the skin at the margins of the lips, the nostrils, the eyelids, &c.

The deeper portion of the epidermis, which connects the outer, horny layer with the true skin, is softer and less transparent. It is made up of minute cells, some of which contain granules of *pigment* or colouring matter. Healthy skin is always more or less pinkish in colour. This is not due to the pigment cells, but to the presence of blood capillaries in the *dermis*, the colour of the blood being seen through the transparent epidermis. We sometimes describe the skin as 'dark' or 'fair,' 'tawny' or 'blonde'; and in these instances the differences in the tint are due to the amount of pigment in the cells of the *pigment layer*. In the European this amount is generally small; it is greatest in the skin of the negro. The pigment layer of the skin is also called the **rete mucosum** (mucous net), and the **Malpighian layer**.

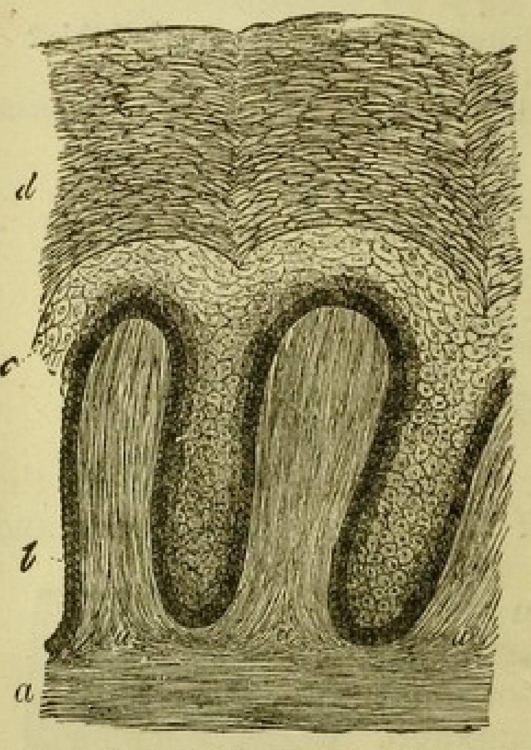


Fig. 150.—**Vertical Section through the Skin of a Negro. Magnified 250 diameters.**

a, dermis, or true skin; *bc*, undermost layer of the epidermis; *b* represents the dark layer of pigment cells; *d*, epidermis, composed of horny scales.

The cells of the **rete mucosum** are nourished by the blood which circulates in the dermis. They are also being continually pushed outward by the growth of new cells beneath; and, as they approach the surface, the pigment disappears, and they become gradually more and more horny, being, in fact, converted into horny scales which take the place of those which are continually worn off by friction from the outer layer.

The **epidermis**, being impermeable to moisture, serves to protect the living tissues beneath it against the absorption of poisons. When it is perfect, poisonous substances may be freely handled; but these substances are readily absorbed into the blood when the cuticle is cut, or when a small portion of it has been torn off.

The **dermis, true skin** (*cutis vera*), or **corium** consists of fibres of *connective* and *elastic tissues*, interwoven with minute blood-vessels and nerve fibres. Its surface is drawn up into finger-like projections called **papillæ**, the largest of which are about $\frac{1}{100}$ of an inch in length. The outer portion is extremely well supplied with blood-vessels. Every papilla has its loop of capillaries.

The deeper portion of the dermis is looser in texture, and contains an amount of fatty tissue. Beneath this again is a loose

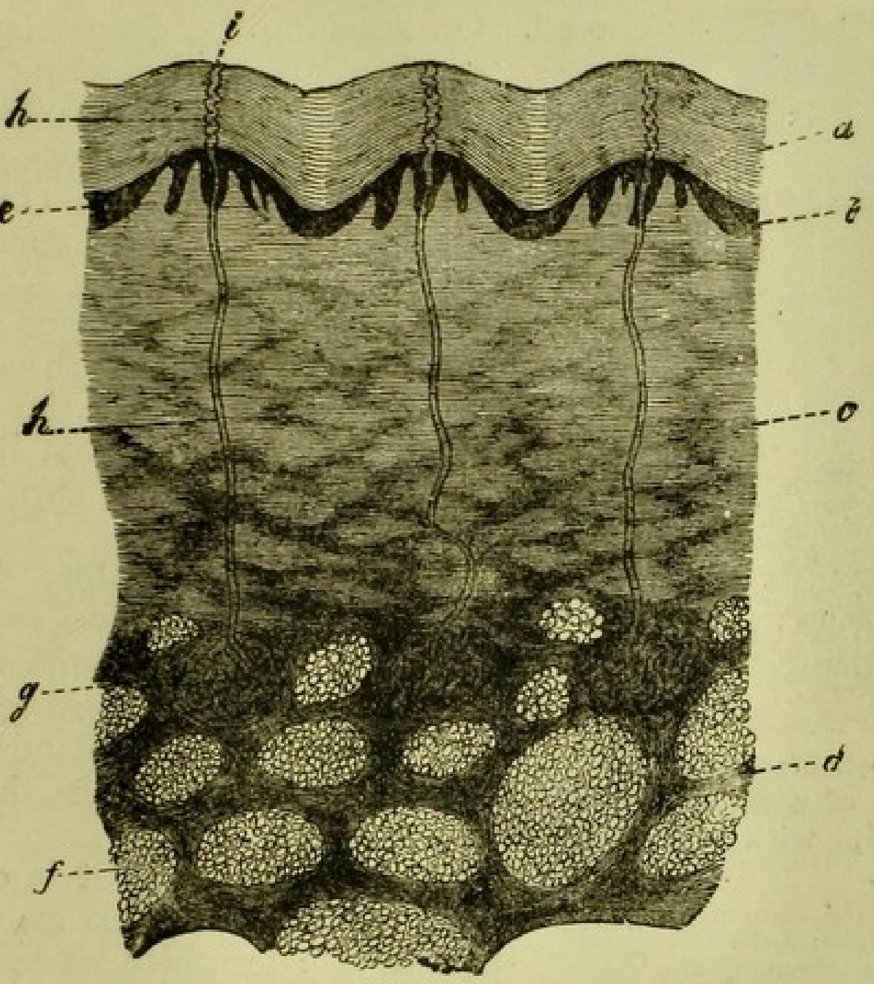


Fig. 151.—**Vertical Section of the Skin and the Sub-cutaneous Tissue. Magnified 20 diameters.**

a, horny layer of epidermis; *b*, Malpighian layer of epidermis; *c*, corium; *e*, papillæ; *f*, fat clusters; *g*, sweat glands; *h*, sweat ducts; *i*, pores.

cellular tissue—the **sub-cutaneous tissue**—which contains a large proportion of fat. The use of this latter tissue is to fill up all the irregularities of surface in the underlying parts, and to give the rounded form and plumpness to the surface of the body. The **fatty tissue** also, being a bad conductor of heat, serves to keep the body warm by preventing the outward passage of heat.

The **sensibility of the skin** as the organ of *touch* is due to the distribution of nerve fibres which terminate in the papillæ of the dermis. These nerve-endings vary considerably in form, and possibly also in function, and will be described in a future lesson.

The **pores** of the skin have already been mentioned as the openings of the ducts of the **sweat glands**. By making a section of the skin we are enabled to trace these **ducts** to the deeper portion of the dermis, where the glands are situated. As the ducts pass through the epidermis they are twisted like a corkscrew, but lower down they are straight or only slightly curved. On reaching the deeper layer of the dermis, or, sometimes, on entering the subcutaneous tissue, the ducts are coiled up into little balls. These little bodies constitute the **sudoriferous, sudoriparous** (Lat. *sudor*, sweat) or **sweat glands**. Each gland is surrounded by a dense network of blood capillaries, giving it the appearance of a reddish ball. As the blood circulates through these vessels, the fluid which we call the **perspiration or sweat** is separated from it, passing up the duct till it reaches the surface of the skin.

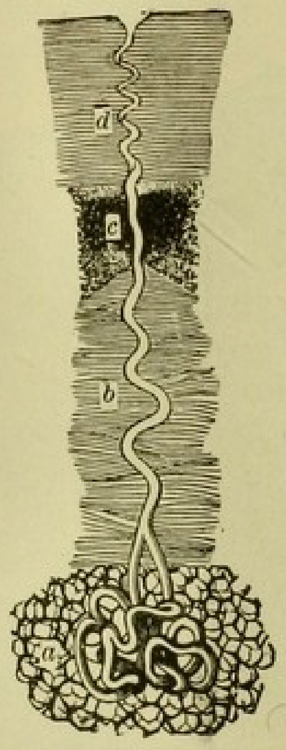


Fig. 152.—**Magnified View of a Sweat-gland, with its Duct.**

a, the gland surrounded by fat-cells; *b*, the duct passing through the dermis; *c*, its continuation through the rete mucosum, and *d*, through the upper epidermis.

The **perspiration** is a watery fluid, containing a small amount of dissolved *common salt*, together with smaller quantities of other salts (see page 81). A little *carbonic acid gas* is also given off by the sweat glands, but this is insignificant compared with that which escapes by the lungs.

From what has been said it is clear that we must look upon the skin as an **excretory organ**—that is, one by which waste materials are separated from the blood circulating in it. Like the lungs, it is a source of loss to the blood; but while the lungs give off a great amount of carbonic acid gas and water vapour, the skin excretes but little carbonic acid gas.

The **excretion of the perspiration** is continuous but exceedingly variable, the average quantity discharged being probably about *two pounds per day* in the adult.

The chief **use of the perspiration** is undoubtedly the protection of the body from too great heat, or, in other words, the equalisation of the temperature of the system. When the surface of the body is cold, the supply of blood to the skin is decreased by the contraction of involuntary muscular fibres which reduce the size of the blood-vessels. At the same time the ducts of the sweat glands are contracted, and consequently the secretion of the perspiration is slow. But when the body becomes overheated by exercise, or when the surface of the body is exposed to great heat, the muscles of the skin relax, the supply of blood increases, the gland ducts open wider, and the perspiration is given off freely. The evaporation of this moisture tends to reduce the temperature of the skin, and consequently that of the body.

We now see how necessary it is that the skin should be cleansed from any matter which may tend to clog its pores, for if the perspiration cannot be freely discharged through the pores, it is reabsorbed into the blood, thus throwing extra work on the other excretory organs, especially the kidneys, which excrete water and urea. The lungs, skin, and kidneys are all similar in their action ; but the work of the skin is more closely allied to that of the kidneys than to that of the lungs. Hence, when the action of the skin is retarded by exposure to cold, the extra work thrown on the kidneys frequently causes a disease in these organs, they being unable to perform their own function in addition to that of the skin. The analogy between the functions of the skin and the kidneys may also be noticed from the fact that in summer, when the skin is active, the excretion of the kidneys diminishes ; and *vice versâ*.

The **sudoriparous glands** are distributed all over the body, but not equally. In the lower limbs and back they are estimated at about 600 to every square inch of surface, while in the palms of the hands there are as many as 2,500 in the square inch.

Generally speaking, the fluid portion of the sweat evaporates as fast as it reaches the surface of the body, and consequently we have no visible evidence of the excretion unless we apply the skin to a very cold surface, when the vapour given off is condensed. Hence the term **insensible perspiration.** But in summer, especially during activity, the fluid collects in globules on the skin, and the perspiration becomes **sensible.** It may also become sensible under the influence of some kinds of mental emotion.

Nails and **hairs** are out-growths of the epidermis or cuticle, and both agree with it in general structure.

A **nail** is simply a thick layer composed of the thin horny scales of the outer portion of the cuticle. At the 'root' of the nail the skin is folded back on itself, so that two layers are facing each other. Thus the nail at this point grows by additions of epidermic cells *above*, *below*, and *behind* ; the new growth above and below adding to the *thickness* of the nail, while additions received behind continually push it forward. The nail continues to receive additions in its thickness on the under surface as long as it remains attached to the skin below it.

Each **hair** consists of a *root* or *bulb* and a shaft or stem. The **root** is imbedded in a recess of the skin called the **follicle**, which is formed by a layer of the dermis, lined with a thin continuation of the cuticle. These two layers form a **sheath** which invests the

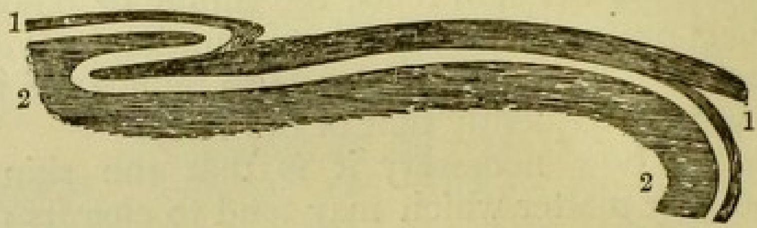


Fig. 153.—**Section through a Nail.**
1, epidermis ; 2, dermis.

root of the hair so closely as to be often pulled out with the hair. From the bottom of the follicle there rises a small **papilla** which is supplied with blood-vessels, and this is the growing point from which the hair is pushed forward by continual additions. The **shaft** of the hair is, like the epidermis generally, devoid of blood-

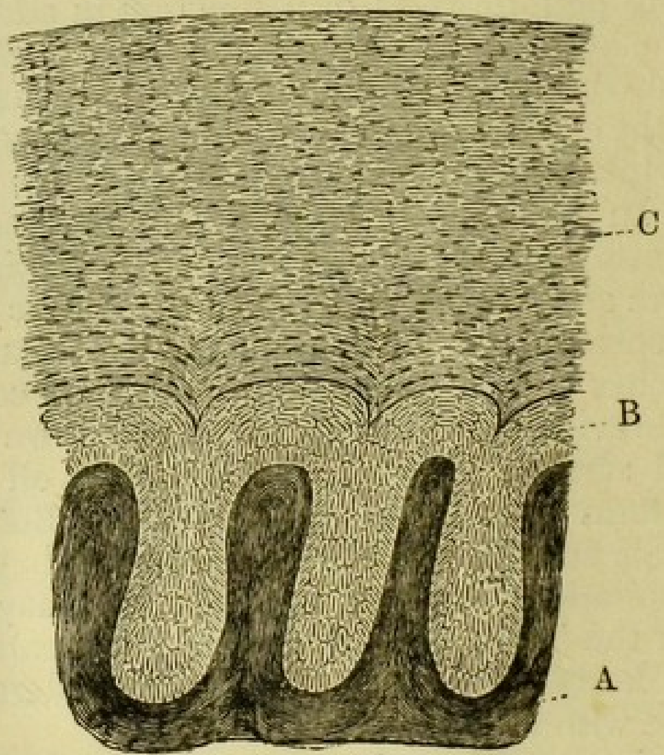


Fig. 154.—**Vertical Section through a small portion of a Nail. Highly magnified.**
A, dermis ; B, rete mucosum ; C, the nail, composed of thickened epithelium.

vessels and nerves. It generally consists of a central *medullary portion* or *pith*, surrounded by a fibrous *cortical* part. In some hairs the medullary portion is wanting.

Each hair is provided with small glands which secrete an oily fluid to lubricate the hair and the surrounding skin. These are called the **sebaceous glands** (Lat. *sebum*, suet). They consist of little saccules communicating with a common duct which opens into the neck of the follicle.

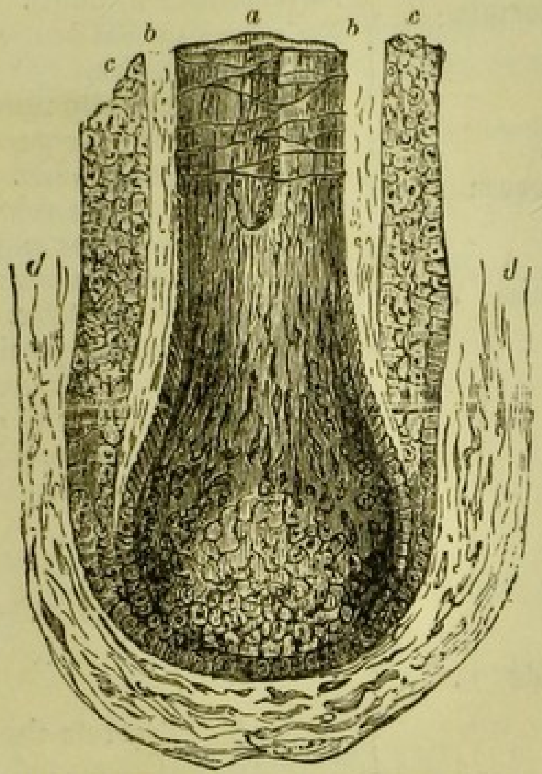


Fig. 155.—**Magnified View of the lower portion of a Hair Follicle.**

a, hair, showing medullary and cortical portions; *b* and *c*, outer and inner layers of the epidermic lining of the follicle; *d*, the dermis of the hair follicle.

Hairs are also provided with **muscles**. These are composed of involuntary fibres, and pass from the side towards which the

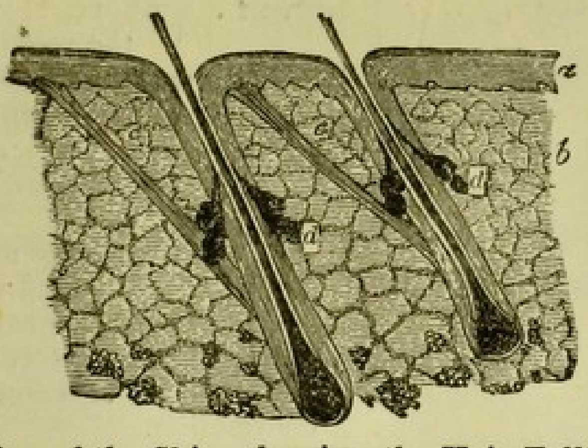


Fig. 156.—**Section of the Skin, showing the Hair Follicles, Sebaceous Glands, and the Muscles of the Hairs.**

a, epidermis; *b*, dermis; *c*, muscles of the hair follicles; *d*, sebaceous glands.

hair slopes obliquely to the outer layer of the dermis. It is evident, therefore, that when they contract they tend to make the hair more erect.

SUMMARY.

- **SKIN.**
  - **Epidermis.**
    - Composed of *flattened scales.*
    - *Horny* and *transparent.*
    - *Impermeable* to fluids.
    - No *nerves* or *blood-vessels.*
    - Simply *protective.*
    - Surface continually removed by friction.
  - **Rete Mucosum.**
    - *Softer* and *less transparent.*
    - Contains *pigment cells.*
    - *Gives colour* to the skin.
  - **Dermis.**
    - Fibres of *connective* and *elastic tissues.*
    - Numerous *blood-vessels* and *nerves.*
    - Drawn up into *papillæ.*
    - *Fat-cells* in deeper portion.
  - **Glands.**
    - Sweat.
      - Situated deep in the *dermis.*
      - Consist of *coiled tubes.*
      - Surrounded by *capillary net-works.*
      - Ducts.
        - Nearly straight through *dermis.*
        - Twisted in *epi-dermis.*
        - Open at the surface (*pores*).
      - Secrete the *perspiration.*
    - Sebaceous.
      - Connected with hairs.
      - Secrete an oily fluid.
      - Secretion.
        - Discharged into the *follicles.*
        - *Lubricates* the hair and skin.
  - **Nails.**
    - Thick, horny plates of *epidermis.*
    - Growth.
      - Only where adherent to skin.
      - Above, below, and behind at the root.
    - Pushed forward by growth behind.
  - **Hairs.**
    - Shaft.
      - Interior *medullary portion* or *pith.*
      - Outer *cortical* or *fibrous portion.*
    - Root.
      - Bulb-like at lower extremity.
      - Imbedded in follicle.
    - Pushed outward by growth at the base.
    - Glands—sebaceous (see above).
    - Muscles—tend to erect the hair by their contraction.
- **PERSPIRATION.**
  - **Composition.**
    - Water.
    - Salts—especially common salt
    - Little carbonic acid gas in solution.
  - **Quantity.**
    - Average about two pounds a day.
    - Greater in summer than in winter.
    - Greater during activity.
  - **Uses.**
    - Removal of waste matter.
    - Tends to reduce the temperature of the body by its evaporation.

QUESTIONS ON LESSON XXVIII.

1. Of what parts is the skin composed? How do these differ from each other?
2. What are the *pores* of the skin? What purpose do they serve?
3. What is the difference between the skin of a European and that of a negro?
4. What is the use of the *epidermis*?
5. What purpose is served by the fatty tissue imbedded in the deeper portion of the dermis and in the tissue beneath it?
6. Where are the sweat glands situated? What are their uses? Describe briefly the structure of these glands.
7. What do you know about the *perspiration*? What circumstances determine the amount of perspiration secreted?
8. How much perspiration is secreted daily? How is it that we sometimes see it on the surface of the skin, while at other times it is *insensible*?
9. Compare the function of the skin with that of the lungs.
10. What is the structure of a nail? How does a nail grow?
11. Describe the structure of a hair, and say how the hair is connected with the skin.
12. What are *sebaceous glands*? What is their use?
13. By what means is the hair made to 'stand on end'?

LESSON XXIX.

THE KIDNEYS.

THE **kidneys**, two in number, are situated at the back of the abdomen, one on each side of the upper lumbar vertebræ. They are deeply seated in the loins, behind the *peritoneum*, and are held in this position by their own vessels, and by a quantity of *areolar tissue* which usually contains much fat. They measure about 4 inches in length, $2\frac{1}{2}$ inches in width, and $1\frac{1}{2}$ inch in thickness, their weight being about $4\frac{1}{2}$ ounces each.

The kidneys are arranged with their concave surfaces directed towards the vertebral column; and the **right kidney**, which is usually shorter and thicker than the left, is generally a little lower, probably on account of the downward extension of the large right lobe of the liver.

The surface of the kidney is smooth, and of a deep red colour. It is covered with a thin fibrous coat—the **capsule**—which invests the organ closely, but which can easily be detached.

In the concave surface of the kidney there is a longitudinal depression called the **hilus**, at which the vessels and nerves enter or pass out. The concavity of the kidney is usually filled in with areolar and fatty tissue, through which the vessels pass to and from the organ; and by carefully removing this substance **three vessels** may be traced to their entrance into the kidney.

These **vessels of the kidney** are (1) the **renal artery** (Lat. *renes*, the kidneys), which conveys bright arterial blood direct from the descending branch of the *aorta* ; (2) the **renal vein**, which collects the blood that has circulated in the capillaries of the kidney, and carries it direct to the *ascending* or *inferior vena cava* ; and (3) the **ureter**, which carries away the fluid secreted from the blood, and conveys it to the *bladder*.

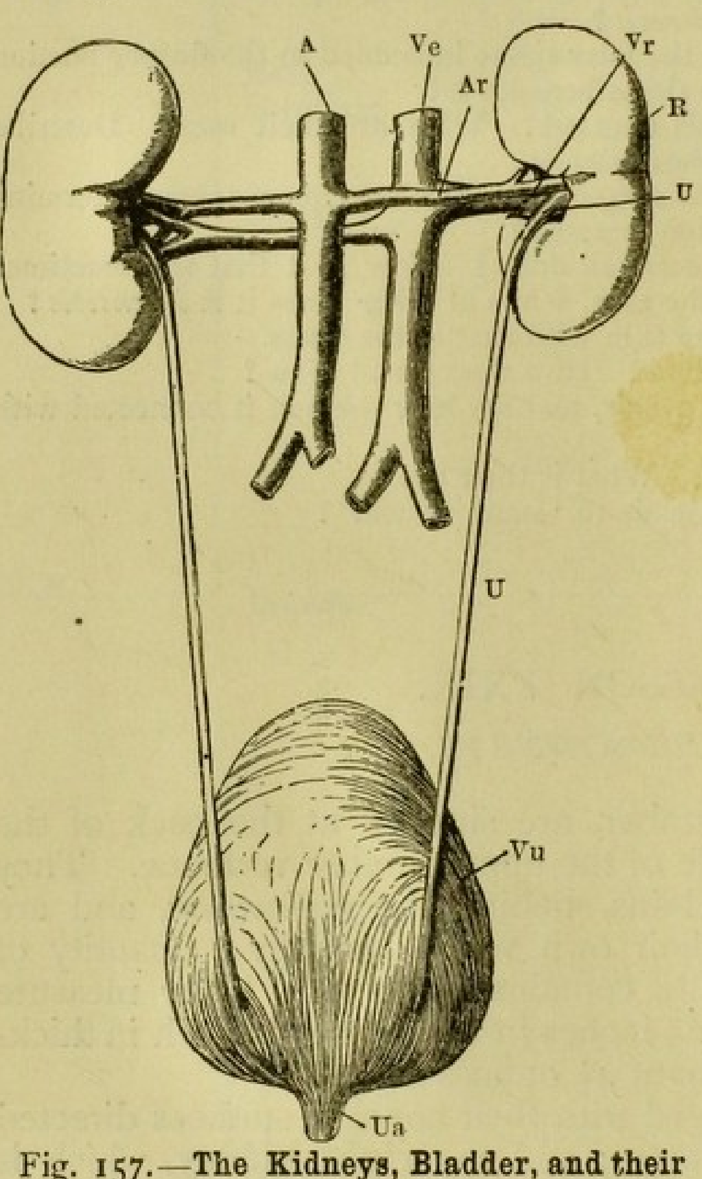


Fig. 157.—**The Kidneys, Bladder, and their Vessels. Viewed from behind.**

R, right kidney ; U, ureter ; A, aorta ; Ar, right renal artery ; Ve, vena cava inferior ; Vr, right renal vein ; Vu, bladder ; Ua, commencement of urethra.

We must now study a **longitudinal section of the kidney**. A clean cut should be made from the outer convex surface straight through to the hilus. It will be noticed that the ureter opens into a cavity with a number of short wide prolongations. The cavity is called the **pelvis** of the kidney, and its branches, **calices** (Lat. *calyx*, a cup). We also observe that the solid portion of the kidney consists of an inner **medullary substance** which has a fibrous appearance, and an outer **cortical substance** of a darker colour.

The **medullary substance** is not really fibrous, but consists of a multitude of minute tubes arranged in separate conical masses called the **pyramids**. The apex or point of each pyramid is turned toward the pelvis of the kidney, into which it projects, presenting a number of minute openings which are the terminations of the little tubes of the pyramid. By squeezing the cut kidney, a little watery fluid may be made to drain from these little tubes into the pelvis.

From this cursory examination of the kidney it would appear that the blood from the renal artery is abundantly supplied to the cortical portion of the organ (hence the dark colour), where a process of excretion goes on, and that the watery fluid (the *urine*) there separated passes through the minute tubes of the pyramids into the pelvis, whence it is conveyed to the bladder by the ureter. This is actually the case ; but in order to understand *how* this is brought about it will be necessary to give a more detailed examination, aided by the microscope.

If we examine a thin prepared section of the kidney under a powerful microscope, we notice that the straight tubes of the pyramids (the **uriniferous tubes**) radiate towards the cortical portion, branching as they go. On reaching the cortical layer they are distributed irregularly, interlacing each other, and finally terminate in little expansions called the **Malpighian capsules.** Into each capsule a small branch of the renal artery enters, and immediately breaks up into looped capillaries which nearly fill the cavity of the capsule. The blood is then collected up by a small vein, which again breaks up into a capillary network around the walls of the uriniferous tube, and is finally conveyed away through the medullary portion to the renal vein. Thus we have another example (see page 155) of blood passing through two distinct capillary systems before entering the great vein which takes it to the heart.

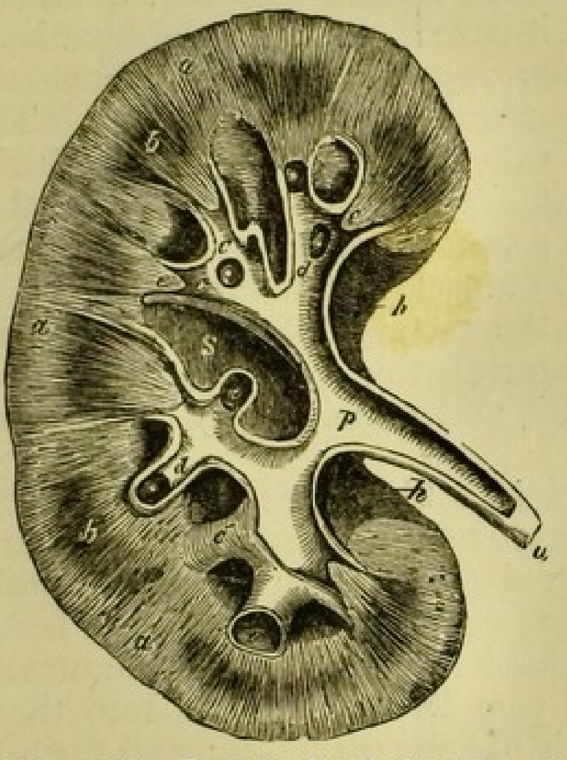


Fig. 158.—**Longitudinal Section of the Human Kidney. One-half the natural size.**

a, cortical substance ; *b*, pyramids—broad portions ; *c*, calyces of the pelvis laid open ; *c'*, calyx, unopened ; *d*, summits of the pyramids projecting into calices ; *e*, narrow parts of pyramids ; *p*, pelvis ; *u*, ureter ; *h*, hilus ; *s*, extension of the hilus.

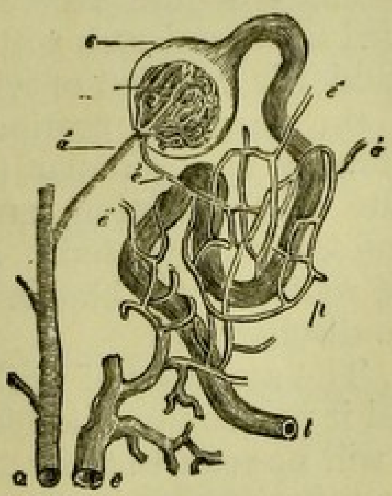


Fig. 159.—**Diagram showing the relation between the Uriniferous Tubes and the Blood-vessels.**

a, small branch of the renal artery ; *a'*, smaller branch passing into a capsule ; *c*, a Malpighian capsule ; *t*, convoluted uriniferous tube ; *e'*, small blood-vessels from the capsule, which subdivide into capillaries *p*, surrounding the tube, and finally terminating in *e*, a small branch of the renal vein.

The **excretion** of the kidney is filtered from the blood both through the thin walls of the capsules and also through the walls of the tubules which are surrounded by the second capillary network. It is probable that the watery part of the urine is separated in the capsules, while the solid portion is excreted chiefly from the capillaries surrounding the tubes.

The **ureters** are the two tubes which convey the fluid excreted by the kidneys into the bladder. They are about fifteen inches in length. The upper end of each, as we have seen, expands to form the pelvis of the kidney; the lower extremity passes *obliquely* through the walls of the bladder at its base.

The **bladder** is a very strong oval bag, about five inches long, situated in the cavity of the pelvis. Its walls contain abundant *involuntary muscular fibres*, and it is covered externally by a layer of the *peritoneum*. It has three openings, two of which—the openings of the ureters—have already been mentioned. The third communicates with a duct called the **urethra**, by which the bladder is emptied of its contents. The neck of the bladder, that is, the narrower portion which gives rise to the urethra, is surrounded by a circular (*sphincter*) muscle which is generally in a state of contraction, and thus the passage of liquid from the bladder is prevented. But at intervals this muscle relaxes, while the walls of the bladder contract, and consequently its contents are discharged.

The secretion of the urinary fluid by the kidneys is continuous, and it passes into the bladder, drop by drop, through the ureters. It will be seen, therefore, that the bladder simply serves to contain the urine so that it may be discharged at intervals from the body. No obstruction is offered to the fluid as it passes from the ureters into the bladder, but it cannot pass backward again into these vessels readily on account of their oblique openings; and, further, because of small elevations of the mucous membrane at these openings which act as valves.

The **urine** consists of *urea* and *uric acid* (both nitrogenous substances), other salts, and certain gaseous substances, dissolved in a large quantity of water.

The **quantity** and **composition of the urine** vary considerably with circumstances, but it is estimated that the kidneys of a healthy man excrete about three pounds of water a day, in which is dissolved a little more than one ounce of urea, and about ten grains of uric acid.

We must therefore look upon the kidneys as great sources of loss to the blood, and in this respect they are like the lungs and the skin. Of these three sources of loss the kidneys only excrete large quantities of nitrogenous matter. The following table will help us to compare the functions of these organs:—

Sources of Loss to the Blood.

1. **The lungs.**	Much water. Much carbonic acid gas.

2. **The skin**
   - Much water.
   - Little carbonic acid gas.
   - Little urea.
3. **The kidneys**
   - Much water.
   - Much urea.
   - Little uric acid.

The **blood which leaves the kidneys** by the renal veins is often said to be the purest blood in the body. It has lost much nitrogenous waste matter. Of course a certain proportion of the blood which enters the kidneys goes to nourish the walls of the vessels of which the organs are almost entirely composed. Hence this blood would tend to become venous by its loss of oxygen and its gain of carbonic acid gas. But this is counterbalanced by the excretion of the urine, which contains relatively more carbonic acid gas and less oxygen than the blood from which it was formed. As a result of this, the blood of the renal vein, which has lost so much nitrogenous matter, is still *arterial* in character.

SUMMARY.

- **KIDNEY**
  - **Weight** . About 4 ounces.
  - **Position** . .
    - At the back of the abdomen.
    - One on each side of the upper lumbar vertebræ.
  - **Covering** . . The *capsule*—a thin fibrous membrane.
  - **Vessels** . .
    - **Renal artery**
      - A branch of the *aorta*.
      - Contains *arterial* blood.
    - **Renal vein** .
      - Leads to the *vena cava inferior*.
      - Contains the purified blood.
    - **Ureter** . .
      - Leads to the *bladder*.
      - Contains the *urine*.
  - **Structure** .
    - **Pelvis** . .
      - Enlargement of the *ureter*.
      - Gives off prolongations called *calices*.
    - **Medullary portion**
      - Composed of minute tubes.
      - Arranged in cones or *pyramids*.
      - Tubes open into the *pelvis*.
    - **Cortical portion**
      - Outer portion of the kidney.
      - Darker in colour.
  - **Excretion** .
    - Excretion continuous.
    - Daily . .
      - 3 lbs. water.
      - 1 oz. urea.
      - 10 grs. uric acid.
      - Various salts.
      - Dissolved gases.
- **BLADDER** .
  - **Structure** .
    - Strong oval bag.
    - Involuntary *muscular fibres*.
    - Lined with *mucous membrane*.
    - Surrounded by *peritoneum*.
  - **Vessels** . .
    - *Ureters*—convey urine from the kidneys.
    - *Urethra*—for the discharge of the urine.
  - **Use** . .
    - To retain the urine, and
    - To discharge it at intervals.

QUESTIONS ON LESSON XXIX.

1. Describe the general form, size, and position of the kidneys.
2. Describe the structure of the kidney as far as it can be seen without the use of a microscope.
3. Name the vessels of the kidney. Describe the nature of the fluid contained in each, and say in which direction it flows.
4. Compare the blood of the renal artery with that of the renal vein.
5. In what way do the kidneys purify the blood? Should the kidneys cease to perform their function, is it likely that other organs would do their work? Give reasons for your answer.
6. Describe the nature of the urine. How does it get from the kidneys to the bladder, and what prevents it from immediately leaving the bladder?
7. Describe the chemical composition of the chief ingredients separated from the blood by the kidneys. How did these materials get into the blood?
8. Describe the structure and use of the bladder.
9. Describe the manner in which the urine is separated from the blood as it circulates in the kidney.

LESSON XXX.

THE NERVOUS SYSTEM—NERVES.

ALMOST every movement of the body, whether voluntary or involuntary, is brought about and governed by some portion of the nervous system. If we *will* to do anything, we do it through the agency of nervous matter, which acts as a medium between the *mind* and the muscles. Thus the nerves do not produce motion by their own contraction, but by their influence over the muscles in which their fibres terminate.

The **nervous system** consists of two distinct parts, called the *cerebro-spinal* and the *sympathetic* systems.

The **cerebro-spinal system** consists of the *brain*, the *spinal cord*, and all the *nerves* given off from the brain and the cord. All the vertebrate animals possess such a system. The nerve fibres of the cerebro-spinal system are distributed chiefly to the skin, thus giving us the sense of touch ; to the other organs of sense—the nose, tongue, ear, and eye; and also to all the voluntary muscles.

The **sympathetic or ganglionic system** consists of a number of ganglia (knots) of nervous matter which give off nerve fibres. The chief portion of this system comprises a double chain of ganglia, situated one half on each side of the vertebral column, and extending from the skull to the pelvis. It also includes various ganglia which supply fibres to certain internal organs. The nerves of the

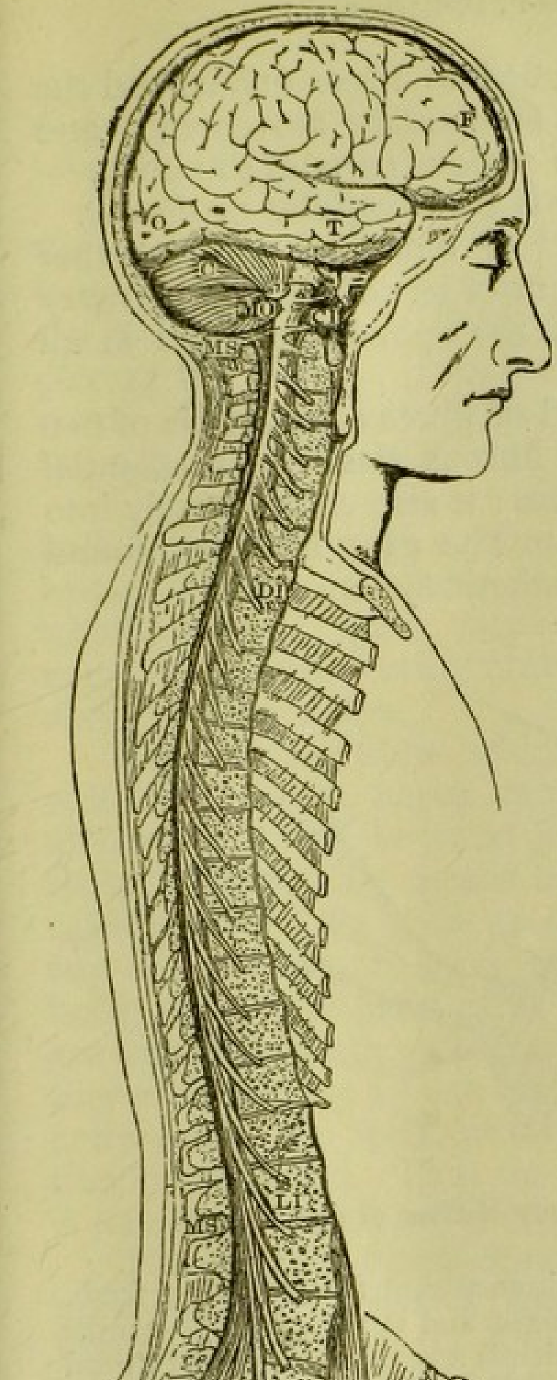


Fig. 160.—The Cerebro-spinal Cavity and its Contents.

F, T, O, frontal, temporal, and occipital portions of cerebrum; C, cerebellum; MO, medulla oblongata; MS, upper and lower extremities of the spinal cord; CI, the first cervical nerve; DI, the first dorsal nerve; LI, the first lumbar nerve.

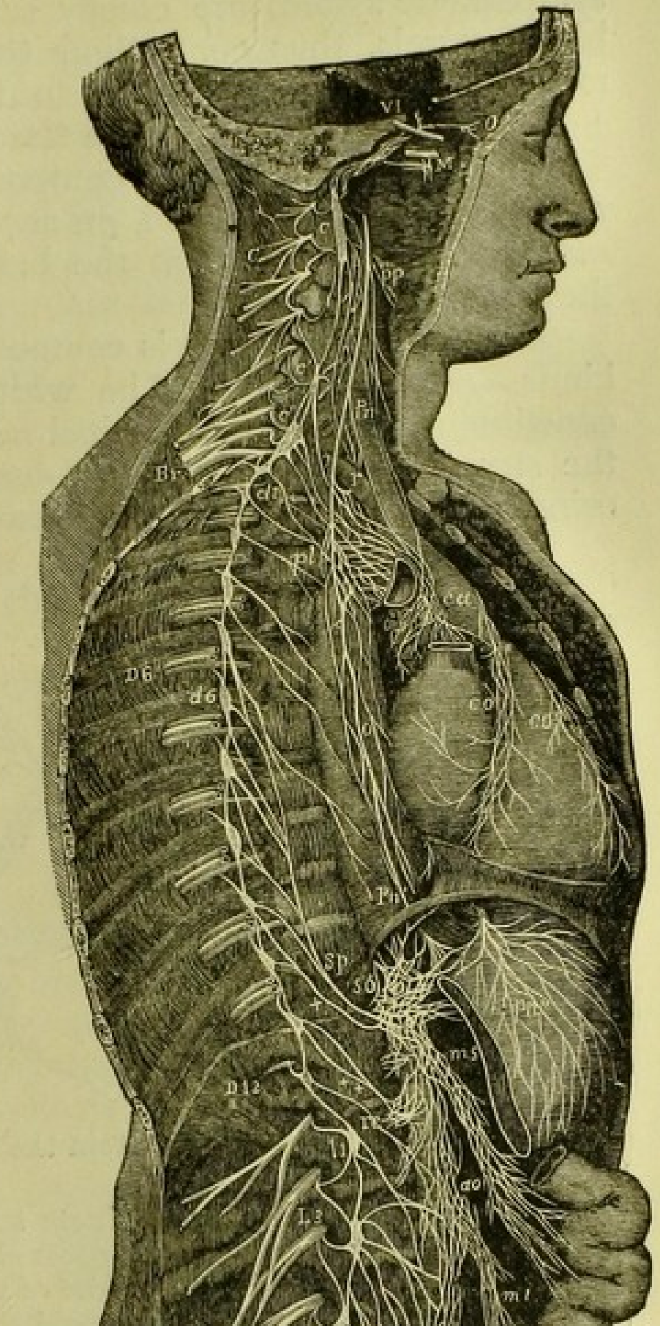


Fig. 161.—The Sympathetic Chain of the Right Side, showing its connection with the principal Cerebro-spinal Nerves.

sympathetic system are chiefly supplied to these organs and the blood-vessels, thus controlling the involuntary movements, and regulating the supply of blood to the various parts of the body.

Nerve substance or **nerve tissue** is either *cellular* or *fibrous.*

The **cellular tissue** is composed of branched cells together with interlacing fibres, and, on account of its colour, is called *grey substance.* It is found in the brain, the spinal cord, and in all the other *nerve centres.*

Fibrous nerve tissue is composed of fibres only, and is of two kinds—*grey* and *white.* The **white fibrous tissue** is an essential constituent of the cerebro-spinal nerves: it also enters largely into the structure of the brain and cord. The **grey fibres** are found principally in the nerves of the sympathetic system.

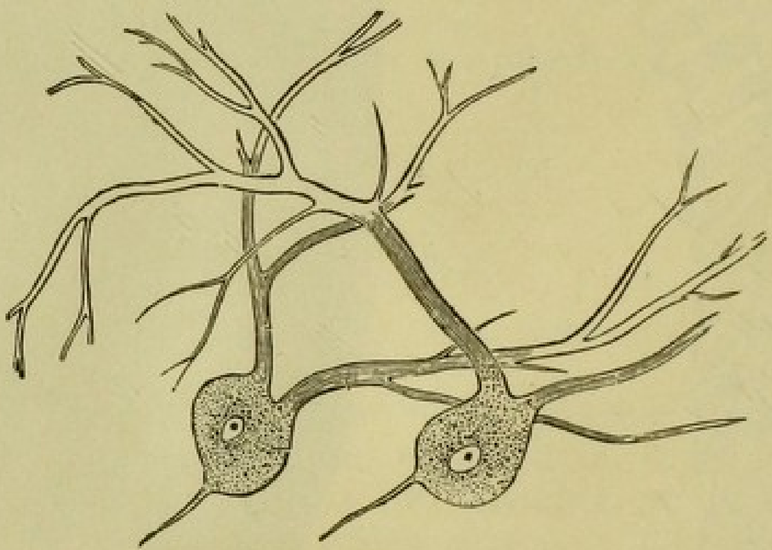


Fig. 162.—**Nerve-cells from the Grey Matter of the Brain.**

Each **white nerve fibre** is a minute semitransparent filament when fresh. But a few hours after death it undergoes changes and is then seen to consist of an outer membrane, in the middle of which is a coagulated central thread (the *axis-cylinder*), surrounded by a white sheath.

The **grey fibres** closely resemble the white, but the white sheath enclosing the axis-cylinder is wanting.

Each *nerve* is a bundle of such fibres, passing to or from a nerve centre, generally bound together by a delicate sheath of connective tissue called the **neurilemma** (Gr. *neuron*, a nerve; and *lemma*, rind). It may be easily distinguished in the body of an animal as having the appearance of white or cream-coloured threads.

We may pass on at once to notice the essential difference between *nerves* and *nerve centres.* A **nerve**, composed of nerve fibres, has no power to *generate* what we may call a nerve impulse, but it can *conduct* an impulse already produced, along its fibres, either to or from the nerve centre with which it is connected. On the other hand, a **nerve centre**, which consists partly of the greyish nerve cells, has the power to *generate* or *produce* an impulse as well as to *conduct* it—it serves as a receiver and a transmitter as well as a generator.

We may compare a nerve centre to a galvanic battery, and the nerves to the wires which convey the electric current. The battery *generates* the electric current, which flows along one of the wires, and returns to the battery by the other wire, thus completing the circuit. The battery, like the nerve centre, *generates*, *receives*, and *transmits*; while the wires of the battery, representing the nerves, simply *conduct*.

This simile may be yet further extended, for as one wire of the battery takes away the current and the other brings it back, so there are nerve fibres which conduct nerve impulses only *to* a nerve centre, while other fibres convey them only *from* the centre.

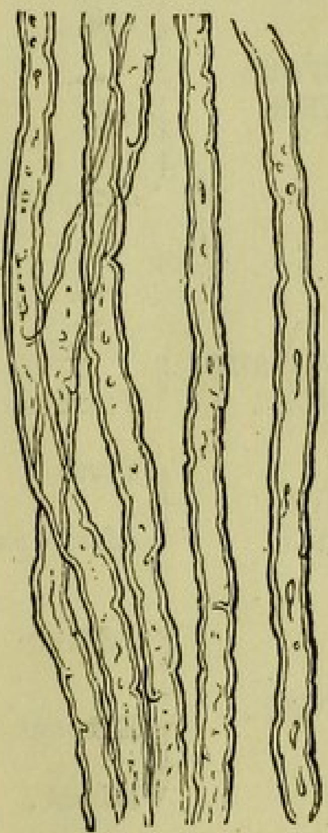


Fig. 163.—**White Nerve Fibres. Magnified.**

Those nerve fibres which conduct impulses only *to* a nerve centre are called **afferent** (Lat *ad*, to; and *fero*, I carry) or **sensory fibres**. By means of these we are capable of feeling pain or of experiencing any other sensation. For example, when a body vibrates rapidly, and the vibrations are transmitted through the air to the ear, they are taken up by the *auditory nerve* and conveyed to the brain, producing the sensation called sound. Thus the auditory nerve is an *afferent* or *sensory* nerve.

Those nerve fibres which convey impressions only *from* a nerve centre are termed **efferent** (Lat. *e*, out; and *fero*). They are also called **motor**, because their office is to produce motion.[1] They originate in a nerve centre, and they terminate in muscular fibres. When they receive an impulse from a nerve centre, they convey that impulse to the fibres they govern, causing them to contract. Thus, when we hear a sharp sound behind us, we quickly turn the head, or start running. The sound vibrations, on reaching the brain, set up a disturbance in the organ. The irritation is then conducted through the efferent or motor nerves which supply certain muscles of the neck or limbs, and causes them to contract.

[1] The terms *afferent* and *efferent* are preferable to *sensory* and *motor*, since the irritation of the former does not always produce sensation; nor does motion always result from the irritation of the latter.

Some nerves are purely sensory, that is, consist of sensory fibres only. Other nerves consist of sensory and motor fibres, and can consequently convey nerve impulses in both directions, only, of course, not by the same fibres. Such nerves are termed **mixed nerves.** The nerves which enable us to see, hear, and smell are purely sensory; but most of the nerves in the body are composed of mixed fibres.

SUMMARY.

NERVOUS SYSTEM	**Cerebro-spinal**	Consists of	Brain and its nerves. Spinal cord and its nerves.
		Fibres distributed to	Organs of sense. Voluntary muscles.
	Sympathetic .	Consists of	Double chain of ganglia, on each side of the vertebral column. Various disconnected ganglia.
		Fibres distributed to	The internal organs. The walls of blood-vessels
NERVE SUBSTANCE	**Cellular** . .	Greyish—in *nerve centres.*	
	Fibrous . .	Nerve fibres—forms *nerves*, and enters into the structure of nerve centres.	
NERVE FIBRES	**Fresh** . . .	A simple semitransparent filament.	
	After death .	A tube, containing a White opaque substance, surrounding The *axis-cylinder.*	
NERVES . .	**Afferent** . .	Convey impressions *to* a centre only. Also called *sensory* nerves.	
	Efferent . .	Convey impressions *from* a centre only. Fibres terminate in muscular fibres. Also called *motor* nerves.	
	Mixed . . .	Contain both *afferent* and *efferent* fibres.	

QUESTIONS ON LESSON XXX.

1. What do you know of the general arrangement of the parts forming the nervous system?
2. What is the *cerebro-spinal system*? To what points are its nerves distributed?
3. Describe the general arrangement of the *sympathetic system.*
4. What is a nerve? What does it look like in the body? What is the difference between a nerve and a nerve centre?
5. What is a *sensory*, and what a *motor* nerve? Give illustrations of the use of each.
6. A boy, seeing an apple on a tree, stretches out his hand to pluck it. What is the general nature and the order of the changes which take place in the nervous and the muscular systems of the boy under these circumstances?

LESSON XXXI.

THE BRAIN.

THE **brain**—the great nerve centre of the body—is the large upper portion of the cerebro-spinal axis filling the cavity of the cranium. It consists chiefly of soft nerve-substance, the general appearance and character resembling that of a sheep or rabbit.

The average weight of the adult human brain is about three pounds, but the size seems to vary very considerably.

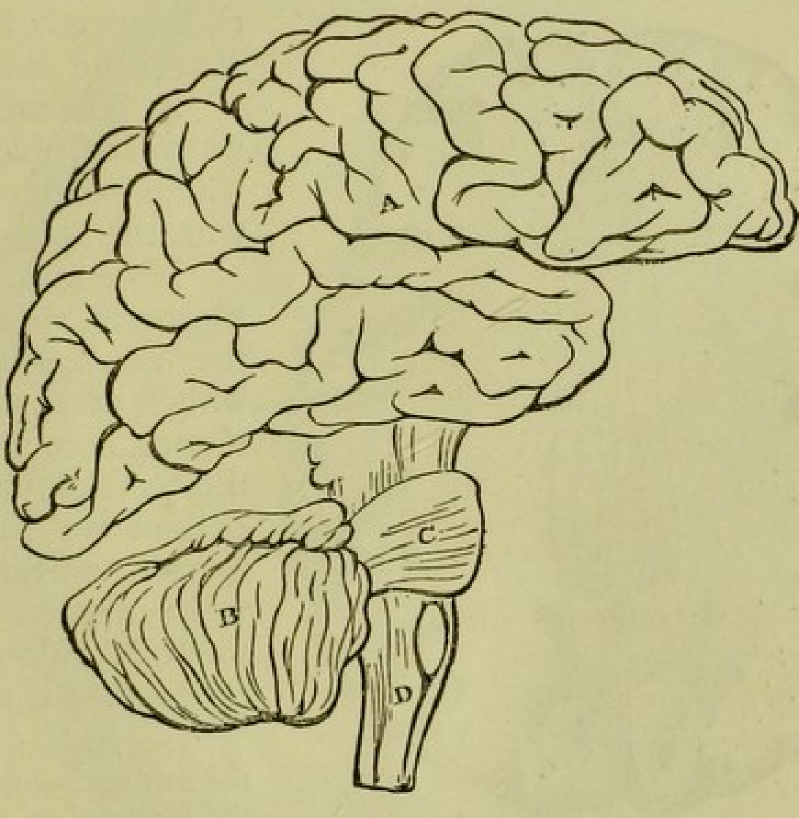


Fig. 164.—**The Human Brain.**

A, cerebrum; B, cerebellum; C, pons Varolii; D, medulla oblongata. The parts are represented as separated from one another somewhat more than is natural so as to show their relation better.

The surface of the brain is covered with a very thin and delicate membrane called the **pia mater** (Lat. pious mother), which consists of a thickly meshed network of small arteries and veins, supported by connective tissue. It is from this membrane that the brain receives its supply of blood, and consequently it contains none but very small blood-vessels. Outside the pia mater is a delicate and transparent serous membrane (see page 148) called the **arachnoid membrane** (Gr. *arachne*, a spider's web; and *eidos*, form). Over this is a third membrane, the **dura mater** (Lat. hard mother), which is very tough and fibrous. Its outer surface is rough, and in contact with the inner surface of the skull, while the inner surface is smooth, and is opposed to the outer surface of the arachnoid.

The brain consists of several parts, the chief of which are :—

1. The **cerebrum** or **greater brain**, which fills all the upper and frontal portion of the cranium, and weighs about nine-tenths as much as the entire brain.

2. The **cerebellum** or **lesser brain**, which lies underneath the back portion of the cerebrum.

3. The **pons Varolii** (Lat. *pons*, a bridge), a broad band or bridge of nerve matter which connects the right and left portions of the cerebellum, passing round the *medulla*.

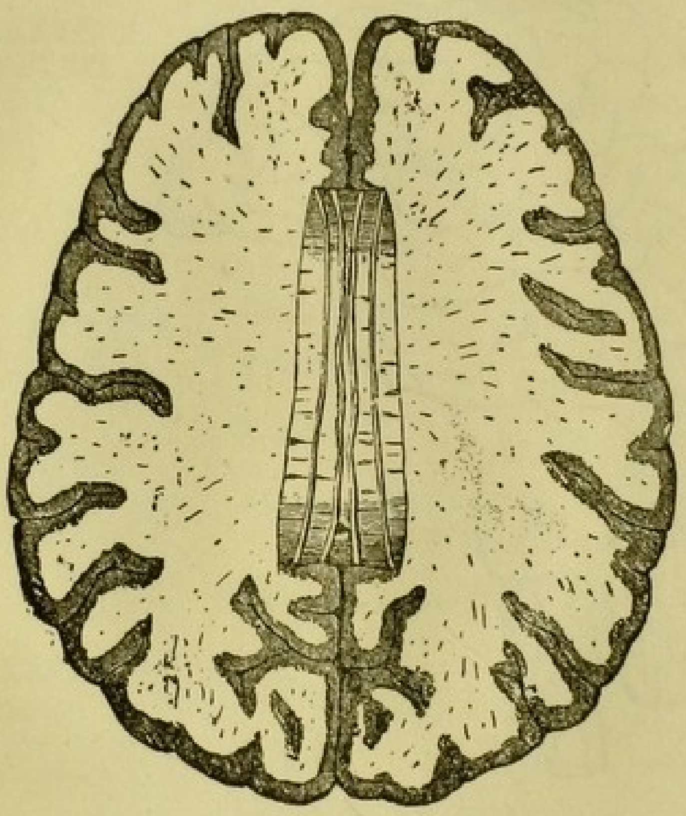


Fig. 165.—**Section through the Cerebral Hemispheres, showing the arrangement of the White and Grey Matter.**

4. The **medulla oblongata** (Lat. oblong marrow), which connects the brain with the spinal cord.

If we make a section of the brain, we may observe the arrangement of the white and grey nervous matter composing it. In the cerebrum and cerebellum we find the grey matter surrounding the white matter, while in the medulla oblongata the arrangement is reversed.

The student, remembering the soft semi-solid condition of the brains of an animal, may be at a loss to know how a section of the organ is to be made; therefore we give the following simple and easy method by which the brain may be hardened and afterwards cut for examination :—Place the complete but skinned head of a rabbit or other animal into a jar of methylated spirit, and let it remain in this for a few weeks. At the end of this time dissect away all the flesh, leaving the skull clean, at least on the whole upper surface. Now, with a small fret-saw, cut gently *just through the skull* in several directions, and remove the bone, piece by piece, till the brain has been entirely exposed. If the brain seems still too soft to handle, let it soak in the spirit a little longer. It will be noticed that several nerves pass from the under surface of the brain through openings in the bones, and it will be well to preserve the origins of these nerves attached to the brain as far as possible.

The **cerebrum** consists of two large **hemispheres**, the *right* and the *left*, separated by a very deep fissure. It is composed of a thick layer of grey matter surrounding white fibrous nerve-substance. The grey matter is drawn up into a number of folds or **convolutions**, by which its surface is greatly increased; and as the *pia mater* (which, it will be remembered, is the source from which the substance of the brain is supplied with blood) dips into all the fissures between these folds, we have reason to believe that the use of this arrangement is to provide the brain with a plentiful

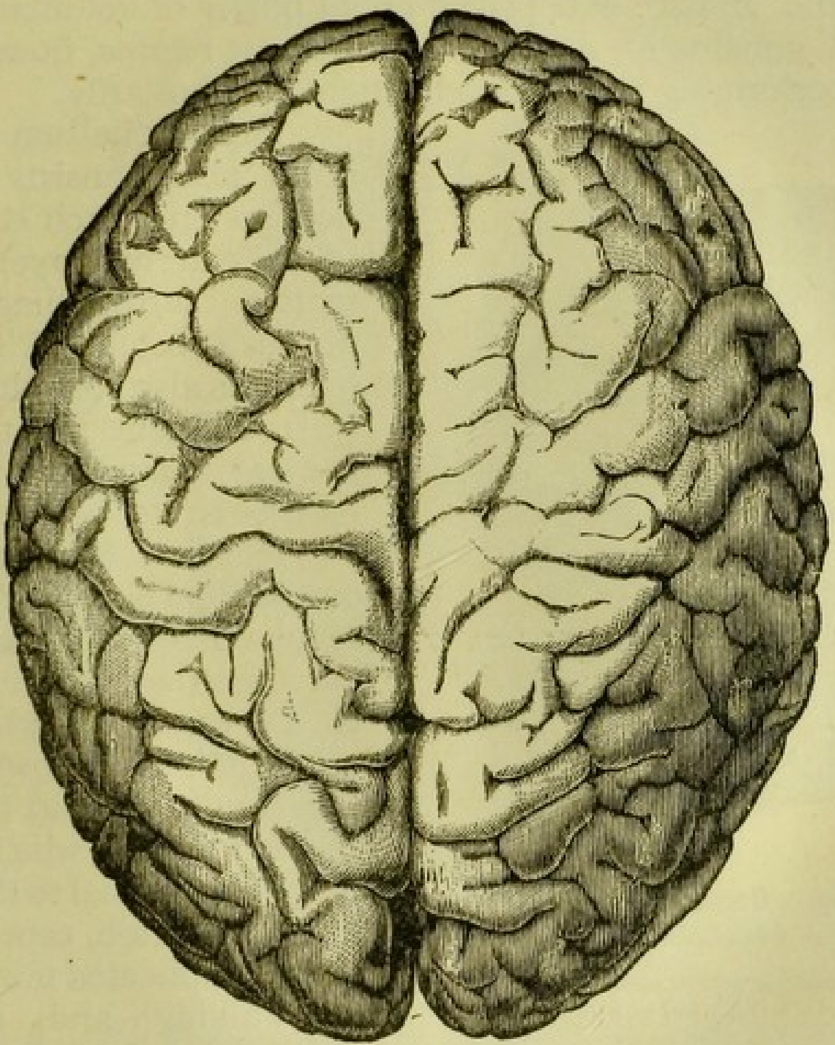


Fig. 166.—**The Upper Surface of the Cerebrum, showing its division into two Hemispheres, and also the Convolutions.**

supply of blood. The other coats of the brain—the *arachnoid* and the *dura mater*—do not dip into the fissures of the grey matter, but pass straight across them.

The **functions of the cerebrum**.—The cerebrum is the chief seat of *sensation*, *intelligence*, the *will*, and the *emotions*. When we examine the brains of various animals, we notice that the size of the cerebral hemispheres and the complexity of the convolutions are proportional to the intelligence of the animal. Thus, in the rabbit, the cerebrum is small in proportion to the brain as a whole, and its surface is smooth. In the ape, the cerebral hemispheres are proportionately larger, and their surfaces are drawn up into a number of convolutions; while in man they are large and still more convoluted. We derive our knowledge of the functions of the cerebrum partly from cases of injury and disease of that organ, and partly from experiments on the lower animals. When the cerebrum is diseased or injured, the power of manifesting mental faculty is more or less lost; when the cerebrum of an animal is removed, the animal is deprived of all power of voluntary movement, and remains in a state of stupor; it retains, however, the power of performing complicated actions involuntarily.

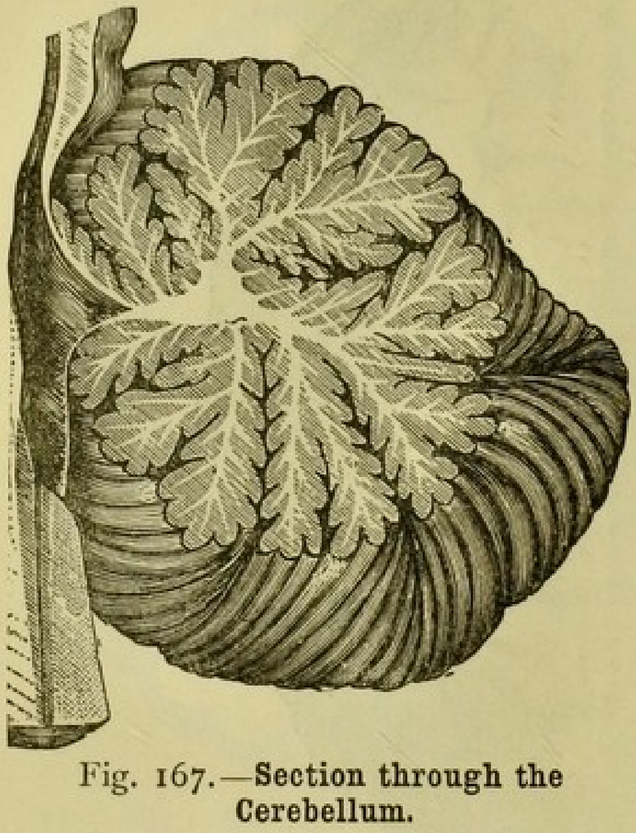


Fig. 167.—**Section through the Cerebellum.**

Showing the peculiar arrangement of the white and grey matter, forming what is known as the *arbor vitæ* (tree of life).

The **cerebellum** or lesser brain also consists of two hemispheres, each composed of an external layer of grey matter surrounding white fibrous substance. The grey matter is also convoluted, but in a different manner, and the *pia mater* dips into the fissures in its surface.

The chief **function of the cerebellum** appears to be the regulation or co-ordination of all muscular movement. It is the organ by which the mind gains a knowledge of the conditions and positions of the muscles, which knowledge is essential to their harmonious action, especially in such complicated movements as walking and running. When an animal has had its cerebellum removed, it can move any voluntary muscle at will, but it cannot walk or fly, nor can it balance its own body, since the muscles do not act with any regularity. Thus, voluntary movements do not *originate* in the cerebellum, but only the power of co-ordinating these movements. An animal retains sensation when its cerebellum has been destroyed, and both the lobes may be sliced away without causing the slightest pain.

The **medulla oblongata** is a mass of white and grey matter which connects the brain with the spinal cord. It is about an inch in length, and is broader above where it is continuous with the hemispheres of the brain. Its grey matter occupies the interior.

We have noticed that the functions of the cerebrum and the cerebellum are not of vital importance, so that death does not instantly follow the removal or destruction of these parts of the brain. But the **functions of the medulla oblongata** are of such a nature that instant death is the result of its destruction. It governs those involuntary movements which constitute the acts of

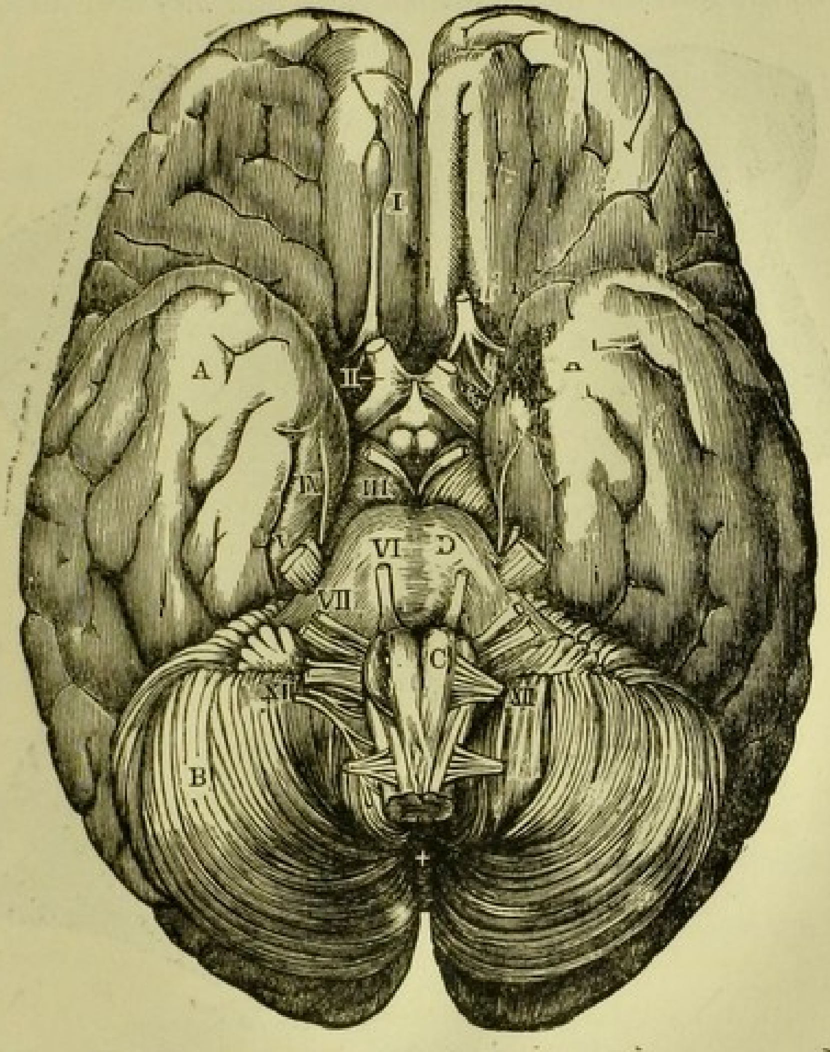


Fig. 168.—**The Under Surface of the Brain, showing the Origins of the Twelve Pairs of Nerves.**

A, cerebrum; B, cerebellum; C, medulla oblongata; D, pons Varolii. The Roman numerals distinguish certain of the cranial nerves.

breathing and swallowing. Hence, when it is destroyed the breathing instantly ceases. It is the only means of communication between the brain and the cord, and is therefore important as a conducting medium. It also possesses properties similar to those of the spinal cord, which will be explained in our next lesson.

From the under surface of the brain twelve pairs of nerves are given off. These are called the **cranial nerves**, and are numbered from before backwards.

The **first pair** are the **olfactory nerves** or the nerves of smell. These are the *sensory* or *afferent* nerves, the fibres of which are supplied to the mucous lining of the nose.

The **second pair** are the *sensory* nerves of the eye—the **optic nerves**, or nerves of sight.

The **third pair** are called the **motores oculi** (movers of the eyes). They are distributed to some of the muscles which move the eyeballs.

The **fourth pair** are *motor* nerves. They supply one of the muscles of the eyes.

The **fifth pair** are very large nerves, containing both *motor* and *sensory* fibres. Each one divides into three branches, and they are consequently called

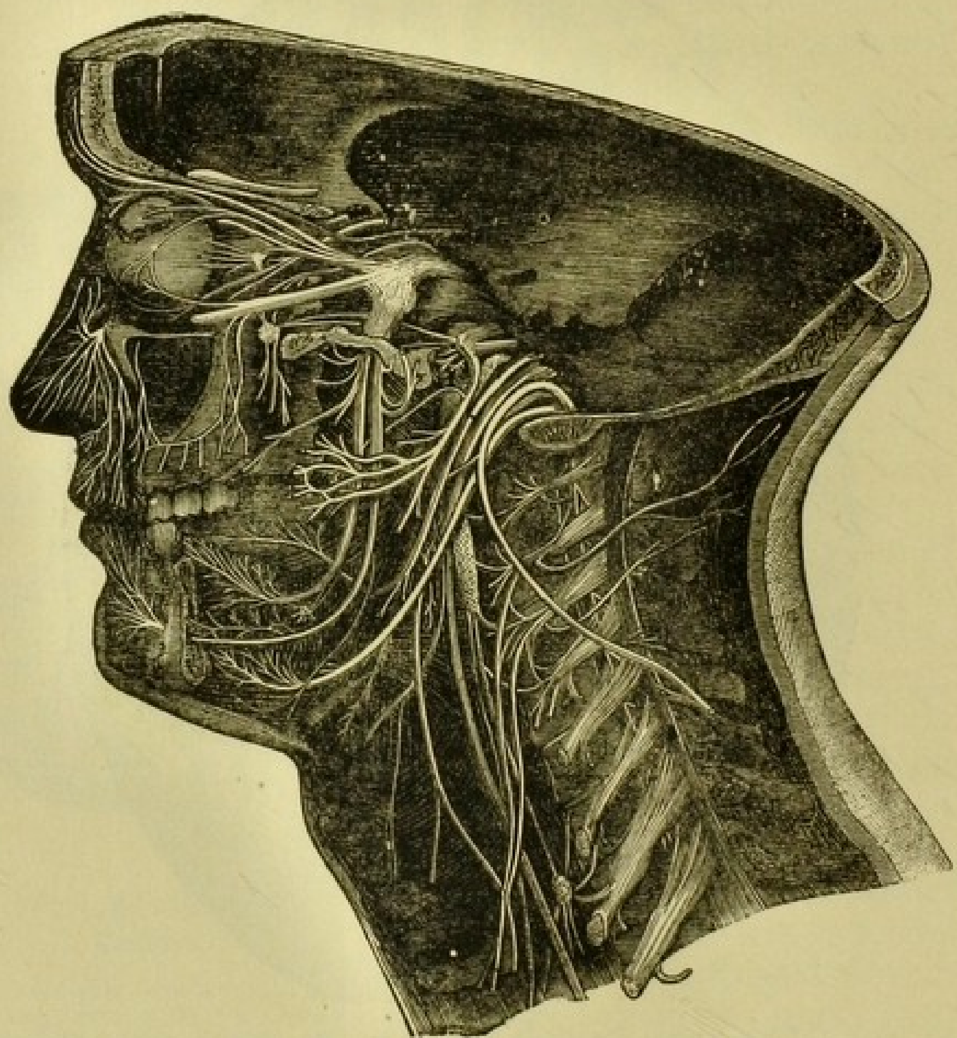


Fig. 169.—**The Cranial Nerves of the Left Side.**

the **trigeminal nerves.** They supply the skin of the face, the muscles of the lower jaw, and the tongue.

The **sixth pair** are supplied to the muscles which turn the eyeballs outwards. Thus the muscles of the eye receive nerve fibres from three distinct pairs of nerves—the third, fourth, and sixth.

The **seventh pair** are called the **facial nerves,** since they supply fibres to the muscles of the face.

The **eighth pair** are the **auditory nerves**—the *sensory* nerves which supply the ear.

The **ninth pair** are *mixed* nerves, called the **glossopharyngeal** (Gr. *glossa*, the tongue; and *pharynx*). Their *sensory* fibres enable us to taste, while the *motor* fibres supply the muscles of the pharynx.

The **tenth pair** are termed **pneumogastric nerves** (Gr. *pneuma*, breath; and *gaster*, stomach). They are very important *mixed* nerves which send fibres to the larynx, lungs, heart, stomach, and the liver.

The **eleventh pair** are *motor* nerves which supply certain muscles of the neck.

The **twelfth pair** are *motor* nerves which supply fibres to the muscles of the tongue.

SUMMARY.

BRAIN	**Coverings**	**Pia mater**	Inner, delicate, vascular. Closely invests the brain. Follows all the convolutions.
		Arachnoid.	A serous membrane.
		Dura mater	Tough, fibrous. Outer surface rough, and in contact with the skull. Inner surface smooth.
	Structure	**Cerebrum .**	Right and left *hemispheres*. Surface convoluted. Fills all upper portion of cranium. Grey matter outside.
		Cerebellum	Right and left *hemispheres*. Surface drawn into folds. Fills occipital portion of cranium. Grey matter outside.
		Medulla .	Connects the brain with the cord. Grey matter *inside*.
	Functions	**Cerebrum .**	Chief seat of sensation. The organ of the will and voluntary motion. The seat of the intelligence.
		Cerebellum	The seat of muscular sense (see page 193). Co-ordinates muscular movements.
		Medulla .	Governs the muscles of respiration and deglutition. A conducting medium between the brain and the cord.

QUESTIONS ON LESSON XXXI.

1. Describe the general structure of the brain, and the manner in which it is protected.
2. What are the chief divisions of the brain? Describe the relative positions of each part, and point out their chief structural differences.
3. Describe the structure and functions of the *cerebrum*. What would be the result of injury or disease in this portion of the brain?
4. What reasons have we for believing that the cerebrum is the seat of the intelligence?
5. Describe briefly the structure and functions of the *cerebellum*. What would be the result of the destruction of this organ?
6. Where is the *medulla oblongata* situated? Describe its general form and structure. What would happen if this portion of the brain were removed?

LESSON XXXII.

THE SPINAL CORD.

The **spinal cord** is a long cylinder of nerve matter which is contained in the *spinal cavity* formed by the *vertebral column.* It extends from the *medulla oblongata* to the *first lumbar vertebra*, and measures about eighteen inches in length. It is nearly as thick as the little finger.

Like the brain, the spinal cord is closely invested by the **pia mater** from which it receives its blood supply. Over this lies the serous **arachnoid membrane**, and exterior to the arachnoid is a continuation of the **dura mater** of the brain.

The **arachnoid membrane** of the cord, unlike that of the brain, is not in contact with the *pia mater*, but forms a loose bag around it. The **dura mater**, also, does not lie close against the vertebræ as it does against the cranium, but is separated from them by a layer of fatty tissue which forms a soft protecting covering, enabling the back to bend without injury to the cord.

The student may often procure an uninjured piece of the cord from the 'loin' of mutton, the 'sirloin' or the 'rib' of beef. After noticing its general character while fresh, he should soak it in spirit till sufficiently hard for cutting sections.

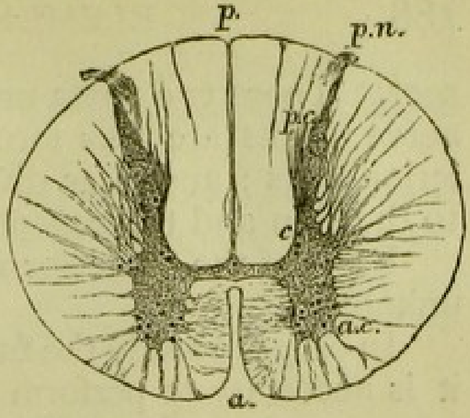
On making a **transverse section of the spinal cord** we notice that the grey nerve-substance is in the interior, and is surrounded by white matter. The cord is divided into right and left parts by two deep depressions or *fissures*. The front or **anterior fissure** is wider than the other, but not so deep. The **posterior fissure** is not a true fissure, but simply a layer of thin connective tissue, penetrating almost to the centre. In the centre of the cord is a very small canal—the **central canal**—which can be seen only with the aid of a microscope.

Large nerves are given off from the spinal cord, right and left, throughout its whole length. These are termed the **spinal nerves.** In the cervical and dorsal regions they emerge in pairs, passing out on each side through openings between the vertebræ. There are thirty-one pairs of these nerves. At the lower end of the cord the spinal nerves come off crowded together in the form of a parallel bundle which is called the **cauda equina** (Lat. horse tail), from its fancied resemblance to the tail of a horse.

The **grey matter** of the spinal cord projects backward and forward on each side, forming the posterior and anterior cornua (Lat. *cornu*, a horn). From the posterior cornu a bundle of fibres emerge, forming the **posterior root** of a spinal nerve. Fibres also pass outward from the anterior cornu, giving rise to an **anterior**

Fig. 171.—**Transverse Section of the Spinal Cord.**

a, anterior fissure ; *p*, posterior fissure ; *c*, grey matter; *pn*, posterior nerve-root ; *ac*, anterior cornu or horn of grey matter ; *pc*, posterior cornu.



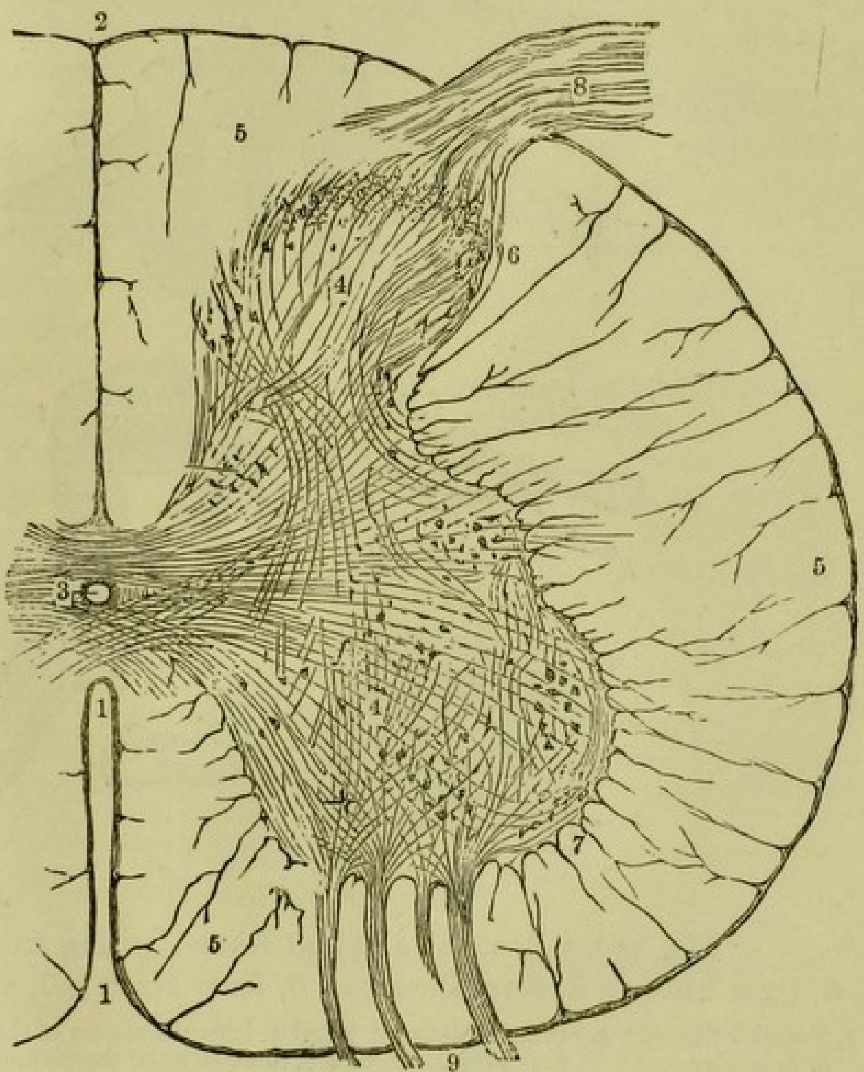


Fig. 172.—**Transverse Section of half the Spinal Cord. Magnified 8 diameters.**

1, anterior fissure ; 2, posterior fissure ; 3, central canal ; 4, grey matter ; 5, white matter ; 6, posterior cornu ; 7, anterior cornu ; 8, posterior nerve-root ; 9, anterior nerve-root.

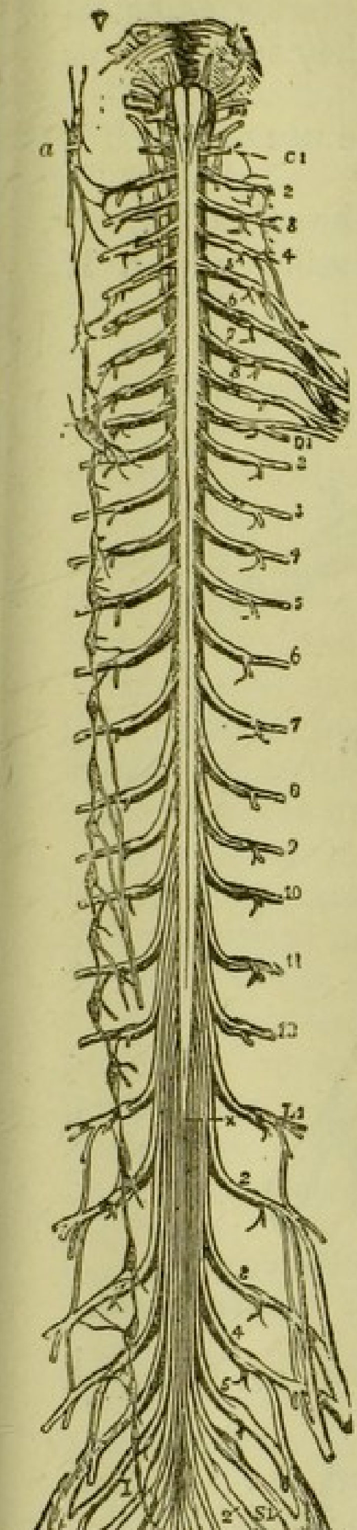


Fig. 170.—**The Spinal Cord and its Nerves (the Spinal Nerves), together with the Sympathetic Chain on one side.**

V, pons Varolii, below which is the medulla oblongata ; C 1 to 8, the cervical nerves ; D 1 to 12, the dorsal nerves ; L 1 to 5, the lumbar nerves ; S 1 to 5, the sacral nerves ; 6, the coccygeal nerve ; ×, the terminal fibre of the cord ; *a* to *x*, the sympathetic chain, showing the connection with the spinal nerves.

root. These two roots unite to form a **spinal nerve trunk.** The nerve trunks are thus formed by the union of anterior and posterior roots ; and after division and subdivision they supply fibres to the skin and the voluntary muscles.

Each of the posterior roots has a ganglion, the use of which is unknown.

In order to study the **functions of the roots of the spinal nerves** it is necessary to perform experiments on living animals :—1. If

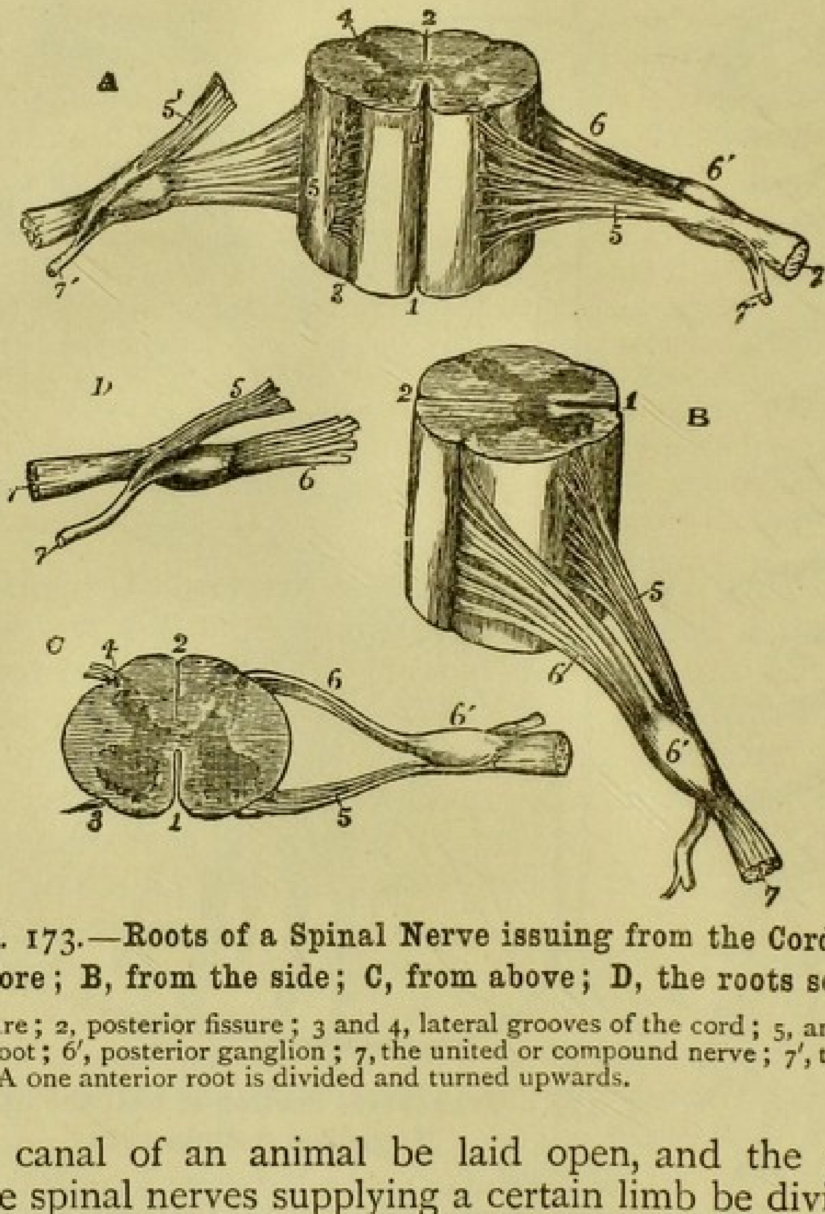


Fig. 173.—**Roots of a Spinal Nerve issuing from the Cord.**
A, from before ; B, from the side ; C, from above ; D, the roots separated.

1, anterior fissure ; 2, posterior fissure ; 3 and 4, lateral grooves of the cord ; 5, anterior root ; 6, posterior root ; 6′, posterior ganglion ; 7, the united or compound nerve ; 7′, the posterior branch. In A one anterior root is divided and turned upwards.

the spinal canal of an animal be laid open, and the **anterior roots** of the spinal nerves supplying a certain limb be divided, the animal will lose all power of voluntary movement in that limb, which will hang in a flaccid condition, but the power of sensation in the limb will remain unimpaired. If now we irritate those ends of the cut roots which remain in contact with the cord, no effect will be produced ; that is, the animal will show no sign of pain, neither will there be any movement of the limb. But if we irritate the other ends, the muscles of the limb will contract violently. Thus we learn that the **anterior roots consist of efferent or motor fibres only.**

2. If we divide the **posterior roots** supplying a certain limb without injuring the anterior roots, the animal will still have control over the voluntary muscles of that limb just as if nothing had happened, but the limb may be pinched or even burnt without producing any sign of suffering. Again, if we irritate those ends of the posterior roots still in contact with the cord, the animal will exhibit unmistakable signs of the most acute pain; but no effect is produced by the irritation of the other ends. Therefore we conclude that the **posterior roots consist of sensory or afferent fibres only.**

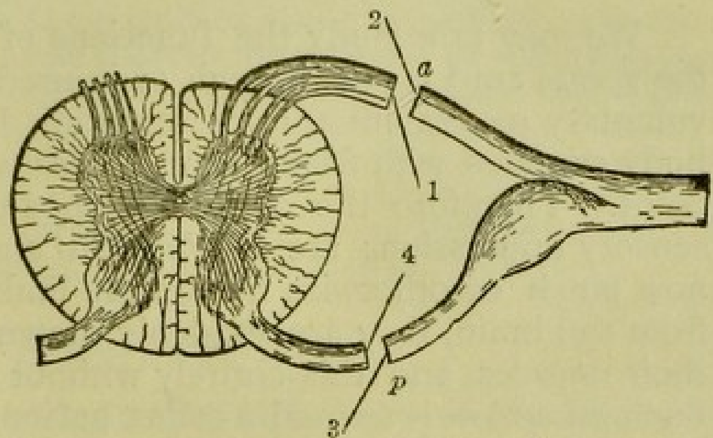


Fig. 174.—**Illustrating the Functions of the Roots of the Spinal Nerves.**

a, anterior root; *p*, posterior root.

Divide at a.—Irritate at 1: no result. Irritate at 2: contraction of muscles supplied with fibres from the root.

Divide at p.—Irritate at 3: no result. Irritate at 4: intense pain.

In a similar manner it may be demonstrated that the **spinal nerves,** formed by the union of the anterior and posterior roots, are mixed nerves, that is, nerves composed of both **sensory and motor** fibres. For, if we cut through the spinal nerves which supply a certain part of the body, both sensation and voluntary movement are lost to that part. And, if we irritate those ends which are in communication with the spinal cord, pain is produced; while, on irritating the other ends, violent muscular contraction is the result.

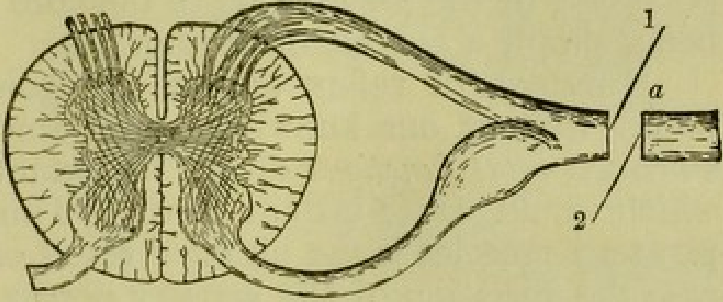


Fig. 175.—**Illustrating the Functions of the Spinal Nerves.**

Divide at a.—Irritate at 1: intense pain. Irritate at 2: muscular contraction.

It is an interesting fact that, when we irritate that portion of a cut spinal nerve which remains in communication with the brain, or, when we irritate the corresponding portion of a divided sensory root, the pain is not felt at the point of irritation, but is always referred to the part in which the fibres of the divided nerve *terminate*. Thus, if we apply an irritant to the spinal portions of nerves which supply the arm, although that limb is cut off from the brain—the seat of all sensation—yet the pain produced will be felt in the fingers and in the skin of the arm. And, even if the arm be entirely cut off, still the sensation will be referred to the lost limb by the brain. This will enable us to explain the cause of the sensation called 'pins and needles' produced by pressure on a nerve at the elbow. The irritation is transmitted direct to the brain by one or more sensory nerves, aud the brain simply refeis the sensation to the extremities of the irritated nerve.

We may now study the **functions of the spinal cord.** When the spinal cord is cut through or injured at any point, all power of voluntary movement and all sensation is lost to every part of the body supplied with fibres from nerves which originate below that point. Therefore the cord is a medium by which motor and sensory impressions are *conducted* to and from the brain. If we now pinch or otherwise irritate the limbs which are thus cut oft from the brain, they are suddenly drawn up by the contraction of their muscles, and this entirely without any exercise of the will. Such an action is termed a **reflex action.** It consists of a disturbance of sensory fibres which is conducted by a sensory nerve to a nerve centre, and a reflection of this disturbance from the nerve centre through one or more motor nerves, causing a contraction of the muscles in which the motor fibres terminate. It will thus be seen that the spinal cord is not merely a *conductor* of impressions, but that it is **a centre for reflex actions.** This power is possessed by the grey matter of the cord only, the white substance being simply a conductor of impulses.

Hundreds of **reflex actions** are going on continually in our bodies without our knowledge, and among them we include the so-called *vital functions* of the important organs, the cessation of which would cause instant death. Thus, the **action of the respiratory muscles** is the ultimate result of a reflex action. In this case the irritation of the sensory nerves concerned is due to the imperfectly aërated condition of the blood. The impression thus made is conveyed to the *medulla oblongata*, and is thence reflected through motor nerves which govern the intercostal muscles, the diaphragm, &c. Even walking, reading, and other familiar actions of voluntary muscles may be reflex movements. Of course such movements are sometimes purely voluntary, especially in childhood, but in time the muscles become so used to certain successions of movements, that they act in their accustomed manner without the control of the will. We may walk without knowing that we are walking; and, in reading, we often unconsciously utter certain sounds on seeing the signs which have so frequently caused us to produce these sounds voluntarily.

It appears that consciousness tends to prevent or reduce the number of reflex movements. Thus, the tickling of the feet during sleep will cause muscular contraction more readily than when we are awake. And again, the unexpected motion of an object near the eyes causes the eyelids to close instantly; whereas, had we been prepared for it, we should probably have been able to keep the eyes open.

If we cut through the substance of the spinal cord on one side only, sensation is destroyed in parts supplied by nerves below the division on *the opposite side of the body*, while the power of voluntary movement is lost on *the same side*. Therefore the **sensory fibres** must cross over immediately on entering the cord, but the motor fibres pass down on the same side on which they leave the cord. This may be further illustrated by dividing the spinal cord into two lateral halves; in which case all sensation is destroyed, while the power of voluntary movement is not affected. It may be proved, however, that the white fibres of the cord, cross over to the opposite side in the medulla oblongata before entering the brain; for if one side of the brain be cut away, all power of muscular contraction is lost on the *opposite* side.

SUMMARY.

THE SPINAL CORD	**Position**	In the *spinal canal* formed by the vertebral column.
	Length	About eighteen inches. Extends from the medulla oblongata to the first lumbar vertebra.
	Thickness	About one-third of an inch.
	Coats	*Pia mater*—delicate, vascular. *Arachnoid*—serous, forming a loose bag. *Dura mater*—tough, fibrous. (A layer of fatty tissue lies between the dura mater and the bony canal.)
	Structure	*Grey matter* internal. *White matter* external. *Anterior fissure.* *Posterior fissure*—deeper and narrower. *Central canal*—microscopic.
	Nerves	Thirty-one pairs—between the vertebræ. Crowded at the lower extremity of the cord—*cauda equina.* Each trunk formed by the union of two *roots.* Roots { Anterior—motor. Posterior—sensory.
	Functions	Conduction of impressions. A centre for reflex action (grey matter). *Sensory fibres*—cross as they enter the cord. *Motor fibres*—cross in the medulla oblongata.

Reflex action	A disturbed condition of sensory fibres— Conducted to a nerve centre— Reflected by the nerve centre along motor fibres to their terminations in muscles— Muscular contraction.

QUESTIONS ON LESSON XXXII.

1. Describe the structure of the spinal cord as revealed in a transverse section. Illustrate your description by a sketch.
2. How is the spinal cord protected? Compare it in this respect with the brain.
3. How are the spinal nerves arranged? How do they pass out from the spinal canal?
4. Describe the arrangement and the functions of the roots of the spinal nerves.
5. How would you prove (1) that the anterior roots consist of motor fibres only, (2) that the posterior roots consist of sensory fibres only, and (3) that the spinal nerves contain both sensory and motor fibres?
6. Give a proof that the spinal cord is a nerve centre.
7. How is it that a man in a fit, though quite unconscious, may go on breathing regularly? What part of the nervous system keeps up and regulates the act of breathing?
8. Why is a man whose back is broken unable of himself to move his legs, though they may move involuntarily when the feet are tickled?
9. When a man's neck is broken death is sometimes instantaneous. How is this brought about?
10. How do we know that the nerve fibres which are employed when a limb is moved are different from those which are set in action when pain is felt in that limb?
11. When your leg is kept for a long time in one position it sometimes 'goes to sleep.' What is the condition of the limb at this time, and how is it brought about?
12. Instances of injury or disease have been met with in which the power of movement in a limb has been lost and yet feeling has remained, and others in which feeling has been lost and yet the power of movement has been retained. State what parts must have been affected by the injury or disease in these cases.

LESSON XXXIII.

SENSATIONS—TOUCH.

THE nervous system is the medium by which we derive a knowledge of the existence of the various parts of the body, and of the external world. This knowledge is based upon **sensations.**

In order to produce a sensation of any kind, three distinct **conditions** are necessary. These are:—(1) some disturbing condition which irritates one or more sensory fibres; (2) the transmission of this irritation along the sensory fibres to the nerve-centre (the brain); and (3) the translation of the irritation in the nerve-centre into a state of consciousness.

Some of the sensations, such as sight and hearing, are produced by means of a specially constructed organ of sense, so that they are distinctly local in their character. Such sensations are called **special sensations.** Others are not localised, but are produced through the agency of nerves which are very widely distributed. These sensations are called **common or general sensations**, and by them we are made aware of the general condition of the body.

Among the **common sensations** may be mentioned *pain*, *warmth*, *hunger*, *fatigue*, and *faintness*. Although some of these sensations are sometimes distinctly localised, yet, at the same time, they are accompanied by a general sensation. For instance, during hunger a distinct pain is felt in the region of the stomach, while there is also a feeling of general discomfort.

One of the common sensations is that which has been termed the '**muscular sense.**' It is that sensation by which we become acquainted with the condition of the muscles. Although the mind may be unconscious of the existence of the muscles of any particular part, yet it is made aware of their condition, and is able to regulate their contraction with extreme precision. Thus, when walking on a windy day, we incline our bodies in proportion to the force of the wind. A person, by means of this sense, may perform such complicated acts as writing or pianoforte-playing without the aid of sight. It is the muscular sense which enables us to estimate the weight of a body by the effort required to lift it. We are most conscious of this muscular sensation when we make the muscles rigid by an effort of the will.

The **special sensations** are five in number. They are—*touch*, *smell*, *taste*, *sight*, and *hearing*.

Sensations are also classified as *objective* and *subjective*.

Those sensations which are produced by external objects or conditions are called **objective sensations**. Sometimes, however, the exciting cause is a peculiar condition of the cerebrum itself, and the sensations thus produced are termed **subjective**. As examples of these may be mentioned noises in the ears, flashes of light before the eyes, and peculiar odours experienced when there is no external cause to produce them. The mind generally refers such sensations to external objects, and hence arise **illusions**.

Sensation may be produced by the irritation of a sensory nerve without the agency of the corresponding organ of sense. Thus, the sensation of sound may be produced by the irritation of the *auditory nerve*. The irritation of a nerve of special sense however, does not produce pain.

The sense of **touch** is sometimes classed among the general sensations, inasmuch as it is very widely distributed, and is so closely allied to *feeling* and *pain*, which are general sensations. But touch proper is a sensation by which we gain a knowledge of the external world, while feeling and pain are sensations by which we are made aware of certain conditions of various parts of the body.

The following example will help to make this distinction clear:—The point of a needle is pressed against the skin. A sensation is at once experienced. This sensation is that of touch, and is at once referred to an external object. But if the needle is made to penetrate beneath the epidermis, a sensation of pain is produced, which continues after the needle has been withdrawn. The pain is no longer referred to an external object, but reveals to us a changed condition in a particular part of the body.

Fig. 176.—**A Nerve of the Finger, with Pacinian Bodies attached. Natural size.**

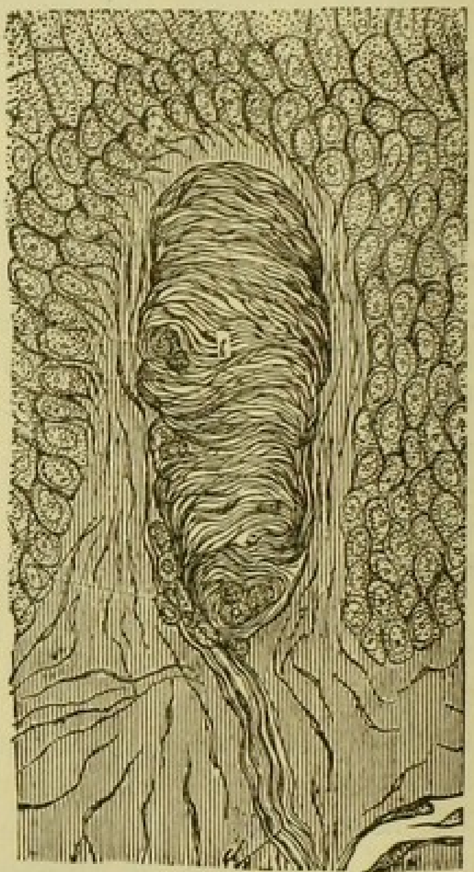


Fig. 177.—**Section of a Papilla of the Skin, showing a Touch Corpuscle. Highly magnified.**

t, tactile or touch corpuscle ; *d*, nerve fibres passing up to it.

The sense of touch may be regarded as a modification of common sensation ; and all parts of the body which are supplied with sensory nerves are to a certain extent **organs of touch** ; but this sense is perfected only in the *skin*, *tongue*, and *lips*.

The **sensibility of the skin** is due to the presence of nerve fibres distributed through the dermis. Some of these nerve filaments subdivide in the skin, and possibly terminate in individual cells ; but many of them, especially in the more sensitive parts of the skin, end in minute bodies of various forms.

The largest of these are oval bodies having a diameter of from $\frac{1}{20}$ to $\frac{1}{10}$ oi an inch. They are called **Pacinian bodies**, after Pacini, their discoverer, and are abundantly distributed in the skin of the *hands* and *feet*. Other smaller bodies, called **touch corpuscles** or **tactile corpuscles**, are abundant in highly sensitive parts of the skin.

In the most sensitive parts of the skin papillæ are very abundant, and the epidermis lying over them is thin. Many of the papillæ are also supplied with touch corpuscles. In other parts, as in the heel, the outer skin is so thick that the sense of touch is dulled.

The degree of sensitiveness of the skin may be measured by the power of distinguishing between two or more sensations pro-

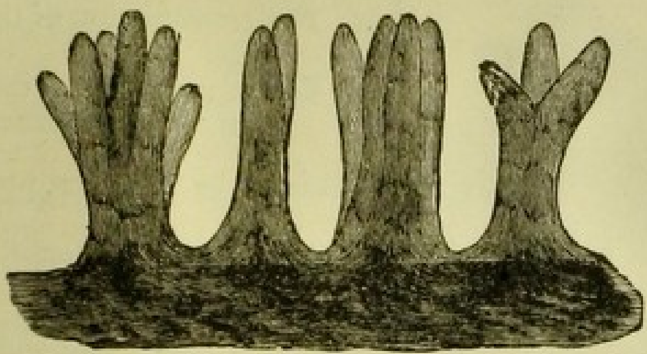


Fig. 178.—**Papillæ of the Skin from the Palm of the Hand. Magnified 60 diameters.**

The epidermis has been removed.

duced at points very near each other. For instance, open a pair of compasses till the points are one inch apart. Apply these points to the palm of the hand, and two distinct sensations are produced. Now apply the points to the skin of the arm, and the sensation is such as would be produced by the application of a single point. Hence we say that the hand is more sensitive to touch than the arm. Two distinct sensations may similarly be produced

On the tip of the tongue,	at a distance of	$\frac{1}{24}$	of an inch.
,, fore-finger	,,	$\frac{1}{12}$	,,
,, nose	,,	$\frac{1}{4}$	,,
,, palm of the hand	,,	$\frac{1}{2}$	,,
,, back of the hand	,,	$1\frac{1}{4}$	inch.
,, back of the neck	,,	2	inches.
,, thigh	,,	$2\frac{1}{2}$	,,
,, back	,,	3	,,

As a further illustration of the varying sensitiveness of the skin, move the compass points over the skin, from the cheek to the lips, and the distance between the points appears to be gradually increasing. This power of distinguishing between sensations is not due to the thinness of the epidermis, but to the abundant distribution of the nerve filaments.

SUMMARY.

SENSATIONS
- **General or common**
  - Not localised.
  - No special organs concerned.
  - Examples:—pain, warmth, hunger, fatigue, faintness, muscular sense, &c.
- **Special senses**
  - *Touch*—Special organ—the skin, tongue, and lips.
  - *Smell*—Special organ—the nose.
  - *Taste* ,, ,, the tongue.
  - *Hearing* ,, ,, the ear.
  - *Sight* ,, ,, the eye.

CONDITIONS NECESSARY
1. The irritation of sensory fibres.
2. The transmission of this irritation to the brain.
3. The translation of the irritation into a state of consciousness.

SENSATIONS
- **Objective**—Caused by irritation produced by outside objects.
- **Subjective**—Caused by a disturbed condition of the cerebrum.

NERVE-ENDINGS
- **Terminal filaments**—probably ending in the cells of the skin.
- **Pacinian bodies**—visible to naked eye—in the skin of the hands and feet.
- **Touch corpuscles**—smaller—abundant in highly sensitive parts of skin.

SENSITIVENESS OF SKIN —depends on
- Thinness of the epidermis.
- The number of nerve endings in a given area.

QUESTIONS ON LESSON XXXIII.

1. What is the difference between common and special sensations? Give examples of each.
2. What is meant by muscular sense? Give an illustration.
3. What are the conditions necessary to produce a sensation? Give examples of sensations produced without the aid of a special organ of sense.
4. May the sensation of sight be produced without the use of the eye? If so, how?
5. What is meant by the terms *subjective* and *objective* as applied to sensations?
6. On what does the sensitiveness of the skin depend?
7. Describe the various modes of the termination of nerve fibres in the skin.
8. What do we mean by saying that the lips are more sensitive to touch than the arm? How may this be proved?

LESSON XXXIV.

THE TONGUE AND TASTE.—THE NOSE AND SMELL.

THE **tongue** is a muscular organ covered with mucous membrane. It is attached by means of muscles to the lower jaw, and is also connected behind with the *hyoid bone*.

The **organ of taste** is the mucous membrane of the tongue, especially that at the upper and back surface, and also the mucous membrane of the posterior portion of the *palate*.

On the under surface of the tongue the **mucous membrane** is smooth and thin, like that of the walls of the mouth generally ; but its upper surface is rendered rough and sensitive to taste by a number of **papillæ** which are richly supplied with nerve terminations.

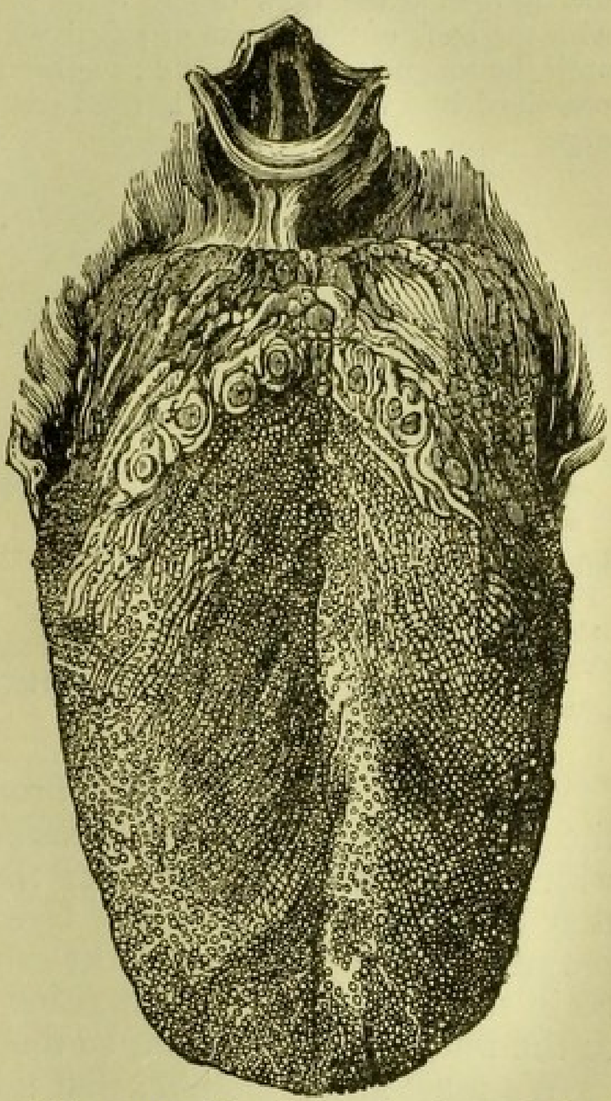


Fig. 179.—**The Upper Surface of the Human Tongue.**

The **papillæ** of the tongue are large compared with those of the dermis ; they are also quite distinct from each other. The smallest and most numerous of these are conical or cylindrical in shape, and are called **filiform** (Lat. *filum*, a thread). Mixed with these are a number of larger papillæ called **fungiform** (Lat. *fungus*, a mushroom) on account of their resemblance in form to certain of the *fungi*. They each consist of a round and broad extremity supported on a narrower stalk, and are easily distinguished from the others by their deep red colour. At the back of the tongue there are from seven to twelve very large papillæ arranged in two rows obliquely, so as to form the letter V with the point turned backwards. These are termed the **circumvallate papillæ** (Lat. *circum*, around ; and *vallum*, a rampart) because they are each surrounded by a kind of wall or rampart.

All the papillæ are richly supplied with blood-vessels and nerves. The nerve fibres are obtained from two sources—the *glossopharyngeal* and the *fifth* pairs of cranial nerves. The former nerves supply the back of the tongue and of the palate, while the latter send their fibres to the middle and tip of the tongue.

It is probable that both these nerves are nerves of taste, although they appear to be dissimilar in their functions. It is easy to prove, for instance, that different portions of the mucous membrane of the tongue and palate possess different powers. Sweet and salt tastes are perceived more readily at the tip than at the back of the tongue. Sugar may be brought into contact with the back of the tongue or palate without any taste being detected, at least until the tongue and the palate have been pressed together. Bitter tastes are perceived best when applied to the back part of the tongue, and acids at the edge.

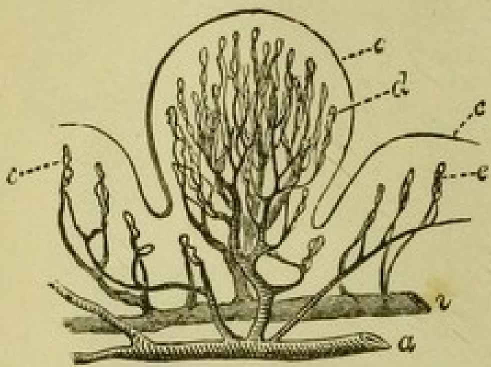


Fig. 180.—**Sectional View of a Fungiform Papilla, showing the arrangement of its Blood Vessels.**

a, artery ; *v*, vein ; *c* and *d*, capillary loops ; *e*, epithelium.

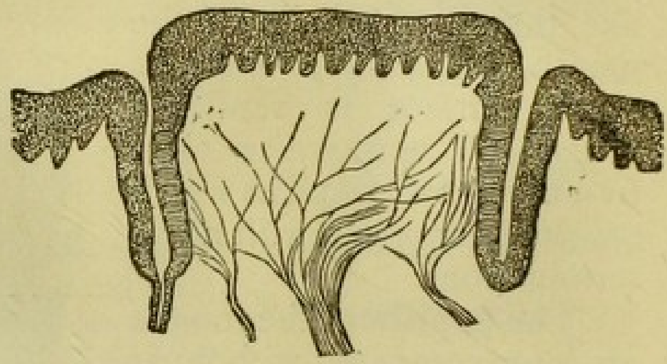


Fig. 181.—**Section of a Circumvallate Papilla, showing the Distribution of its Nerve-Fibres.**

It appears that, in order to produce the sensation we call taste, the particles of the substance tasted must come in actual contact with the nerve-terminations of the mucous membrane ; that is, they must penetrate the outer layer of the membrane which covers the nerve-endings. Hence the substance to be tasted must either be in solution, or must be capable of being dissolved in the saliva or the mucus of the mouth, so that it may be easily absorbed.

We must also remember that there is no sensation without the brain—that we do not taste a substance till the irritation of the sensory fibres has been transmitted through these fibres to the brain.

Many of the sensations which we call **taste or flavour** are not simple but very complex, in which both smell and touch play a very important part. Smell is so closely associated with the sense of taste that the odour of a substance frequently suggests the taste, and the taste sometimes suggests the odour. When the sense of smell is temporarily destroyed during a severe cold, taste is often partially or entirely lost until the sense of smell returns. This explains also the common practice of holding the nose while taking a dose of nauseous physic.

The **organ of smell** is the mucous membrane which lines the surfaces of the ethmoid bone, this portion only of the nasal cavities being supplied by filaments of the olfactory nerves.

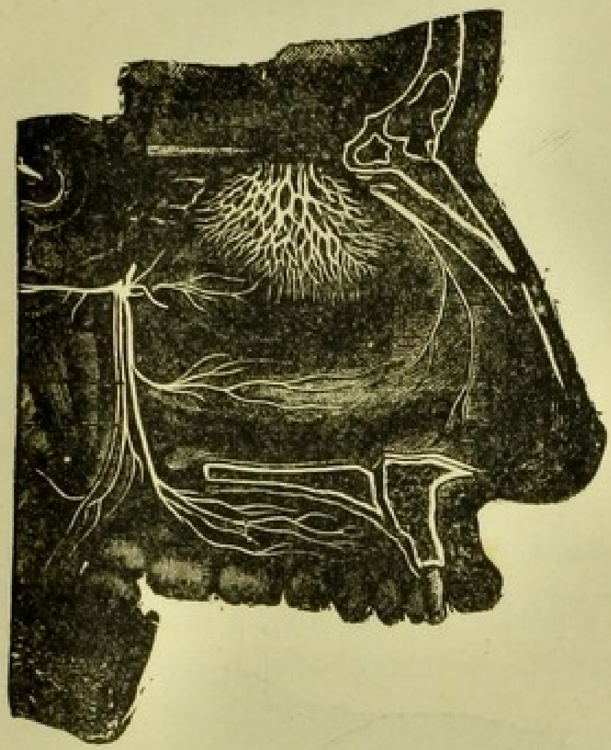


Fig. 182.—**Nerves of the Outer Wall of the Left Nasal Cavity.**

During ordinary breathing through the nose, the air passes gently through the lower and wider portions of the nasal cavities, without disturbing to any great extent the air which is enclosed by the scroll-like folds of the turbinated bones. Consequently, even though the air may contain particles of odorous matter, few or none of them come into contact with the terminations of the olfactory nerve, and little or no sensation of smell is experienced. When we wish to perceive an odour more distinctly, we 'sniff' the air. In doing this we close the mouth so as to direct the whole of the inspired air through the nose ; and then draw in the air by repeated short and sudden inspirations. This causes upward and abrupt rushes into the nasal cavities, the effect of which is to disturb the comparatively still air of the olfactory part of the nose, and to exchange some of it for the air containing the odorous substance. As soon as the particles of this substance touch the olfactory nerve-endings, a sensory impulse is transmitted to the brain, and the sensation of smell is experienced.

The **loss of smell** during a cold is sometimes due to the

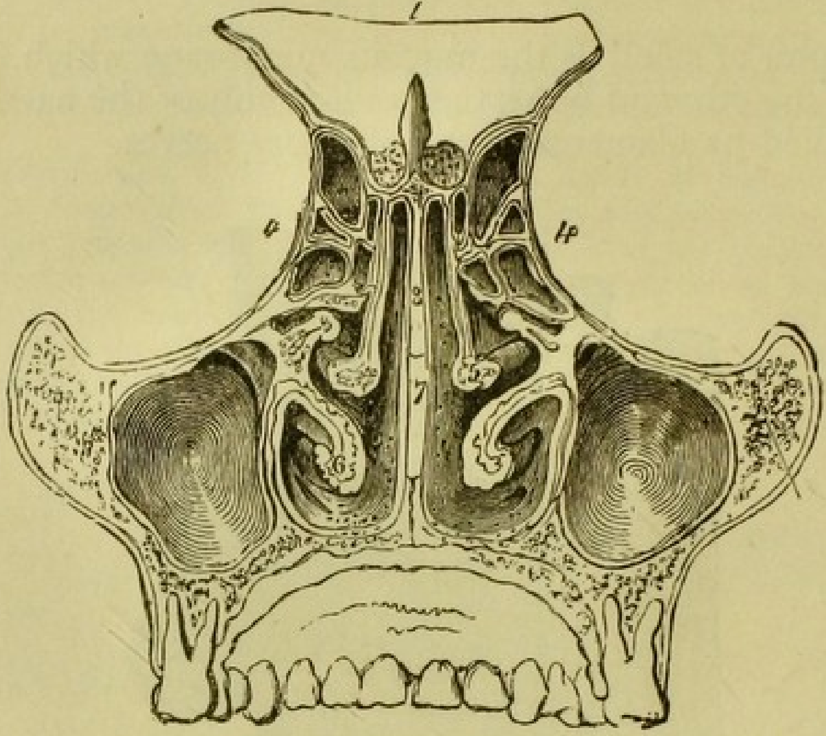


Fig. 183.—**Section of the Nasal Cavities, seen from behind.**

1, frontal bone ; 3, perpendicular plate of the ethmoid bone ; 4, ethmoidal cavities ; 5, middle turbinated bone 6, inferior turbinated bone ; 7, vomer ; 8, malar or cheek-bone.

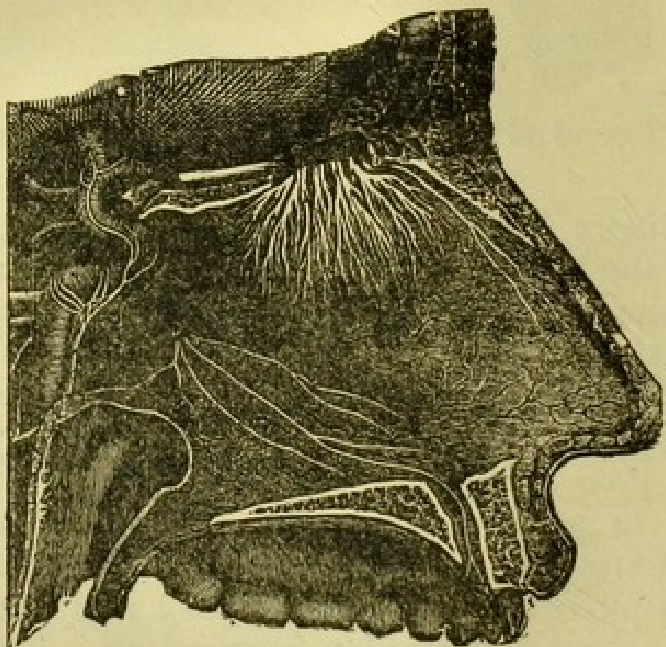


Fig. 184.—**Nerves of the Septum of the Nose, seen from the right side.**

swollen condition of the mucous membrane surrounding the ethmoidal cavities, by which they are shut off from the common cavity through which the air passes.

SUMMARY.

- **TONGUE**
  - A muscular organ.
  - Covered with *mucous membrane.*
  - **Mucous membrane**
    - Smooth and thin on under surface.
    - Raised into numerous *papillæ* on the upper surface.
  - **Papillæ**
    - **Filiform**
      - Elongated and pointed.
      - Smallest and most numerous.
    - **Fungiform**
      - Resembling certain *fungi* in form.
      - Larger than the filiform.
      - Distinguished by their deep red colour.
    - **Circumvallate**
      - The largest.
      - Arranged in the form of the letter V.
      - At the back of the tongue.
      - Surrounded by a wall or rampart.
  - **Nerves**
    - **Glosso-pharyngeal**
      - Supplies the back of the tongue and palate.
    - **Fifth pair**
      - Supplies the fore portion of the tongue.
- **TASTE**
  - Both pairs of nerves probably concerned.
  - Substance to be tasted must be soluble.
  - The irritation of the sensory nerves must be transmitted to the brain.
  - Sweet and saline tastes perceived chiefly by the tip of the tongue.
  - Bitter tastes at the back part of the tongue, acid at the edge.
  - Closely associated with the senses of touch and smell.
- **SENSE OF SMELL**
  - **Organ**
    - The mucous membrane of the ethmoidal portion of the nasal cavities.
  - **Conditions**
    - Air must enter the ethmoidal cavities.
    - Particles of the odorous substance must come into contact with the olfactory filaments.
    - The irritation thus produced must be transmitted to the brain.

QUESTIONS ON LESSON XXXIV.

1. Describe the general structure and uses of the tongue.
2. How does the mucous membrane of the tongue differ from that of the other parts of the mouth ?
3. Describe the general form and arrangement of the different kinds of papillæ on the surface of the tongue. Of what use are these papillæ ?
4. From what sources does the tongue receive its nerve supply ?
5. What is the organ of taste ? What are the conditions necessary for the production of the sensation called taste ?
6. How do the different portions of the mucous membrane of the tongue differ with regard to the sensations they produce ?

7. How would you prove that the sense of smell is intimately associated with that of taste?
8. Describe the general structure of the walls of the nasal cavities. How are these cavities separated from the mouth, the brain, and from each other?
9. What is the course taken by the air when we breathe (1) with the mouth open and (2) with the mouth shut?
10. By what part of the nose do we smell? How does sniffing assist the sense of smell?

LESSON XXXV.

THE EYE AND VISION.

The **organ of vision** consists of the *eyeball*, which, with its muscles, blood-vessels, nerves, fatty tissue and other protecting structures, completely fill the orbit or eye-socket.

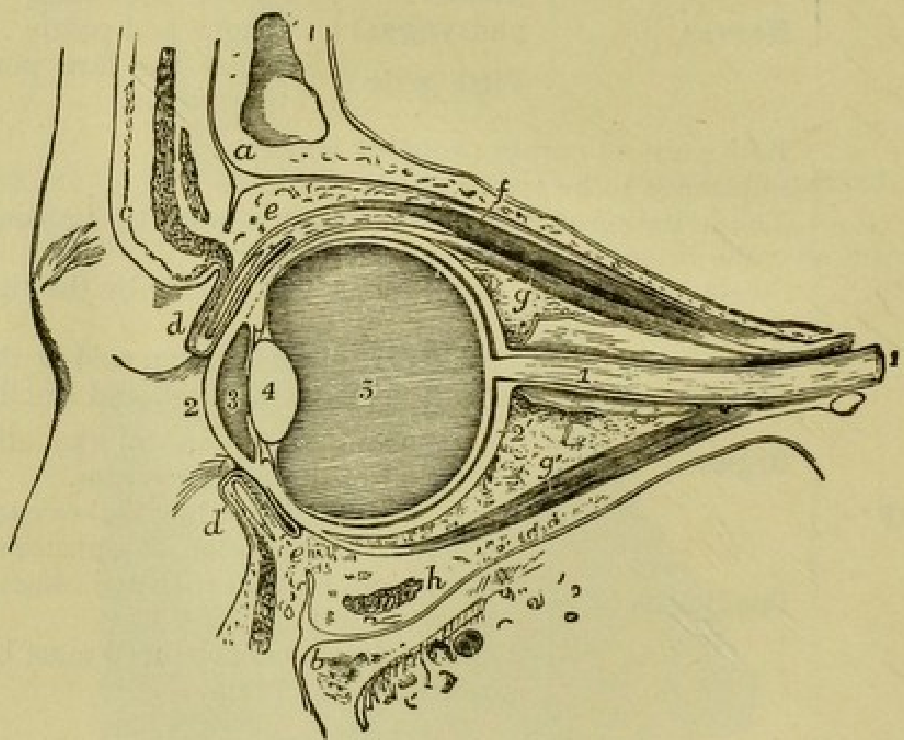


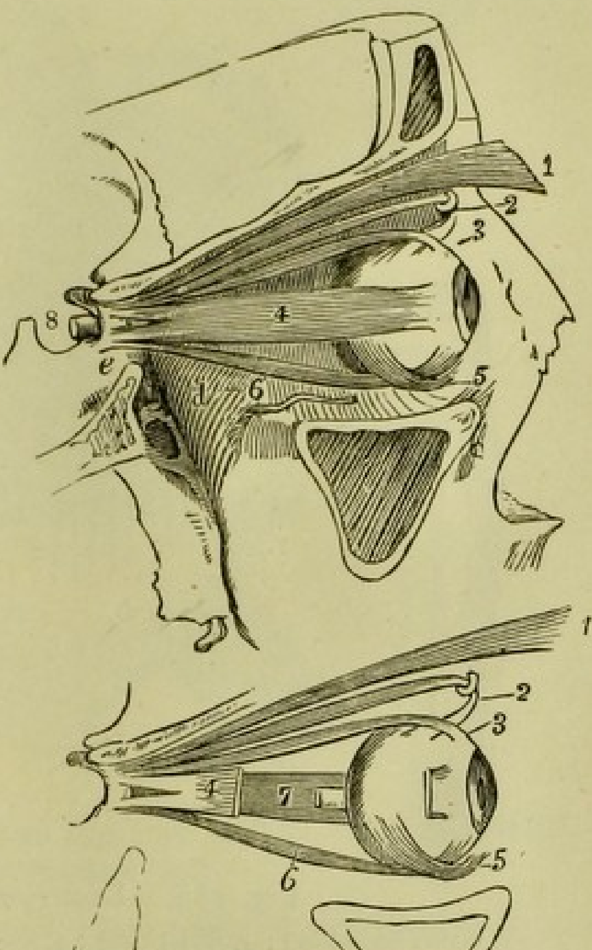
Fig. 185.—**Section through the Orbit and its Contents.**

a, frontal bone; *b*, superior maxillary bone; *c*, eyebrow; *d*, eyelids; *e*, conjunctiva; *f*, the muscle which raises the upper lid; *g* and *g'*, recti muscles; *h*, inferior oblique muscle cut across; 1, optic nerve; 2, cornea; 2', sclerotic; 3, aqueous chamber; 4, crystalline lens; 5, vitreous chamber.

In front the ball of the eye is protected by movable folds of the skin or integument called the **eyelids**. The inner surfaces of the lids are lined by a mucous membrane called the **conjunctiva**, which is also reflected over the front of the ball. The upper eyelid is larger and more movable than the lower one, and it is chiefly by the elevation and depression of this lid that the eye is opened and closed. The eyelids are closed by the contraction of muscular fibres which are arranged in the form of a ring around the eye. This circular muscle is called the **orbicularis** (Lat. *orbiculus*, a little circle). The lower lid has no special muscle to depress it, but the upper eyelid is raised by the contraction of a muscle which comes forward from the back of the orbit.

The eyeball is moved by six muscles, four of which are called *straight* muscles, and the other two *oblique*. The four *recti* (Lat. *rectus*, straight) come forwards from the back of the orbit, and are named superior, inferior, external, and internal, from their positions. The **superior rectus muscle** turns the front of the eyeball upwards, the **inferior rectus** turns it downwards; and the **external** and **internal recti** turn the front of the eyeball outwards and inwards respectively.

The **superior oblique muscle** comes forward from the back of the orbit, and then, becoming tendinous, passes through a kind of pulley of fibres attached to the frontal bone. It then turns backwards and outwards, and is attached to the outer and back portion of the eyeball. Hence, when this muscle contracts, it turns the eyeball obliquely outwards and downwards. The **inferior oblique muscle** springs from the lower and front portion of the orbit, and passes obliquely backwards and outwards. By its contraction the front of the eyeball is turned upwards and outwards.



Figs. 186 and 187.—**The Muscles of the Right Orbit.**

e, sphenoid bone; 1, muscle which raises the upper lid; 2, pulley and tendon of the superior oblique; 3, tendon of the superior rectus; 4, external rectus—partly removed in fig. 188; 5, inferior oblique muscle; 6, inferior rectus; 7, internal rectus; 8, optic nerve.

The front of the eyeball is kept clean and moist by a saline fluid which is secreted continuously by the **lachrymal gland** (Lat. *lachryma*, a tear). This gland is about the size of a small almond, and is situated in the upper and outer portion of the orbit. It is very similar to the salivary glands in structure. It is provided with several small ducts by which the *lachrymal fluid* is conducted to the upper surface of the eyeball. The fluid gradually moves over the surface of the ball, assisted by every motion of the eyelid, till it reaches the inner angle formed by the eyelids, having carried with it any particles of dust which may have adhered to the eyeball. The lachrymal fluid now enters the **nasal or lachrymal duct** by means of two small **lachrymal canals**, and is then conveyed into the nose.

When there is a redundant secretion of the lachrymal fluid, such as may arise from irritation of the conjunctiva by powerful vapours &c., or from some strong mental emotion, the nasal duct cannot

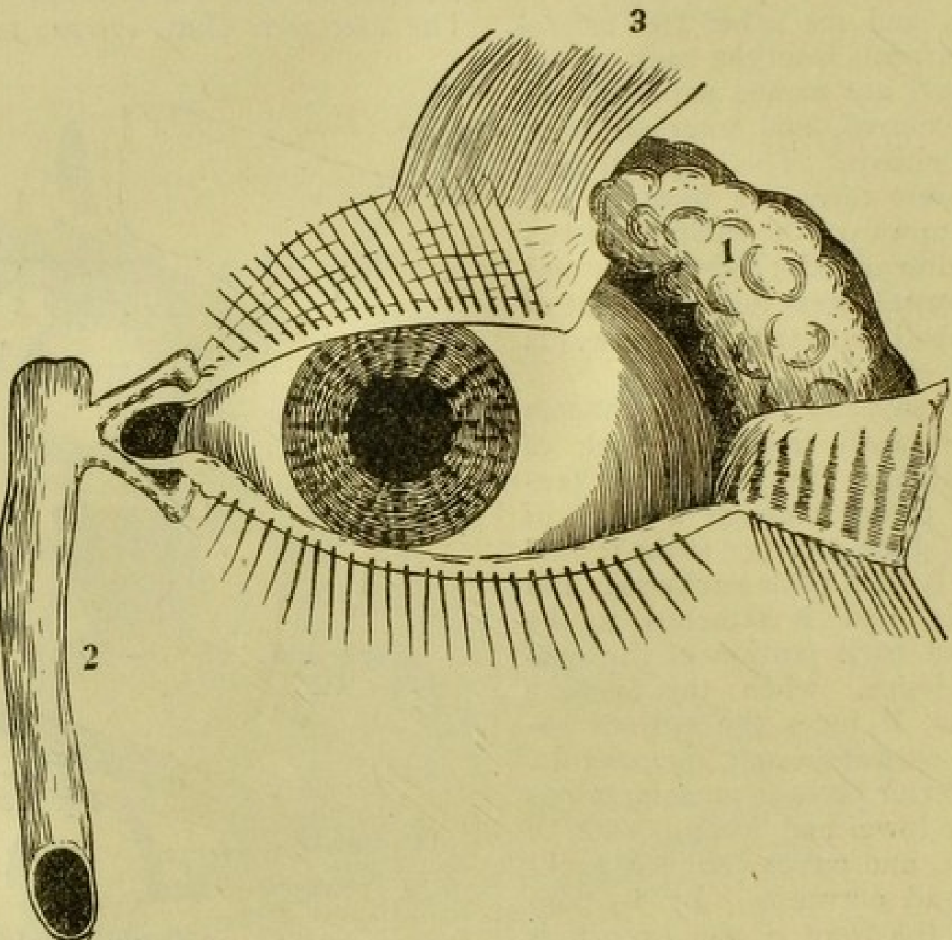


Fig. 188.—**Lachrymal Apparatus.**

1, lachrymal gland ; 2, nasal duct ; 3, the muscle which raises the upper lid.

convey away the fluid as rapidly as it is secreted. The tears then accumulate between the eyelids and the eyeball, and at last roll in drops over the cheeks.

In addition to the muscles mentioned above, the ball of the eye is protected and supported by a large quantity of loose **fatty and connective tissue**, which, acting like a cushion or pad, serves to deaden the effect of pressure or blows.

The general form of the **eyeball** is globular, but the front portion projects somewhat, being a portion of a smaller sphere. It measures about one inch in diameter.

The eyeball has **three distinct coats.** The external consists of the *sclerotic coat* and the *cornea*, the middle coat is formed by the *choroid membrane* and the *iris*; the inner is termed the *retina*.

The **sclerotic coat** (Gr. *skleros*, hard) **or tunic of the eye** is a strong opaque fibrous membrane which extends over the whole of the ball with the exception of about one-sixth of its surface in front. This coat is the thickest, and by far the strongest, and is the one on which the maintenance of the form of the eye depends.

The **cornea** (Lat. *cornu*, a horn—a transparent horny coat) is continuous with the sclerotic coat, and covers the front of the eye-

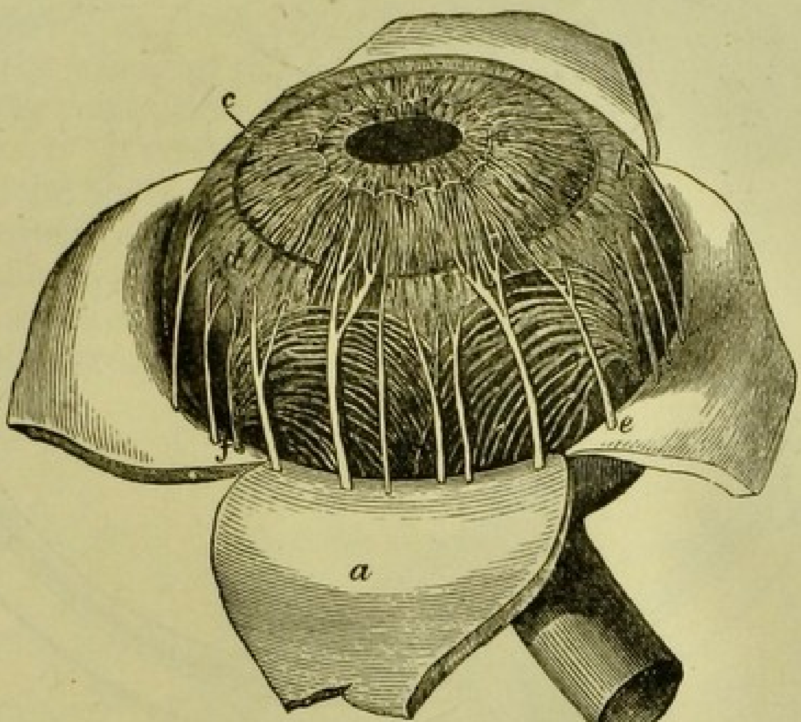


Fig. 189.—**The Choroid Membrane and Iris, exposed by the removal of the Sclerotic and Cornea.**

a, part of the sclerotic thrown back; *b*, ciliary muscle; *c*, iris; *e*, one of the ciliary nerves; *f*, blood-vessel.

ball. It forms the prominent spherical surface before mentioned, and is clear and transparent. It is not supplied with blood-vessels.

The **choroid coat** is a dark-brown membrane lying within and against the sclerotic. It consists of a thickly set network of blood-vessels, supported by connective tissue, and loaded with cells containing a dark pigment or colouring matter. One use of this coat, as we shall presently learn, is to darken the chamber of the eye, and thus prevent the reflection of light. Just before the choroid coat reaches the edge of the cornea, it becomes modified, being raised into a number of ridges which constitute the **ciliary processes.**

The **iris** (Lat. a window) is the circular curtain, seen through the cornea, which gives the colour to the eye. Its outer border is continuous with the choroid coat, which, like the sclerotic, does

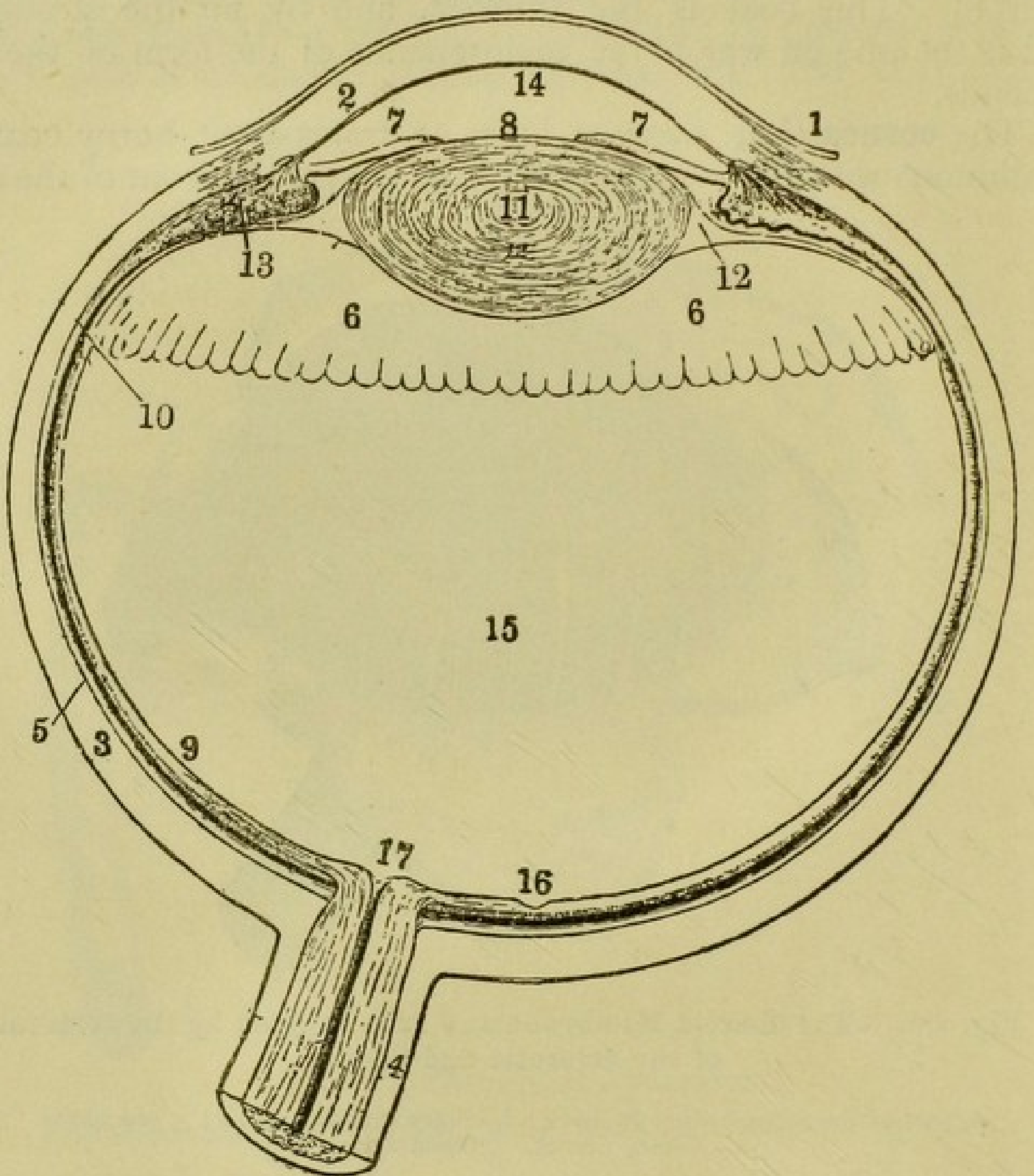


Fig. 190.—**View of the Human Eye, divided horizontally through the middle.**

1, conjunctiva; 2, cornea; 3, sclerotic; 4, sheath of the optic nerve; 5, choroid; 6, ciliary processes; 7, iris; 8, pupil; 9, retina; 10, anterior limit of the retina; 11, crystalline lens; 12, suspensory ligament; 13, ciliary muscle; 14, aqueous chamber; 15, vitreous chamber; 16, yellow spot; 17, blind spot.

not extend over the front of the ball. It is perforated in its centre by a circular aperture called the **pupil.** The iris is a contractile membrane. It is provided with unstriped muscular fibres, some of which are arranged in a ring around the pupil, while the others are radiating. When the circular fibres contract, the pupil is made smaller; when the radiating fibres contract the pupil is dilated. By these means the diameter of the pupil is made to vary from $\frac{1}{3}$rd to $\frac{1}{20}$th of an inch, and the quantity of light admitted into the eyeball is regulated. The outer rim of the iris is firmly connected with the external coat of the eye, at the junction of the cornea with the sclerotic coat, by the **ciliary ligament**.

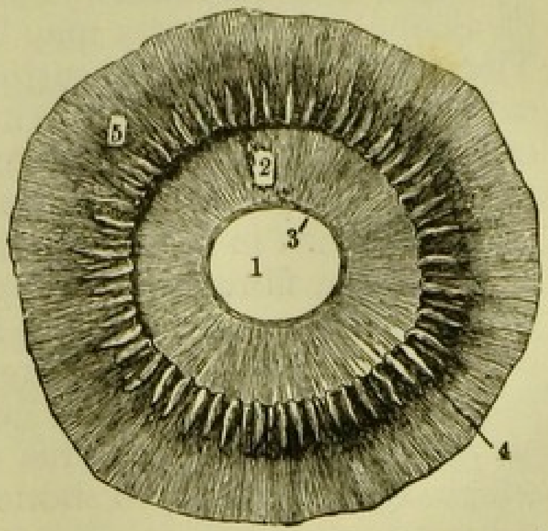


Fig. 191.—**Ciliary Processes and Retina as seen from behind. Twice the natural size.**

1, pupil; 2, posterior surface of the iris; 3, circular muscle of the iris; 4, ciliary processes; 5, portion of the choroid.

The **retina** is a delicate membrane which lies within the choroid coat. It is only from $\frac{1}{200}$th to $\frac{1}{50}$th of an inch thick, and covers the whole of the choroid with the exception of the *ciliary processes*. It consists of an expansion of the fibres of the optic nerve, supported by an extremely delicate connective tissue.

Close behind the iris is a doubly convex, transparent, solid body

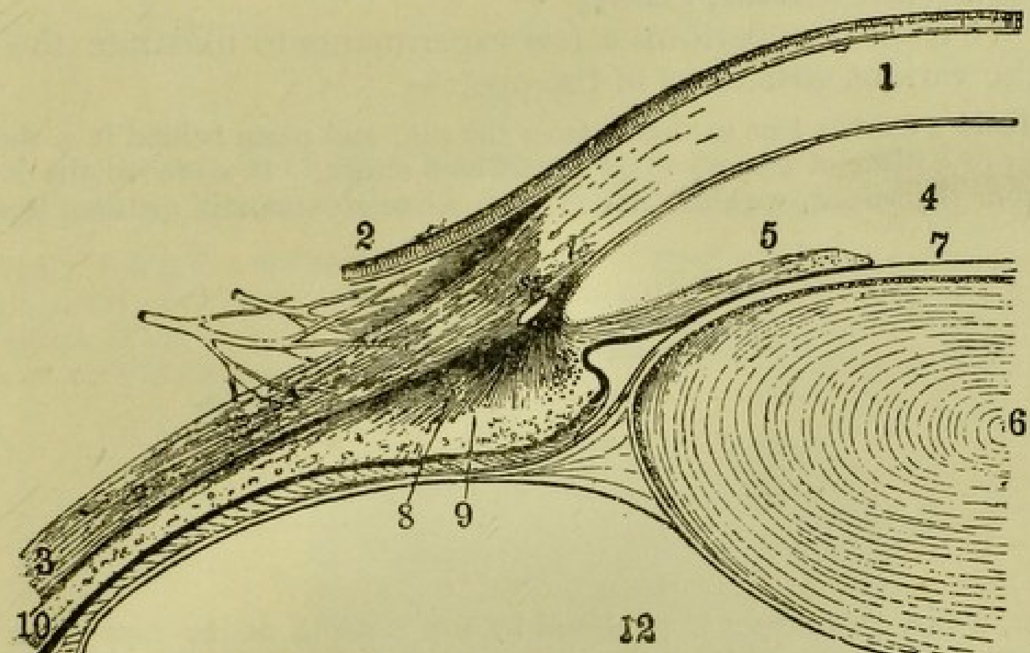


Fig. 192.—**The Connections of the Cornea, Sclerotic, Iris, Ciliary Muscle, Ciliary Processes, and Lens.**

1, cornea; 2, conjunctiva; 3, sclerotic; 4, aqueous chamber; 5, iris; 6, centre of the lens; 7, capsule of the lens; 8, ciliary muscle; 9, ciliary process; 10, choroid; 11, retina (anterior portion); 12, vitreous chamber.

called the **crystalline lens.** Its front surface, which is less convex than the back, is in contact with the iris; and a space is enclosed between these structures and the cornea in front. The crystalline lens measures about ⅓rd of an inch in diameter, and consists of layers, one within another, like the onion. If the lens be hardened in alcohol, these layers may be easily separated from each other. The crystalline lens is surrounded by a membrane called the **capsule**, and is kept firmly in its place by a strong and elastic frame called the **suspensory ligament**, which extends from the capsule to the ciliary processes of the choroid. This ligament keeps the crystalline lens in a state of tension.

Muscular fibres radiate backwards from the junction of the cornea and the sclerotic, and are attached to the outer surface of the choroid coat. These fibres form the **ciliary muscle.** When they contract they pull the choroid forward, causing the suspensory ligament to relax. This in turn causes the crystalline lens, which is also elastic, to shorten its diameter and become more convex.

The space between the cornea in front and the iris and lens behind is filled with a watery fluid known as the **aqueous humour**, and the whole of the globe of the eye behind the crystalline lens is filled with a transparent semi-solid substance called the **vitreous humour** (Lat. *vitreus*, glassy).

We shall now perform a few experiments to illustrate the uses of the various structures of the eye :—

Hold a convex lens so that it faces the sun, and place behind it a sheet of paper or a piece of ground glass to act as a screen. If we move the lens to or from the screen, we shall notice that, when at a certain distance from the

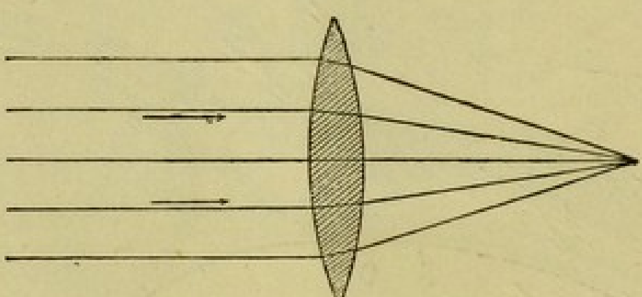


Fig. 193.

latter, a very bright spot is produced by the meeting of the rays which pass through it. Hence we learn that, **when rays of light pass through a convex lens, they converge to one point** (the *focus*) (fig. 193).

Now take the lens into a room which is illuminated only by a single candle-flame, and turn the lens to face this flame at the distance of a few feet, again holding the screen behind. We now notice that, at a certain distance from the lens, we get a sharp, distinct, and inverted image of the flame on the screen. Since the image is inverted, we know that the rays from the candle have crossed each other previous to the formation of the image (fig. 194). If we bring the candle-flame *nearer* to the lens we shall observe that the distinct image is formed *further behind* (fig. 195), and *vice versâ*. Thus, if we want a permanent distinct image of a moving object, we must keep the screen in a corresponding motion. From this experiment we learn that, **a convex lens will form an inverted image of a luminous object; and that, the nearer the object is to the lens, the greater is the distance between the lens and the image.**

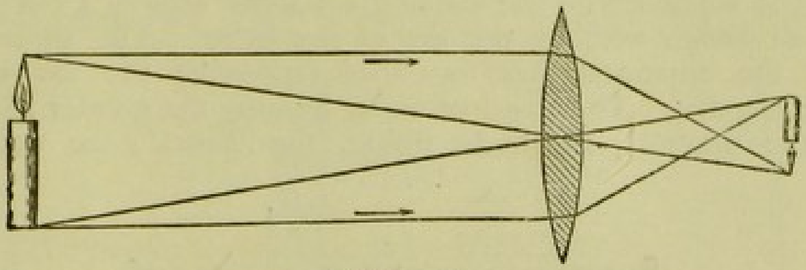


Fig. 194.

Next, substitute for the lens just used another one with more convex surfaces, and notice that the distance at which the distinct image is formed is less than in the preceding experiment. And by repeating the experiment with a variety of lenses we shall learn that, **the more convex the lens, the shorter the distance at which the sharp image is produced**; and *vice versâ.*

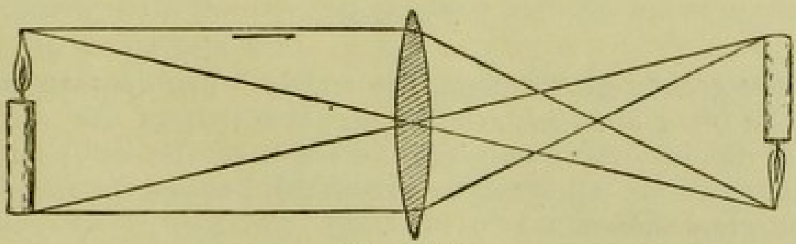


Fig. 195.

We will now turn our attention to a piece of apparatus by which we can illustrate the uses of the various parts of the eye :—

In fig. 196 A is a water-tight box, the back, B, of which consists of a square of glass, the rest being made of wood or metal blackened on the inside. In the centre of the front, F, is a circular hole, over which is fitted a watch-glass with its convex surface turned outward. G is a sheet of ground glass which

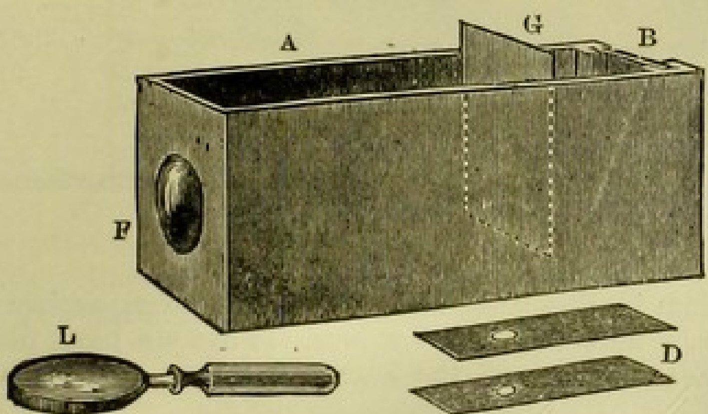


Fig. 196.

may be moved forward and backward in the box so as to receive images formed at various distances from the watch-glass. D represents two 'diaphragms' with different apertures, which, being placed behind the watch-glass, may be used to limit the amount of light admitted; and L is a convex lens attached to a handle. Fig. 197 represents the same apparatus in section. If we cover the box with a black cloth, we convert it into a '**camera obscura**,' that is, a dark chamber in which the images of outside objects may, with the aid of the lens, be caught on a screen. If we fill the box with water, the convex surface of the liquid in contact with the watch-glass itself acts as a convex lens, thus producing an image without the use of the latter. The student will now notice that the apparatus just described represents the various important structures of the eye. The wood or metal forming the greater part of the box represents the *sclerotic*; the black lining, the *choroid*; the watch-glass, the

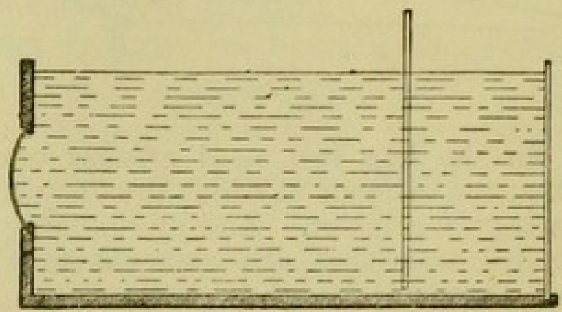


Fig. 197.

cornea; and the ground-glass screen, the *retina*. The diaphragms are to take the place of the *iris*; and the magnifying-glass that of the *crystalline lens*. The water in the box represents the *humours* of the eye; and by using a transparent material for the back, we are enabled to see the images which fall on the ground-glass screen.

The following experiments are to be performed in a darkened room:— Place a lighted candle a few feet in front of the watch-glass, and on a level with its centre. Now move the ground-glass screen to and fro between the watch-glass and the back of the box till a distinct inverted image of the candle is thrown on it. The rays of light from the candle, on reaching the watch-glass, are refracted or bent, producing an image (fig. 198). The water is the

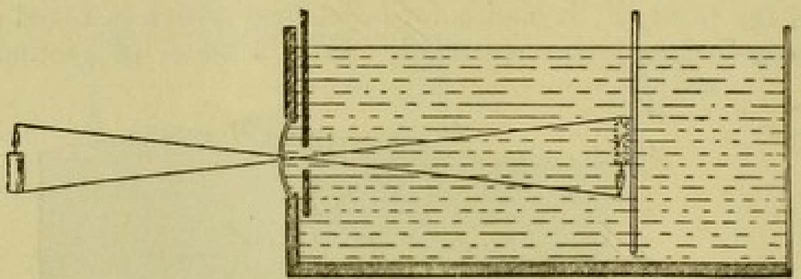


Fig. 198.

refracting medium in this case, and, having a convex surface in contact with the watch-glass, it acts like a convex lens. Thus we have illustrated the **use of the transparent cornea of the human eye,** and **also of the watery fluid behind it.**

Now repeat this experiment, first placing a convex lens behind the watch-glass, and notice that the image is formed at a shorter distance than when the water is the only refracting medium (fig. 199). In the same manner **the crystalline lens assists in the formation of images in the eye,** and helps to bring the images forward to such an extent that they are clearly defined on the retina.

While the image of the candle-flame still falls on the ground-glass screen, insert one of the diaphragms between the watch-glass and the lens. The image now is not so bright as before, since a large proportion of the light is shut off, but it is sharper; or, in other words, the definition is better. Also, by using diaphragms with different apertures, we find that, the smaller the

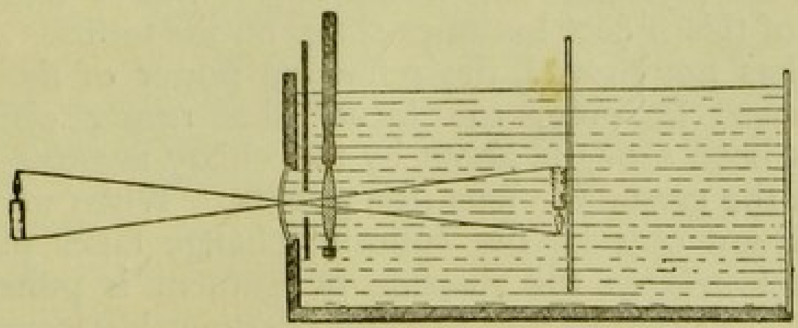


Fig. 199.

aperture, the sharper the image. Thus we have illustrated the **use of the iris**—the diaphragm of the eye, in shutting off the extraneous light which tends to blur the image produced.

We may illustrate the formation of images in the eye by a more simple apparatus than that just described:—Procure a globular glass flask to represent the eyeball, and attach to the side of it a circular and perforated piece of opaque paper to represent the iris (fig. 200). Now fix a convex lens on a cork, and a piece of ground glass on another cork. Place the convex lens in front of the iris, and the ground-glass screen a few inches from the flask on the opposite side. The lens, of course, represents the crystalline lens,

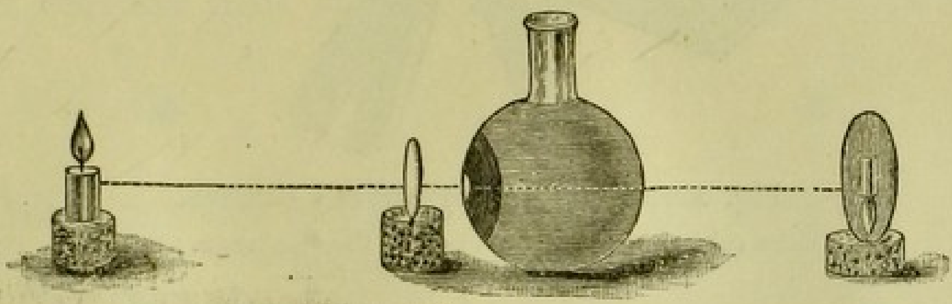


Fig. 200.

and produces the same effect as if it were behind the iris; and a clear inverted image of a candle-flame may be formed on the ground glass by adjusting the distance as in our previous experiments.

As our last illustration, we may compare the eye as an optical instrument to the photographer's camera. This consists of a dark box fitted with a convex lens in front and a ground-glass screen behind. Rays of light from illuminated objects in front of the camera first pass through a diaphragm which cuts off the outer rays. The central rays then pass on to the lens, by which they are made to converge and form inverted images on the screen. This screen is movable, so that it may be adjusted to receive the images of objects at different distances without changing the lens.

In the eye the retina is the screen on which the images fall; but this screen is not moved forwards and backwards as in the photographer's camera. If we look at an object at a certain distance, we see that object distinctly because its image is distinct on the retina; but other objects in the same direction which are either nearer or more remote are more or less indistinct. If we now direct the attention to another object nearer than the first, the image of this object becomes sharp on the retina. And, since the retina has not moved, the refractive power of the eye must have increased in order to 'focus' this nearer object. This change has been brought about by the ciliary muscles acting indirectly on the crystalline lens (see p. 208). When we turn from near to distant objects, the opposite change takes place. The ciliary muscle relaxes, the suspensory ligament is pulled towards the edge of the choroid, and the lens becomes less convex. Thus

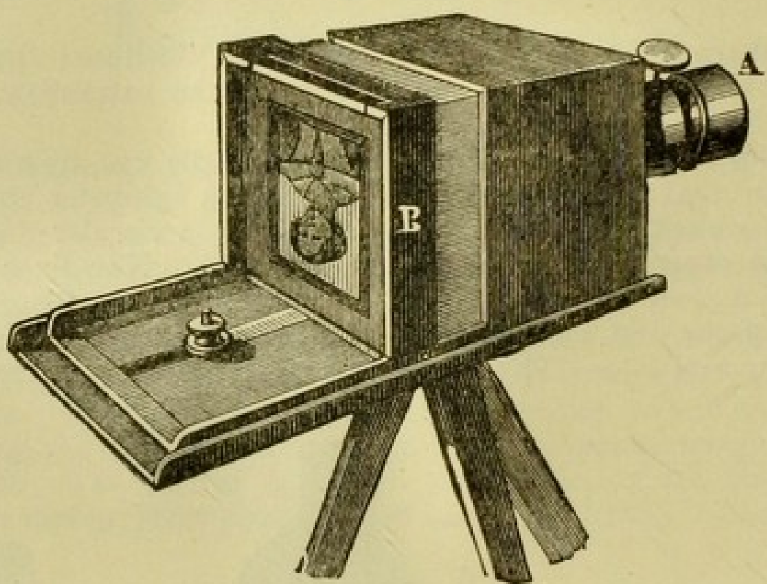


Fig. 201.—**The Photographer's Camera.**

A, a brass tube containing the lens and the diaphragm; B, the screen on which the image falls.

the adjustment of the eye depends on the ciliary muscle and its consequent action on the crystalline lens.

In some persons the cornea is more convex than usual, and in others the refractive power of the crystalline lens is above the average. In these cases the retina is too far back for the image to be sharply defined, and consequently the vision is indistinct. Such persons are said to be **short-sighted**; and they may remedy their defective vision by wearing *concave* glasses, which cause rays of light to diverge.

As old age advances the cornea frequently becomes *less convex*, and the refractive power being as a consequence decreased, the retina is not far enough back to receive the sharply-defined image of near objects. In such cases the persons are **long-sighted,** and should wear convex glasses to assist the convergence of the rays.

It may now be asked, if the images of objects on the retina are inverted, how is it that we do not see the objects themselves inverted? In answer to this we may say that we do not *see* with the retina, but with the *brain*. The rays of light make impressions on the nerve-endings in the retina, but there is no sense of vision until the disturbances in these nerve-terminations are transmitted through the optic nerve and reach the brain, which is the seat of all sensation.

The **retina** is not equally sensitive in all parts. A certain point almost exactly opposite the centre of the pupil is by far the most sensitive to luminous impressions. It is marked by a slight depression of surface, of a pale yellowish colour, and is called the **macula lutea**, or **yellow spot** (fig. 190). When we look at an object, that part of it is most distinctly defined in the retinal image which is in a straight line with the yellow spot and the centre of the pupil. When we wish, therefore, to see an object as clearly as possible, it is necessary to turn the eyeballs so that it shall be on this line—the axis of vision.

The **optic nerve** enters the back of the eyeball at a point about $\frac{1}{10}$th of an inch from the yellow spot on the nasal side. This point is insensible to light, and is known as the **blind spot**. To prove this, close the left eye, and look steadfastly on the left dot below with the right, holding the page at a distance of about a foot.

Now move the book *very slowly* towards the eye, keeping it still steadily fixed on the left dot. At a certain point (generally about six inches from the eye) the right dot will suddenly disappear, owing to its image falling on the blind spot; but, on bringing the book nearer, it will reappear as its image leaves this point.

The **retina has the power of retaining the impressions made on it** for a short time—about $\frac{1}{8}$th of a second. Consequently, the falling raindrops often look like lines, the spokes of a rapidly revolving wheel do not hide objects behind them, and a lighted stick moved very rapidly appears as a line of light.

The **sensibility of the retina** is readily exhausted. Thus, if we look at a very bright light for a time, that portion of the retina on which its image falls soon becomes exhausted; so that, if we turn from the bright light and look on a sheet of white paper, we see a dark spot. The rays of light from the apparently dark spot fall on the part of the retina which has been exhausted.

White light is composed of a multitude of colours—the colours of the rainbow—as may be proved by allowing a beam of such light to pass through a prism of glass. If we look steadily for some time on a bright red spot on a sheet of white paper, and then turn the eyes aside to a clear portion of the paper, or to the ceiling, we see a *green* spot. The sensibility of that portion of the retina on which the red rays fell has been exhausted so far as those rays are concerned, and it remains sensitive only to the other colours which compose white light. Consequently, when the white light from the paper falls on the exhausted portion of the retina, the red rays produce no effect, and we see the **complementary colour** to red; that is, the colour produced by the combined effect of all the *other* rays of the white light. Conversely, if we exhaust a portion of the retina with green rays, we produce the complementary *red* image.

Some persons are **colour-blind**, that is, they cannot distinguish between two or more colours, different rays affecting the retina in exactly the same manner. This is probably due to a defect in the retina.

SUMMARY.

- **Contents of the Orbit** . . .
  - Eyeball.
  - Muscles.
  - Blood-vessels.
  - Nerves.
  - Fatty tissue.
  - Lachrymal or tear apparatus.
- **THE EYE** .
  - **Lids** . .
    - Consist of folds of the skin.
    - Lined with a mucous membrane (the *conjunctiva*), which is also reflected over the front of the ball.
    - Closed by the circular *orbicularis* muscle.
    - Upper lid raised by a special muscle.
  - **Muscles** . .
    - **4 Recti**. .
      - *Superior*—turns the eyeball *upwards*.
      - *Inferior*—turns the eyeball *downwards*.
      - *External*—turns the eyeball *outwards*.
      - *Internal*—turns the eyeball *inwards*.
    - **2 Oblique** .
      - *Superior*—turns the eyeball *outwards* and *downwards*.
      - *Inferior*—turns the eyeball *outwards* and *upwards*.
  - Lachrymal apparatus
    - *Lachrymal gland*—in the upper and outer part of the orbit.
    - Several small *ducts*.
    - Secretion .
      - Constant.
      - Moistens the eyeball.
      - Carried off by the *nasal duct*.

THE EYE (*continued*)

- **Coats**
  - **Outer**
    - *Sclerotic* — Tough, fibrous opaque.
    - *Cornea* — Transparent. Covers the front central portion of the eye.
  - **Middle**
    - *Choroid* — Contains black pigment. Terminates in front by the *ciliary processes.*
    - **Iris** — A circular perforated diaphragm. Aperture called the *pupil.* Pupil contracted by circular muscular fibres; and Dilated by radial fibres.
  - **Interior** — **Retina** — Nervous structures. Connective tissue.
- **Lens**
  - Situated just behind the *iris.*
  - Double convex. Elastic.
  - Back surface more convex than the front.
  - Enclosed in a *capsule.*
  - Held by the *suspensory ligament* at its circumference.
  - Ligament relaxed by the contraction of the *ciliary muscle.*
- **Chambers**
  - **Aqueous** — Between the *iris* and the *cornea.* Contains a watery fluid.
  - **Vitreous** — Includes the greater portion of the ball. Contains a transparent jelly-like substance.
- **Optics**
  - The eye a *camera obscura* or *dark chamber.*
  - Rays of light converge as they enter the *cornea.*
  - Convergence increased by the *lens.*
  - Image (inverted) falls on the *retina.*
  - **Short sight** — Cornea or lens too convex. Remedy — wear *concave* glasses.
  - **Long sight** — Cornea or lens too flat. Remedy — wear *convex* glasses.
  - **Blind spot** — At entrance of *optic nerve.* Totally insensitive to light.
  - **Yellow spot** — $\frac{1}{10}$ of an inch outside the blind spot. Marked by a slight depression. Most sensitive part of the retina.
  - Retina retains impressions for about $\frac{1}{8}$th of a second after its exciting cause ceases.

QUESTIONS ON LESSON XXXV.

1. What structures form the orbit of the eye? What does the orbit contain?
2. How is the ball of the eye protected from injury?
3. How are the eyelids moved?
4. Describe the arrangement of the muscles which move the eyeball. Describe also the action of each muscle.
5. Where do the tears come from? Why do the tears roll over the cheeks when people cry?
6. Are tears produced at all times? If so, what becomes of them?
7. Describe the structure of the ball of the eye.
8. Where is the *cornea*? What is its use?
9. What is the *iris*? Where is it placed? What is its use? How does it act?
10. What is the *pupil*? How and why does it change in size?
11. What is the *retina*? Where is it situated? Which portion of the retina is most sensitive, and which portion is quite unaffected by light?
12. Through what parts of the eye must light pass before it reaches the retina?
13. What is meant by 'long-sight' and 'short-sight'? What is the cause of each, and how may each be remedied?
14. Sometimes, as in cases of cataract, the crystalline lens has to be removed. What difference does its removal make in the power of seeing
15. Why is the eyeball black inside?
16. Describe an experiment by which you would illustrate the formation of images in the eye.
17. What change takes place in the form of the crystalline lens when we direct the attention from a near to a distant object?
18. Compare the eye with a photographer's camera.
19. Why does a rapidly revolving spark look like a circle of fire?
20. What do you notice when you look at a sheet of white paper after gazing intently on a bright green object? Explain the cause.

LESSON XXXVI.

THE EAR.

THE **ear** consists of three parts :—the *external ear*, the *middle ear* or *tympanum*, and the *internal ear* or *labyrinth*. The last of these divisions is the essential part of the organ of hearing, the other two being concerned merely in the collection and transmission of sound vibrations.

The **outer ear** consists of the *pinna* (Lat. a wing), that part which projects from the side of the head, and the *auditory canal*.

The **pinna**, being concave, is especially adapted for the collection of sound waves which are reflected by it into the canal. It consists of a cartilaginous framework, surrounded by a certain amount of fatty tissue and a few small muscles, the whole being covered with integument. The pinna is thrown into several elevations and depressions, the names of which may be learnt from the accompanying illustration.

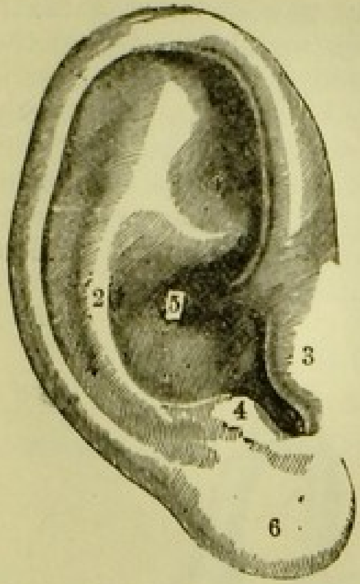


Fig. 202.—**Outer surface of the Pinna of the Right Ear.**

1, helix; 2, antihelix; 3, tragus; 4, antitragus; 5, concha; 6, lobule.

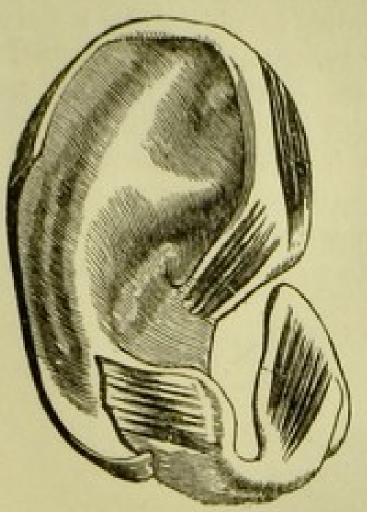


Fig. 203.—**Outer surface of the Right Pinna, showing its muscles.**

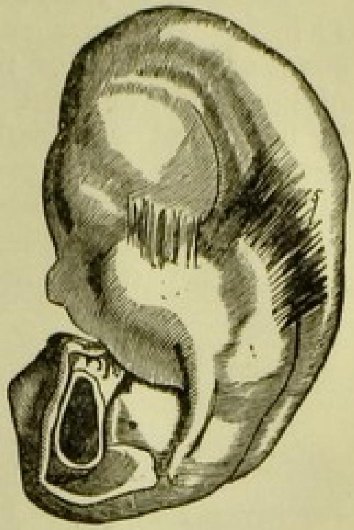


Fig. 204.—**Inner surface of the Right Pinna.**

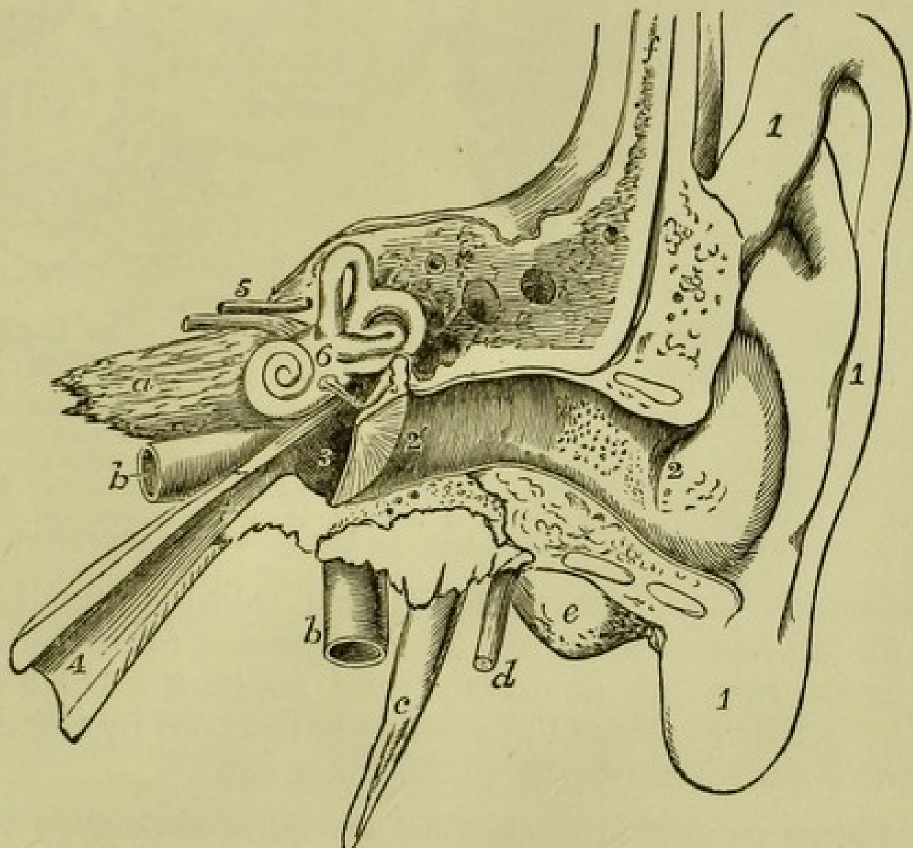


Fig. 205.—**Diagrammatic front view of the Left Ear.**

A portion of the temporal bone has been detached.

1, the pinna and lobe; 2 to 2′, the auditory canal; 2′, the tympanic membrane; 3, the cavity of the middle ear—above 3 is the chain of small bones; 4, Eustachian tube; 5, the facial and auditory nerves; 6, placed on the vestibule of the labyrinth, above the fenestra ovalis; *a*, *c*, *e* and *f*, portions of the temporal bone · *b*, internal carotid artery; *d*, branch of the facial nerve.

The **auditory canal** extends inward from the pinna to a distance of about $1\frac{1}{4}$ inch. Its inner extremity is closed by a very thin membrane called the **drum of the ear** (or the **tympanic membrane**), which is stretched across it obliquely. The walls of the canal are formed partly by cartilage and partly by bone, and are lined with a continuation of the skin. This skin, at the outer portion of the canal, is provided with small hairs, and also a number of glands, similar in structure to the sweat glands, which secrete the *cerumen* or *ear wax*. Both the hairs, which are inclined outwards, and the wax, tend to arrest dust particles, and to prevent the intrusion of insects.

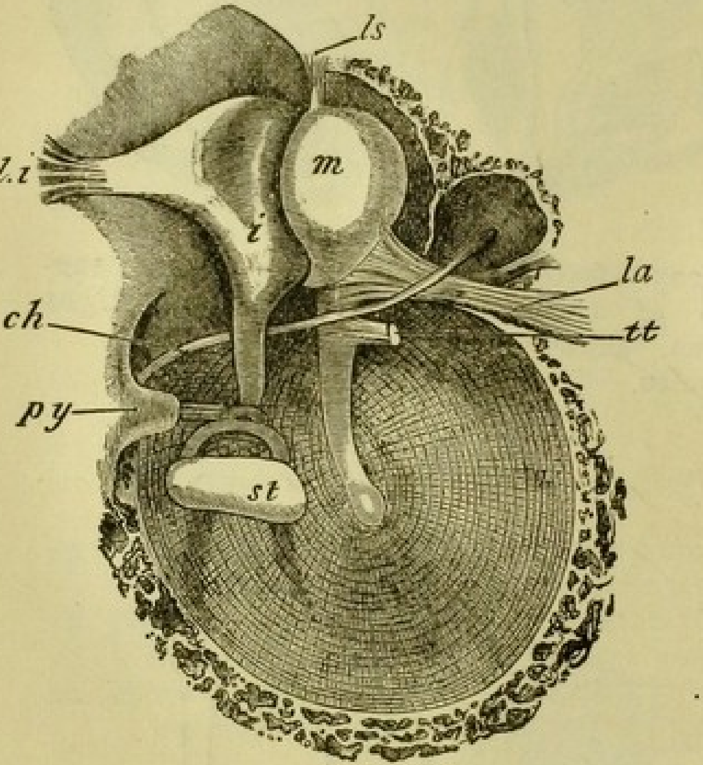


Fig. 206.—**The Left Tympanic Membrane and the Auditory Bones.**

m, malleus ; *i*, incus ; *st*, stapes ; *py*, pyramid from which the tendon of the muscle of the stapes emerges ; *tt*, tendon of a muscle cut short ; *la*, anterior ligament of the malleus ; *ls*, superior ligament of the malleus ; *li*, ligament of the incus ; *ch*, branch of the facial nerve.

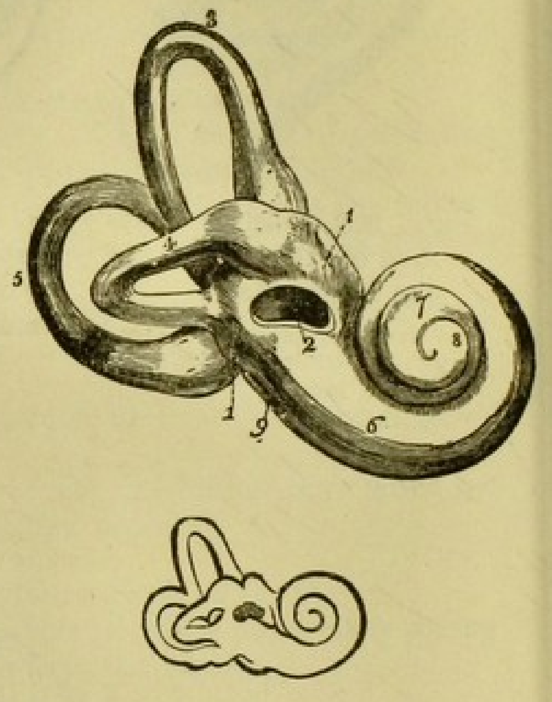


Fig. 207.—**The Right Bony Labyrinth.**

1, vestibule ; 2, fenestra ovalis ; 3, 4, and 5, semicircular canals ; 6, 7, and 8, the cochlea ; 9, fenestra rotunda. The smaller figure below shows the natural size.

The **middle ear** or **tympanum** (Lat. a drum) is a small irregular cavity in the temporal bone. It is separated from the auditory canal by the tympanic membrane, and contains a chain of small bones by means of which the vibrations received by the drum are transmitted across the cavity to the inner ear.

These **bones** are three in number, and are called respectively the *malleus* or *hammer*, the *incus* or *anvil*, and the *stapes* or *stirrup*. The handle of the **malleus** is attached throughout its length to the drum of the ear, and consequently vibrates with it. The vibratory motion is then taken up by the **incus** and the **stapes** in turn. This last bone fits into an opening in the inner wall of the tympanum, thus transmitting the sound vibrations to the inner ear.

The *middle ear* contains air, and communicates with the pharynx (see p. 65.) by means of the **Eustachian tube.** By this arrangement the air pressure is generally equalised on the two sides of the drum. The Eustachian tube, being narrow, is easily blocked by the meeting of its opposite walls; and if this occurs at a moment when the pressures on the internal and external surfaces of the drum are unequal, a peculiar sensation is experienced, and hearing is for the time defective. But by performing the act of swallowing, the tube is opened and the normal pressure restored.

The **internal ear** consists of a very complex cavity hollowed out of the bone (the *osseous labyrinth*), which contains a similar cavity (the *membranous labyrinth*) bounded by membranous walls.

The **osseous labyrinth** consists of three parts:—the *vestibule* (Lat. *vestibulum*, an entrance), the *semicircular canals*, and the *cochlea* (Lat. a snail).

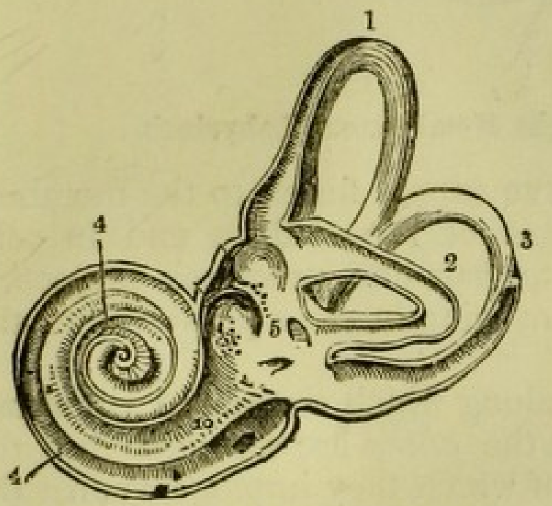


Fig. 208.—**Interior of the Left Labyrinth.**

1, 2 and 3. semicircular canals; 4, cochlea; 5, vestibule.

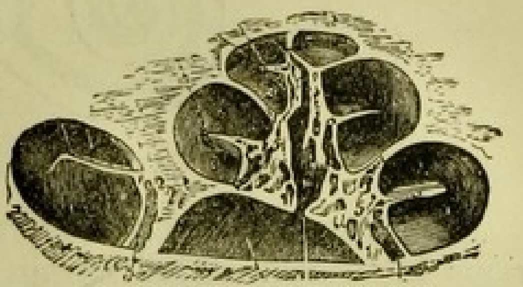


Fig. 209.—**The Osseous Cochlea divided through the middle.**

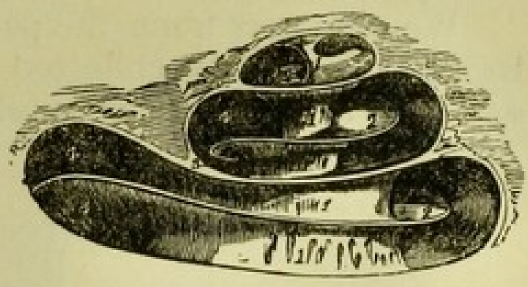


Fig. 210.—**Diagrammatic view of the Osseous Cochlea laid open.**

The **vestibule** is the central chamber of the osseous labyrinth; it communicates with the semicircular canals behind, and the cochlea in front. It is separated in part from the tympanum by an opening—the **fenestra ovalis** (the oval window)—to which we have already referred as being closed by the broad part of the stapes.

The **semicircular canals** are three tubes which communicate with the vestibule by five openings. They are dilated at their ends, and two of them unite at one extremity before entering the vestibule.

The **cochlea** is a spiral tube, in shape like the shell of a snail. It consists of two and a half turns, wound round a central pillar called the **modiolus** (Lat. the nave of a wheel). A thin layer of bone projects from the modiolus, following the convolutions of the cochlea. The cochlea communicates with the tympanum by an opening called the *fenestra rotunda* (round window), which is closed by a membrane.

The **membranous labyrinth** lies within the osseous labyrinth, and agrees with it in general form. The space between them is filled with a fluid called the **perilymph** (Gr. *peri*, around ; and *lympha*, clear water). The membranous labyrinth is itself filled with a liquid called the **endolymph** (Gr. *endo*, within ; and *lympha*). A number of minute crystals of carbonate of lime, called **otoliths** (Gr. *ous*, the ear ; and *lithos*, stone) are suspended in the endolymph of the membranous labyrinth.

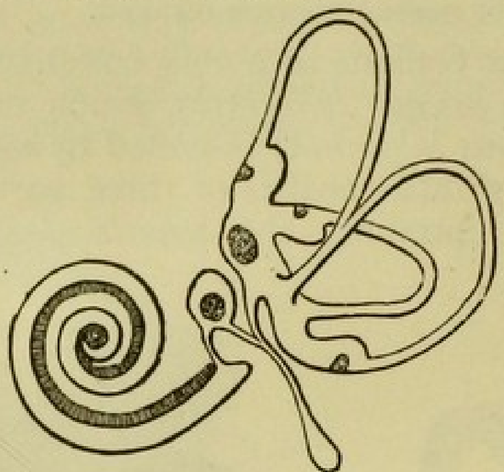


Fig. 211.—**Plan of the Right Membranous Labyrinth.**

Branches of the **auditory nerve** supply fibres to the membranous labyrinth. The terminations of these fibres end in cells which are provided with delicate hair-like processes projecting into the endolymph, some of them lying in close proximity to the otoliths.

We may now trace the path along which the sound vibrations travel. The waves collected by the *pinna* are reflected into the *auditory canal*, at the extremity of which they impinge against the

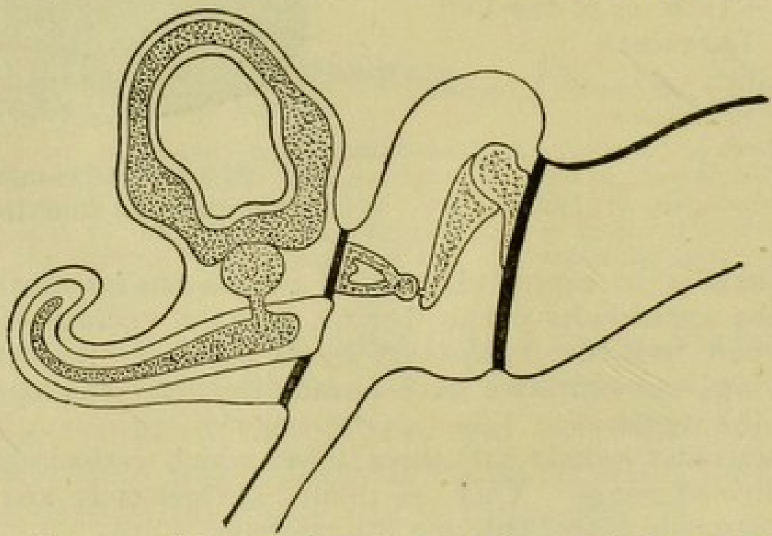


Fig. 212.—**Diagram illustrating the relative positions of the various parts of the Ear.**

1, auditory canal : 2, tympanic membrane ; 3, malleus ; 4, incus ; 5, stapes ; 6, fenestra ovalis ; 7, fenestra rotunda ; 8, Eustachian tube ; 9, membranous labyrinth ; 10, semicircular canal ; 11, vestibule ; 12, cochlea.

drum. The vibrating membrane then communicates its motion to the chain of small *bones*, by which it is transmitted to the *perilymph* of the inner ear. This fluid communicates the vibration to the *endolymph*, and thence to the *otoliths*, hair-like processes, and the terminations of the *auditory nerve*. This nerve conveys the disturbance to the *brain*, giving rise to the sensation of hearing. Sound vibrations may also be transmitted to the auditory nerve through the bones of the skull, without penetrating the structures of the ear.

It is probable that the cochlea enables us to determine the *pitch* of a note, and also to distinguish between the *qualities* of different sounds; while the semicircular canals aid us in distinguishing sounds according to their *intensity* or loudness, and also in determining the directions from which the sounds proceed.

SUMMARY.

- **EAR**
  - **Outer**
    - **Pinna**
      - Cartilaginous framework.
      - Fatty tissue.
      - Muscles.
      - Skin.
      - Collects sound waves and reflects them into the *auditory canal*.
    - **Canal**
      - $1\frac{1}{4}$ inch long.
      - Closed internally by the *drum*.
      - Glands—secrete '*wax*.'
      - Hairs—directed outwards.
  - **Middle**
    - An irregular cavity in the temporal bone.
    - **Bones**
      - *Malleus*.
      - *Incus*.
      - *Stapes*.
    - **Openings**
      - *Fenestra ovalis*—closed by the stapes.
      - *Fenestra rotunda*—closed by a membrane.
  - **Internal**
    - **Osseous labyrinth**
      - **Vestibule**
        - Central portion.
        - *Fenestra ovalis*.
      - **Canals**
        - Three in number.
        - Open into the vestibule.
      - **Cochlea**
        - A spiral tube.
        - $2\frac{1}{2}$ turns round the *modiolus*.
        - Fenestra rotunda.
    - **Membranous labyrinth**
      - Within the osseous.
      - Similar in shape.
      - Surrounded by *perilymph*.
      - Contains *endolymph*.
      - *Otoliths* and hair-like processes.
      - Terminal fibres of *auditory nerve*.

- **Path of the Sound Waves**
  - Pinna.
  - Auditory canal.
  - Drum.
  - Ossicles.
  - Perilymph.
  - Endolymph.
  - Otoliths and hairs.
  - Auditory nerve.
  - Brain.

QUESTIONS ON LESSON XXXVI.

1. Describe the structure of the outer ear, and explain the uses of its parts.
2. What is the drum of the ear? Persons are sometimes rendered permanently deaf by a violent explosion. Explain how this happens.
3. Describe the arrangement and uses of the parts of the middle ear.
4. Write what you know about the structure and functions of the inner ear.
5. A person may be deaf although the ear is perfect in all its parts. Explain this.
6. In what way does a vibrating body produce the sensation of hearing?

LESSON XXXVII.

THE VOICE.

THE organ of voice is the **larynx**, which is a modification of the upper portion of the trachea. It consists of a cartilaginous frame-

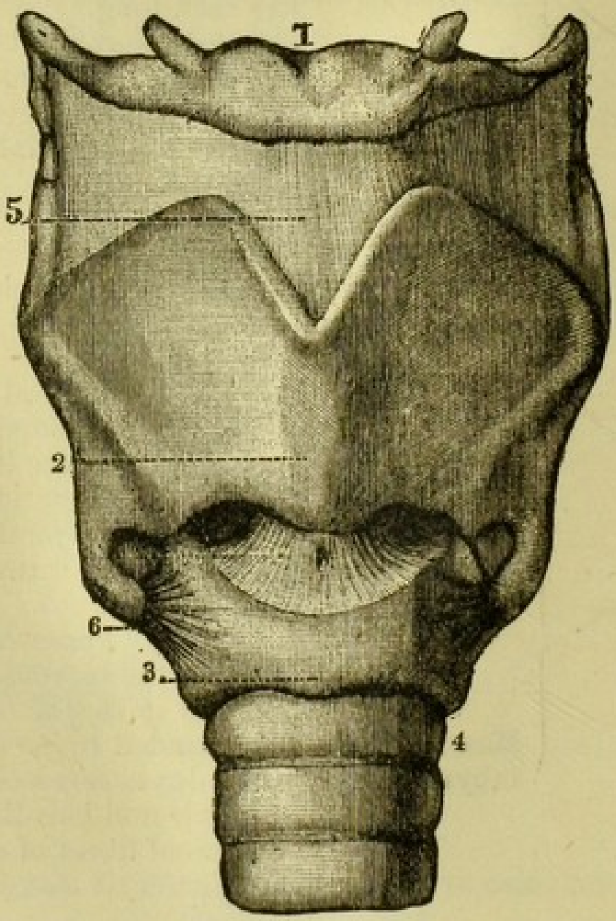


Fig. 213.—**Front view of the Larynx.**

1, hyoid bone; 2, thyroid cartilage; 3, cricoid; 4, first cartilaginous ring of the trachea; 5, membrane; 6, ligaments.

work, the parts of which are movable on each other, the motion being produced by the contraction of various muscles. The thyroid and cricoid cartilages have already been described (see p. 140).

The highest (posterior) portion of the cricoid is surmounted by two pyramidal cartilages called the **arytenoid cartilages.** These form movable joints with the cricoid, to which they are held by ligaments. They must also necessarily accompany the cricoid cartilage in all its movements.

The arytenoid cartilages are connected with the interior surface of the front part of the thyroid cartilage by means of two bands of

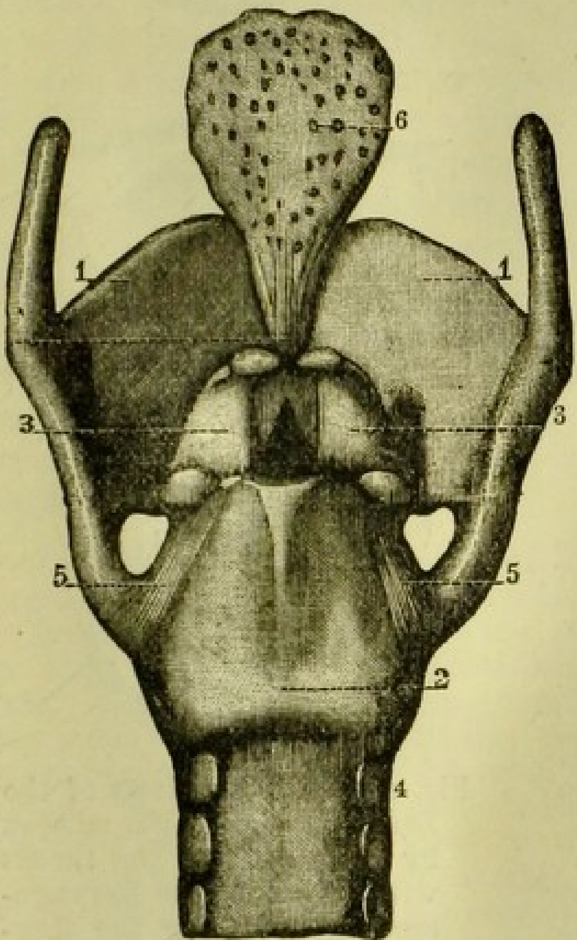


Fig. 214.—**Back view of the Larynx.**

1, thyroid; 2, cricoid; 3, arytenoid cartilages; 4, upper ring of the trachea; 5, ligaments; 6, epiglottis.

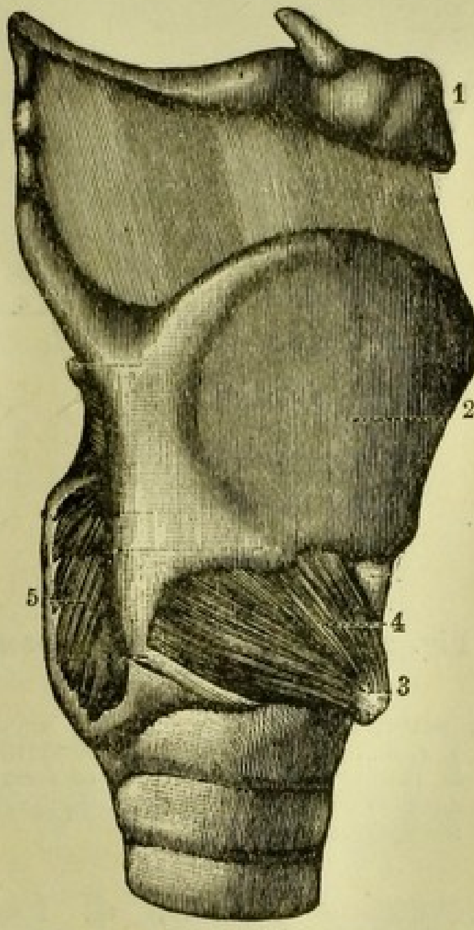


Fig. 215.—**Side view of the Larynx.**

1, hyoid bone; 2, thyroid; 3, cricoid-anterior part; 4, crico-thyroid muscle; 5, crico-arytenoid muscle.

elastic fibres which are imbedded in folds of mucous membrane. These fibres form the so-called **vocal cords.** They are both attached to the thyroid cartilage close to the middle line, and consequently, when they are stretched, their edges are brought nearly parallel, so that only a thin slit is left for the air to pass between them.

The **epiglottis** has nothing to do with the production of sound. It is a cartilaginous lid, the lower and narrower portion of which is fastened by elastic bands to the front part of the thyroid cartilage. Its use is to close the upper opening of the larynx (the space between the vocal cords) during the act of swallowing, thus

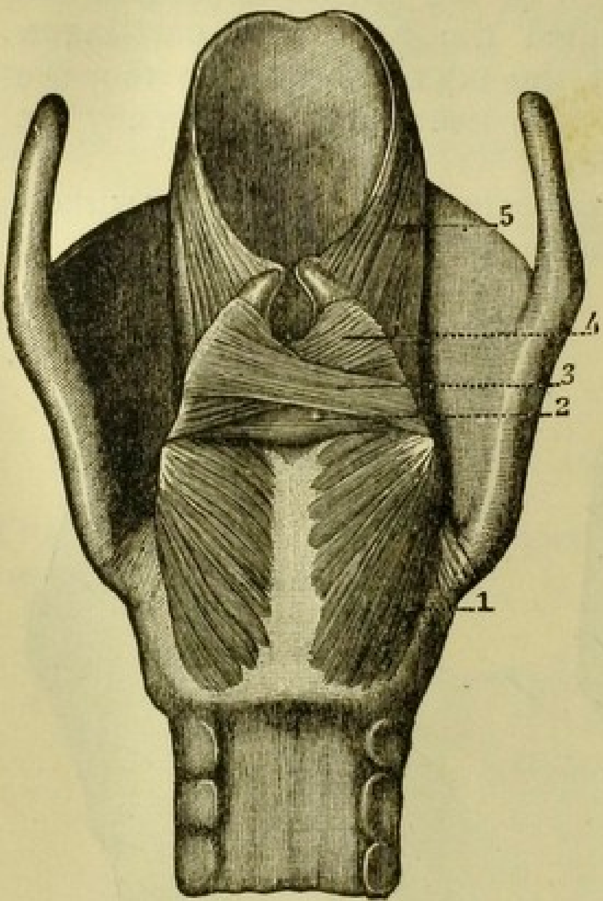


Fig. 216.—**Posterior Muscles of the Larynx.**

1, posterior crico-arytenoid; 2, arytenoid; 3, 4, oblique fibres passing round the edge of the arytenoid cartilages to form 5, the muscles which connect these cartilages with the epiglottis.

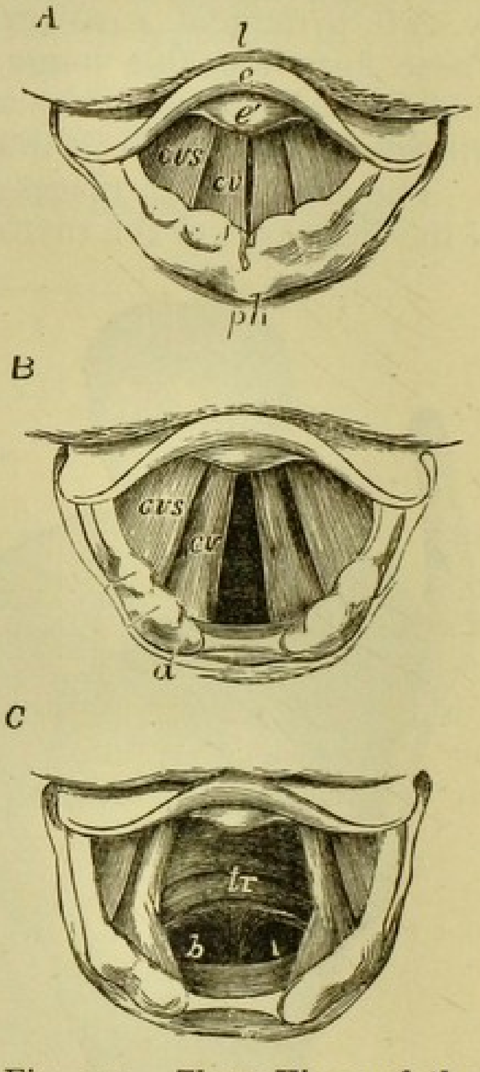


Fig. 217.—**Three Views of the Larynx during Life, as seen by looking down the throat with the aid of the Laryngoscope. A, during the singing of a high note; B, during quiet breathing; C, while taking a very deep breath.**

l, base of the tongue; *e*, upper free part of the epiglottis; *e'*, lower portion of the epiglottis; *ph*, front wall of the pharynx behind the larynx; *a*, tip of the arytenoid cartilage; *cv*, vocal cords; *cvs*, superior or false vocal cords, which do not aid in the production of the voice; *tr*, front wall of the trachea; *b*, commencement of the two bronchi.

preventing particles of food or drink from passing into the trachea.

During quiet breathing the vocal cords are relaxed, the glottis is wide, and the air passes through freely. When we wish to speak or sing, we cause certain muscles to stretch the cords and bring them near each other. Under these conditions the out-rushing air sets them in vibration, thus producing sound.

The contraction of muscles connecting the thyroid with the arytenoid cartilages (the *thyro-arytenoid* muscles) causes them to approach each other, and so relaxes the vocal cords. When the *crico-thyroid* muscles contract, they cause the cricoid cartilage to rotate in such a manner as to tilt the arytenoid cartilages backward, and so to put the cords on the stretch. Other muscles are so arranged that they pull asunder the edges of the arytenoid cartilages to which the cords are attached and thus open the glottis; while others, acting in the opposite direction, tend to bring the cords close to and parallel with each other.

The pitch of a note depends on the number of vibrations per second: the more rapid the rate of vibration, the higher the pitch. For example, 128 vibrations per second will produce the bass C; 256, the tenor C; 512, the treble C; and 1,024, the octave above; and so on. If we stretch a wire or string, we can make it vibrate by plucking it; and by either shortening the string or by increasing the stretching force, we increase the rate of vibration, and so heighten the pitch of the note produced. The rate of vibration also depends on the thickness of the string; the thicker the string, the less the rate of vibration. The more the vocal cords are stretched, the higher the pitch of the note given out.

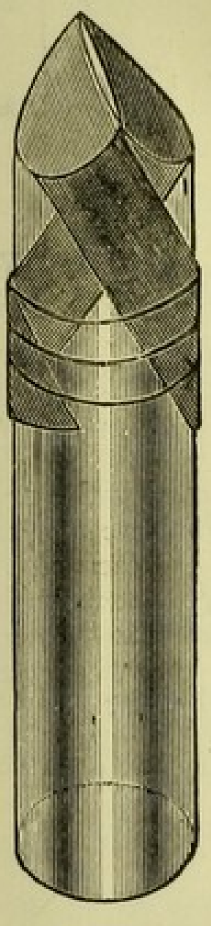


Fig. 218.—**Illustrating the manner of producing a Musical Sound by sending a current of air between two stretched Elastic Bands.**

We may imitate the production of sound by the larynx as follows:—Take a glass tube, about $\frac{5}{8}$ of an inch in diameter, and grind one end down to an angle of 45° on two opposite sides (see fig. 218). Now stretch over these ground edges two thin strips of elastic band, leaving only a narrow space between, and secure by tying round with thread. By blowing a current of air between these stretched bands they are made to vibrate, thus producing a sound; and by altering the length of the tube, and changing the stretching force of the elastic bands, we can vary the pitch of the note.

The *quality* of the note depends on various conditions, among which may be mentioned the shape of the mouth, the position of the tongue, the communication or non-communication between the pharynx and the nasal cavities, the position of the larynx, &c.

In young persons the larynx of the male is constructed exactly like that of the female; but on reaching a certain age the larynx of the male rapidly increases in size, becoming more prominent in the front of the throat. The enlargement of the larynx causes a corresponding increase in the length of the vocal cords; hence the change in the pitch of the voice.

SUMMARY.

LARYNX	**Thyroid**	The upper cartilage. Wide in front ; open behind.
	Cricoid	A complete ring cf cartilage. Wide behind ; narrow in front.
	Arytenoid	Small pyramidal. Surmount the upper posterior edge of the cricoid. Jointed with the cricoid.
	Glottis	The communication between the *pharynx* and the *larynx*. Bounded on each side by the *vocal cords*.
	Epiglottis	A thin movable layer of cartilage. Closes the glottis during the act of swallowing.
	Vocal cords	Bands of elastic fibres. Embedded in mucous membrane. Relaxed during quiet breathing. Stretched during speaking and singing. Attached to *arytenoid* cartilages behind, and to the *thyroid* in front.

QUESTIONS ON LESSON XXXVII.

1. Describe the structure of the *larynx*.
2. What are the *vocal cords*? In what way do they assist in the production of the voice?
3. By what means are we enabled to sing notes of different pitch ?
4. Describe the arrangement of the vocal cords. How do their positions vary (1) when we sing a note of high pitch, and (2) when we heave a deep sigh?

SYLLABUS

(SCIENCE AND ART DEPARTMENT).

First Stage or Elementary Course.

Questions will be confined to the undermentioned points in the elements of anatomy and physiology.

With the exception of the characters of the corpuscles of the blood, no information upon points of structure needing the use of the compound microscope is required for this stage. The information demanded under 'Chemical Preliminaries' must be precise, but no further chemical knowledge will be required.

No candidate will be allowed to pass who makes gross errors in the answers to questions relating to the matters enumerated under the headings A, B, C, and D *a* to D *i*, inclusively.

A. Anatomical Preliminaries.

The general build of the body.

The form, the position and the uses of the following parts of the skeleton:—skull, vertebræ, ribs, sternum; scapula, clavicle, humerus, radius, ulna, carpus, metacarpus, phalanges (of the hand); pelvis, femur, tibia, fibula, tarsus, metatarsus, phalanges (of the foot).

The more obvious distinctive characters of integument, mucous membrane, connective tissue, tendon, ligament, cartilage, bone, muscle, and nerve.

The position in the body, and the general form and size, of the following internal organs:—The brain and spinal cord; the pharynx, gullet, stomach, and intestines; the salivary glands, the liver and the pancreas; the posterior nares, the larynx, trachea, and lungs; the kidneys and the bladder; the heart and the great vessels; the spleen; the diaphragm.

B. Chemical Preliminaries.

The characters of the elementary bodies, carbon, oxygen, hydrogen, and nitrogen.

The composition of air, water, carbonic acid, ammonia, carbonate of lime, and phosphate of lime.

The chemical elements of which proteid substances, fat, starch, sugar, urea and uric acid are composed.

The results of the combustion of carbon and of hydrogen.

The ultimate chemical products of the decay and putrefaction of the dead body.

C. General View of the Animal Body in Action.

The evidence that the body constantly wastes during life ; the nature of the waste products, and of the compensation for waste ; the essential characters of food stuffs.

The part played by oxygen in the economy.

The nature and uses of secretory glands.

The physiological properties of muscular tissue.

The modes in which muscles give rise to movements.

The physiological properties of nervous tissue.

The number, position, and uses of the sensory organs.

The general functions of the brain and of the spinal cord.

The maintenance of the erect posture.

Local and general death.

D. Special Physiology.

a. The Circulatory System.

The arrangement of the chambers of the heart and the form and position of its valves.

The general differences between arteries, veins, and capillaries.

The course of the circulation of the blood ; and the reasons why the blood moves in only one direction.

The meaning of the beat of the heart, of the pulse in the arteries, and of the jet-like flow of blood from a cut artery.

The evidence of the circulation obtainable in the living body.

b. The Blood.

The phenomena presented by blood drawn from the body.

The form, size, and structure of the corpuscles of the blood.

The general composition of the blood.

c. The Respiratory System.

The obvious differences between arterial blood and venous blood.

How venous blood can be converted into arterial blood out of the body.

Where and how venous blood is converted into arterial blood in the body.

In what respects the air which leaves the lungs differs from that which enters them.

The arrangement of the ribs, sternum and intercostal muscles ; the manner in which the walls and the floor of the chest change their position during the respiratory movements.

Why air enters the chest during inspiration ; why it leaves the chest during expiration.

The course of the air, when breathing takes place through the nose.

Where and how arterial blood is converted into venous blood in the body.

The conditions which give rise to asphyxia.

d. The Urinary System.

The composition of the urine, so far as its chief constituents are concerned.

The structure of the kidney, so far as it is visible to the naked eye. The manner in which the ureters open into the bladder.

e. The Skin.

The essential composition of the sweat.

The obvious differences between the dermis and the epidermis.

f. The Liver.

The manner in which the blood enters and leaves the liver.

The obvious characters and properties of the bile. The use of the gall bladder.

g. Animal Heat.

The sources of the heat of the body. The manner in which heat is distributed through the body, and the temperature of the body regulated.

h. The Alimentary System.

The quantity of dry solid and gaseous aliments required daily by an adult man.

The classification of food-stuffs.

The economy of a mixed diet.

What becomes of proteid, fatty, amyloid, and mineral food-stuffs respectively.

The obvious characters and functions of the salivary, gastric, and pancreatic secretions.

The manner in which nutritive matters are absorbed, and innutritious matters excreted, from the alimentary canal.

i. The Muscular System and Animal Mechanics.

The different kinds of levers, with examples of them in the body.

The nature of joints, with examples of ball and socket, hinge and pivot-joints.

The structure of muscle, of tendon, and of bone, so far as it can be made out by the naked eye or a simple lens. The mode of attachment of muscles.

k. The Senses.

The conditions of sensation. The different kinds of sensation.

The means of measuring the acuteness of the sense of touch in different parts of the body.

The general structure of the organ of smell, and the manner in which its function is performed.

The eyelids, and the manner in which they are moved. The lachrymal apparatus. How tears are formed, and what becomes of them. The form of the eyeball. Such characters of the cornea, the sclerotic, the choroid, the iris, the aqueous and vitreous humours, the crystalline lens, and the retina, as are discernible by ordinary dissection. The comparison of the eye with a camera obscura; the uses of the cornea and crystalline lens. The working of the iris.

The manner in which the movements of the eyeball are effected.

The blind spot. The duration of luminous impressions. Complementary colours.

l. The Nervous System.

The structure of the spinal cord, so far as it is visible to the naked eye. The arrangement and the functions of the roots of the spinal nerves.

The evidence that the spinal cord is capable of effecting reflex action.

The influence of the medulla oblongata upon the respiratory movements.

The evidence that the higher faculties of the mind have their seat in the brain.

The olfactory and the optic nerves; their connection with the brain; and the distribution of their fibres in the nose and eye.

EXAMINATION PAPERS.

Instructions.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

The value attached to each question is shown in brackets after the question, but a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

The Examination in this subject lasts for three hours.

You are permitted to *attempt* only *eight* questions.

Elementary Stage.

1883.

1. How many ribs have you? Where are they placed? How do they move? What moves them? What purpose is served by their moving? How do the lower ribs differ from the upper ones? (16)

2. When you cut open a large vein and see the valves, what do they look like? Describe a simple method of proving on your own body how the valves of the veins act. What is the use of the valves, and what would happen if the valves of the veins of the leg were absent or did not act? (16)

3. What do you understand by the abdominal cavity? How are its walls formed? What part of the alimentary canal is placed in it and what is not? What is the general disposition of that part of the alimentary canal which lies in the abdominal cavity? (16)

4. Of what chemical elements is the fat of meat composed? Of what chemical elements is the lean of meat composed? Why is it possible to live on the lean of meat alone, but not on the fat alone? And why is it best to eat both lean and fat? (16)

5. When a man gets a large piece of meat in his windpipe, he is choked, and when he goes into foul air, such as 'choke-damp,' or is shut up in a confined space, he is also choked or suffocated. What is the immediate cause of the choking or suffocation which takes place in both these cases? (9)

6. What is the pulmonary artery? Where does it start from and where does it lead to? Describe carefully the appearance of certain structures which may be seen in it just as it springs from the heart. (9)

7. Of what two parts is the skin composed, and how do they differ from each other? What are the most important uses of the skin, and what are the structures in the skin which correspond to these uses? (9)

8. Several large arteries are spread over the stomach and intestines, and break up into capillaries in the walls of those organs. By what course does the blood get back from those capillaries to the right side of the heart? (9)

9. When any one cries where do the tears come from? Are tears produced when one does not cry, and if so why are they not seen? (9)

10. What is gastric juice? Where and how is it formed? Of what use is it in digestion? (9)

11. The blood flows through a muscle along blood-vessels, arteries, capillaries, and veins, all closed tubes, and yet the blood nourishes the muscular fibres which are outside these blood-vessels. How does the nourishment then get from the blood-vessels to the muscular fibres? (9)

12. You can move your fingers and you can feel with your fingers. Instances of injury or disease have been met with in which the power of movement in the arm has been lost and yet feeling has remained, and others in which feeling has been lost and yet the power of movement has been retained. State what parts must have been affected by the injury or disease in these cases. (9)

1884.

1. What is a capillary? About how wide is a capillary? In what parts of the body are capillaries found? What changes does the blood undergo in the capillaries of the lungs? What changes does the blood undergo in the capillaries of a muscle? (16)

2. How is the skull fastened on the spinal column? How are the movements of turning and nodding the head brought about? Why does a man nod when he goes to sleep sitting up? (16)

3. Where is the mitral or bicuspid valve placed? Where are the aortic semilunar valves placed? How does the mitral valve differ from the aortic semilunar valves in structure and action? (16)

4. What food-stuffs are present in each of the following articles of food:—a slice of bread and butter, a basin of porridge, a mutton chop, a boiled potato, a glass of milk, a boiled cabbage? One kind of food-stuff differs in a most important particular from all others. What is that kind of food-stuff, and what is that important particular? (16)

5. What is the sternum, and what is it made of? How are the bony ribs connected with it? In what way does it move during breathing? (9)

6. What is it gives to blood its redness? Suppose you were able to remove from blood all the red corpuscles, without otherwise changing it, what kind of fluid would be left behind? *i.e.* What would the fluid look like and what would be its chief properties? (9)

7. What is the large intestine? Where is it placed? Where does it begin and where does it end? What changes does the food undergo in it? (9)

8. What does fresh bile look like? Where does it come from, and where does it go to? What are its uses? (9)

9. What is the crystalline lens? Where is it placed? Sometimes the crystalline lens has to be removed; what difference does its removal make to the power of seeing? (9)

10. Explain what is meant by the roots of spinal nerves. How may it be proved that the two roots of a spinal nerve have different functions? (9)

11. Describe the various movements which make up the act of walking. Explain why the top of a man's head moves up and down as he walks. (9)

12. Very often when your leg is kept for a long time in one position it 'goes to sleep.' What is the condition which we thus call 'going to sleep,' and how is it brought about? (9)

1885.

1. What is the shape of the human thorax or chest? What structures form its walls? Name all the important organs which are contained in it, and state the position of each. (16)

2. In what important respects does the blood in the pulmonary veins differ from the blood in the pulmonary artery? Describe the structures in which the bronchial tubes end, and explain how these structures are adapted for bringing about the above differences. (16)

3. Describe what is seen when the right auricle of the heart is laid bare in a sheep's or bullock's heart, and give an account of the walls of the auricle, and of the position and characters of the several openings leading into and out of the auricle. Why does the blood not flow back into the veins when the auricle contracts? (16)

4. Describe carefully the form and position of the stomach. Of what structures are the walls of the stomach composed? What parts of an ordinary meal are digested in the stomach, and what parts are digested elsewhere? (16)

5. Of what parts is a tooth composed? How do these parts differ from each other? How is a tooth fastened into the jaw? (9)

6. What is the position of the kidneys, and what is their general structure? What changes take place in the body when the kidneys are so injured or diseased that they are no longer able to secrete urine? (9)

7. In what parts of the body are no blood-vessels found? How are these parts nourished? (9)

8. What is the medulla oblongata? Where is it placed? Why does an animal generally die when the medulla oblongata is seriously injured? (9)

9. In what parts of the body is connective tissue found? What does it look like when examined by the naked eye, and what does the microscope show it to be composed of? (9)

10. What, in speaking of the eye, is meant by the 'blind spot'? How may its existence be shown? What conclusions may be drawn from its presence? (9)

11. What is the thoracic duct? Where does it end? What does it contain after an ordinary meal? What does it contain when no food has been taken for some time? (9)

12. Sometimes persons are killed by sleeping in a close room in which a charcoal stove is burning. What is it, in such a case, which kills them? (9)

1886.

1. About how much air do we take into the chest at a breath? What makes it go in? What makes it come out? What is the effect on the lungs of trying to take a deep breath, if, while trying to take it, we keep the nose and mouth tightly closed? (16)

2. What is the composition of fat, and how does it differ from that of sugar? What is meant by the digestion of fat? Where and how does it take place? (16)

3. Of what parts is the wrist-joint made up? How do the movements of the hand which you can make at the wrist-joint differ from those of the foot which you can make at the ankle-joint, and why? (16)

4. How, in a living body, does the blood flow from a cut artery; and how from a cut vein? Why is the flow different in the two cases? How can you best stop the bleeding from a cut artery, and how from a cut vein? (16)

5. What is a muscular fibre? About how big is a muscular fibre of one of your own muscles? Explain how muscular fibres are built up into an ordinary muscle. (9)

6. How does the arrangement of the blood-vessels and the circulation of the blood in the liver differ from the arrangement of the blood-vessels and the circulation of the blood in a muscle? What purpose is served by the peculiar blood supply of the liver? (9)

7. Where is the spinal cord placed? Where and how does it end above and below? What can you learn concerning its structure without using a microscope? (9)

8. How does the upper part of the cavity of the nose into which the nostril leads differ from the lower part? What different functions are performed by the two parts? (9)

9. Of what two distinct parts is the skin made up? How do they differ from each other in structure, and what are the chief uses of each part? (9)

10. What is saliva? Where and how is it formed? What are its uses? (9)

11. Explain how it comes about that your body has about the same temperature on the hottest day in summer and the coldest day in winter. What is that temperature? (9)

12. When a body has been buried for some time, nothing is left but the bones. Why have all the other parts disappeared, and what has become of them? (9)

1887.

1. Where is the tricuspid valve placed? What is its form and structure? Describe how it appears when seen in a sheep's heart. Explain how it works in carrying on the circulation of the blood. (16)

2. Where is the diaphragm placed? What important organs touch it on the one side, and what on the other? What structures pass through it, and through what part of it do they pass? What are the two kinds of tissue of which it is mainly made up, and how does each of these act in carrying on the work of breathing? (16)

3. Where does the small intestine lie? Where and how does it begin, and where and how does it end? What is the general structure of its walls? What changes does food undergo in the small intestine? (16)

4. What parts go to form the elbow-joint, and how are they arranged to form that joint? How is it that we are able to move the forearm on the arm in one way only, and that to a certain extent only? (16)

5. What is the colour of venous blood when it flows from a vein, as for instance when a man is bled in the arm? What is the colour due to? If venous blood were spread out in a thin sheet over a large surface, would it change colour? If so, why? (9)

6. What is the nature of the several food-stuffs present in milk? Why is milk so largely used, and so desirable an article of food? (9)

7. Describe what may be seen by the naked eye, or with the help of a simple lens, when a long bone in a dried skeleton, the femur or humerus for instance, is sawn through lengthwise. How would a bone, taken from a recently dead body, and similarly sawn through, differ in appearance from the above? (9)

8. How do the 'red' and 'white corpuscles' of the blood differ from each other? About how big is a red corpuscle and a white corpuscle in human blood? What is the name and nature of the fluid in which the blood corpuscles swim in a living blood-vessel? (9)

9. What is the medulla oblongata, and where is it placed? What is its form and general appearance? What are its more important functions? (9)

10. When is the pupil of the eye large, and when is it small? How does it become large, and how does it become small? What purposes are served by these changes in its size? (9)

11. What is the general composition of urine? What substances which are present in urine and so leave the body by the kidney, also leave the body by the skin or by the lungs? What substances present in urine do not leave the body in appreciable quantity by the skin or lungs? (9)

12. When a man faints he generally falls down. Why does he fall down? (9)

1888.

1. What structures form the roof, the front wall, and the back wall of the cavity of the abdomen? Mention the most important organs which lie in the cavity of the abdomen, and describe as accurately as you can the general form and position of each of these important organs. (16)

2. State the exact place in the aorta and in the pulmonary artery where valves are found. Describe the form of these valves, and their nature (as far as can be ascertained without a microscope). Explain exactly what happens to them during and after a contraction of the ventricles. (16)

3. How does the blood in the pulmonary veins differ from the blood in the pulmonary artery? How is that difference brought about? Under certain circumstances the blood in these vessels may be almost exactly alike: What are these circumstances? (16)

4. Give an account of any one of the ribs, say the fifth or sixth, describing its form, and stating how it is connected to other parts of the body. In what ways can it be moved by muscles, and what muscles can move it? (16)

5. What is meant by a food-stuff? What are the three chief classes of food-stuffs, and how do they differ from each other? Give examples. (9)

6. How are spinal nerves joined on to the spinal cord? What is the evidence that the two roots have different uses? (9)

7. What is the portal vein? Where does it begin? Where does it end? Is the blood flowing in the portal vein always of the same quality, or does it vary? If so, when and how? (9)

8. What is cartilage, and how does it differ from bone? State as fully as you can, all the places in a grown-up body in which cartilage is found. (9)

9. What does a nerve look like when seen with the naked eye? What is shown by the microscope to be its structure? What is going on in the nerves of the arm when we move the arm? (9)

10. What is meant by the clotting of blood, and what changes take place in blood when it clots? What other fluids in the body, besides blood, clot like blood? (9)

11. With what part of the nose do we smell? What is the nerve by which we smell? From what part of the brain does it start, and how does it reach the nose? Why does closing the nostrils do away with certain so-called tastes? (9)

12. What is perspiration, and how is it produced? What is meant by 'sensible' and 'insensible' perspiration? (9)

1889.

1. What is the composition of ordinary atmospheric air? State exactly how expired air differs from inspired air, and explain how these differences can be proved. Explain the bad effects of breathing over again air which has been already used for breathing. (15)

2. State the form, position in the body, and general structure of the stomach. What are the chief changes that an ordinary meal undergoes in the stomach, and in what condition does the food which is not absorbed by the stomach pass through the pylorus into the duodenum? (15)

3. What is a capillary? About how big is a capillary? How does a capillary differ from an artery and from a vein? What changes take place in the blood as it passes through a capillary in such a tissue as a muscle? In what parts of the body are no capillaries to be found? (15)

4. Describe the form and general structure of the left ventricle of the heart. Describe the valves as they may be seen when the cavity is laid open. Explain how the ventricle empties itself at each beat of the heart. (15)

5. Give an account of the position and general structure of the liver. Where does most of the blood supplying the liver come from? Does that blood which thus reaches the liver while digestion is going on, differ from the blood which reaches the liver when no food has been taken for some time? If so, how? (10)

6. Explain how it is that the body has always nearly the same temperature, whatever be the temperature of the surrounding air. (10)

7. What is "serum" of blood? What are the most important bodies present in it? How does serum differ from plasma? (10)

8. What is the pupil? By what means does it grow larger, and by what means does it grow smaller? Why does it generally become small in the light, and large in the dark? (10)

9. What is meant by proteid food? Give examples. Why cannot we live without proteid food? Why is it desirable to have other food beside proteids? (10)

10. What is the form, general structure, and position of the spleen? Where does the blood coming from the spleen go to? (10)

11. Describe the structure of a muscle as far as can be made out without a microscope. What is meant by the contraction of a muscle? What change of form takes place in a muscle when it contracts? (10)

12. What are the lacteals? How does the chyle which they contain after a meal get into the blood? (10)

1890.

1. What structures form the walls of the thorax, or chest? How is the thorax made air-tight? What important viscera are contained in it, and what positions do they occupy in it? Explain how changes in the diaphragm alter the size of the thorax. (15)

2. If a heart, a sheep's heart, for instance, removed from the body, were put before you, how could you tell which was the top, which the bottom, which the front, and which the back? What are the chief differences between the left ventricle and the right ventricle, and what purposes are served by these differences? (15)

3. What is the spinal cord? Where is it placed? Explain how the spinal cord is protected from injury by the structure and arrangements of the walls of the cavity in which it lies. (15)

4. Of what chemical elements are fat and starch composed? How do fat and starch differ from each other? What changes does starch and what changes does fat undergo in the alimentary canal? Where and how are those changes brought about? (15)

5. What do the red and white corpuscles of the blood look like when a drop of blood is examined under a high power of the microscope, and how do they differ from each other? State an important use of the red corpuscles. (10)

6. What is the most important substance and, next to the water, the most abundant substance present in urine? Of what chemical elements is this substance composed, and how does it come about that the kidneys are always to a greater or less extent engaged in secreting this substance? (10)

7. How in a *dead* body can you tell an artery from a vein? What are the chief differences between them, and why are they thus different? (10)

8. What are the two chief parts of the skin, and how do they differ from each other? How does the skin of the lip differ from the skin of the heel, and why? (10)

9. What differences can be observed, without the aid of any microscope, between (*a*) a bone just fresh from the body, (*b*) one which had been dried and kept for some time, and (*c*) one which had been steeped in acid for some time? (10)

10. What is meant, in speaking of vision, by "the blind spot," and how can its presence be demonstrated? What conclusions concerning the nature of sight can be drawn from the existence of the blind spot? (10)

11. What parts go to form the hip-joint? What movements of the hip-joint can be carried out? How are they limited, and why? (10)

12. Describe the course taken by the air in breathing until it reaches the glottis or pharynx; and explain why it is better to breathe through the nose than through the mouth. (10)

1891.

1. Describe the form, position, and general appearance of the sternum. What is the nature of the material of which it is composed? What changes of position does it undergo in breathing? (15)

2. Give an account of what may be seen by examining the right auricle of the heart from the outside. State how you would proceed to lay open the cavity of the right auricle in order to show to the best advantage the structure and relations of the auricle, and carefully describe what may be seen in the auricle thus laid open. (15)

3. Describe the form, position, and general structure of the small intestine. How does the small intestine differ from the large intestine? State briefly the changes which the food undergoes, (1) in the small, (2) in the large intestine. (15)

4. Give an account of a valve in a vein, describing how it appears when seen by the naked eye or with the help of a lens. Describe its nature, and explain how it works. Which veins possess many valves, which few, and which none at all? (15)

5. What is the nature of cartilage? How does it differ from bone, and from tendon? State as fully as you can in what parts of a full-grown body cartilage is found. (10)

6. Describe the portal vein, stating how it begins, where it runs, and how it ends. Does the blood, as it passes along the portal vein after a full meal has been taken, differ from the blood passing along the same vein when no food has been taken for some time? and if so, how? (10)

7. What is the structure of the diaphragm? How does the diaphragm act in breathing? (10)

8. What is a clot of blood composed of? When you cut a large clot of blood open, does the inside look different from the outside? and if so, why? How may a colourless clot be obtained? (10)

9. When you touch a body with your finger, you can tell whether the body is rough or smooth; why cannot you do this if the skin of the finger be injured or removed? In what part of the body is the sense of touch most acute? in what parts least? How can you determine this accurately? (10)

10. What is the general structure of the spinal cord? Explain what happens if the spinal cord be damaged, (1) at the level of the bottom of the neck, (2) at the level of the middle of the back. (10)

11. Explain as fully as you can what you do when you "hold your breath." What changes are taking place in your lungs while you are holding your breath? Why cannot you hold it for more than a very short time? (10)

12. After violent exercise a man says "he is very hot." Is he really hotter than usual? If not, explain how this is? (10)

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