LESSONS IN PHYSIOLOGY

FOR USE IN SCHOOLS

INCLUDING

ANATOMY, PHYSIOLOGY, AND HYGIENE

AND

THE EFFECTS OF ALCOHOL AND OTHER STIMULANTS ON THE HUMAN BODY AND MIND

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AUTHOR'S PREFACE.

THE writer of this volume has endeavored to present the leading facts and principles of Anatomy, Physiology, and Hygiene in the simplest and briefest manner consistent with the great scope of these subjects. While the book may contain more Anatomy than books of its kind usually do, the writer justifies it on the ground that no thorough knowledge of Physiology and Hygiene can be had without a considerable amount of detail in Anatomy, which is the fundamental science. The main physiological facts and principles and good working rules of Hygiene, however, are also given, and in such a manner that the teacher can enlarge upon them if necessary.

Technical language as far as possible has been avoided. Nearly all words which may be new to the pupil are either defined in the text or in the glossary which is combined with the alphabetical index at the close of the book.

The "Practical Illustrations" at close of many of the Lessons suggest the experimental method of study. Any considerable amount of experimenting in this subject is, however, impracticable. Experiments on living animals and the dissection of animals before the class should be avoided. The teacher should prepare carefully beforehand all specimens he may exhibit, and everything not needed in demonstrating a subject should be kept out of sight.

Where skeletons, manikins, and charts are not provided in the schoolroom, the teacher may make excellent substitutes for them by enlarging diagrams and pictures found in larger works on the subject.

The statements in regard to the effects of alcoholic and other stimulants are drawn from reliable authorities, and may be regarded as nearly correct as the existing condition of our knowledge of these subjects will permit.

TABLE OF CONTENTS.

[For ready reference to any particular subject, see Alphabetical Index at close of volume.]

Part I.

HOW THE MOVEMENTS OF THE BODY ARE PRODUCED, OR THE MOTORY APPARATUS.

Part II.

HOW THE BODY IS NOURISHED, OR THE NUTRITIVE APPARATUS.

PART III.

HOW THE BODY IS GOVERNED, OR THE SENSORY APPARATUS.

PART IV.

GENERAL INFORMATION ON FOODS AND STIMULANTS.

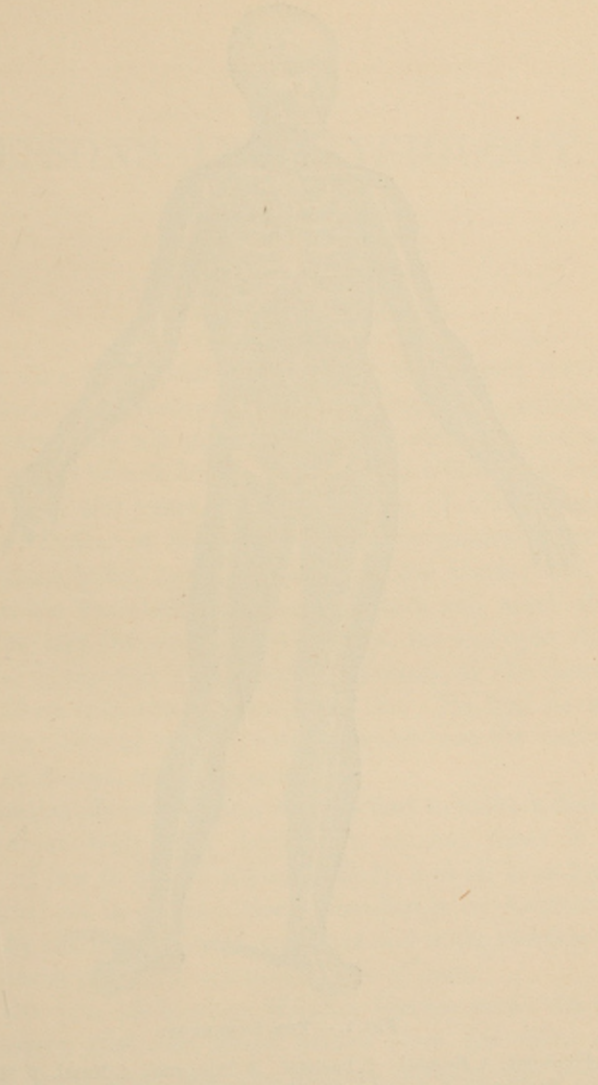


FIG. 1. — THE SKELETON.

Note. — Point out: 1. Frontal. 2. Parietal. 3. Temporal. 4. Nasal. 5. Malar. 6. Superior Maxillary. 7. Inferior Maxillary. 8. Cervical Vertebræ. 9. Clavicle. 10. Scapula. 11. Sternum. 12. Ribs. 13. Humerus. 14. Radius. 15. Ulna. 16. Carpus. 17. Metacarpus. 18. Phalanges of Hand. 19. Lumbar Vertebræ. 20. Ilium. 21. Ischium. 22. Pubes. 23. Femur. 24. Patella. 25. Fibula. 26. Tibia. 27. Tarsus. 28. Metatarsus. 29. Phalanges of Foot.

LESSONS IN PHYSIOLOGY.

INTRODUCTION.

1. At a time when great advancement had already been made in mathematics, astronomy, architecture, sculpture, painting, and rhetoric, very little was yet known of the structure and uses of the parts of the human body. Hippocrates, a Greek philosopher who was born 460 years before the time of Christ, and was called the "Father of Medicine," had some general knowledge of the human body, more especially of the bones; but, upon the whole, his knowledge was very limited, and much that he taught was very inaccurate. He taught, for example, that the use of the brain was to secrete the mucus of the nose, and that the heart and arteries contained air. He had no knowledge of the nervous system, and supposed that the nerves and tendons, or sinews, were the same.

Erasistratus, about 300 B.C., was the first to make a dissection of the human body after death. In ancient times it was a violation of law to dissect a human body, and all investigations were carried on in secret. Some knowledge of Anatomy was obtained by the dissection of monkeys and other animals whose organs were supposed to resemble those of man.

Since the year 1619, when William Harvey made the important discovery that the blood passed from the veins to the heart, and from there into the arteries, through the body, and back again into the veins, progress in the knowledge of the human body has been quite rapid. From that date to the present the science of medicine, which depends upon a knowledge of the human body, has made wonderful progress. Great pestilences, which formerly swept away people by the thousand and ten thousand, are now comparatively rare. Nearly every dangerous disease is under control, and the prospects for future conquests are very encouraging. All this is due to the fact that many men have devoted years of study to the structure and uses and care of the human body.

2. The science which treats of the structure, or make-up, of the body is called *Anatomy*, from two Greek words meaning to cut apart or dissect. Thus, when we learn what the parts of the body are, how they look, and how they are connected together, we are learning Anatomy.

3. The science which treats of the actions and uses of the various parts is called *Physiology*, which means "a discourse on nature." Thus, when we learn how the blood circulates, how the muscles contract, the uses of the various fluids, and how the body grows, we are learning Physiology.

4. The rules which should govern us in taking care of the body and preserving it in a state of health are discussed under the name *Hygiene*, a word derived from the name of the Greek goddess, Hygeia, who was supposed to watch over the health of the people.

These three subjects, the sciences of Anatomy and Physiology and the art of Hygiene, are usually discussed together in schoolbooks under the common term, "Physiology." In order to a thorough understanding of the lessons in this book, it is necessary to know the meaning of a few terms which will frequently occur.

5. All animal and vegetable bodies, or, in other words, all *living things*, are made up of and originate from **cells.** A cell is generally a minute body, requiring a microscope to enable us to distinguish it. There are, however, some comparatively large cells in the animal and vegetable worlds. The egg of a bird, for example, is a cell; and in some fruits, as the orange, the cells may easily be seen with the unaided eye.

A *living cell* is generally in the form of a tiny bag, and is filled with a fluid called **protoplasm** (first form). In this fluid usually is to be seen a still smaller bag called the *nucleus* (kernel), and sometimes a dark spot is seen yet within this, called the *nucleolus* (little nucleus).

Cells vary much in shape: some are globular, some cylindrical, some flat, some like threads or fibers. They are short-lived and are constantly changing their form. New cells are produced from old ones, and old ones disappear or become inactive and changed in shape. In the blood, millions are born and millions die every minute. By their birth, growth, and death, the body lives, and all the work of the body is performed in and by them. All growth is by the multiplication of cells, and death is the cessation of life in all the cells. As far as human wisdom and skill can find out, they are the very seat of that mysterious something we call **life**.

6. The term **tissue** is frequently used in works on Physiology. Let us have a clear idea of what is meant. Generally speaking, tissue is a name applied to any part of the *substance* of the body. For example, a portion of the lungs would be called lung tissue; a portion of the brain would be spoken of as brain tissue, and so on. More strictly speaking, a tissue is any portion in which the cells and cell arrangement is distinct, forming a mass which has peculiar appearance and physical properties. Thus, parts made up of cells in the form of fibers are called *fibrous tissue*, as in the tendons and ligaments; parts made up of grains or minute masses are called *granular tissue*, as in the liver and other glands; the muscles and nerves, being composed of minute tubes, are often called *tubular tissue;* parts made up of a net-work or meshes of fibers are called *connective*, or *areolar, tissue.* The special study of tissues is really a science by itself, and is called **Histology**. A full discussion is not necessary in a work of this kind.

The tissues are appropriately compared to the *materials*, as wood, stone, brick, glass, etc., which enter into the building of a house.

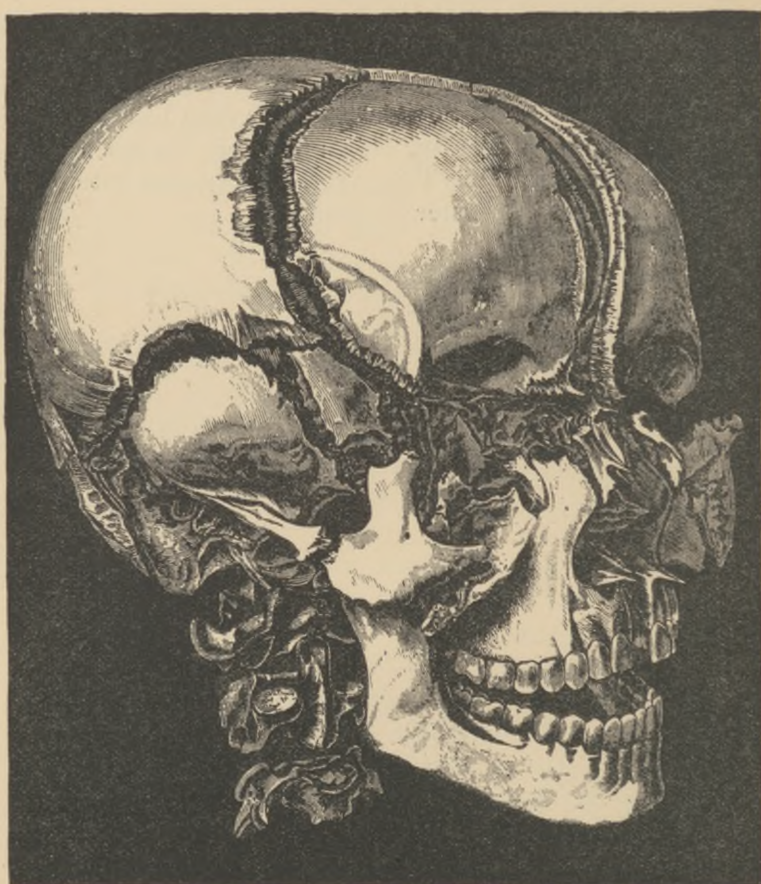
7. An **organ** is any part of the body; that is, any collection of tissues that does *special work*, as the brain, the organ of mind; the lungs, the main organ of breathing; the stomach, the principal organ of digestion; the heart, the organ of circulation, and so on. The organs may be appropriately compared to the doors, windows, roof, walls, and foundation of a house.

8. A number of organs working together to perform a common work, are called a **system**. Thus the organs which prepare the food are called the *Digestive System;* those which circulate the fluids are called the *Circulatory System*. Several systems working for the same general purpose are called, sometimes, an **Apparatus**. Thus, the Digestive, Circulatory, Respiratory, and Secretory Systems are all concerned in the *nourishment* of the body, and taken together are called the *Nutritive Apparatus*. Read carefully the Table of Contents, which may be taken as the basis of a complete classification or outline of the parts of the body.

9. Some knowledge of Chemistry is necessary to a thorough understanding of all the subjects discussed in Physiology, but anything like lengthy explanations cannot be given here. The student must be content with a partial understanding, until he has studied Chemistry. A few points, however, ought to be noticed.

Of the seventy or more simple elements which are known to chemists, the human body contains only fourteen. Of these only three — carbon, hydrogen, and oxygen — make up by far the greater part of the substance of the body. Oxygen and hydrogen, chemically combined, form water. If a human body weighing one hundred and forty pounds be placed in an oven and thoroughly dried, it would then weigh but twelve pounds. This shows what proportion of the body is water. If the solid portion left were put into a very hot furnace for several hours, only a handful or two of white ashes would be left; the remainder would disappear in the form of an invisible gas, which on analysis could be shown to be composed of carbon and oxygen. The oxygen of the air has united with the carbon of the body. The ashes would be found to consist mainly of salts of lime, potash, and soda. Some one has facetiously remarked that a man is composed of a few pounds of charcoal (carbon) and several pails of water, and he was not far from the truth. These few elements are combined in various ways so as to form a score or more of distinct substances, as albumen, gelatine, fat, sugar, several kinds of salts and acids.

In the ordinary decay of the body after death, a great many chemical substances are formed by the breaking up of compounds, and the forming of new ones. Many of these new substances are very poisonous; therefore a dead body should be removed in the most effectual manner, so that the health of the living may not suffer from these substances getting into the air we breathe or into the water we drink.



BONES OF THE HEAD.

Note.— Point out: 1. Frontal. 2. Parietal. 3. Temporal. 4. Occipital. 5. Sphenoid. 6. Ethmoid. Also: 7. Nasal. 8. Lachrymal. 9. Vomer. 10. Inferior Turbinated. 11. Palate. 12. Malar. 13. Superior Maxillary. 14. Inferior Maxillary.

Part I.

HOW THE MOVEMENTS OF THE BODY ARE PRODUCED, OR THE MOTORY APPARATUS.

CHAPTER I.

THE SOLID FRAMEWORK, OR THE OSSEOUS SYSTEM.

LESSON 1.

Bones of the Head.

1. **There are 200 bones in the human body,** not including the teeth nor the minute bones, or ossicles, of the internal ear. Of these 200 bones, 34 are in the central line of the body, and are single. The remaining 166 are in pairs, one on each side of the central line. It is convenient to divide them into three groups: bones of the head, bones of the trunk, and bones of the limbs. These groups may be again divided into smaller groups. We may thus the more easily become familiar with them. By frequently consulting this and the two following lessons in connection with a chart or skeleton, you may soon learn to know and name all the bones in the body. It is, however, more important that you should know the nature and uses of bones, and how to care for them, than to know their individual names.

2. The **twenty-two bones of the head,** taken together, form what is commonly known as the skull. That part of the skull which encloses the brain as in a box is called the **cranium.** There are eight bones in the cranium, firmly joined together in the adult, and in some cases part of them are found completely grown together. You may ask, why the necessity of so many pieces in the

cranium? Why is it not all in one piece, since the bones are so closely joined? If a window contained but one large pane of glass, when your ball struck it the whole window would be broken. But if it contained a number of small panes, you would break only a small part of the window. So with the bony box which holds the brain. But there are other reasons. The bones are solid and firm, as they must be for protection. The brain must increase in size as the body grows. The bones are at first a little distance apart, and as the brain enlarges they have room to enlarge also. (See lesson on Joints.)

3. The **frontal**, or front-bone, forms the forehead and a portion of the roof of the eye cavities. Exactly opposite the frontal is the **occipital** (back of head). It rests on the spinal column, and joins the head to the trunk. In the portion which curves under to form a part of the base of the skull is a large round opening through which the spinal cord joins the brain. The **parietal** (a wall) bones join each other in the middle line of the top of the head like the two sides of the roof of a house. They form mainly the sides and top of the cranium. They are the most nearly regular in shape of any of the bones of the body, being almost rectangular. The **temporal** bones (from *tempus*, time, because a man begins to get gray hair first on that part of the head) form that part of the skull which lies mainly between the ears. This bone has three rather distinct portions. One which projects as a ridge into the center of the floor of the brain cavity is called the **petrous** portion (from *petrus*, a stone, because this part is one of the first to ossify in early life). It contains the delicate parts of the internal ear. That part which forms the "bump" you can feel just behind the ear is called the **mastoid** portion. It is filled with cavities containing air, and which communicate with the cavity of the middle ear. That part which spreads out to form the side of the cranium is called the **squamous** (scale-like) portion.

The **sphenoid** (wedge-like) is a very irregular bone forming a part of the base of the skull. It is joined to all the other bones of the cranium, and to nearly all of those of the face. It is like the "keystone" of an arch, locking the other bones firmly together. It has many holes through which nerves and blood-vessels of the brain pass. In its center are some large cavities containing air, and communicating with the cavity of the nose. The **ethmoid** (sieve-like) bone is irregular and full of cavities, also connected with the cavities of the nose. The nerve of smell passes through it from the brain to the nose. It lies in front of the sphenoid, and mainly between the eye cavities.

Now write down the names of the **bones of the cranium**, arranging them thus:—

BONES IN PAIRS.

Temporal.
Parietal.

SINGLE BONES.

Ethmoid.
Sphenoid.
Occipital.
Frontal.

4. The remaining fourteen bones of the head are grouped as **bones of the face**: **Nasal**, small flat bones forming the "bridge" of the nose; the **malar**, or cheek-bones; the **lachrymal** (Greek, meaning "a tear"), very small bones at the inner, lower corner of the eye cavities. The duct which carries the tears down to the nose passes through it; the **palate** bones forming the back part of the roof of the mouth; **inferior turbinated** (scroll-like), one in each nasal cavity; **superior maxillary**, upper jaw-bones; **inferior maxillary**, lower jaw; **vomer** (plowshare), forming the bony partition between the nasal cavities.

The superior maxillary bones contain a large cavity filled with air and communicating with the nasal passages. The teeth which are not properly classed as bones are set in cavities (called *alveoli*) of the superior and inferior maxillary bones. The inferior maxillary is the largest bone of the face, and the only bone of the head which is freely movable on the others. It has a slight side motion as well as an upward and downward, thus making it capable of grinding the food.

You should now write down the names of the bones of the face, arranging them as directed for the bones of the cranium, remembering that only two, the vomer and the inferior maxillary, are single; the others are in pairs.

LESSON 2.

Bones of the Trunk.

1. The **trunk**, or body proper, contains fifty-eight bones, grouped for convenience of description, into: bones of the thorax, of the spinal column, and of the pelvis.

2. The **thorax** consists of the ribs, the sternum, or breast-bone, the clavicle, or collar-bone, and the scapula, or shoulder-blade. There are twelve pairs of **ribs** (occasionally thirteen pairs, and sometimes only eleven). The upper, or first seven pairs, are joined by separate short pieces of cartilage to the sternum, and are called *true ribs*. The other five pairs are called *false ribs*. Of these, the first or upper three pairs, are joined, but not by separate cartilages, to the **sternum**. The last two pairs are not united at all to the sternum, and are called *floating ribs*. All of the ribs are articulated to the spinal column, and have considerable freedom of motion, rising and falling in breathing. As they rise they increase the cavity in the chest by being brought more nearly at right angles to the spinal column. Tight lacing makes the ribs more curved and shorter, thus lessening the size of the thoracic cavity.

The sternum, so called from its hardness, is somewhat in the shape of an ancient short sword. In the adult it is usually in three pieces, — the upper, called the *manubrium* (handle); the middle, the *gladiolus* (little sword); and the lower extremity is called the *ensiform*, or *xiphoid* appendage. In early life there are eight pieces in the sternum, and in old age all the pieces are frequently united solidly into one. Sitting too much in a stooping posture, or bending long over one's work, will cause the sternum to sink in by the bending of the cartilages which attach it to the ribs, thus making the person flat-breasted, and diminishing the space for the organs of the chest.

The **clavicle** (key, from its resemblance to an ancient form of that article) acts as a brace to keep the shoulder in position. When it is broken, the shoulder falls downward and forward. It is somewhat different in the sexes, being a little more curved and much heavier in men. This is due, doubtless, to the fact that men as a rule are accustomed to using their arms for heavier work. Every one has observed that a woman cannot wield an ax or throw a stone with the same dexterity that a man can. The shape of the clavicle offers the explanation. This bone is more frequently broken than any other bone in the body, and usually by a fall on the shoulder.

FIG. 2.—THE SPINAL COLUMN.

The **scapula** is somewhat in the shape of a mason's trowel. It connects the arm to the body by giving attachment to several powerful muscles. The scapula and clavicle are sometimes grouped with the bones of the upper limbs.

3. The **spinal column** proper consists of twenty-four irregular bones called *vertebræ* (singular, *vertebra*, that which turns). A typical vertebra has: (1) a *body* or solid portion, rounded in front and nearly flat behind; (2) an *arch*, which is made up of (*a*) two portions next to the body, called *pedicles* (little feet), (*b*) two *laminæ* (plates), and (*c*) seven *processes* (projections). Two of these projections are for articulation with the vertebra above and two for the vertebra below; two project laterally, one on each side, and are called **transverse processes.** The laminæ meet to form a projection backward, which in some of the vertebræ is quite long. It is called the **spinous process,** and from this we get the name *spinal column* (literally, a column of spines). The transverse and spinous processes are for the attachment of muscles, which are numerous and large in this region. The arch forms an opening, which, when all the vertebræ are together, makes a continuous channel called the **spinal canal.** In it the spinal cord lies, and is well protected from injury by the peculiar shape of the vertebræ.

The first vertebra is called the **atlas,** from the name of the god of heathen mythology who was supposed to support the earth on his shoulders. The second is called the **axis,** because it is the pivot on which the head rotates. It has a peg-like projection which fits into the atlas and turns as a pivot when the head is moved from side to side. This pivot is held in place by a strong ligament, and when a criminal is hung this ligament is usually broken, and the pivot presses on the spinal cord at its junction with the brain and death results instantly. The head rocks backward and forward upon the atlas very much as a rocking-chair moves on the floor, except that the rockers of the occipital bone fit in grooves of the atlas so that no side motion is permitted.

The mechanical arrangement of the occipital bone, atlas, and axis, whereby the two motions of the head, from side to side and back and forth, are made, is a wonderful example of adaptation of means to an end. When you nod an affirmative answer, the occipital bone rocks on the atlas, and the axis and atlas are fixed. When you shake your head in denial of a proposition, the atlas rotates on the axis, and the occipital bone and atlas are fixed on each other. So you see it is a double-acting hinge. The atlas is prevented from rotating too far by strong ligaments which permit it to go just so far and no farther. (See lesson on Joints.)

The first seven vertebræ, including the atlas and axis, are called **cervical** (of the neck); the next twelve form attachments for the ribs, and are called **dorsal** (of the back); the last five are called **lumbar** (of the loins). The lumbar vertebræ are the largest; the dorsal have the longest spines.

The spinal column taken together is admirably adapted for the double purpose of a support or axis of the body and a protection for a principal portion of the nervous system, the spinal cord. Being made up of separate bones it is flexible to a sufficient degree, yet these bones are so well locked together that sufficient rigidity is secured. It is easily deformed, especially in young people, by constantly sitting or standing in a bent position. You should sit upright and stand straight. Do not form habits of stooping, or leaning, or bending over a desk.

4. The **pelvis** (a basin) consists of the sacrum, the coccyx, and the two innominata bones. The **sacrum** (sacred, because this part of an animal was once used in sacrifices) consists of five solidly united and modified vertebræ. The **coccyx** (cuckoo, because it has a fancied resemblance to the bill of that bird) is similar to the sacrum in form, being made up of four united vertebræ. These two bones are a modified continuation of the spinal column. The **innominata** (nameless, because they do not resemble anything) are in early life composed of three pieces, the lower, called the *ischium*, or seat-bone, the front portion, called the *pubes*, or share-bone, and the upper, broad, expanded part, the *ilium*, or hip-bone. The place where the three pieces unite is in the form of a deep cup which makes a socket for the head of the femur.

5. There is one bone which has no immediate connection with any other bone in the body. It is called the **os hyoides**, or hyoid-bone. The name is from the Greek and means "U-shaped." You can readily find what is called "Adam's apple" in the front of the neck. Place your finger just above this and press firmly. You feel something solid. It is this bone. Make an attempt to swallow while your finger is on the spot. You feel the bone rising and moving from under your finger. It gives a solid attachment to thirteen pairs of muscles which move the tongue, and aid in swallowing and in speech.

LESSON 3.

Bones of the Limbs.

1. The sixty **bones of the upper limbs** are: (1) The **humerus**, the long bone of the arm; (2) the **ulna**, and (3) **radius**, the two bones of the forearm. The upper end of the ulna forms the tip of the elbow. The ulna and radius are to some extent the reverse of each other. While the ulna forms the main part of the joint at the elbow the radius forms the joint at the wrist. The ulna is the more stationary, the radius the more movable.

The radius is larger at the lower end, and the ulna larger at the upper end. Place your hand on the table with the palm down. Now turn the hand over with the back down. Observe that the radius, which is on the side next the thumb, seems to revolve around the ulna. For this reason it is named the radius, or spoke. The ulnar nerve passes near the tip of the elbow, and when it receives a sudden jar a peculiar tingling sensation is felt in the forearm and hand; we then say we have struck our "funny-bone," or "crazy-bone." (4) The **carpus**, or wrist, has eight bones arranged in two rows. You need not memorize their names, but it may be interesting to refer to them. Beginning with the side next the thumb the first bone in the upper row is the *scaphoid* (boat-shaped); the second is the *semi-lunar* (half-moon); the third, the *cuneiform* (wedge-shaped); the fourth and smallest of all is the *pisiform* (pea-shaped). Beginning next the thumb in the second or lower row, we have first, the *trapezium;* second, the *trapezoid;* third, the *os magnum* (large bone), the largest of all; and fourth, the *unciform* (hooked). The bones of the wrist are small and rounded, firmly bound together with ligaments. This arrangement secures great strength, combined with freedom of motion in all directions. (5) The **metacarpus** (beyond the carpus), or hand, consists of five long bones enlarged at the ends. The bones of the fingers are called (6) **phalanges** (rows of soldiers). There are fourteen of them, three to each finger and two to the thumb.

2. The sixty **bones of the lower limbs** are: (1) The **femur**, or thigh-bone, the longest and heaviest bone in the body. The height of the person depends more on the length of this bone than on any other; that is, a tall person is so because this bone is much longer; not because all the bones are longer. (2) The **tibia** (a flute, because used as such in ancient times) is commonly known as the shin-bone. It is the principal bone of the lower leg. It has a sharp ridge in front, which comes just beneath the skin, and blows on this part are apt to be painful, and wounds are made which are sometimes difficult to heal. (3) The **fibula** (a brace) is a slender bone fixed to the tibia at each end, but standing at some distance from it in the middle. It strengthens the leg, helps to brace the ankle, and serves to attach several powerful muscles. (4) The **patella**, or knee-cap, is in the shape of a chestnut, and lies over the heads of the femur and tibia, and glides upon them as the knee is bent. Its use is to lessen friction and protect the joint. (5) The **tarsus**, or ankle, consists of seven bones. The largest is the *os calcis*, or heel-bone. It projects backward and downward, and gives attachment to the powerful tendon of the large muscles of the calf of the leg. The *astragalus* is that bone which joins the ankle with the leg. The *cuboid*, the *scaphoid*, and the internal, middle, and external *cuneiform*, are smaller, and are placed in front of the astragalus. (6) The **metatarsus** (beyond the tarsus) consists of five long bones forming the instep of the foot. (7) The **phalanges**, fourteen in number, are the bones of the toes.

3. A glance at the skeleton will reveal many resemblances between the bones of the upper and those of the lower limbs. The number of bones is the same in each. The patella has apparently no corresponding bone in the upper limbs, but the *olecranon* process (tip of the elbow) occupies a corresponding position, and in early life is a separate piece.

Point out as many resemblances and differences as you can in the bones of the upper and those of the lower limbs. What bone corresponds to the femur? What to the tibia? to the fibula? to the metatarsus?

LESSON 4.

The Joints, or Articulations.

1. The human body is a wonderful piece of mechanism. This is shown very forcibly by the manner in which the bones are joined together to form the **skeleton**, or framework. Every joint is a perfect machine of its kind. Before we can understand this part of the human mechanism, we must know something of the parts which go to make up a joint.

The parts of a movable joint are: the edges or extremities of two bones, ligament, cartilage, synovial membrane, and synovia.

2. **Ligaments** are bundles or bands of fibrous tissue, pliable, elastic, and very strong, which connect the bones at the joints in a manner similar to leather or strap hinges on a door. Some are quite thin and ribbon-like; others are thick, heavy bands; others are like cords. Some simply pass from one bone to the other, across the joint; others completely surround the joint as with a cap. Such are called **capsular ligaments**, and are found in all joints which have much movement. In the knee-joint, strong, cord-like ligaments cross each other between the ends of the bones like the letter X. If all the ligaments be cut through, the joint generally falls apart. This is not always easy to do, as the ends of the bones are frequently irregular, and sometimes, as in the knee and elbow, lock into each other; besides, the ligaments are very tough, and it requires a very sharp knife to sever their fibers.

When a bone is dislocated (put out of place), the ligaments are usually torn, or very much strained, and a long time is required for them to recover fully their original condition. There are some very rare instances, however, where the ligaments, being unusually long and elastic, the person is able to dislocate and put back certain joints, as the hip and shoulder, at will. Such persons cannot, of course, perform all kinds of work. The ligaments are so tough that the bone may be even broken near the joint without tearing them.

3. **Cartilage**, or gristle, is that bluish pearly white substance seen on the ends of the bone when a fresh joint is cut open. All bones are at an early stage cartilage, as will be seen in a future lesson; but the kind of cartilage found in the joints and some other parts of the body never changes to bone, and is called **permanent cartilage**. A thin layer of this kind covers the extremities, or edges, of all bones in the joints. It is much softer than bone, although quite firm, and acts as a cushion to lessen shocks, as in walking, running, and leaping. In some joints, as in the lower jaw with the temporal bone, and in the spinal column, a separate piece of fibro-cartilage (a variety containing fibrous tissue) lies between the bones. The weight of the body in an upright position causes considerable compression of these cartilaginous discs of the spinal column, but they return slowly to their original condition when the weight is removed. Hence a man is actually about half an inch shorter in the evening than in the morning. These fibro-cartilages in the spinal column, by yielding when the body is bent, permit a considerable bending of the axis of the body.

4. In machinery, parts which have a "bearing" on each other, as it is called, must be oiled to lessen the friction. The movable joints of the body are exactly like the bearings in machinery — they need lubricating. Nature has provided an arrangement by which they are self-oiling. A thin membrane inside of the ligaments encloses the joints, and is attached by its edges to the bones near their ends. In very early life it is a complete bag attached by its outer wall to the ends of the bones; but later, the part within the joint disappears, leaving it like a short, wide tube, with the bones for plugs at the ends. The inner surface of this membrane secretes a slippery, transparent fluid, resembling the white of an egg, and called **synovia**, or "joint-water." If this bag is punctured, the synovia runs out, and temporary stiffness of the joints will follow. However, in healthy persons the wound will close up, and a new supply of synovia will be secreted. Disease of this membrane may result in permanent stiffness of the joint.

5. **Joints Classified.** — Anatomists have described joints as

belonging to three principal classes, which are again divided and subdivided. A full description of all the kinds will be found in Gray's "Anatomy," and other large works on the subject. These general classes are movable, immovable, and mixed. The term **immovable** must not be taken in a literal sense, as all joints are capable of some movement when great force is applied. The nearest to a perfectly immovable joint are some of those between the bones of the skull; but in early life all are capable of some movement.

The so-called **movable** joints are found mostly in the limbs, where great freedom of motion is needed. The most completely movable joint is the ball-and-socket joint, such as the hip and shoulder. The hemispherical extremity of one bone fits into a cup-like cavity of another. So perfect is this fitting in the hip-joint that even when all the ligaments are cut the bone will be held in place by the pressure of the atmosphere, just as when you moisten a smooth coin and make it adhere to the window-pane by pressing it slightly. In the shoulder the cavity is shallower than in the hip-joint, but this allows still greater freedom of motion, although making the joint more liable to be dislocated. In fact, surgical records show that the shoulder is more frequently put out of place than any other joint. The knee, ankle, and elbow are examples of hinge-joints, the motion allowed being only in two directions, — back and forth. The rotary or pivot-joint, as already described, is found in the atlas and axis. The *immovable* joints are capable of motion only under extreme circumstances. Those between the bones of the cranium are called **sutures** (seams), and are somewhat like the dovetailing of cabinet-work — projections from one bone fitting into indentations in another. In the **mixed** articulations the motion is produced, not by the gliding or turning of one bone on another, but by both bones being fastened to a fibro-cartilage, which, by its yielding, permits motion.

PRACTICAL ILLUSTRATIONS.

At the butcher's stall procure a fresh, whole joint from the leg of an ox or sheep. Trim off the fat and lean meat, if any. Work the joint to show how the bones move inside of the ligaments. Cut through the ligaments with a sharp knife, and thus expose the cartilaginous ends of the bones. Observe the synovia, which will run out the instant you penetrate the ligaments. The synovial membrane is simply the delicate, transparent lining of the inside of the capsular ligament; and you may not be able to separate it, but you can observe how smooth and moist it is.

Notice the smooth, bluish white ends of the bones. Observe how firm, yet how soft, they are. Try your knife on them. You cannot cut deep. That which you can cut with the knife is the cartilage. The bone will resist the knife, unless it be from a very young animal.

When you have cut nearly all the ligaments through, try to tear the joint apart. You will find it not easy to do, so strong are the uncut portions of the ligament.

LESSON 5.

Forms, Nature, Properties, and Uses of Bones.

1. **Bones are of many different shapes**, the form of each particular bone being that which adapts it to a particular use. Where a cavity is enclosed, as in the head, most of the bones are **flat**, or rather like parts of the shell of a nut, concave on one side and convex on the other. The ribs are flat and curved so that taken together they form a cage for the lungs and heart, but by their movements it becomes an extensible cage which can enlarge itself and permit air to enter the cells of the lungs. The bones of the limbs are mostly cylindrical with enlarged extremities. The cylindrical form is the strongest in proportion to the weight and size. The greater size at the ends gives more room for attachment of muscles and surface for the bearing of the joints. Those which have enlarged ends are called **long** bones by the anatomists, although some of them, as the phalanges, are comparatively short. The small bones of the wrist and ankle are called **short** bones. They are peculiarly well adapted, when bound together by ligaments, to form joints

where great variety and quickness of motion is necessary. The rapid and varied motions of the hand on the wrist, required in many kinds of handicraft, could not be produced by any other kind of mechanical contrivance. The vertebræ, some of the bones of the head, and the bones of the pelvis are classed as **irregular** bones. The irregularity in the shapes of bones is not an accidental occurrence. Every curve and projection, every ridge and hollow, are for a purpose, either for the attachment of certain muscles, to take part in the formation of a cavity for enclosing delicate organs, or for the passage of blood-vessels and nerves. The long bones are levers for the muscles in producing the various motions of the body.

2. **All bones are covered** except at their articular extremities and edges with a thin, tough membrane called the **periosteum** (around the bone). It is closely connected with the bone substance, and appears to be a part of it, yet by care it may be separated. It is almost completely made up of a fine net-work of blood-vessels. From it the bones derive their blood-supply, the minute vessels dipping from it down into the bone substance. When it is peeled from a fresh, young bone, minute red points may be observed on the surface of the bone. They are the places where blood-vessels which enter the bone have been broken. In old age the periosteum grows thin and more adherent to the bone. In a young and vigorous person this membrane may be dissected away and a portion, or even the entire bone, be cut out, and in a short time a new growth of bone from the periosteum will have taken place. This is one of the wonderful feats of modern surgery. Skillful surgeons have saved many a limb from amputation by this operation. The cavities of long bones are lined with a similar membrane, called the **endosteum** (within the bone). This membrane is supplied with blood by a few main blood-vessels which enter the bone through openings about as large as a pin, in the body of the bone.

3. **Bone substance** appears to the unaided eye to be made up of two rather distinct kinds of tissue, which are usually described as *compact* and *cancellous* tissue. There is, however, no real

difference of tissue, the compact being simply an apparently solid mass of bone with no openings, or spaces, while the cancellous (lattice-like) tissue is the same bony substance containing many spaces filled during life with marrow and blood-vessels, and in dead bone with air. In the flat, irregular, and short bones the compact tissue is mainly on the surface, and the cancellous in the interior. In long bones the compact tissue forms nearly the entire shaft, or cylindrical portion, and the cancellous tissue makes up nearly all of the extremities except a thin layer on the surface. Thus, where strength is required with little bulk, the compact tissue is found, and where bulk with little weight is needed cancellous tissue is found.

4. In the dry bone of the leg of an ox or sheep, you will observe a large cavity running through the entire shaft. In the living animal this cavity is filled with a soft, oily substance called **marrow**. In adult bones it is of a yellow color, and consists mainly of fat, throughout which some blood-vessels and nerves are distributed. In young and growing bones, and largely in the ends of all bones, it is of a red color, and consists mainly of blood-vessels. The use of the marrow is mainly to furnish protection for, and a means of distribution of, the numerous blood-vessels which are needed to nourish the bone. In early life, it is supposed to perform an important office in the manufacture of blood-corpuscles. The student is referred to recent large works on Physiology for a discussion of this subject.

5. The flat bones of the skull are made up of two plates, or tables, of compact tissue, with a layer of cancellous tissue between, called the **diploe**. There is an obvious advantage in this, as the shock of a blow on the head is lessened. Sometimes a blow on the head causes no external fracture, yet the person continues to have some brain trouble — perhaps remains unconscious. The skillful surgeon, by means of an instrument called a *trephine*, cuts out a circular piece of bone, and through this opening explores the under surface of the bone. Frequently it is found that the inner table is broken, and a portion of bone presses upon the brain. This being adjusted, rapid recovery results. It also happens sometimes that a blow upon the top of the head causes fracture of the ethmoid bone, without injury to the other bones. The force is transmitted through the arch of the skull, and the parts of the ethmoid, being delicate, are broken. Rarely is there serious trouble, however, the only evidence that the ethmoid is broken being shown by examination after death, which may occur from other causes years afterward. This shows how well protected the brain is in its bony box. When the blow is direct, the force is distributed through the bones, and when indirect, the roundness of the skull causes the missile to glance off. Injuries to the brain, although they do occur, are comparatively rare.

6. Minute Structure of Bone. — Although to the unaided eye a piece of bone seems to be a solid mass like a rock, yet if it be ground down very thin and examined under a high power of the microscope, with a good light, it appears to be full of holes, which contain as much space as the bone matter itself. By examining both cross and longitudinal sections, it can be shown to contain numerous little channels running in various directions. These are called *Haversian canals*, from the anatomist, Havers, who first discovered them. The bone substance is arranged around these channels in many thin layers, not unlike the coats of an onion, and some investigators have described little fibers running through these layers, as it were, pinning them together. In the midst of these layers are seen what appears to be oval, dark spots, with dark lines radiating from them, and joining the Haversian canals. These dark spots are called *lacunæ* (little lakes), and the lines *canaliculi* (little canals). The *lacunæ* are really bone-cells, and the *canaliculi* are processes or branches of the cells. Through all these, in the living bone, the plasma, or thin part of the blood, filters as through a sponge, and brings the material which builds up and keeps the bony tissue in repair.

7. Composition of Bone. — Two simple experiments will prove that bone is composed of two distinct kinds of matter. (1) If a long bone be immersed in a weak acid for a day or two, it will become soft and flexible so that it may be tied in a knot; yet it retains the same bulk and shape, and microscopic views of sections of it show the same structure as it had before. It will, however, have lost in weight, and the acid can be shown to have united with earthy, or mineral salts. (2) Again, if a bone be put into a hot fire, and left until it has burned perfectly white, it will be found to have lost in weight, and be very brittle and fragile, yet retaining the original form and structure. It is evident that the acid removed the part which gives the bone solidity, and the fire removed the part which gives it toughness and elasticity; also that the parts were intimately blended. The part removed by the acid is called mineral, or earthy matter, and forms about two-thirds by weight of the entire bone. It consists mainly of phosphate of lime and carbonate of lime, the former weighing about one-half, and the latter about one-tenth, of the entire bone. The part removed by the fire is mainly gelatine, usually spoken of as organic, or animal matter, because not produced in the mineral kingdom, but a product peculiar to living beings. A portion of the gelatine is dissolved out of bones when they are boiled for soup. It is the jelly we see when pigs' or calves' feet have been boiled and allowed to cool. Gelatine forms a large part of the skins of animals. When united with tannic acid it forms leather. The glue used by cabinet-makers and others is hardened gelatine made from the waste portions of skins of animals used in making leather.

FIG. 3.—STRUCTURE OF BONE ENLARGED.

In young persons the proportion of organic matter is greater than in adults, and the bones are consequently softer and more flexible. In old age the proportion of inorganic, or mineral matter, is greater, and the bones are harder and more brittle. In the disease called "rickets" there is a deficiency of mineral matter, and the bones become bent and deformed by the mere weight of the body. There are some rare cases of a disease in which there is a great deficiency of the organic matter, and bones become so fragile that the mere contraction of the muscles in moving the limbs may break the bones. Works on surgery record cases where men broke their bones by simply turning over in bed, or by throwing a club, or catching a toe in the carpet.

8. Properties of Bones. — Bones possess certain *properties* which make them peculiarly adapted to their uses in the body. They are flexible and elastic to a certain degree; were they much more so, they could not support the weight of the body. They are more flexible in youth, when the weight of the body is less, and the activity greater. The bones of a child will bend before they will break. They have a certain degree of hardness which fits them for protecting delicate organs within, and gives them the required stiffness for levers for the muscles, and for supporting the weight of the body.

Although of no value in a physiological sense, it is interesting to know that bones are exceedingly durable. Fossil bones have been found which bear evidence of having belonged to animals which existed before man came upon the earth. One case is recorded where the bones of a mastodon were found in such an excellent state of preservation that the workmen who dug them up greased their boots with the marrow. Some of these fossil bones contained gelatine enough to make a nutritious soup.

Bones, when used as levers, are about twice as strong as oak wood, more than three times as strong as lead, and twenty-two times as strong as sandstone.

9. Uses of Bones. — From what has been said in the foregoing lessons, the pupil may infer many of the uses of the bones in the human body. They may be summed up under three heads: (1) *For support:* They form the framework around and within which the soft parts are arranged and kept in position. Without the bones the body would be a shapeless mass. (2) *For protection:* The delicate brain, the yielding lungs, the massive liver, the stomach and intestines, the principal blood-vessels and nerves, the sensitive eye, and the delicate mechanism of the internal ear, are all guarded and protected by the bony framework. (3) *As aids to motion and locomotion:* The muscles, which are the prime movers of the body, would be of little use were it not for the bones to form solid points of attachment, and to be used as levers in producing the great variety and complexity of motions of which a trained human being is capable. What a wonderful machine is the human hand! The numerous small bones, with their muscles acted upon by nerves, are capable of executing an almost infinite variety of movements, which may follow each other in such rapid succession that the eye cannot follow and keep trace of them.

The bones of animals are useful to man in various ways. Many useful and ornamental articles can be cut from them. Ground to powder, they make the best fertilizer known. They are a source of phosphorus, phosphate of soda, and superphosphate of lime, which are valuable chemicals used in the arts and in medicine; also of animal charcoal, or bone-black, used for making shoe-polish, for painting, and in the purification of sugar.

PRACTICAL ILLUSTRATIONS.

1. Get the long bone of a turkey's or chicken's leg. Find a wide-mouthed bottle, long enough to receive it. Fill the bottle about five-sixths full of water; then fill up with muriatic acid, and shake or stir until water and acid are mixed. Let the bone remain in this diluted acid for two days. If then the bone is not soft enough to be tied in a knot, add a few drops more acid, and let stand another day. If you get too much acid, it will dissolve the gelatine also.

2. Get from the butcher a large piece of the bone from the leg of an ox. See that it is the end and part of the shaft of a long bone. Saw it through lengthwise with a meat-saw. Observe the compact and cancellous tissues and the marrow.

3. Procure, if possible, a piece of fresh bone from the leg of a calf or lamb. Try to separate the periosteum with a knife. Observe the red points where the blood-vessels are broken when the membrane is torn off.

4. Get a large piece of beef-bone, and, after cleaning off all ligaments and fat, weigh it carefully and note the weight. Place it in a hot fire in the stove or fireplace, and let it remain about three hours, or until it turns perfectly white. When cool, observe that it has not lost in bulk, and that the shape is not changed. Now weigh it carefully again, and note the loss of weight. Strike it with a hammer, and observe how easily it is broken. When broken, notice the structure within, and compare it with the unburned specimen of No. 2.

LESSON 6.

Development, Growth, and Hygiene of Bones.

1. **Development of Bone.** — In man, and in all of the higher vertebrate animals, the skeleton, or framework, is, in the embryo state, composed of cartilage and membrane. As it develops, bony tissue appears gradually, taking the place of the cartilage or membrane. In the lowest forms of vertebrate animals, as in some of the fishes, the skeleton remains cartilaginous through life. This is another illustration of the great law in nature that the very young of higher animals resemble the adults of the lower forms. Except in the case of some of the flat bones of the head, all the bones in the human body are said to be developed from cartilage; that is, the cartilage cells gradually disappear and are replaced by bone cells, and bony matter is deposited within and between the cells. This process is called **ossification** (bone-making). The process of ossification begins before birth, and is not entirely completed in all the bones until old age. At birth a part of nearly every bone is ossified, and some are almost completely so.

The development of bony matter begins at certain points, called **centers of ossification**, within the bone, and proceeds in all directions from these centers. In short bones there is usually but one center of ossification; in long bones, usually three. In some irregular bones there are several; in the sacrum, as many as thirty-five.

2. The shaft of a long bone is developed first as a separate piece from one center; the heads, or articular extremities, from separate centers. In the skeleton of a human being less than twenty years of age, a plainly marked line may be seen between the head and shaft of each long bone. A smart blow may cause a separation of the head from the shaft. This takes place sometimes during life, by accident; that is, a bone may break at this point more easily than at any other. The *epiphysis* (growing upon), as the head of the bone is called in this early stage, does not become completely united

to the *diaphysis* (growing through), or shaft, until about the age of twenty. Observations on animals show that they live about five times as long as the time required to complete the union of these parts. Thus, in the dog, it takes place at four years, and its lifetime is about twenty years; in the horse at six, and its lifetime is thirty years. Unless man is an exception to the rule, he ought, then, to live to the age of one hundred years, and we need not hope to see the term prolonged much beyond this period. There are no authentic records of men in modern times, at least, who have lived beyond one hundred and six years.

3. At birth the flat bones of the skull are separated from each other by spaces which are filled by a soft membrane. At several points where corners of bones meet, these spaces are of considerable size. One just back of the forehead is diamond-shaped, and sometimes an inch in diameter. This usually remains open until the second year, and rarely through life. The others are smaller, and are situated at the back and sides of the head. These spaces are called **fontanelles** (little fountains), because the large arteries at the base of the skull may be felt lifting the brain at each pulsation. Sometimes new centers of ossification start in the membrane of a fontanelle, or between the edges of the different bones, and the results are separate small bones, called *Wormian bones*, from Wormius, who first described them.

4. In the development of the bones of the head certain open spaces, or cavities, are left. Some of these have already been mentioned. The one in the frontal bone just over the eyes is called the **frontal sinus**. It is caused by a separation of the outer and inner plates of the bone. This cavity varies much in size, sometimes not over an eighth of an inch, and again over an inch in diameter. For this reason it is impossible to judge of the exact size of the brain by measuring the outside of the skull. The thickness of the bones of the skull also varies much, — from an eighth of an inch to one inch or more.

These cavities all communicate with the air-passages of the nose, and are lined with mucous membrane. The troublesome disease called **nasal catarrh** is an inflammation of the mucous membrane of the nasal passages, and sometimes extends to these cavities in the different bones of the head. In a common cold in the head they are sometimes inflamed and painful. Exposure to very cold air may affect this membrane, and serious results follow. The well-known senator, Roscoe Conkling, died from inflammation of the brain, caused by an inflammation of the mucous membrane lining the cavities of the mastoid process, the direct cause of which was exposure to cold in the severe "blizzard" which occurred in New York a few years ago.

5. Small bones, about the size of a grain of corn, are found in some very muscular men, growing in the tendons of certain muscles of the hands and feet, where such tendons glide over a joint. Such bones are called **sesamoid** bones, from their resemblance to a certain seed (sesame). The patella is really a sesamoid bone in the tendon of the large muscle which extends the leg. It is the only sesamoid bone which is present in all individuals. The use of these bones is to lessen friction. They act in a manner similar to pulleys.

In one or two cases on record a bone has been found extending from the hyoid bone to the temporal. It is called the **epihyal bone.**

6. **Growth and Repair of Bone.**—Like other parts of the body, bone is constantly renewing itself, old material being removed and new taking its place. The change is not so rapid as in the softer tissues, and not so rapid in old bones as in young, yet it is going on, as certain experiments on animals prove. If a sheep be fed with madder, a vegetable red coloring-matter, in a day or two the bones will be tinged with red. If the madder be discontinued the original color will return. In young animals a single day is sufficient to show the reddish tinge. In older animals it requires a longer time.

When a bone is broken nature immediately sets to work to repair the injury. At first a thin fluid is poured out on the broken surfaces, and in a few days this becomes thick like jelly. New bony matter develops within this *provisional callous*, as it is called, and the bone is welded, as it were, together. There is always more of the new material than what would be merely necessary to unite the parts. This causes a knot, or lump, in the bone at the broken place. In young and vigorous persons this extra amount of material is in time almost or entirely absorbed and removed. In old persons it usually remains through life. A broken bone should be "set"; that is, the ends brought as nearly evenly together as possible; otherwise more or less deformity of the limb will follow. This adjustment is not always easy to accomplish, as the muscles by contracting tend to pull the fragments, and cause them to lap over each other. Frequently when the surgeon has taken all possible care to set a bone and keep it in place, carelessness on the part of the patient or his attendant, may cause displacement and subsequent deformity. Then the surgeon may be blamed, and even prosecuted at law, for what was not his fault at all. It usually requires five or six weeks for a broken bone to become united, and then it should be used with care for some time longer.

7. Hygienic Summary. — Hints on the proper care of the bones have been given incidentally in the foregoing pages. The following is a summary of hygienic advice based upon the anatomy and physiology of bone: —

(1) Do not try to hasten the process of learning to walk, especially if the child be "fleshy." Its weight may cause bending of the long bones of the legs, producing "bow-legs" or "knock-knees." Let the child make efforts to stand on its feet. Do not place it upon its feet, nor allow it to remain long standing even when it has arisen by its own efforts. Deformities of the lower limbs may be produced by the child getting into a habit of placing the soles of its feet together as it lies in the cradle.

(2) Care should be taken that the child does not sleep always upon one side, as this may cause one side of the head to grow larger than the other or produce deformity in the shoulder.

(3) Pupils in school should not lean over their desks too much. Desks should not be too high, as this will throw one shoulder higher than the other; nor too low, as this will produce "stoop-shoulders."

(4) Ladies should not be so foolish as to try to produce a small waist by tight lacing. A prominent physician once re-

marked that tight lacing was a good thing, as it killed all the foolish girls, and permitted the wise ones to grow to womanhood. This was stating it rather strong, but certainly it is a foolish custom, for not only does it produce actual deformity of the bones of the thorax and injure the internal organs, but it destroys the natural shape of the body, and thus violates a law of taste in art. Really sensible and refined people do not admire an unnaturally small waist. The Greek statues of beautiful women, which have been admired by artists the world over, do not show small waists. There is nothing objectionable in wearing a corset if it fit the body and be not tightly drawn by lacing. A corset should be laced comfortably close with elastic cords, so that all movements of the body may be made with perfect freedom.

(5) Young people should avoid sitting or standing long at a time in one particular position, as undue pressure on any particular part may impede the proper circulation of the blood, and it must be remembered that bones demand a supply of blood as well as other parts of the body. Moreover, when the bones are flexible, long-continued pressure upon them will cause a gradual but sure bending.

(6) An erect posture should be maintained when sitting or standing; the shoulders should not be permitted to fall forward. Youth is the time when good or bad habits are formed. Try to form habits of carrying the body with ease and grace. If you do not think occasionally about the necessity of proper habits of sitting and standing, you will easily fall into habits of stooping, or lounging, or leaning, which will surely tell, when you have grown to manhood or womanhood, in rounded shoulders, contracted chest, and perhaps crooked spine.

(7) Old persons should be particularly careful to avoid falls, as a fall which would not injure a young person in the least may produce serious fractures of bones, — fractures that may never completely unite.

(8) The bone is a living, growing part of the body, and needs proper nourishment; hence, good food, fresh air, proper exercise, avoidance of excesses of all kinds; or, in other words,

whatever tends to the making of pure blood, is essential to the healthy condition of bones as well as of other parts of the human body. Does the use of alcoholic stimulants affect the bones? Perhaps not directly, but certainly it does indirectly, as will be inferred from what has already been said. Alcohol interferes with the proper nourishment of the body, and the bones will inevitably suffer in time as a natural consequence. An illustration of this is found in some cases of professional beggars in cities, who give their children gin or whiskey when they are babies, for the purpose of arresting development, and keeping them small and puny, that they may excite compassion in those from whom they beg.

PRACTICAL ILLUSTRATIONS.

1. Get a pig's foot from the butcher. Boil it until the meat separates readily from the bones. Select one of the long bones, and, having cleaned it thoroughly, see if you can find the line of union of the articular head (epiphysis) with the shaft. Strike it a smart blow with a stick. A separation will take place at this point. This experiment will be successful nearly every time, because animals that are slaughtered for food are usually those which have not yet reached the age when the bones have become completely ossified.

2. If you can find the skull of any small animal, as a cat or dog, break it and find the air-cavities in the bones. The dry skulls of oxen or hogs may frequently be procured for this purpose. In the cat a very large cavity may be observed in the mastoid process.

EXERCISES FOR REVIEW OF THE OSSEOUS SYSTEM.

[These questions are purposely arranged promiscuously, with no references to any particular lesson or section, that the pupil may exercise his skill in finding answers to them. He should first try to answer the question without referring to the book; if he cannot do this, let him search for the answer in the foregoing pages, using the index at the end of the volume, if necessary, in finding that part of the text which treats of the subject.]

1. What is the advantage, if any, of so many bones in the cranium?
2. Name three general uses of bones.
3. What are the parts of a joint?
4. What are the uses of ligaments?
5. Why is a man taller in the morning than he is in the evening?
6. What bones glide upon each other when you nod an affirmative answer?
7. What is ossification? When does it begin? When is it completed?
8. What is the skeleton in the earliest stage of its existence?
9. What lubricates the joints? What is the most movable joint in the body?

10. What is the cause of "bow-legs" and "knock-knees"? What causes round shoulders?

11. What part of a bone is removed by burning?

12. At what period of life would you find yellow marrow in the bones? What is the composition of yellow marrow? of red marrow?

13. What bone has a pivot on which the head is rotated?

14. What part of a bone is dissolved by an acid?

15. Where would you find fibro-cartilage?

16. How do alcoholic stimulants affect the bones?

17. Can you state one argument in favor of tight lacing?

18. What are Haversian canals? What is their use?

19. Where and what is the *frontal sinus?*

20. What is the *periosteum* and its use?

21. What is the *synovia?* What is its use?

22. Name the first and second vertebræ? What vertebræ are the largest?

23. What part of a bone is partially dissolved when it is boiled for soup?

24. What is a *suture?*

[The above and many more similar questions may be assigned for review lessons after the class has completed the study of the osseous system. The teacher may, as an occasional exercise, demand written answers to questions requiring the pupil to use his own language, and not that of the text-book.]

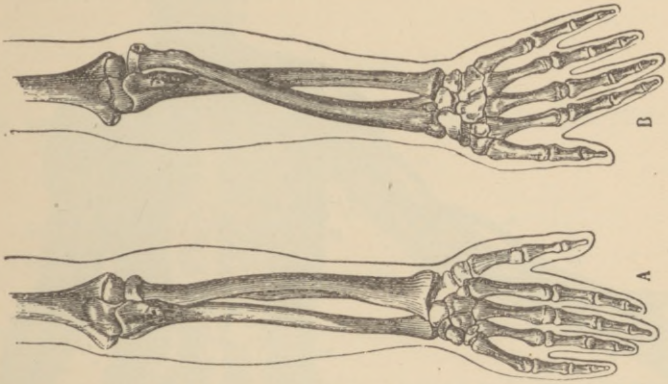


FIG. 4.—RIGHT HAND AND FOREARM.
A, Palmar, or front view; *B*, Dorsal, or back view.

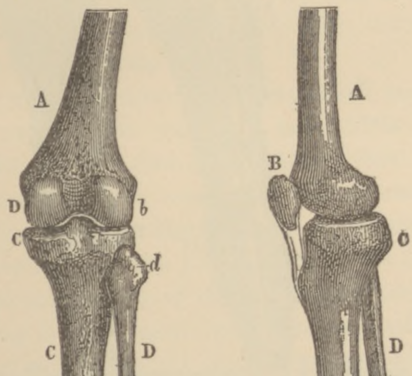


FIG. 5.—FRONT AND SIDE VIEWS OF KNEE-JOINT.
A, Femur; *B*, Patella; *C*, Tibia; *D*, *d*, Fibula.

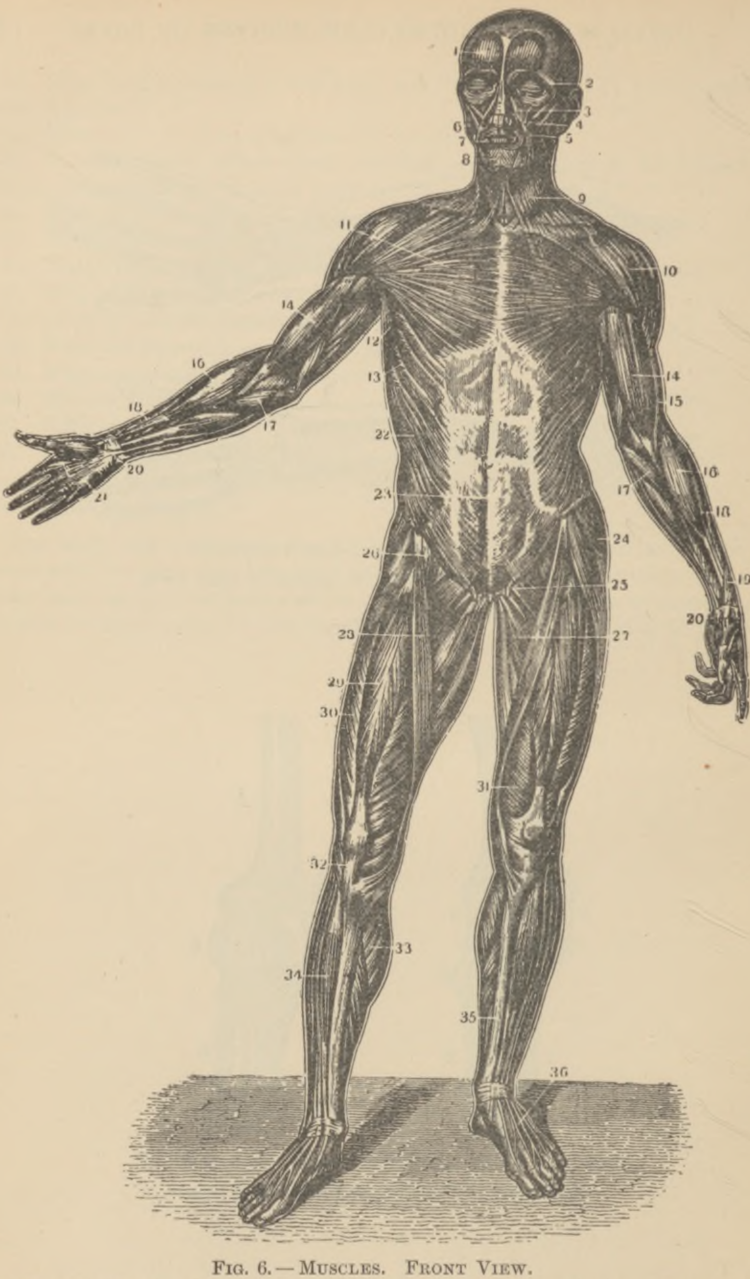


FIG. 6. — MUSCLES. FRONT VIEW.

1, Occipito-frontalis; 2, Orbicularis palpebrarum; 9, Platysma myoides; 10, Deltoid, 14, Biceps; 11, Pectoralis major; 23, Sartorius; 33, Gastrocnemius.

NOTE. — Advanced students may name the muscles referred to by the other figures.

CHAPTER II.

THE FRAMEWORK CLOTHED WITH FLESH, OR THE MUSCULAR SYSTEM.

LESSON 7.

General Description of Muscles.

1. With some slight exceptions, which will be mentioned in another place, all motions of the body are produced by contractions of bundles of fibers, called **muscles.** They are the lean meat of an animal, and give general form to the body and make up the greater part of its weight. The angular space where two or more large muscles lie side by side is usually filled with fat, which does not interfere with their action, but gives the body a more even outline.

The skin contains numerous very small muscles, which contract when exposed to cold and raise little lumps, producing what is called "goose-flesh." Similar action of the muscles in the skin of a dog's back causes the hair to stand on end. Muscular fibers are found in the walls of the stomach and intestines, and in the coatings of the blood-vessels, and their contraction is a part of the machinery of digestion and circulation. The act of swallowing is performed by muscular contraction in the gullet. Minute muscles in the middle ear act when we give attention to sounds. The modulations of the voice are produced by the contraction and relaxation of numerous small muscles. The eyeballs are moved by six sets of muscles. Minute muscles regulate the amount of light admitted into the eye, and others adjust the parts of the eye to the different distances of objects. The heart is a muscle of peculiar construction, and the tongue is made up of several muscles covered with mucous membrane.

2. Sizes and Shapes of Muscles. — While the longest muscle in the body is about two feet, the shortest is but a small fraction of an inch in length. In weight they vary from a few grains to several pounds. The most common form is spindle-shaped (*fusiform*); that is, large in the middle and tapering to each end. Some are fan-shaped (*radiating*), some like a feather consisting of fibers converging to one side of an axis (*penniform*), or to both sides of an axis (*bipenniform*). A few muscles are like circular bands, and when they contract diminish the size of the opening they surround; such are called *sphincter* muscles.

3. How Muscles are named. — There are about five hundred distinct muscles in the human body, each having a special use, and all have been named and minutely described by anatomists. The names are usually derived from the Latin. These names were given to them when Latin was the language of the learned. Latin is to-day a common language among scientific men in all civilized countries. So you will find in English, French, and German works on Anatomy the same words used for names of most of the parts of the body.

Muscles are named from: (1) their shape, as *deltoid* (like the Greek letter delta); (2) their location, as *tibialis* (near the tibia); (3) points of attachment, as *sterno-cleido-mastoid*, (sternum, clavicle and mastoid process); (4) their action, as *flexors* (bending), *extensors* (extending); (5) their divisions, as *biceps* (two-headed), *triceps* (three-headed).

A few of the more important muscles are here mentioned. The *occipito frontalis* passes over the top of the head, and raises the skin over the eyes and moves the scalp. The *temporal* and the *masseter* raise the lower jaw, and are capable of closing the teeth very forcibly. Some wonderful feats are performed, lifting weights, holding out chairs, etc., by persons with strong jaws. The temporal muscle may be felt moving if you place your finger on the temple and work your jaws. In the same manner you may feel the contraction of the masseter by placing the fingers just below the cheek-bone. The *sterno-cleido-mastoid* has a long name, but it is an important muscle. It can be felt as a thick cord in the side of the neck. When the head is turned to one side, it stands out as a ridge. When one acts alone it turns the head to one side. When both act together they bow the head. The *pectoralis major* on the breast pulls the arm forward. It is the principal muscle used in moving the wing of the bird, and is very large in the rapid-flying birds. The *intercostals* are small muscles between the ribs. They move the ribs in the act of breathing. The *deltoid* on the shoulder raises the arm. The *biceps* can be seen and felt contracting on the front of the arm when it is bent at the elbow. The *triceps* is on the opposite side, and straightens or extends the arm. The *sartorius* (tailor) is the longest muscle of the body, and passes from the outer side of the hip-bone to the inner side of the upper end of the tibia, and is used in crossing the leg, whence the name "tailor's muscle." The *gastrocnemius*, one of the bulkiest muscles, forms mainly the calf of the leg. It raises the heel, and is one of the principal muscles used in walking and leaping.

4. Attachments of Muscles. — They are usually attached to bones, or, rather, to the periosteum of the bone; but sometimes to cartilage, to ligaments, to the skin, and to other muscles. In some cases they are attached directly by the muscular fibers, but usually by means of fibrous cords, or bands, called *tendons.* In some of the muscles of the limbs, the tendons are much longer than the muscles themselves. If you close your fist very tightly, you may observe cords standing out under the skin of the wrist. These are the tendons of the muscles which move the fingers. Here, for convenience, the power is placed at some distance from the part to be moved, the muscles which move the fingers lying in the forearm. Their tendons all pass under strong ligaments which encircle the wrist. If they were not thus held down, when the hand is bent and the fingers moved the tendons would be drawn away from the wrist. Similar ligaments hold the tendons down on the inner side of the fingers. In this respect the tendons are like ropes passing over pulleys. The direction of the force is changed.

The rounded tendons we observe standing out under the skin in the arms and legs are called, in common language,

leaders. In an animal they are generally called **sinews.** The ancient Greeks had but one word, *neuron*, for both tendons and nerves. They did not know that they were entirely distinct and for widely different uses. Some people, even to-day, imagine that a man's strength lies in his nerves, for they sometimes speak of a muscular man as a "nervy man." Tendons are not elastic, or at least very slightly so, but they are very flexible and tough. An animal when being dressed by the butcher is hung up by the tendons ("ham-strings") of the legs.

Tendons may be distinguished from *nerves* by their *pearly and glistening appearance* and by their *greater strength.*

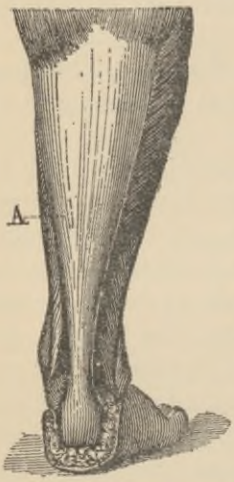


FIG. 7.—LOWER PORTION OF THE LEG, SHOWING TENDON OF ACHILLES.

One tendon at least deserves special mention. It is called the **Tendon of Achilles,** is attached to the heel-bone, and is the combined tendon of the muscles of the calf of the leg. It is the thick cord you can feel behind the ankle. It is so named from the fabulous story of Achilles, the Greek hero, whose mother dipped him when a child in the river Styx and thus made him invulnerable, except in the part which she held in her hand and which did not get dipped. When he grew to be a man he was wounded in battle in this part of his body, and the wound caused his death. This tendon is sometimes too short and the heel is drawn up, the deformity being known as "club-foot." In many cases it may be cured by cutting the tendon beneath the skin with a peculiar instrument, in which case new fibrous material grows in to fill the gap, and the tendon thus becomes longer. Children born with deformed limbs should as early as possible be examined by a competent surgeon, as in many cases if taken in time the deformity can be removed.

PRACTICAL ILLUSTRATIONS.

1. Get the "hock-joint" of an ox, calf, or sheep from the butcher. This joint corresponds to the ankle-joint in man. These animals have a very long metatarsal bone, which raises the ankle a considerable distance from the ground. Imagine a man with one metatarsal bone, and it as long as the tibia, and that he walked on his toes instead of the sole of the foot, and you will have an arrangement similar to the hind-leg of a horse, ox, or sheep. The object in procuring this particular joint is that you may get a good idea of a tendon. The Tendon of Achilles, or a portion of it, may be shown attached to the heel-bone. Cut it across to show the structure and density. Observe how flexible, yet how strong.

2. The tendons, with their attachments to muscles, may be best shown in the leg and foot of a rabbit. These animals are easily obtained in the winter from farmers' boys in the country, and are usually found in the markets of the cities and towns. When the skin is removed, by pulling it from above downward, as you would take off a glove, an excellent view of the tendons and the ends of separate muscles is had. Note the glistening, pearly appearance. By separating a single tendon and pulling upon it, you may observe how the toe is drawn back. This can be shown, perhaps, better in the foot of a cat or dog.

LESSON 8.

Nature and Actions of Muscles.

1. **Structure.** — If a piece of raw, lean meat (muscle) be examined with the unaided eye, it will appear to consist of layers of fibers which are not very distinct. If cut "across the grain," the surface appears in irregular masses, looking like the ends of bundles of fibers. Boiling separates the fibers somewhat, so that we can easily split it into finer and still finer threads, until at last we arrive at a thread finer than the finest hair, which we cannot further divide. Before the microscope revealed the real structure of this thread, it was called the *ultimate* fiber, and in many books this term is still used, although, as we shall see, it is not the ultimate, or last division. If one of these fibers be placed under the microscope, and examined by a high power, fine lines, ten thousand to the inch, running both across and lengthwise, may be seen, as it were,

dividing it up into little squares, or blocks. Treated with certain chemicals, it splits crosswise into discs, or plates, and with different treatment into rows of little blocks, like strings of beads. A transparent membrane covers the fiber, enclosing it as a sheath, or tube. These little blocks have been called *muscle-cells*, or *sarcous elements;* a row of them a *fibril* (little fiber). The tubular sheath is called the *sarcolemma* (flesh-rind), or *myolemma* (muscle-rind).[1] The fibers are glued together in small bundles, and these again into larger bundles, by a very fine cobweb-like tissue called *perimysium* (around the muscle). This tissue also forms a sheath for the entire muscle, blending at the ends into the tendon.

All the muscles of the body which are under the control of the will, are constructed in this manner, and, from the appearance of the fibers under the microscope, are called *striated*, or striped muscles. The involuntary muscles are simpler in their structure, being made up of cells in the form of flat, tapering bands interlacing in all directions. The heart is not under the control of the will, yet it has the structure of a voluntary muscle.

2. Composition. — The exact chemical composition of muscle is yet an unsolved problem. All that can be said is that it contains an albuminous substance called *myosin*, which seems to be peculiar to muscle. It is very probable that living muscle is chemically different from dead muscle; in other words, the death of the muscle is a chemical change in its composition. It is known to all that soon after the death of an animal the muscles become stiff. This stiffness in a little while passes off and the muscles become relaxed as before. This stiffness must be due to a chemical change which is not well understood.

3. How Muscles act. — Muscles produce motion by **contrac-**

[1] "It can be shown that a muscle-fiber, when recently taken from a living animal, must, in reality, be of a fluid, or, at least, of a semi-fluid nature. So that it is impossible to affirm that either the discoid or the fibrilloid structure actually exists in the muscle-fiber itself; it must rather be assumed that both forms of structure are really the result of the application of reagents (chemicals), which solidify the originally fluid mass, and split it up in a longitudinal or transverse direction." — *Rosenthal.*

tion and **relaxation.** Contraction is a change of form in the muscle. It grows shorter and thicker, and thus pulls upon the part which is attached to it. There is a very slight change in bulk also; the contracted muscle is a very little smaller than before. Relaxation is the return to its original condition. Nearly every muscle has its antagonist; that is, one muscle by its contraction draws a part in one direction, another by its contraction pulls it in an opposite direction. Thus the biceps and triceps of the arm are antagonists, the former bending the arm, the latter drawing it straight again.

Muscles have no power to contract of themselves. They must be stimulated in some way. Ordinarily our muscles contract in obedience to our will, but this is only another way of saying that a stimulus passes from a nerve center in the brain through a nerve to the muscle. Separate a muscle from the nerve center and it will not contract unless stimulated in some manner. Mere currents in the air may be the stimulant; thus the muscles of a beef continue to twitch for some time after it is dressed. A sharp blow with a stick on a muscle, recently separated from a living animal, will cause contraction. Electricity and application of strong acids will cause contraction. In man and the higher animals this power to contract ceases in a few minutes after death, except in some cases of death by certain diseases it may continue for an hour, or if powerful currents of electricity be applied, contractions may be produced for an hour or longer. In the frog or snake it lasts much longer, and in the turtle contractions may be produced four days after death, or even longer.

The stimulus need not be applied directly to a muscle. If we dissect out a portion of a nerve leading to a muscle, and apply the stimulus to that, contraction will take place in the muscle. This raises the question, Is the irritability in the muscle substance, or is it due to the nerves acting upon the muscle? This is as yet an unsettled question among physiologists. It will be a difficult point to settle because every part of a muscle is supplied with filaments of nerves, and when we apply a stimulus to one we apply it also to the other.

4. Voluntary and Involuntary Muscles. — Most of the striated muscles contract usually only in obedience to the will, and they are said to be voluntary muscles. All voluntary muscles, however, act at times involuntarily. For example, we accidentally touch a hot stove, the muscles contract and move the hand before we have time to exercise the will, or simultaneously with the consciousness of the pain. When we tickle the limbs of a sleeping person they move, although he is unconscious. The muscles of the eye-lids are partially under the control of the will; we wink unconsciously, yet for a time we can keep from winking. This involuntary action of voluntary muscles is a wise provision to keep us out of danger. (See Reflex Action in lessons on the Nervous System.) The non-striated muscles are without exception involuntary. Thus motions of the walls of the stomach and intestines go on, and the food is moved along in the digestive canal while we are all unconscious of any action.

5. Relation of Muscles to Bones. — Muscles would be useless in the higher animals without bones, and bones would be useless in any animal without muscles. Taken together they are the locomotive and food-obtaining machinery of the body, as well as its means of defense.

The long bones act as levers, and all the bones act as fulcrums for the muscles. A lever is an inflexible bar, or rod, which moves about a fixed point called a *fulcrum*. The force used to move a weight, or exert another force, is called the *power*. The load moved, or force produced, is called the *weight*.

The power multiplied by the distance through which it moves, is equal to the weight multiplied by the distance it moves. This is the law of the lever. By this law what is gained in power is lost in time (or distance), and what is gained in time (or distance) is lost in power. Now the muscles frequently so act upon the bones that they gain in time (or distance), but lose in power. To illustrate, place a five-pound weight in the hand, straighten the arm, and hold it out horizontally. To do this requires a muscular effort or power equal to about one hundred pounds. Now bend the arm at the elbow, and bring the weight over on your shoulder, at the same time placing your other hand on the biceps muscle. You observe that the muscle has only shortened itself a little, while the weight in your hand has moved through the fourth part of a very large circle.

6. Strength of Muscles. — The strength of a muscle and the power it is capable of exerting are not the same. A muscle in itself is a soft, yielding mass which can be torn asunder without much force, yet the same muscle contracting in obedience to a stimulus from the nerves is capable of exerting very great power. By the hands alone, David L. Dowd of Springfield, Mass., in 1883, lifted 1442¼ pounds. W. B. Curtis of New York City, in 1868, by means of harness attached to his body, lifted the enormous weight of 3239 pounds. Insane persons, and patients in delirium, sometimes exert great power with their muscles. It seems that under an unnatural stimulus they have greater power than when called into action by the mere exercise of the will. Patients in convulsions have been known to tear some of the muscles of the limbs completely asunder by their rapid and forcible contraction.

The power capable of being exerted by muscles is not in proportion to the size of the animal. A man can drag on a level surface nearly his own weight, while a horse cannot, under the same circumstances, drag more than two-thirds of his weight. Insects are, in proportion to their weight, the strongest of animals. Some beetles have been known to drag forty times their own weight.

The ability to lift heavy weights is no true test of a healthy person. Training and inherited peculiarities have much to do with it. A man may be healthy and long lived and yet have but comparatively little muscular power. The ability to produce *rapid* motions is characteristic of some persons, and to lift or drag heavy weights is characteristic of others. The power in both cases may be greatly enhanced by proper training and practice.

LESSON 9.

Hygiene of Muscles.

1. **Exercise and Rest.** — A healthy condition of the muscles, as well as of all other organs of the body, depends upon a proper alternation of exercise and rest. There is no absolute rest; that is, some part of the body is always in motion. When all motion ceases, life is at an end. But no particular set of muscles works constantly. The heart contracts seventy times in a minute, yet between the contractions there is a brief period of rest, and the total of these periods of rest is equal to about nine hours a day. In the act of respiration, which is continually going on, one set of muscles rests while another set works. Whenever, from derangement of the nervous system, which controls all muscular action, the heart beats more rapidly than usual, a corresponding lessening of activity follows. If the motion is excessive, exhaustion of its power and entire cessation of its motion take place. The same is true of the muscles of respiration. Undue activity is followed by undue inactivity. Thus, in a general sense, ceaseless activity is the law of our being, yet each particular organ, or set of muscles, must have their periods of inactivity.

2. **Exercise a Necessity.** — As stated in our Introduction, physical life seems to consist of the constant birth, growth, and destruction of cells. The birth or creation of a cell implies the need of material to build it. The destruction of a cell implies the removal of the material which composed it. This importation of new material to build cells, and exportation of old material, is favored by activity of the muscles; this activity causing an increased flow of blood to the muscle, the blood bringing the new material and removing the old. Action, then, is the law of animal life, action not only in the minute parts but in parts taken as a mass. The power of contraction is due to the life of a muscle; this life we have seen is the activity of the cells. There is thus a mutual necessity for action; the mass-motion producing activity in the cells, and the activity in the cells renders the mass-motion possible.

The foregoing paragraph must not be construed as an argument for materialism. When we say life consists of activity of the cells, we are simply stating the limitations of science. The power which causes this birth, growth, and destruction of cells is beyond our comprehension. It must be a power outside of matter, and science cannot deal with it. This is in reality an argument for the existence of a God.

3. **Rest a Necessity.** — While motion may be continual in the cells, it cannot be in the mass. We know that continual motion of a part exhausts it, and death is the result. This exhaustion seems to be simply the loss of power to create and destroy cells. Rest, then, is as absolutely necessary as exercise.

4. **Frequent Alternation of Exercise and Rest.** — Long-continued exercise of any one part is not only disagreeable, but injurious. Try to hold a book at arm's length for five minutes. Easy enough for the first quarter of a minute, it becomes really painful at the end of a minute, and to hold it five minutes would be absolute torture. The muscles used in extending the arm are in a state of contraction the whole time, and they become wearied by the exertion. Contraction is not the normal state of a muscle. It has a certain *tonicity*, as it is called, or state of readiness to contract, but is soon exhausted by continued contraction. It is much easier to push the book out and draw it back rapidly for five minutes than to keep it out that long, because half of the time one set of muscles is working and another set is resting. For the same reason, walking is not so fatiguing as standing still. In walking, different sets of muscles are alternately brought into action; but in standing still, certain muscles are required to be kept in a state of constant contraction to keep the body in an upright position. When a man is shot through the head, he falls instantly, because the bullet paralyzes a nerve center which controls the muscles, and those muscles which maintain the body upright immediately relax.

Long-continued action of one set of muscles should be avoided. Persons whose occupation requires a sitting posture should improve every opportunity to stand upright, if it is but for a minute at a time. Where writing is to be done, it should not be done altogether in a sitting position. A high desk, where one can stand and write for a change, is a valuable hygienic aid to bookkeepers and others who write a great deal. On the other hand, persons whose occupation requires a standing position, should avail themselves of all opportunities of sitting down. Women, in their housekeeping duties, should contrive to do a part of their work sitting, as there is usually enough to do which must be done standing. When sitting or standing, a mere change in the position of the limbs, so as to bring the weight of the body upon a different place and sustain it by different muscles, will give relief and be beneficial.

5. **Kinds of Exercise.** — In many cases a man's occupation gives him the proper amount and variety of exercise. The farmer, for example, needs little or no exercise beyond that which his occupation compels him to take. He need only guard against straining and over-working his muscles. But persons of sedentary occupations, or those whose occupations call for exercise of certain muscles to the exclusion of others, should take care that the muscles unused in their work should have exercise in some other way.

Walking is one of the best forms of exercise for the majority of people, as it brings into action almost all of the muscles of the body. Persons, however, who have narrow and flat chests, and inherit consumption, should take such exercise as will bring into action the muscles of the arms, shoulders, back, and chest, and thus develop greater lung capacity.

Horse-back riding is beneficial in many cases where the physical strength is not great. It is largely a passive form of exercise, and benefits other organs than muscles by the shaking it gives them. If the horse does not have an easy gait, this shaking may be too violent. A great many muscles are, however, brought into action in the constant effort to maintain one's equilibrium. It is a very suitable form of exercise for women under all ordinary circumstances. *Carriage riding* is more particularly suitable for invalids and very delicate persons.

Boat rowing, *swimming*, and *skating*, when not overdone, are valuable forms of outdoor exercise for those who can indulge in them. *Gymnastic exercises*, such as the use of clubs, dumb-bells, ropes, poles, etc., have a proper place, but frequently are abused by those who are not trained to a proper gradation and moderation of the exercises. Outdoor games, such as *croquet* and *lawn tennis* are very beneficial, as there is scarcely any danger of over-indulgence.

Running, *leaping*, *boat racing*, *base-ball* and *foot-ball playing* are apt to be injurious to many by being violent and prolonged. *Running* and *leaping* are more appropriate for children, since their bodies are light and dangers from falls and shocks cannot be so great.

6. **Violent Exercise** should always be avoided. Straining the muscles is injurious, Lifting heavy weights is apt to overtax the muscles. Leaping may not injure a child, but in a heavy man the violent effort to raise the body and the sudden jar of lighting may prove serious, occasioning rupture of abdominal muscles or of some internal part. There is also danger of ruptures in running, throwing and lifting weights. *Long-continued* exercise may prove serious by over-stimulating the action of the heart. Take, for example, the case of the girl who tried to excel her companions in jumping the rope the greatest number of times. Failure of the heart caused sudden death.

If one would like to attempt feats of lifting, he should begin by lifting light weights, and very gradually increase them from day to day. The story is told of Milo, an ancient Greek, that he carried a calf every day until it grew to be an ox, and then killed it with a blow of his fist, and ate the whole of it in one day. The latter part of the story we cannot believe, but the first part is not incredible.

7. **Effects of Muscular Exercise on Other Organs.** — One of the immediate effects of exercise of the muscles is an increased action of the heart, sending a greater amount of blood to the surface as well as an increased flow of blood through the particular muscles exercised. "The glow of exercise" on the face is familiar to all. When not unduly prolonged this is beneficial to all the organs of the body. Respiration is increased, and

more oxygen is taken in, and more carbonic acid gas thrown out; digestion is aided if the exercise be not severe and does not follow too soon after a full meal; the action of the liver, kidneys, and all the glands of the body is increased, and the brain and nervous system is beneficially stimulated.

8. Best Time for Exercise. — One should not indulge except in the mildest form of exercise immediately after eating a hearty meal, as all the energies of the system are needed in digesting the food; neither is it good to exercise much just before eating. The morning is generally the best time for sedentary persons to take physical exercise, although gentle exercise before retiring will often insure sound sleep which might not otherwise be possible.

9. Other Favorable Conditions. — Exercise should be taken in pure air, out of doors always if the weather is good. Since, as we have seen, exercise increases respiration, it is the more essential that the air we breathe should be fresh and pure.

Exercise taken when the mind is cheerful is more beneficial than when the opposite is the case. It is not best to take exercise simply for the sake of the exercise. The mind should not dwell on the fact that we are exercising for our health. Some other motive should actuate us. Take a walk to enjoy the sunshine and fresh air, to hear the birds sing, or to see the sights of a city, to see a friend, to gather flowers, or to collect insects, minerals, or shells. It would be well if all business and professional men had an *avocation* as well as a *vocation;* that is, that they had some side issue, some favorite study of nature which would take them out of doors in search of specimens, or for making observations of natural phenomena. A passion for hunting or fishing in professional and business men is often a means of prolonging their lives and insuring more effective work, as it sends them to the woods and fields, and compels them to take in a pleasant way the exercise and air which they greatly need. Even some mechanical avocation, as using tools in making trinkets, or in trying to invent some machine or mechanical device, followed in leisure hours, is beneficial in taking the mind from the routine of daily work, and bringing unused muscles into action.

Hard work seldom kills people. It is worrying and fretting added to their work that takes men off in the prime of life or makes them old before their time. This point will be more fully discussed in the lesson on the Hygiene of the Nervous System.

10. Effects of Alcohol on the Muscles. — The general nature and effects of alcohol and alcoholic drinks will be treated in a separate chapter, but it will be appropriate in this connection to note the special effect on the muscular system. All alcoholic drinks, as wine, beer, ale, whiskey, gin, rum, brandy, hard cider, etc., have a bad effect on the muscles when used for any considerable length of time, even when moderately indulged in. It was formerly believed that alcohol increased a man's strength, and it was the custom among farmers to serve out whiskey, or some other strong drink, to "harvest hands," and during slavery-times many planters gave their slaves a daily ration of rum. Governments also issued rations of whiskey to soldiers and sailors, especially during active service. Even in these days many laboring-men in towns and cities think it absolutely necessary to have beer as regularly as their meals. Alcohol, indeed, *apparently* increases the strength, for it stimulates to greater exertion. It is like the spur and whip to the horse, making him put forth all his strength, but does not increase his strength. There may be rare occasions when a stimulant is needed to cause a man to use all his strength of body or mind for a brief period, that he may accomplish a certain task with the design of resting afterwards to make up the loss. Such occasions, however, do not occur to one in ten thousand persons; besides, in such cases, a milder and safer stimulant, as strong coffee, tea, or chocolate, will answer just as well, or better.

Alcohol has its proper place among medicines, and may be employed to advantage in treating certain diseases, and even be the means of saving life in the hands of a skillful physician; but as a beverage, or for every little ailment, its use brings more harm than good.

A drunken man staggers, and speaks incoherently. Sometimes he sees double, and he imagines other persons are intoxicated.

These peculiarities are explained by the fact that alcohol so affects the nerves that they lose control of the muscles. The muscles do not co-ordinate; that is, one set of muscles does not work in the proper alternation with another set, hence the man cannot walk straight, and cannot use tools with precision. The muscles of the tongue do not act in accordance with the will, and articulation is imperfect. The muscles that move the eyeballs do not work in harmony, and he sees separate images with the two eyes. The eyeballs roll unsteadily, hence the images he sees appear to stagger and have the effect of being drunk.

But suppose a man uses alcohol moderately so that he is never visibly affected. Then the effect on the muscles is not so immediate, but in time will tell in loss of physical strength and power of endurance, because the digestive system is affected, and through it the nourishment of the muscles. Muscles which do not receive their proper nourishment degenerate and lose their natural tone and elasticity. This point will appear more apparent when we come to study the Digestive System.

The statements in this work concerning the effects of alcohol are not the imagining of a fanatical reformer, but are based upon the experiments and observations of leading physicians and men of science.

EXERCISES FOR REVIEW.

1. Name the kinds of muscles as to volition. As to structure.
2. Why are muscles sometimes called *tubular* tissues?
3. What is the use of tendons? How distinguish tendons from nerves?
4. Write the names of six important muscles and locate them.
5. Why should we take exercise? When should we take exercise?
6. Why the need of rest?
7. Why are alcoholic beverages injurious to the muscular system?

Part II.

HOW THE BODY IS NOURISHED, OR THE NUTRITIVE APPARATUS.

CHAPTER I.

HOW THE FOOD IS PREPARED, OR THE DIGESTIVE SYSTEM.

LESSON 10.

From the Hand to the Stomach.

1. **The Mouth.** — In most of the lower animals the mouth is used for the purpose of seizing the food, and in many for seizing and receiving only, as their food is swallowed whole. In the higher animals, including man, the food is masticated and mixed with saliva as a preliminary preparation for further digestion in the stomach and intestines. Man is more highly favored, being provided with two wonderful machines called hands, for seizing and conveying food to the mouth. In ancient times the hands, or simply the thumb and finger, were used alone for conveying all solid food to the mouth. Forks are a modern invention, and even now they are not used by the Chinese, who make use of two round sticks for this purpose.

The mouth is the beginning of a canal, or tube, of varying size, called the *alimentary canal*, the entire length of which is over thirty feet, and includes the *pharynx*, *esophagus*, *stomach* and *small and large intestines*. These, with the *teeth*, *salivary glands*, *liver*, *pancreas*, and *spleen*, are usually described as *organs of digestion.*

The tongue when at rest forms the principal part of the floor of the mouth; the hard palate, which is composed of parts of the superior maxillary and palate bones and is covered with mucous membrane, forms the roof. The back part of the mouth is called the *fauces*. It has an opening into the pharynx; and from the top of this opening, like a curtain, hangs the *uvula*, or hanging palate, and on either side, beneath the mucous membrane, lie the *tonsils*. These are peculiar glands whose use is not certainly known. They sometimes become troublesome by growing unnaturally large, and may be cut out by the surgeon without serious results. Inflammation of this part is known as *quinsy* or *tonsilitis*.

The lips form the front boundary, and the cheeks the sides of the mouth. The cheeks are composed mainly of a large, flat muscle called the *buccinator* (trumpeter, because used in blowing a trumpet). The contraction of this muscle, with the aid of the tongue, keeps the food between the teeth in the act of mastication.

2. The Teeth Classified. — As to duration, teeth are of two kinds: (1) *temporary*, *deciduous*, or *milk* teeth, twenty in number, appearing between the seventh month and close of the second year; (2) the *permanent* teeth, thirty-two in number, appearing usually between the fifth and twenty-first years. As to form and use, there are four kinds of teeth: (1) *incisors*, four in front part of each jaw, thin, broad, and sharp, with one root, and adapted for cutting; (2) *canines* (upper usually called "eye-teeth," lower "stomach teeth"), two in each jaw, one on each side of the incisors, sharp, conical, with single, long roots, and adapted for tearing; (3) *bicuspids*, or *premolars*, four in each jaw, two behind each canine, having two cusps or points, with usually a single root; (4) *molars*, six in each jaw, back of the bicuspids, the largest of the teeth, have several cusps, and from two to five roots (generally three in the upper teeth, and two in the lower), and adapted for crushing and grinding. The third molar is called the wisdom tooth, because it usually does not appear until near the age of maturity. The canine teeth (named from *canis*, a dog) are much elongated in the dog and cat and some other animals, and are called tusks, or "tushes." They are useful in these animals in seizing their prey.

Of the temporary teeth there are four incisors, two canines, and four molars in each jaw.

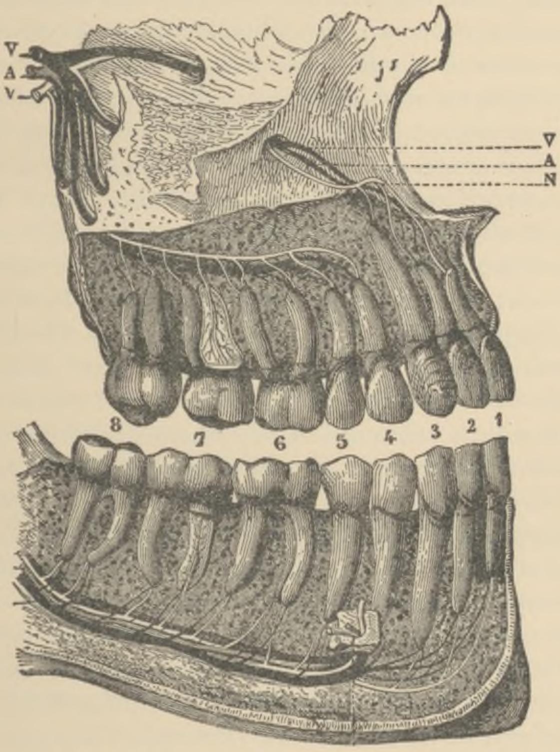


FIG. 8.—SECTION OF THE JAWS. RIGHT SIDE.

V, A, N, Veins, Arteries, and Nerves of the Teeth. The root of one tooth in each jaw is cut vertically to show the cavity and the blood-vessels, etc., within it. 1 to 8, Permanent Teeth.

3. Structure of the Teeth.—Each tooth consists of a *crown*, that part above the gums; a *root*, or *fang*, that part within the bone; and a slightly constricted portion between root and crown, and covered by the gums, called the *neck*.

The entire tooth contains a cavity which during life is filled with a soft substance called *dental pulp.* Each tooth has a vein, an artery, and a nerve which enter at the point of the root and branch out through the dental pulp. The body of the tooth, both crown and root, consists of a dense, white substance harder than bone, called *dentine.* Under the microscope it is seen to consist of many minute, branching tubes (*dental tubuli*) radiating from the pulp cavity outward, with a substance between, called *intertubular tissue.* The dentine is similar to bone in composition, but has a greater proportion of earthy matter. The crown of the tooth is covered with a very hard substance, called *enamel.* It is thickest at the top of the crown and gets thinner towards the neck, where it disappears. It is shown by the microscope to consist of minute, hexagonal rods lying parallel to each other and pointing towards the dentine. It is the hardest substance in the organic world and one of the most durable. It is harder than iron and most metals. It is composed of 96.5 per cent earthy matter. The root of the tooth is covered with a substance closely resembling bone in composition and structure. It is called *cement*, *crusta petrosa*, or *cortical substance.*

4. Development of the Teeth. — The time of eruption of the teeth varies considerably, but by comparing a great many cases the following average time has been made out: —

For the *temporary set:* The seventh month, two middle incisors; ninth month, two lateral incisors; twelfth month, first molars; eighteenth month, canines; twenty-fourth month, last molars. For the *permanent set:* Between sixth and seventh year, first molars; seventh year, two middle incisors; eighth year, two lateral incisors; ninth year, first bicuspids; tenth year, second bicuspids; eleventh to twelfth year, canines; twelfth to thirteenth year, second molars; seventeenth to twenty-first year, wisdom teeth.

The permanent teeth are formed beneath the temporary ones, and in their growth push against them, causing the roots of the latter to be absorbed. Sometimes, however, the temporary teeth do not become absorbed fast enough, and the permanent teeth grow out to one side, producing an unsightly irregularity. The temporary teeth should be watched and, if necessary, removed by the dentist before the permanent teeth are too far along.

5. Peculiarities of the Teeth. — Some persons have teeth naturally so good that they never decay, while the teeth of others decay even before they have reached their growth. Many theories have been advanced to explain this early decay of the teeth, but none are satisfactory. Decayed teeth are found among all races and nations of people, but perhaps more frequently among the highly civilized. One of the most reasonable theories for the early decay of teeth among civilized people is that they do not use the teeth enough, the arts of cooking and preparing the food dispensing with the necessity of much mastication. But whatever the cause of their decay, experience shows that proper care of teeth will make them last longer.

Teeth may be extracted and placed back in the jaw so that they will grow tight again, and may even be transferred from one person's jaw to that of another. Modern dentists have achieved great perfection in the art of preserving and replacing teeth that have begun to decay. For the special care of the teeth, see Hygiene of Digestion.

6. Uses of the Teeth. — Every child knows that the teeth are for the purpose of dividing the food and preparing it for swallowing. But they have other uses. In many animals they are for defence and for securing food. In man they serve a nobler purpose. They aid greatly in articulating and forming the sounds of our language. Certain consonant sounds are called *dentals* because made by the help of the teeth. They also add to the beauty of the face.

7. The Salivary Glands. — These are small bodies which *secrete* — that is, manufacture from the materials brought by the blood — the **saliva**, which bears such an important part in digestion. There are three of these glands. The largest, called the *parotid* (near the ear), is beneath the skin, just in front of the ear, around the lower jaw. Its secretion is poured into the mouth through a small tube called *Stenson's duct*, which opens opposite the second molar tooth of the upper jaw. The next largest is the *submaxillary*, lying below the angle of the lower jaw.

Its duct opens in the floor of the mouth, and is called *Wharton's duct.* The *sublingual*, the smallest, lies beneath the tongue, and opens by a number of ducts (from eight to twenty), called *ducts of Rivinianus.*

These glands consist of many small lobules, like bunches of grapes, each of which is made up of numerous small vesicles (little bags), each with a tube which joins others, and finally unites in the main tube or duct. Can you imagine a great number of little rooms, each with very thin walls, through which material which has passed through the walls of the blood-vessels also, passes and there undergoes a chemical change, forming a new substance, which passes out of these rooms through narrow passage-ways, and finally into one larger passage, and from thence into a chamber many times as large. If you can, you have a picture of what takes place in the salivary glands. The fluid manufactured by these glands becomes mixed with the mucus from the mucous membrane of the mouth, and is then called *saliva.* It is a clear liquid, slightly sticky, readily frothing, that is, gathering bubbles of air, and is composed mainly of water, but contains a peculiar substance which is found nowhere else in the body, and is called *ptyalin.* This is one of the organic "*ferments*," a name given to certain substances which act chemically upon other substances and change their nature, that is, actually decompose them and recombine their elements to form a new substance. The use of ptyalin is to convert the *starch* of the food into *sugar.* We shall learn of other "*ferments*" before we get through the book.

8. Other Uses of Saliva. — Besides the principal function of changing starch to sugar, the saliva has other and important uses. (1) *It moistens the food*, rendering it: (*a*) softer and thus more easily masticated; (*b*) more easily swallowed; (*c*) so it may be tasted. (2) *It moistens the mouth, pharynx, and esophagus:* (*a*) protecting them from injury by the food; (*b*) making articulation easier. (3) *It entangles bubbles of air* and carries them to the stomach, a certain amount of oxygen being necessary for digestion.

9. Digestion in the Mouth. — The food does not remain long enough in the mouth to undergo more than a slight change. It is reduced to a finer state and mixed with the saliva which acts further when it has reached the stomach and intestines, but a slight amount of starch is changed to sugar even in the mouth.

Absorption, or the passage of fluids into the blood-vessels, is an important part of the digestive process. A certain amount of the food is absorbed in the mouth. A little of the water containing sugar and salts in solution is absorbed directly into the blood-vessels. Poisonous substances may be absorbed from the mouth, and in quantity sufficient in some cases to produce death. If a drop or two of prussic acid be placed on the tongue, or on the mucous membrane lining the mouth, death occurs in a few minutes, although not a particle of it reaches the stomach. Boys who take their first chew of tobacco learn in a disagreeable manner that the entire system may be affected by simply placing certain substances in the mouth.

10. The Pharynx is a short, wide portion of the alimentary canal which receives the food from the mouth and passes it into the esophagus. It is composed of muscles, some of which run with the fibers up and down, and some with the fibers circularly. It is lined with a mucous membrane, continuous with that of the mouth and esophagus. There are seven openings from the pharynx; one to the mouth, one to the esophagus, one to the larynx, or beginning of the windpipe, two to the nose cavities, and two to the *Eustachian tubes*, which lead to the middle ear.

We have no longer control of the food when it has passed into the pharynx, as all the muscles of the alimentary canal, except those of the mouth, are involuntary. The length of the pharynx is about four inches.

11. The Esophagus, or *gullet*, is the name of the tube which extends from the pharynx to the stomach. It is about nine inches in length, and lies behind the windpipe, the heart, and the lungs, and passes through the diaphragm or muscular partition dividing the cavity of the thorax from the abdomen. Its walls are elastic and lie collapsed when no food or drink is passing. The outer coat or wall is made up of two layers of muscular fibers, the outer of which run up and down, the inner, circularly. The middle coat is a layer of loose tissue, called the cellular or submucous coat. The inner coat is a mucous membrane, continuous with that which lines the entire alimentary canal.

When a portion of food enters the esophagus, the muscles, one ring after another, contract behind it and thus force it along to the stomach. These muscles act with considerable force. Some one tried a singular experiment. He tied a ball to a string which passed over a pulley and had a weight fastened to the other end. Forcing the ball down the throat of a dog, he found that the esophagus could pull the ball with sufficient force to lift nearly half a pound.

12. (1) In this lesson we have described the organs which perform three important acts in the process of digestion: (*a*) **Mastication**, or the grinding of the food; (*b*) **Insalivation**, or the mingling of the food with saliva; and (*c*) **Deglutition**, or the act of swallowing. (2) We have learned that one of the important chemical changes which food must undergo before it can enter the system has been commenced: **The conversion of starch to sugar.** (3) We have learned that **absorption** commences even in the mouth.

PRACTICAL ILLUSTRATIONS.

1. Procure a human tooth from a dentist. Fasten it in a clamp, or into a hole in a piece of wood, and grind it down on the side nearly half way to the center on a coarse grindstone. Then rub it on a fine whetstone until the surface is smooth. Then brush it clean in water. The cut surface will show in a general way the structure of the tooth. The dentine, enamel, and cement will have a slightly different appearance, and the relative proportions of each can be seen. To show the minute structure would not be practicable, as an exceedingly thin section and a good microscope would be necessary.

2. Grate or scrape a potato. Rub with water on a piece of muslin stretched over a vessel of any kind. The milky looking fluid that passes through the cloth is water mixed with undissolved starch. Pour the contents of the vessel into a glass tumbler, and let stand for an hour. You will observe that the starch settles to the bottom; and you can by care pour off the water, leaving the starch in the bottom. Turn out the wet starch on a piece of blotting paper. In a little while the starch will be dry and appear as a fine, white powder.

3. Put a little of the dry starch in a bottle, and add a quantity of saliva, which you must obtain from your mouth after thoroughly rinsing it out with

water. By working your jaws and the muscles of your face vigorously for a minute the flow of saliva will be increased. Let the mixture of starch and saliva stand in a warm place for two hours. Test it for grape sugar as follows: —

Procure a small lump of sulphate of copper (blue vitriol, or blue stone). Any druggist will give you enough for the purpose. Dissolve it in clear water. For a few cents the druggist will make for you an ounce of solution of potassium hydrate (caustic potash). Now place a little of the saliva and starch mixture in a large iron (or tinware) spoon, add to it about ten drops of the caustic potash solution, and then two or three drops of the sulphate of copper solution. Then hold the spoon over the chimney of a large lamp until the mixture boils, which it ought to do in a few minutes. The liquid, which was at first a bluish white, should, if grape sugar be present, turn to a brick-red color. This is a chemical test for grape sugar, and demonstrates that the starch has been converted into sugar by the action of the saliva. This is an interesting experiment, and can be made successful if proper care be taken.

4. As preliminary to the succeeding lesson, and partly applicable to the foregoing, perform the following experiment to illustrate absorption through membranes.

Procure a fresh egg with an unbroken shell. By careful tapping on the table crack the shell at the small end, pick off the broken pieces, taking care not to break the thin membrane just within the shell. If you break or tear this membrane, you must try again on another egg. After removing about a square inch of shell make a small hole through shell and membrane in the opposite end of the egg, taking care to keep the egg with this hole up so that the contents of the egg cannot escape. Now fix the egg on a support, so that the part exposing the membrane will be immersed in water. This can be done either by using a bottle with a mouth just wide enough to allow the egg to stand upright in the neck without falling into the bottle, or, if this is not convenient, you can use a tumbler even full of water with a pasteboard cover, and a hole cut in the latter just large enough to hold the egg and allow the end to dip in the water. In the course of an hour or less you will see the contents of the egg rising through the hole in the upper end. A sufficient quantity of water has been absorbed through the membrane to force the contents out at the hole.

LESSON 11.

The Stomach.

1. It is a common notion that digestion is carried on altogether in the **stomach**. But as we shall see, only a part of the digestive process takes place in this part of the alimentary canal.

The stomach is a pear-shaped bag or enlargement of the alimentary canal, lying in the upper and mainly in the left part of the abdominal cavity. Its position is more nearly vertical when the body is in an upright position than is usually represented in pictures. It varies much in size in different individuals, and also according to the amount of its contents. When moderately full, its average is twelve inches in length, four inches in breadth, and two inches in thickness, and holds about three pints. The left end projects beyond the entrance of the esophagus, and is called the *fundus*. The opposite or smaller end is called the *pyloric* extremity. The place where the esophagus ends is called the *cardiac*, or heart orifice; and the entrance to the intestine below is called the *pyloric* orifice. This opening is guarded by a kind of valve formed by a fold of the mucous lining, called the *pylorus*, or gate-keeper.

The walls of the stomach consist of four coats: (1) The outer, or *serous* coat, is a portion of the *peritoneum*, which lines the abdominal cavity, and covers all the organs within it, and which will be more fully described under the Secretory System. (2) Beneath this is a *muscular* coat, some of the fibers of which run lengthwise, and some circularly, and some diagonally. (3) Next is a *cellular*, or submucous coat, like that which is found beneath the mucous membrane throughout the alimentary canal. (4) The inner coat is the *mucous* membrane continuous with that of the esophagus and intestines. This mucous membrane lies in many folds or wrinkles, which greatly increases its surface. It contains many small depressions called *alveoli*, at the bottom of which appear orifices of short tubes called *gastric follicles*. From some of these comes mucous; from others, *gastric juice*, which is the peculiar product of the lining of the stomach, as saliva is of the salivary glands.

2. The Gastric Juice is a clear liquid consisting mainly of water with a small proportion of an acid and a peculiar ferment called *pepsin*. This ferment possesses the power of changing *albuminous* substances into *albuminose*, or as it is sometimes put, converting *proteids* into *peptones*. To make this statement clear it is necessary to know that *albuminous* substances, or *proteids*, are those which contain nitrogen (hence called also *nitrogenous*) and are chemically similar to albumen. The white of an egg is almost pure albumen. This class of substances exists in eggs, lean meat, milk, grains, and in many vegetable seeds and nuts. Different varieties are produced from different articles, as *casein* from milk, *fibrin* from meat, *gluten* from grains, and *legumin* from beans and peas. Albuminous substances, or as they are sometimes called "*albuminoids*," are not soluble in water, and hence cannot be absorbed. *Albuminose*, or *peptone*, is soluble and is readily absorbed.

Gastric juice has no effect on starch, sugar, nor fats. Its sole office is to convert the albuminous portions of the food into a soluble form. Fat meat, or the unrendered fat of animals, is properly *adipose tissue.* It consists of a net-work of fibers enclosing the fat proper. While the gastric juice does not act upon the fat, it does dissolve this fibrous net-work, as it is of an albuminous nature, and releases the fat.

3. Digestion in the Stomach.—The process which the food undergoes in the stomach is called *chymification;* that is, the making of *chyme.* This is a word derived from the Greek and meaning "juice." It is applied to the food in the stomach after it has been thoroughly mixed and dissolved, or reduced to a semi-fluid mass. This is accomplished by two different agencies, *mechanical* and *chemical:* (1) The contraction of the muscular walls keeps the contents continually rolling about, passing from one end to the other and back again many times. This motion is called *peristaltic* (wrapping up) or *vermicular* (worm-like), as it has the appearance of a worm crawling. The food is thus "churned," and thoroughly mixed and broken up. The *pylorus* permits only a portion of the fluid contents to pass through unless the substance be some indigestible body, as a button or coin, which may have been swallowed. This may force its way through the gate into the intestines. (2) The contents of the stomach are by the churning action thoroughly mixed with two fluids which are capable of exerting chemical action on certain parts of the food. These fluids are *gastric juice* and *saliva*, but as the former is an acid fluid and the latter an alkaline fluid, they cannot act in each other's presence unless one be greater in quantity or stronger than the other. The gastric juice is the stronger in this case, and prevents the saliva acting unless in the central part of a *bolus*, or mass of food, where it has not yet penetrated. The action of the saliva although mainly suspended in the stomach is renewed in the intestine.

Chymification, or stomach digestion, requires from one to five hours or more, varying according to the nature and quantity of the food. Thus, according to Dr. Beaumont's observations, boiled rice was digested in one hour, while boiled cabbage required four hours, and roast pork five and one-fourth hours.

4. **Why does not the Stomach digest itself** since it is composed of albuminous matter, and gastric juice dissolves such readily? This is a question often asked, and it is one difficult to answer. The probability is that the stomach *does* digest itself to some extent, and is renewed by the rapid growth of new cells. This view is favored by the fact that in some cases of sudden death the walls of the stomach are found, on post mortem examination, to be partially digested. Besides, gastric juice is not produced in any quantity except when food is in the stomach, and then it is rapidly absorbed by the food. The mucus, which is at the same time poured out in abundance, also, doubtless, prevents the action of the gastric juice on the walls of the stomach.

5. **Absorption from the Stomach.**—During the process of chymification, a considerable part of the fluid contents of the stomach passes directly into the blood, through the mucous membrane and the walls of the blood-vessels. Much of the water, some of the sugar, and *albuminose* are absorbed as they come in contact with the mucous membrane. Fats and albuminous matter and starch are not absorbed, but pass on to the intestine to be acted upon there. Poisons and medicines are absorbed, should they be taken with the food, but more rapidly if taken when the stomach is empty.

6. **Alexis St. Martin.**—In the year 1822 a young soldier named Alexis St. Martin, a Canadian by birth, but serving in the United States army, was wounded by the accidental discharge of a gun. Dr. Beaumont, the army surgeon who attended him,

found the food which the man had eaten an hour before, issuing in a half-digested state from the wound in his side. In time the wound healed, but it was found that the injured part of the walls of the stomach, instead of reuniting, grew fast to the edges of the wound in the abdominal wall, leaving an opening two and a half inches in circumference, through which the interior of the stomach could be seen, and the contents taken out for examination at any time.

Dr. Beaumont wished to improve this rare opportunity to study the processes of digestion, and so kept the patient a long time and tried many experiments upon him. He learned much that was interesting and valuable concerning stomach digestion. Since that time many observations have been made upon living animals by cutting through to the interior of the stomach, and sewing its walls to the abdominal walls until they united, thus forming by intention what was accidental in the case of St. Martin.

There have been cases, also, where surgeons have been compelled to make similar openings in the human stomach for the purpose of introducing food in case of closure of the esophagus. In such cases digestion was not perfect because the patient was deprived of the saliva. A medical journal not long ago gave an account of a German physician who constructed an artificial esophagus which worked admirably. A boy had swallowed some caustic poison which destroyed the lining of the esophagus, and when it healed its walls had grown together, and the boy would have starved, had not an opening been made in the stomach. In order that the boy might get the benefit of the saliva, and enjoy the taste of his food, the surgeon fixed a rubber tube with a funnel shaped extremity long enough to reach from the stomach to the mouth. Fastening one end into the opening in the stomach, the boy could chew his food, transfer it from his mouth to the rubber tube, and allow it to pass to the stomach. This seems like a marvelous tale, but it is no more wonderful than many other feats of modern surgeons.

7. Circumstances affecting Stomach Digestion. — The stomach appears to act better upon a large than upon a small quantity of food; hence food that is somewhat bulky is better than food highly concentrated, and two or three good meals in twenty-four hours are better than many small ones. The stomach seems to have a tendency to act *periodically*. If one is accustomed to meals at the same hour every day, and then changes the time, digestion is not so perfect. The stomach, like every other organ, **needs rest**; hence, eating at short intervals, so as to keep food all the time in the stomach, is very unfavorable to digestion.

Strong emotions, as anger, fright, grief, excessive joy, and anxiety, check digestion. A cheerful and contented state of mind favors digestion. Digestion proceeds most rapidly when the **temperature** of the stomach is about a hundred degrees Fahrenheit. Large quantities of ice-water or very cold food will lower the temperature, and arrest digestion. The normal temperature of the stomach is, however, soon regained after cold fluids enter it. Ice-water and ice-cream are frequently denounced as very bad for the stomach; but if one becomes accustomed to the former, and indulges moderately in the latter, no harm results in the majority of cases. When the body is heated by exercise, a quantity of an ice-cold drink may prove injurious or even fatal, by the sudden shock to the nervous system.

Digestion is not quite so rapid during **sleep**, because the circulation of the blood is not so complete, and the nerve force of the system is less active. A hearty meal just before retiring usually causes disagreeable dreams. Healthy children and animals, however, generally go to sleep after eating, and their digestion appears to be perfect. It is probably true, that while digestion may proceed more slowly during sleep, it is none the less perfect, and beneficial to the system. A small quantity of food eaten before retiring frequently favors sound sleep.

Exercise, if severe, immediately after eating is unfavorable; but gentle exercise, by increasing the flow of the blood from the heart to the extremities of the blood-vessels, is favorable to digestion.

PRACTICAL ILLUSTRATIONS.

1. Get a piece of the stomach of an ox. Wash it thoroughly, and boil it for an hour or more. The inner coat will show the elevations and depressions which increase its absorbing surface. The mucous coat can be separated from the muscular.

2. The stomach of a pig resembles, in shape and size, the human stomach very closely. If one can be procured, it will be interesting to have it prepared for exhibiting to a class. Cut a slit in the side sufficiently large to enable you to turn it inside out. Then wash it thoroughly to remove the mucus and food, and turn it right side out again. Keep in water until ready to exhibit. Show the mucous lining by turning it partly inside out. Note the thickness of its walls, and how easily they may be distended.

[It must be borne in mind always that many points cannot be demonstrated without a great deal of careful preparation. For example: if one should dissect out the main arteries that supply the stomach with blood, and inject into these a mixture of plaster of Paris and red lead, a beautiful illustration of the general blood supply of the stomach would appear. The fluid would fill and distend all except the most minute of the arteries, and solidifying there would show their number and positions very plainly. Further, if certain finer coloring fluids were injected into the blood-vessels, then a small portion of the stomach be hardened by soaking in certain liquids, then cut into exceedingly thin sections by a *microtome* (machine for cutting thin sections), and placed under the microscope, a beautiful exhibit of the capillary net-work of the blood-vessels in the mucous and cellular coat would appear. But these experiments require skill and patience and the use of material beyond the reach of the ordinary student and teacher. They are mentioned here that the pupil may know how the anatomist and physiologist obtain the knowledge given in works on the subject.]

LESSON 12.

The Intestines.

1. **The Small Intestine.** — When the chyme leaves the stomach through the pyloric orifice, it enters the small intestine, which is a tube about twenty feet in length lying coiled in the central part of the abdominal cavity. The first part of it, about ten inches in length, is called the **duodenum.** It extends from the stomach first upward, then backward and toward the right, then

to the left in front of the spinal column, and ends at a point opposite the second lumbar vertebra.

The next division is called the **jejunum** (empty, because found so after death). This portion is about seven feet in length, and a little smaller than the duodenum. The third division is called the **ileum** (to twist). It is about twelve feet in length. These divisions are of little importance, as the structure and size are similar throughout the small intestine.

2. The Large Intestine. — This portion of the alimentary canal, about five feet in length, is a continuation of the small intestine, but much larger in diameter. It does not begin simply by an enlargement of the small intestine, but is like a separate tube with the upper end closed, and the small intestine, like a smaller tube, entering at a point about two and a half inches from the end. This closed end, or

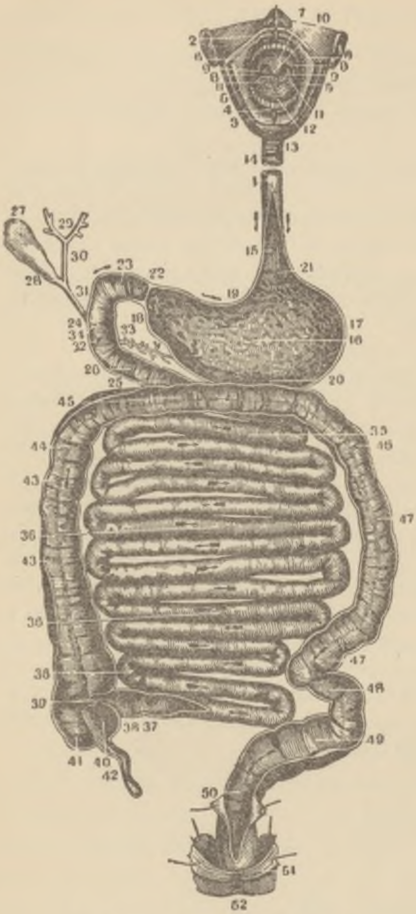


Fig. 9. — Alimentary Canal.

10, Uvula; 9, Fauces; 8, Tonsils; 14, Esophagus; 21, Cardiac orifice; 16, Stomach; 22, Pyloric orifice; 23, Duodenum; 27, Gall bladder; 29, 30, Hepatic duct; 26, Cystic duct; 31, Common duct of the bile; 33, Pancreatic duct; 41, Cœcum; 43, Ascending colon; 45, Transverse colon; 47, Descending colon; 47, 48, 49, Sigmoid flexure of the colon; 50, Rectum; 36, Ileum; 25, Jejunum; 40, Ileo-cœcal valve; 42, Vermiform appendix. The advanced student of anatomy may name the parts opposite the numbers not mentioned here.

part above the entrance of the small intestine, is called the **cœcum** (blind). At the closed end of the cœcum is a small tube about as thick as a goose quill, and from three to six inches long. No use is known for this **vermiform** (worm-like) **appendix,** as it is called. Sometimes cherry stones, or other indigestible objects which may be swallowed with the food, find lodgement in this tube, and result in serious inflammation of the intestine. Swallowing cherry stones and other hard seeds of fruits is a bad practice.

The **colon** is the next portion of the large intestine. It nearly surrounds the small intestine, the different portions taking different names from their positions. There is thus (1) the *ascending colon*, on the right side; (2) the *hepatic flexure*, or bend near the liver; (3) the *transverse colon;* (4) the *splenic flexure*, or bend near the spleen; (5) the *descending colon*, on the left side; and (6) the *sigmoid* (S-shaped) *flexure*, where it joins the **rectum** (straight), which is the last portion of the large intestine.

3. **Structure of the Intestines.** — Like the stomach, the intestines throughout consist of four coats, — **serous, muscular, cellular,** and **mucous.** The mucous and cellular coats in the small intestine are wrinkled by numerous folds, called *valvulæ conniventes.* These are covered with minute projections, as thickly placed as the fibers in a piece of velvet. These projections are called **villi** (singular, *villus*, a tuft of hair). The surface for **absorption** is thus enormously increased. Each villus contains the termination of a vein, an artery, and a *lacteal.* The latter will be more fully described under the Circulatory System. The mucous coat contains also various small glands, which secrete the **intestinal juice.**

4. Before we discuss **Digestion in the Intestines,** we must first describe certain organs which lie outside of the alimentary canal, since they furnish fluids which play an important part in this digestion.

LESSON 13.

The Liver, Pancreas, and Spleen.

1. **General Description of the Liver.** — A **gland** is an organ which either separates materials from the blood, or manufactures certain fluids from the elements furnished by the blood, or modifies fluids which pass through it. The liver is the largest gland in the body. It lies mainly in the right and upper portion of the abdominal cavity. Its length from side to side is from ten to twelve inches, its breadth from before backward is from six to seven inches, and its thickness from above downward is about three inches. It weighs in an adult three or four pounds. The number 5 prevails in the parts and appendages of the liver. It has five *ligaments*, or folds of the peritoneum, which hold it in place; five *lobes*, or divisions; five *fissures*, or furrows, on its under surface; and five different *vessels*, or sets of tubes, carrying material to and from it.

2. **Structure of the Liver.** — The surface is covered with a thin membrane, being a continuation of the *peritoneum*, which lines the abdominal cavity, and covers all the organs within it. To the unaided eye its substance, when cut through, appears as a soft, semi-solid mass, with tubes of varying sizes scattered here and there. A careful examination with the microscope reveals the fact that all of these tubes continue to divide and subdivide, until they finally terminate in a fine net-work of minute vessels. The terminations of these vessels is in and between little masses of cells called *lobules*, the cells and vessels being held together by areolar (fibrous) tissue. Branches of the nerves also penetrate to every part. In these lobules, or collections of cells and tubes, important work is carried on, as the liver is one of the greatest of the laboratories in this wonderful house of ours.

3. **The Vessels of the Liver** are important, and deserve a partial description: (1) The **portal vein** is made up of branches from the stomach, spleen, and intestines. It enters the liver, and divides and subdivides until it terminates in the net-work above described. It carries during digestion materials absorbed

from the stomach and intestines, some of which undergo important changes in the liver. (2) The **hepatic artery** supplies the liver with pure blood, just as every other organ is supplied. (3) The **hepatic veins**, of which there are several, carry out of the liver the blood which is carried in by the portal vein and hepatic artery, and empty it into the main channel of the venous circulation. (4) The **hepatic duct** begins in the lobules as a fine net-work of tubes, which unite to form larger and larger tubes, and finally terminates in one large one. This duct conveys the **bile** which is manufactured in the liver to the intestine. (5) The **lymphatics** are a part of a system of vessels which permeate the whole body, and will be described in another lesson.

4. **Bile.** — This secretion of the liver is a clear, yellowish, or greenish yellow fluid, with a peculiar odor and bitter taste. It is composed mainly of water, but contains certain salts and a coloring matter which gives it a peculiar character. In some animals, the horse for example, the bile passes from the liver through the hepatic duct to the intestine, but in man it passes directly into the intestine only during digestion. At other times it "backs up," as it were, into a bag, called the *gall cyst*, or *gall bladder*. This bag lies on the under surface of the liver, and is attached to it by fibrous tissue, but is in no manner a part of it. The bile reaches the gall bladder through a tube called the *cystic duct*, which joins the hepatic duct to form the *common bile duct* (*ductus communis choledochus*), which enters the duodenum just below the stomach. Thus, during digestion, the bile formed in the liver passes down the hepatic duct into the common bile duct, and from thence into the intestine; but when there is no digestible material in the intestine, the orifice of the common bile duct closes, and the bile backs up, and as it cannot return to the liver, because the hepatic duct is already full, it passes up the cystic duct into the gall bladder, and is there retained until needed in the intestine. The gall bladder, then, is a reservoir to hold the bile during the intervals of digestion.

5. **The Functions of the Liver.** — It was formerly thought that the function of the liver was merely to secrete the bile. It is

now known that it has other and important uses, one of which is the conversion of grape sugar to **glycogen** for the purpose of storage, and converting it back again into sugar as the latter is needed by the system.

The following facts will explain the nature of this "glycogenic function" of the liver: (1) Grape sugar, or **glucose**, is one of the heat-producing elements of food, which is in constant demand in the system, and is found but sparingly in nature. (2) **Starch** is an abundant substance, but from its insoluble nature it cannot be absorbed into the blood. (3) The **saliva** and **pancreatic juice** are capable of converting starch and also cane sugar into glucose. (4) The demand for sugar in the system is constant, but digestion is periodical and not constant. (5) Glucose, being soluble, is readily absorbed. (6) Glucose, being soluble, cannot easily be stored in the system ready for constant use. (7) Glycogen resembles starch in not being soluble, and can be easily stored in the cells of the liver, and converted into sugar as needed by the system.

The word *glycogen* means "glucose generator," so called from its readiness to change to sugar. It can be separated from the liver of a recently killed animal, and resembles starch somewhat in appearance, hence is sometimes called *animal starch*. Starch is found mainly in the vegetable kingdom, and only sparingly in some of the lowest forms of animal life; and glycogen is found mainly in the animal kingdom, and only sparingly in the lower forms of vegetable life.

6. The Pancreas. — This gland (called "sweetbread" in animals) plays an important part in the digestive processes. It has been named by the Germans, "the abdominal salivary gland," as its secretion, the **pancreatic juice**, resembles saliva in its action. The word *pancreas* means "all flesh," and was given to this gland before its real nature was known. It lies behind the stomach, is from six to eight inches long, one and a half inches broad, and from a half to one inch thick, weighing about three ounces. It is the shape of a dog's tongue. In structure it resembles the salivary glands. The fluid it secretes passes into the duodenum through the pancreatic duct.

The **pancreatic fluid** contains three peculiar ferments, one called *amylopsin*, which converts starch to sugar; another called *trypsin*, which converts albuminous foods into albuminose; and a third called *steapsin*, which renders fats and oils capable of being absorbed.

7. The Spleen. — This is a peculiar organ, located at the left extremity of the stomach. Its use is not clearly determined, although it is commonly described along with the organs of digestion. It is called a ductless, or blood, gland, because it secretes no special fluid, and has no duct. It is oblong and flattened in shape, and varies much in size, but is usually about five inches long, three to four inches broad, and about one and a half inches thick, and weighs about seven ounces. It is well supplied with blood-vessels and lymphatics. In malarial fevers it is frequently much enlarged, and the person is said to have an "ague cake." In some cases it has been known to attain the weight of twenty pounds. In appearance it resembles the liver, but is darker in color.

As to **structure**, it consists of numerous blood-vessels, and a substance called spleen pulp, the whole traversed with fibrous bands. Since the spleen is slightly larger after a meal, it is supposed to act as a reservoir for the extra amount of blood manufactured in the digestive process. Broken red blood-cells are found in it, hence it has been said to be for the destruction of these blood-cells, or, as it is sometimes put, "it is the grave of the red corpuscles." It is supposed also to be one of the places where blood-corpuscles are produced.

It has been removed many times from living animals without serious results, but in some cases several small spleens have developed in its place, and in others certain lymphatic glands have increased in size. The ancients supposed it was the seat of melancholy and anger, hence the expression, "he vents his spleen" applied to one who expresses his angry feelings.

LESSON 14.

Intestinal Digestion and Absorption.

1. **Chyle.** — As soon as the chyme passes into the small intestines from the stomach, it is subjected to the action of three different fluids, which have already been described, viz.: the *bile*, the *pancreatic juice*, and the *intestinal juice*. The result of the action of all these fluids upon the chyme is a milky white fluid, which has received the name of **chyle**, and the process of producing it is called **chylification**. The food, however, is not all converted into chyle, as much of it is indigestible, and the undigested portions remain mixed with the chyle, until the latter is absorbed.

The *white appearance* of the chyle is due to the minute globules of fat which it contains. If a little oil be mixed with water in a bottle, the oil will rise to the top, and both liquids will appear transparent, or nearly so. Now if the bottle be vigorously shaken, the oil and water will mix, and the whole have a white appearance like milk. A close examination shows it to be composed of many very small globules of oil floating in the water. The globules will soon come to the top again if allowed to rest. If a gummy, or mucilaginous, substance be mixed with the oil and water, and the whole shaken, a permanent mixture will be formed. It is then called an **emulsion.** The white color is caused by the many minute globules reflecting the light in all directions.

The Chyle is an Emulsion. — The sugar and peptones in solution correspond to the water and mucilage in the experiment, and the oil globules come from the fat or oily food that is eaten. The breaking up of the fat into minute globules is caused by the bile, pancreatic juice, and intestinal juice. Some authors state that these digestive fluids convert part of the fats into a kind of soap.

2. **Action of the Saliva.** — As we learned in a previous lesson, the action of the saliva was mainly arrested in the stomach by

the presence of the gastric juice, which is an acid fluid. When it arrives in the intestine, the bile and pancreatic juice, being alkaline, neutralize the gastric juice, and thus permit the saliva to resume its work of converting starch to sugar.

3. Action of the Bile. — Certain constituents of the bile are believed to be waste material which the liver separates from the blood, and which, if allowed to remain, would poison the entire system. Certain other of its constituents are believed to be formed in the liver, and are doubtless concerned in the emulsifying of the fats to prepare them for absorption.

4. The Action of the Pancreatic Juice. — This fluid, as we have learned, contains three distinct ferments, which act respectively upon the starch, the albuminoids, and upon the fats. It is, therefore, an assistant to the saliva, the gastric juice, and the bile.

5. The Intestinal Juice is believed to exert an action upon the three classes of food, viz.: fats, albuminoids, and starch, and thus resembles the pancreatic juice in function.

6. Absorption from the Intestine. — In the stomach, absorption is by veins alone. Fats cannot be absorbed in this manner, and in the intestine another method of absorption is provided. It is by the **lacteals**. These are minute, thread-like tubes, which take their beginning in the **villi** of the small intestine, and uniting into larger vessels, finally empty into one large tube called the *thoracic duct*. This is about the thickness of a goose quill, and from eighteen to twenty inches in length, extending along the front of the spinal column, and emptying its contents into the left subclavian vein, near the top of the sternum.

Thus there are two methods of absorption in the intestines: **by the veins** and **by the lacteals**. The veins absorb water, holding in solution sugar and albuminose, and the lacteals absorb mainly emulsified fats, but also some of the albuminose and sugar.

PRACTICAL ILLUSTRATIONS.

Pour about a tablespoonful of clear water into a bottle. Add the same quantity of castor oil. Observe that the liquids do not mix, the oil remaining at the top, and that both liquids are nearly transparent. Now shake the bottle vigorously for a minute or two. Observe the change — a white fluid resembling milk. Close examination will show the minute globules of oil floating in the water. This is an emulsion. The oil and water will in time separate, the globules of oil coming to the top, and running together will become clear as before. To make a permanent emulsion some mucilaginous or gummy substance must be mixed with the oil and water, and agitated.

Milk is a good example of a natural emulsion. The water holds in suspension minute globules of oil (butter), surrounded by the casein, which is of an adhesive or gummy nature.

LESSON 15.

Uses and Kinds of Food.

1. **Assimilation.** — What becomes of the absorbed material? It passes, as we have seen, either directly into the blood-vessels, or indirectly by means of the lacteals, and becomes a part of the blood. Thus the blood is constantly being renewed by additions from the digestive tract. But what is the final disposition of the absorbed material? It is used in building up the system, supplying the waste, and furnishing material for new growth. This process is called **assimilation.** Thus what existed yesterday as a part of an ox, an egg, or a head of cabbage, may to-day be a part of the tissues of your brain, muscles, or bone.

2. **Summary of Digestive Processes.** — We may state the various processes which the **food** undergoes from the time it appears on the table until it becomes a part of our bodies, as follows: **Prehension,** or the seizing of the food; **mastication,** or the grinding and crushing of the food; **insalivation,** or the mixing of the food with saliva; **deglutition,** or swallowing; **chymification,** or stomach preparation; **chylification,** or intestinal preparation; **absorption,** or the passage of the prepared material from the alimentary canal into the blood-vessels; **circulation,** or the conveying of the material to the various tissues of the body; **secretion,** or the separation of certain materials from the blood, and combining them in the glands to form the various fluids of the body; **assimilation,** or the incorporation of the food material with the

material of the body. These various processes may all be carried on at one and the same time. The processes of circulation and secretion will be discussed in succeeding chapters. The others have been explained.

3. Classification of Foods. — I. As to composition, foods are divided into two great classes: (1) **Carbonaceous**, or **non-nitrogenous**, including all those which do not contain nitrogen. These are again divided into two classes: (*a*) **Carbo-hydrates**, or those in which carbon predominates. These are mainly **starch** and **sugar**. Nearly every vegetable substance contains either one or both of these valuable food elements. (*b*) **Hydro-carbons**, or those in which hydrogen predominates. These are **fats** and **oils**, the former being solid, and the latter liquid, at the temperature of the body. A great many vegetable foods contain oils; the fats are derived mainly from the animal kingdom. (2) **Nitrogenous**, or **albuminous**, including all those which contain nitrogen, as well as carbon, oxygen, and hydrogen. They are: **albumen**, found nearly pure in the white, also in the yolk, of the egg; **fibrin** and **gelatine**, the principal parts of the flesh of animals; **legumen**, in beans, peas, and some other vegetables; **gluten**, found in all grains, especially in the outer part of the wheat grain; and **casein**, in milk.

II. As to nutrition, foods are divided into two great classes. (1) **Calorifacient**, or heat-making, and (2) **histogenetic**, or tissue-making. The heat-making foods are mainly the carbonaceous, and the tissue-making mainly the nitrogenous. It has been demonstrated that man cannot live on one of these classes of food to the entire exclusion of the other. All food articles, however, contain both of these elements, but in varying proportions. A few articles only contain them in the proper proportion, and life may be sustained by their exclusive use. Thus milk contains butter (carbonaceous) and casein (nitrogenous); eggs contain oil and albumen; wheat, rice, and other grains contain starch and gluten; beans contain starch and legumen; and any one of these articles could be used to the exclusion of all other articles of food.

4. Animal Heat. — The temperature of the interior of the human body in health remains nearly the same under all circumstances. Thus a man may remain for a few minutes without danger in an oven heated to 350° Fahrenheit, yet the temperature of his body will be but slightly affected. On the other hand, a man may endure a temperature of 40° below zero, Fahrenheit, without greatly lowering his body temperature. In the first instance, the evaporation of the perspiration will keep the temperature from rising, and in the second instance, the heat that is abstracted by the atmosphere is resupplied by combustion of fuel in the shape of carbonaceous food in the body.

Therefore in winter, and in cold climates, men must have food to keep up the body temperature, as well as to supply the waste and produce growth of new tissues. The heat-making food is needed to some extent in all climates, and at all seasons of the year, as the temperature of the body is in most cases a little higher than that of the surrounding atmosphere.

In cases of starvation, the fat of the body is absorbed and carried into the general circulation, to be burned up as fuel to keep up the animal heat. When it is exhausted, the muscles and other soft parts are drawn upon, until finally death follows from lack of fuel to keep up the temperature essential to life. A starving animal becomes lean from this consumption of reserve material. Clothing answers to a certain degree the place of food by keeping in the animal heat.

5. **Recapitulation.** — Thus we have learned that there are two great classes of foods, those which contain nitrogen, and those which do not; and that the first of these is for building and keeping the body in repair, and the second for keeping it warm. Also, that nature provides in reserve a storehouse of fuel in the shape of the fat of the body for use in emergencies. How the fuel is consumed will be discussed under the Respiratory System, and the process of absorption, whereby the reserve store of material is carried into the blood to be consumed or used again, will be described under the Secretory System.

LESSON 16.

Hygiene of Digestion.

1. There is a tendency among certain writers on Hygiene to overrate the relative importance of this part of the subject. If the laws of health in regard to fresh air, exercise, sleep, cleanliness, temperature, and use of stimulants be strictly observed, our appetite will in a great measure be a sufficient guide in the matter of diet. There are, however, certain principles which ought to be kept in mind in choosing our food and in the manner of preparing and eating it.

2. Quantity of Food.—It is impossible to lay down rules regarding the amount of food necessary to maintain the body in the best possible condition. The proper amount depends upon a variety of conditions, some of which are here given: (1) During the **growing period**, when the system needs food to produce increase in size as well as to supply waste and create warmth, it is evident that more food is needed in proportion to the weight of the body than at other times. (2) More food is required in *cold climates* and in winter than in summer unless particular care is taken to select foods rich in carbonaceous material. (3) Persons whose *occupations* demand much bodily exertion need more food, other things being equal, than those whose occupations are sedentary. A lady who had kept a boarding-house for railroad laborers and afterwards one for college students declared that she made as much money boarding the students at half the price paid by the laborers, for they ate only half as much. (4) Some persons eat less than others under the same circumstances of age, temperature, occupation, etc., and we can account for it only by the supposition that they have either formed a *habit* of eating less, or that there is a difference in *temperament* whereby the waste and repair in the cells goes on more slowly. (5) Persons in a *depressed* state of mind, or engaged in work calling for exercise of the *emotions*, should eat less, as the digestive organs under such circumstances do not act so readily. (6) An increase in the amount of pure air inhaled seems to increase the appetite and the need for food in the body, as there is more rapid consumption of fuel caused by the increased amount of oxygen taken into the system. We have all observed the increased appetite of those who are hunting and fishing or rambling in the woods and fields.

To sum up, the **appetite** if not perverted is a good guide as to the proper quantity of food. A healthy appetite must not be confounded with mere pleasure of the taste of food or an unnatural craving for certain articles. Plain, substantial food will not pervert the appetite, and can do no harm to a healthful person if eaten until there is actually no desire for more.

3. Quality of Food. — Man is an omnivorous creature. Taking the world over, all imaginable things that are digestible, and even some which are not digestible, are eaten by human beings. In Eastern Asia, Island of Java, in Northern Europe, and along the Amazon River, the natives eat clay, which affords no nourishment, but is said to allay hunger; probably by diluting the real food, causing it to spread over a greater surface and be more readily absorbed. There is no bird or beast, no insect or reptile, that the Bushmen of Africa will not eat. What is eagerly sought after and relished by some nations is disgusting to others. Hunger has probably driven men to eat certain articles in the first place, and habit, which finally became inherited, kept it up in the tribe or nation.

Neither mere taste nor habit should be the sole guide in choosing food. Two important facts should always be borne in mind: (1) The food should be *wholesome;* that is, free from any poisonous elements. Food is unwholesome which is taken from vegetables or animals not in a healthy condition. Germs of disease are in this way introduced into the system. Food is frequently unwholesome when it has commenced to decay. In the decay of many animal and vegetable substances poisonous compounds are produced. Stale vegetables and "high" meats should be avoided. (2) The food should contain a due proportion of heat-making and tissue-making elements. Since the former is more in demand in the winter, foods containing starch, sugar, and fats or oils should predominate. During the hot season, lean meats, soups without fat, and watery vegetables and acid fruits are not only more agreeable, but more in accordance with the needs of the system.

Food should not be too highly concentrated, nor too easy of digestion, nor yet too bulky and difficult of digestion; for in the first case, the stomach will have but little exercise, and in the second case it may be overworked and become unduly enlarged, and either extreme will tend to produce dyspepsia.

There has been much controversy as to whether a purely vegetable or a mixed diet of animal and vegetable food is preferable. Man may live and be healthy on purely vegetable food, as has been demonstrated by the experience of thousands, yet this does not prove that a mixed diet is unwholesome. The majority of scientific men who have expressed an opinion are in favor of a mixed diet. Dr. Carpenter, an eminent authority in physiology, is of the opinion that a well-selected vegetable diet conduces to the highest *physical* development, while a moderate proportion of animal food seems to favor the highest *mental* development.

4. Cooking. — The object in cooking food with most people is to render it more palatable. The flavor seems to be developed or changed by the process of heating. But with many kinds of foods cooking makes them also more easily digested, by softening or rendering them more capable of being absorbed. Cooking also destroys certain parasites which may infest meats. Pork, as is well known, sometimes contains **trichina**, a minute parasitic animal which multiplies and develops rapidly in the human stomach, and then finds its way to the muscles to enter a dormant state or become encysted, the irritation thus produced causing a painful and frequently fatal disease. Beef and mutton and pork may contain the germs of tapeworms, which will develop in the human alimentary canal and cause an annoying, if not serious, disease. Heating meats to the boiling point of water destroys these animals, and renders the meats containing them harmless.

There are many methods of cooking meats and vegetables, but perhaps the only one that is objectionable is *frying*, as it is ordinarily practiced. If, however, the fat be made very hot before the meat is put in, the surface is seared and made crisp, and the fat does not penetrate the meat. While the fat is not injurious in itself, if permitted to penetrate the meat, it prevents the action of the gastric juice on the albuminous matter, and digestion is thus retarded. Fried meats should be eaten at once, as the fat will penetrate the fibers if the meat be allowed to remain long after being cooked. Foods eaten while warm are usually more easily digested, as the temperature of the stomach is not lowered.

5. **Variety in Diet.** — Our appetites seem to demand a variety of food. One soon tires of the same article prepared precisely in the same manner every day. To eat one roast quail each day for thirty days in succession was until recently considered an impossible feat, but stimulated by heavy wagers several have succeeded by great effort in accomplishing it. There are some articles, however, which we never seem to tire of, when a few other articles are eaten with them. Bread with milk or eggs may be relished for a very long time. Either of these foods contain all the elements necessary to sustain life. We occasionally find a person who has lived from childhood to old age almost exclusively on a diet of bread and milk. Many Eastern people, as the Hindoos and Chinese, live almost exclusively upon rice. It is not best to have a great variety at each meal, as then we are tempted by the taste of the viands to eat more than the appetite really demands.

6. **Regularity in Eating.** — In view of what was said in a previous lesson concerning the tendency of the digestive organs to act periodically, you will infer that meals should be at regular hours. If we become accustomed to having meals regularly, shortly before the time comes we feel hungry. This sensation will pass away if the meal is delayed, and probably will not return again until the time of the next regular meal. Now, if we eat after the hunger sensation has left us, our appetites cannot be a true guide to the proper amount of food. The

digestive system then becomes like a musical instrument out of tune.

7. Frequency of Meals. — The custom of eating three times in twenty-four hours is perhaps the best one, yet with sedentary persons a habit of eating but twice in twenty-four hours may be formed with excellent results. Some eat four and even five times a day without apparent ill effects. Young children should eat oftener than adults, but a habit of eating between meals at irregular hours is a bad one.

8. Manner of Eating. — Plenty of time should be taken for meals. Eat slowly, that you may have time to masticate thoroughly, and that the saliva and gastric juice may have time for secretion. The glands require time to respond to the nervous stimulus excited by the smell and taste of the food and its presence in the mouth and stomach. We are less liable to eat too much when we eat slowly. Lively conversation at meals favors digestion, as a cheerful state of mind favors the action of the glands.

9. Temperature of Food. — It would appear reasonable that warm foods would be more easily digested, since they do not change the temperature of the stomach, yet some persons seem to suffer no ill effects whatever from the use of ice water or iced tea at meals, and can eat with impunity quantities of ice cream. Others cannot tolerate cold drinks and foods. As a rule it behooves all to be cautious concerning ice cold foods and drinks, as many a case of dyspepsia may be traced to their use.

10. The Use of Condiments. — Salt seems to be a necessary addition to food, yet there are some who claim that all food contains a sufficient amount naturally and that none should be added. This is an extreme view, and is doubtless an erroneous one. There are, it is said by travellers, tribes in Africa who use no salt with their food; but they also state that the water of that country contains salt, and that Europeans while travelling in that country do not feel the want of it. Salt gives relish to many kinds of food which otherwise are almost tasteless. It seems to develop or bring out their flavor. An excessive use of salt is no doubt injurious, as it creates thirst, the gratification of which may be the cause of overworking the absorbent vessels and excretory glands in getting rid of the superfluous water.

The spices, as pepper, cloves, nutmeg, cinnamon, etc., are relished by most persons, and a moderate use of them seems to do no harm. An excessive use of them blunts the sense of taste. Habit has much to do with their toleration by the system. Children generally dislike pepper, while adults generally like it. The Mexicans, as is well known, are accustomed to eating red peppers as we would eat cabbage or potatoes.

11. **Water.** — It is an almost universal custom to take either water or some fluid consisting mainly of water along with the food. Some have contended that this retards digestion, but unless excessive quantities be used this cannot be true, as the water dissolves certain portions of the food, and is rapidly absorbed from the stomach, carrying along with it products of digestion. Excessive quantities overtax the absorbent vessels and dilute the fluids of digestion to an undue degree. The amount to be taken should vary with the nature of the food. Some kinds of food, being largely composed of water, require less, and others, being dry, require more. The natural desire or sensation of thirst is usually a good guide. Highly seasoned food creates an unusual desire for water, and for this reason should be sparingly eaten.

The use of *warm or hot water* at meals is highly recommended. The beneficial effects of tea, coffee, and chocolate are frequently due to the fact of their being warm drinks. Persons with weak digestive powers are doubtless benefited by drinking warm fluids at meals.

Water should be wholesome; that is, free from injurious ingredients. We cannot say water should be pure, for pure water does not exist in nature. Water so readily dissolves solids and absorbs gases that all water contains more or less foreign substances. Perfectly pure water is not agreeable to the taste. A certain amount of mineral salts and absorbed gases give water its sparkle and life and make it palatable.

But decaying organic matter, and an excess of mineral salts, and the presence of germs of disease in water make it unwholesome. The selections of wholesome waters will be discussed in another chapter.

12. Effects of Tea, Coffee, and Chocolate on Digestion. — These drinks have little, if any, *direct effect* on the digestive organs. They doubtless aid digestion from the fact that they are taken as warm drinks, thus keeping up the natural temperature of the stomach. Indirectly they affect digestion by retarding waste in the system. In this sense they may be regarded as negative foods. It has been observed that persons who use these drinks habitually require less food. When used in excess they injuriously affect the nervous system in some persons, and more especially in the young, and thus indirectly affect the digestive organs, which, like all other organs, are controlled by the nerves.

13. Effects of Alcohol on the Digestive Organs.— Alcohol is a food only in the negative sense that it retards waste in the system. It affords no nourishment, and while small quantities thoroughly diluted may increase the appetite, and for a short time stimulate the digestive powers of the stomach, any continued use of it, even in a diluted form, will result in serious injury to all of the digestive organs. Its first effect is to increase the flow of blood to the capillaries. This causes engorgement of the blood-vessels of the stomach. They become distended and weakened. The man who takes alcoholic stimulants to improve his appetite and digestion soon gets into a condition where he will have no appetite, and digestion will be improperly performed unless he gets his accustomed stimulant. But every time it requires a little more to produce the effect, until a habit of taking considerable quantities is formed, and this increased quantity tends to pervert and destroy the functions of the parts; for all powerful stimulation or activity is followed by a corresponding depression or inactivity.

The **liver** is affected by a habitual use of alcoholic drinks. It becomes hardened, and sometimes covered with little lumps, producing what is known among physicians as "hobnail liver."

Sometimes there is "fatty degeneration," the liver substance partly disappearing and fat being deposited throughout its mass.

It is no longer a question of opinion among physicians as to whether an excessive use of alcoholic liquors injures the digestive organs. It is an *established fact.* The records of every hospital in the country will show hundreds of proofs of the injury done by alcohol upon these organs. As to the question whether the milder alcoholic drinks, as beer, ale, porter, and the weaker wines and hard cider, when used in moderation, have an evil effect, there are many different opinions among physicians; but this much is true, and almost all admit it, that a moderate use of the milder forms of drink inevitably leads to deeper indulgence, and excess is thus soon reached, and the final result is the same. Physicians almost universally agree as to the evil effects upon the young. During the period of growth all stimulants and narcotics have the effect, in a greater or less degree, of retarding natural development.

14. Tobacco and Digestion.—In many cases the smoking or chewing of tobacco leads to dyspepsia of the worst form. In chewing tobacco the salivary glands are excited when no food is present to use the saliva. This valuable fluid is therefore wasted, and the constant stimulation of the glands tends to weaken them, and the quality of the saliva is deteriorated and less effective in converting starch to sugar. Through the nervous system the smoking of tobacco frequently produces injurious effects upon the heart and circulation of the blood, and thus indirectly affects digestion.

It is a common belief that the use of tobacco leads to the use of alcoholic liquors; but there is no good ground for such a belief. Some physicians are of the opinion that it is in a certain sense a substitute for ardent spirits, and in many cases prevents men from forming habits of drinking. Physicians and men of science are almost unanimous in the belief that tobacco is very injurious during the growing period of life, and we all know that if the habit is not formed in youth there is little danger of its being formed late in life.

15. Care of the Teeth. — As formerly stated, there are cases in which the teeth decay early in spite of all precautions, and again other cases in which without care they remain sound until old age; yet experience shows that it pays to take care of the teeth, as frequently their early decay is directly traceable to neglect. Particles of food left in the mouth ferment and form acids which destroy the teeth. The enamel may be cracked and broken by biting threads, cracking nuts, and in similar ways. Very cold and very hot foods and drinks tend to crack the enamel. When once the enamel is broken and foreign substances come in contact with the dentine the decay is usually rapid. The moral is: *Keep the teeth clean; avoid extremely hot and extremely cold foods and drinks, and use the teeth for masticating food only.*

Use a soft tooth brush and a little mild soap and water after each meal. Occasionally a little powdered charcoal used on the brush will keep the teeth white, but if used frequently it will wear the enamel. *Never use a metal toothpick.*

EXERCISES FOR REVIEW.

1. Name the classes of teeth as to duration. As to form and use.
2. What is the hardest substance in the animal kingdom? What is its use?
3. What is the use of the salivary glands? What is the "abdominal salivary gland"?
4. Name the openings of the pharynx. Of the stomach.
5. The uses of saliva. What is ptyalin? What is its action?
6. What propels the food from the mouth to the stomach? Could a man swallow while standing on his head?
7. What part of the digestive process takes place in the mouth? In the stomach? In the intestines?
8. What is the gastric juice? Why does the stomach not digest itself?
9. Name some of the circumstances affecting stomach digestion.
10. What vessels carry material into the liver? What vessels carry material out of the liver?
11. What are the functions of the liver? What is glycogen?
12. Name the ferments of the pancreatic juice. State the uses of each.
13. How does the bile get into the gall bladder? How does it get out? What is the use of the gall bladder?
14. Why is chyle white? What is an emulsion?

15. What materials are absorbed from the stomach? What are the agents of absorption in the stomach? What is absorbed from the intestine that is not absorbed in the stomach?

16. What are villi? Their use?

17. Name the kinds of food as to composition. As to nutritive value.

18. Name all the processes of digestion.

19. How does alcohol affect the mucous coat of the stomach? In what manner may tobacco be injurious to the digestive organs?

20. What part does water play in the digestive processes?

21. Is alcohol a food?

22. Give directions for caring for the teeth.

23. Write an essay on "The Liver," using the following outline of points: location, size, weight, color, covering, ligaments, vessels, lobes, minute structure, secretion, glycogenic function, effects of alcohol upon.

CHAPTER II.

HOW THE NOURISHMENT IS CARRIED THROUGH THE BODY, OR THE CIRCULATORY SYSTEM.

LESSON 17.

The Heart.

1. Definition and Location.—The heart is the main organ of circulation in all higher animals. It is a muscular pump which receives the blood from certain pipes (veins), and by its contractions forces it through other pipes (arteries) to every part of the body. It lies between the lungs, its greater portion being on the left of the middle line of the thorax. Its broadest part, or base, points upward, backward, and to the right; its smaller end, or apex, points downward, forward, and toward the left. A line drawn at right angles to the long axis of the body and touching the upper border of the cartilage of the third rib will mark its upper portion. Its apex lies behind the space between the cartilages of the fifth and sixth ribs, a little to the left of the sternum, where it can be felt beating.

2. Size and Shape.—The human heart is about the size of the fist of its possessor, or usually in a grown person, five inches in length, $3\frac{1}{2}$ inches in breadth, and $2\frac{1}{2}$ inches in thickness, and weighs from eight to twelve ounces. The heart of a full-grown sheep or hog is about the same size and shape as the human heart. Its shape is that of a cone, somewhat flattened.

3. Cavities.—The heart is divided by a partition running lengthwise into two distinct portions, called the right and left sides. It is really a double organ, one side pumping venous blood, the other side pumping arterial blood. Each side has two cavities, the upper called **auricles**, into which the blood is received, the lower called **ventricles**, from which the blood is discharged.

4. The Right Auricle is a little larger than the left, with thinner walls and shows when cut open the following parts:—

1. Openings.

(*a*) Mouth of the *superior vena cava*, the large vein which brings the blood from the upper part of the body.

(*b*) Mouth of the *inferior vena cava*, the large vein which brings the blood from the lower part of the body.

(*c*) The mouth of the *coronary vein*, which returns the blood from the substance of the heart itself.

(*d*) The mouths of many little veins, which also return blood from the walls of the heart.

(*e*) The opening into the right ventricle.

2. Valves.

(*a*) The *Eustachian valve*, which is scarcely perceptible in the adult, but previous to birth, when the circulation takes a different course, it is a fold of the lining of the heart and serves to direct the blood from the left auricle through an opening in the right auricle. This opening closes at, or shortly after, birth.

(*b*) The *coronary valve* is a fold of the lining which prevents the blood from going back into the coronary vein.

5. The Right Ventricle is the same size as the left, but the walls are much thinner. When laid open it shows:—

1. Openings.

(*a*) From the auricle.

(*b*) From the pulmonary artery which carries the blood to the lungs.

2. Valves.

(*a*) **The Tricuspid** (three-pointed). It consists of three triangular flaps of tough membrane hanging from the opening and connected by fibrous cords to fleshy columns in the walls of the ventricle. When the heart contracts to throw the blood out, these flaps are pulled together and close the opening so that the blood cannot pass back into the auricle.

(*b*) **Semilunar** (half-moon) valves. These are like little pockets in the walls of the mouth of the pulmonary artery. The pockets open towards the artery, and when the ventricle contracts and forces the blood into the pulmonary artery, they offer no resistance, but the blood is prevented from returning, by the pockets filling up and bulging out so as to close the opening.

6. **The Left Auricle** is more simple than the right, showing only (*a*) the openings of the four pulmonary veins which return the blood from the lungs, and (*b*) the opening into the ventricle below.

7. **The Left Ventricle** is similar to the right, showing:—

1. OPENINGS.

(*a*) From the left auricle.

(*b*) From the aorta, or great arterial trunk, which sends blood to all parts of the body.

2. VALVES.

(*a*) **The Mitral** (from the resemblance to a bishop's cap, or *miter*); similar in construction and action to the tricuspid valves, except that there are but two instead of three triangular flaps of membrane. It prevents the blood from returning to the auricle.

(*b*) **Semilunar** valves in the mouth of the aorta. They are exactly similar in structure and use to the semilunar valves in the pulmonary artery.

8. **The Pericardium.**—The heart is well protected from injury, yet has perfect freedom for the necessary motion. It hangs by the large blood-vessels which are connected with it, and is surrounded by a fibrous membrane, the *pericardium* (around the heart), which encloses it like a bag. This membrane blends with the coats of the large blood-vessels, and is attached at one point to the diaphragm, so that it helps to hold the heart in position. It is lined with a serous membrane which turns and covers the heart also. This serous membrane secretes a fluid

which keeps the surfaces moist, so that the heart may move without friction. When the membrane is diseased, the fluid sometimes is greatly increased in quantity, producing what is known as "dropsy of the heart."

9. Structure.—The cavities of the heart are lined with a serous membrane which is continuous with the inner coat of the blood-vessels. It is sometimes called the **endocardium** (within the heart). The heart itself consists mainly of muscular fibers intricately interlaced and attached to fibrous rings surrounding the openings between the auricles and ventricles and around the mouths of the blood-vessels. The contractions of these muscular fibers lessens the cavities and forces the blood onward.

10. The Motions of the Heart consist of alternate contraction (systole) and relaxation (diastole) of its muscular walls. The two auricles contract at the same instant, sending the blood into the ventricles, which are at that instant relaxed. Then the two ventricles contract, forcing the blood into the arteries, and at this instant the auricles are relaxed. These contractions and relaxations follow each other so rapidly that the whole appears like a wave motion passing from the base to the apex of the heart. When the ventricles contract, the heart is tilted so that the apex strikes the wall of the chest. The heart pulsates, or contracts and relaxes, on an average, in the adult, seventy times per minute. In infancy motion is more rapid, becoming less in youth and manhood up to middle and old age. At birth it is from 130 to 140 per minute. The pulsations are more frequent in women than in men, more frequent during exercise and just after eating, and less frequent during sleep. The rate varies much in diseased conditions. It has been known to be as low as twenty and as high as 160 per minute.

11. The Sounds of the Heart.—During the pulsation two distinct sounds are heard. The first is dull, and caused by the contraction of the ventricles, the opening of the semilunar valves, and the rush of blood into the aorta. The second sound is sharp, and caused by the shutting of the semilunar valves. Between the second and first sounds there is an interval of silence, These sounds are valuable aids to physicians in discovering disease of the heart; for when there is a change in the natural condition of the heart, the sounds vary in character.

12. The Work of the Heart. — Dr. B. W. Richardson has found that the amount of work done by the heart of a healthy adult man is equal to raising 10,400 pounds to the height of one foot in one hour; or, from another point of view, it is equal to sending the blood 207 yards in a minute, or seven miles in an hour, or 5,150,880 miles in a lifetime of eighty-four years. The number of pulsations in that time would aggregate 2,869,776,000.

PRACTICAL ILLUSTRATIONS.

1. Get from the butcher the heart of a sheep or pig. If possible, get it with the lungs attached; and tell the man who cuts it out of the animal to be careful not to destroy the bag containing the heart. Place the whole in a vessel of cold water, and let it stand for an hour to remove the blood. Remove carefully the fat from around the blood-vessels at the base, but be careful to preserve the pericardium.

2. Cut a slit in the pericardium just large enough to push the heart out through it. Observe the smooth, shining surface of the heart and of the inside of the pericardial sac.

3. Cut a small piece from the apex of the heart. Observe the solid, muscular mass at the cut surface. Cut several thin slices until you come to the cavities of the ventricles. Note the difference in the thickness of the walls of the right and left sides. By carefully cutting away the lower end you can look into the ventricles and see all the cords and membranes of the mitral and tricuspid valves. Observe the muscular columns on the walls of the ventricles.

4. If the heart has not been separated from the lungs, only a part of the blood-vessels attached to the heart will have been cut off. Find the cut end of the aorta and push a piece of rubber tubing into it. If this be not at hand, you can use a flexible twig of willow, or something similar. In the same manner find the cut ends of the superior vena cava and the inferior vena cava, and trace them into the heart. If the pulmonary artery and veins have not been severed, you may find them, and, by cutting slits in them, insert twigs or tubes. You may have some difficulty in finding veins, as they are soft tubes, and collapse when empty, but arteries stand out like rubber pipes and are more easily found.

5. Now push your finger up through one of the ventricles and try to reach the cavity of the auricle. Then cut down carefully from above against your finger. Enlarge the opening until you can observe the valves from the auricle side. Notice the points where the sticks which you had thrust into the blood-vessels have come out.

6. Show the semilunar valves by slitting down the aorta and pulmonary artery.

7. By the aid of these directions and the description of the heart given in the lesson you will have no difficulty in making this dissection, and it will amply pay for the time and trouble. No clear idea can be had from descriptions alone, no matter how complete they may be.

LESSON 18.

The Blood-Vessels.

1. The blood-vessels are a system of elastic pipes which convey the blood or nourishing material to all parts of the body. They are of three kinds,—arteries, veins, and capillaries. The arteriés are those vessels which carry blood from the ventricles of the heart and distribute it to all parts of the body. The veins are the vessels which return the blood from all parts of the body to the auricles of the heart. The capillaries are the fine tubes which connect the veins with the arteries throughout the tissues of the body.

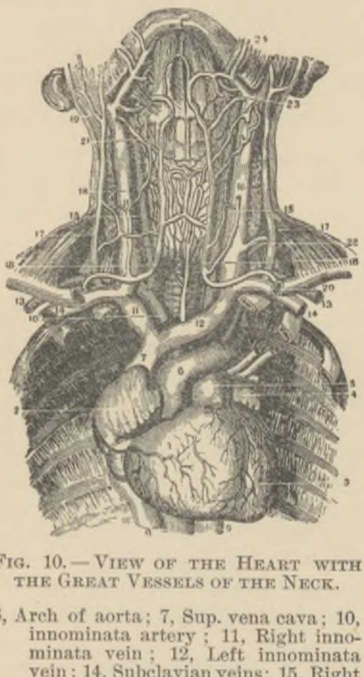


FIG. 10.—VIEW OF THE HEART WITH THE GREAT VESSELS OF THE NECK.

6, Arch of aorta; 7, Sup. vena cava; 10, innominata artery; 11, Right innominata vein; 12, Left innominata vein; 14, Subclavian veins; 15, Right common carotid artery; 16, Jugular veins.

2. The Aorta.—This is the main trunk of the arterial system, which divides and subdivides until all parts of the body are reached with branches. It is about one inch in diameter, and commences at the upper part of the left ventricle, ascends behind the sternum, then curves over from left to right, and backward to the third dorsal vertebra, then descends along the left side of the spinal column to the lower border of the fourth dorsal vertebra, where it takes the name of the thoracic aorta. The part above this point is called the *arch.* The *thoracic aorta* passes through an opening in the diaphragm in front of the last dorsal vertebra, and then takes the name of the *abdominal aorta*, which terminates on the left side of the fourth lumbar vertebra, where it divides to form the right and left common iliac arteries.

3. The Principal Arteries. — The aorta gives off from its arch, generally, five branches: (1) the *right and left coronary*, which supply the heart-substance with blood; (2) the **innominate** artery, which ascends, and opposite the top of the sternum divides into the **right carotid** and **right subclavian** arteries; (3) the **left carotid**; and (4) the **left subclavian.** The two carotid arteries each divide opposite the larynx into the **internal** and **external carotids.** The former enters the cranium, and branches to different parts of the brain. The latter supplies the face and scalp by numerous branches. The subclavian arteries supply the arms and part of the chest. One branch, the **vertebral,** passes along the spinal column through openings in the transverse processes of the cervical vertebræ, and entering the skull, the two join to form the **basilar** artery, which again divides and each branch sends branches to the carotid arteries, which are also joined by an anastomosing branch. Thus a complete circle (called the *Circle of Willis*) is formed at the base of the brain; and if the blood is from any cause checked in one set of vessels, the other set ensures a supply.

FIG. 11. — SIDE VIEW OF THE SUPERFICIAL ARTERIES AND VEINS OF THE NECK.

The subclavian arteries take the name of **axillary** under the arm, and **brachial** in the upper arm, dividing at the elbow into the **ulnar** and **radial** arteries. Branches from the ulnar and radial join in the palm of the hand and form the **palmar arch,** from which small arteries are given off to the fingers.

Returning to the aorta, the principal branches below the arch, are: (1) The **cœliac axis,** a short, thick artery which divides into the **gastric,** supplying the stomach, the **hepatic,** supplying the liver, and the **splenic,** entering the spleen; (2) the **superior mesenteric**; and (3) the **inferior mesenteric,** supplying the intestines.

The terminal branches of the aorta are the **right** and **left common iliacs,** which are about two inches in length, and divide to form the **internal** and **external iliacs.** The former supplies the organs within the pelvis, and sends branches to its walls. The latter extends to the thigh, taking the name of **femoral** after it leaves the trunk. As it passes behind the knee it is called the **popliteal** artery. Below the knee it divides into the **anterior** and **posterior tibial** arteries. An arch is formed by their union in the foot called the plantar arch, from which branches pass to the toes.

4. Structure of the Arteries. — These tubes are composed of three distinct coats: (1) The *outer*, of connective tissue, with elastic fibers; (2) the *middle*, of elastic and muscular fibers, the latter being more numerous in the smaller arteries; (3) the *inner*, a serous membrane resembling that which lines all cavities of the body not accessible to air. If a string be tied tightly around an artery the middle and inner coats will be severed, but the outer will remain uninjured. The outer coat gives strength, the middle elasticity and contractility, and the inner coat affords a smooth surface for the flow of the blood.

When an artery divides, each branch is smaller than the main artery, but the combined area of the two is greater than the area of the main one. Thus, if all the arteries could be fused into one, we would have a funnel-shaped tube, with the smaller end at the heart. The arteries in many places send branches which join each other. This is called **anastomosing.** This is of great advantage to the surgeon, for should he be obliged to tie a main artery, the blood can flow around through these anastomosing branches and re-establish the circulation.

5. The Principal Veins. — These vessels are more numerous than the arteries. They are divided into three sets: (1) The

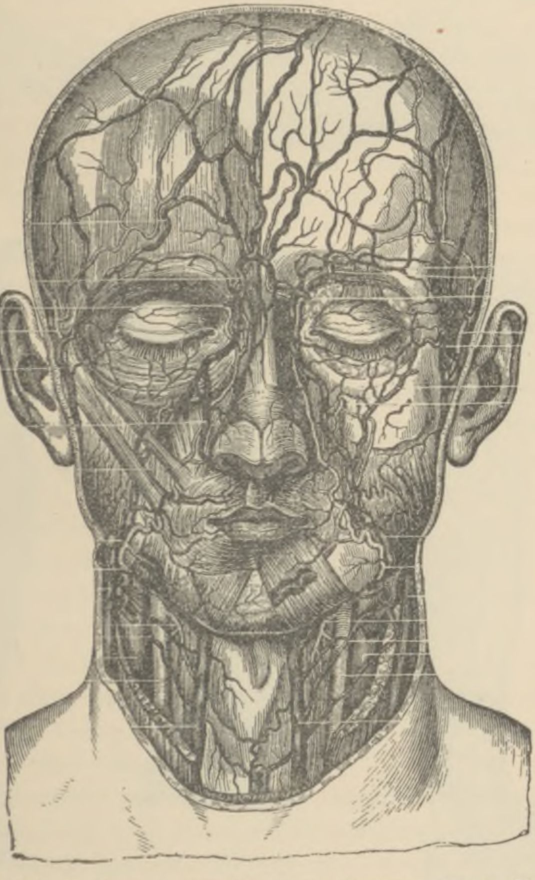


FIG. 12. — A FRONT VIEW OF THE RELATIVE POSITIONS OF THE VEINS AND ARTERIES OF THE FACE AND NECK.

On the right side the superficial vessels are seen, and the deep-seated ones on the left.

superficial, found near the surface of the body, generally small and very numerous; (2) the *deep*, found accompanying the arteries, usually enclosed in the same sheath with them, and generally two to each artery; (3) the *sinuses*, venous channels found only in the interior of the cranium, and formed by a separation of the dura mater, or membrane covering the brain.

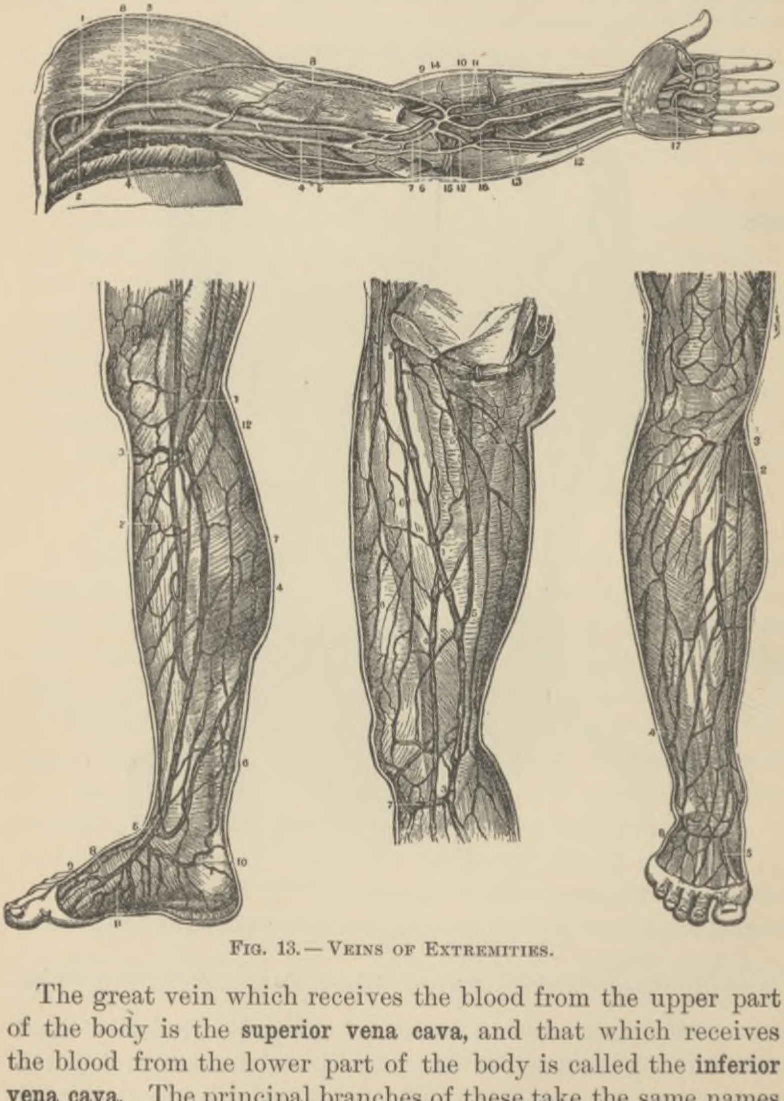


FIG. 13.—VEINS OF EXTREMITIES.

The great vein which receives the blood from the upper part of the body is the **superior vena cava**, and that which receives the blood from the lower part of the body is called the **inferior vena cava.** The principal branches of these take the same names as the arteries which they accompany. The **sinuses** of the dura mater have special names. The word *sinus* used in this connection must not be confused with the word which describes air-cavities in the bones of the skull, as the *frontal sinus*. The superficial veins may be seen in many places, as on the back of the hand, standing out like cords beneath the skin. They join the deep viens, and the larger ones have special names.

6. The Structure of Veins. — Like arteries they have three coats, which differ mainly in the comparative weakness of the middle coat and the scarcity of muscular and elastic fibers. For this reason a vein collapses when empty, while an artery remains an open tube. Most of the veins are provided with *valves*. These are simply folds of the inner and middle coats, which permit the blood to pass freely towards the heart, but prevent its flow in the opposite directions. The veins freely anastomose with each other, in the same manner as the arteries.

7. The Capillaries. — The blood-vessels which connect the arteries and veins were called capillaries, from the Latin word for hair, because of their extreme smallness. Their usual diameter is not more than $\frac{1}{3000}$ of an inch. But they make up in numbers what they lack in size, for they are so thickly distributed that there is scarcely a point on the body where a fine needle could be inserted without puncturing one or more of them. They are found in every tissue of the body except in the nails, hair, epidermis, and cornea of the eye. Their walls are a thin, transparent membrane, through which liquids and gases may freely pass. They are thus important agents in *absorption*. (See Digestive System.)

The blood which passes into the capillaries throughout the tissues of the body from the systemic arteries is of a bright red color, but after it has gone through and reached the veins it is darker and has lost certain elements and gained others. · The capillaries which terminate the pulmonary artery, however, receive dark blood and deliver it in a bright red condition to the pulmonary veins. These changes of material will be explained under other headings. Suffice it to say here, that through the capillary walls all the important *changes of material take place.*

8. The walls of the larger veins and arteries are supplied with small arteries and veins. These are called *vasa vasorum* (vessels of the vessels). The walls of the small blood-vessels are supplied from the blood in the vessels themselves.

PRACTICAL ILLUSTRATIONS.

1. Cut off two or three inches from the aorta of an ox, sheep, or pig. Remove all fat, and place it in a cup of water for several days. You may then separate by carefully working with a dull knife the three coats of the vessel. The outer coat can be turned back on the others as you would turn up the sleeve of your coat. Then the middle coat may be turned back on the inner coat in a similar manner.

2. Test the elasticity and strength of arteries by pulling and stretching a piece of the aorta. Compare a piece of the aorta with a section of the vena cava. Both vessels may be obtained from the heart and lung specimen (or a similar one), mentioned in a former lesson.

3. Instruct pupils to find the following arteries on their own persons by feeling the pulsation with the finger: The *radial* artery at the wrist near the base of the thumb; the *ulnar* on the inner, or little finger, side of the wrist; the *carotid* artery at the side of the neck just below the angle of the jaw; the *temporal* on the temple just in front of the top of the ear; the *facial* on the lower jaw exactly half-way between the chin and the angle of the jaw; a branch of the facial by holding the lower lip at the corner of the mouth between thumb and finger; another branch by holding the upper lip in the same manner; the *supra-orbital* on the edge of the frontal bone just above the centre of the eye; the *infra-orbital* on the malar bone at a point just below the centre of the eye. There are many other places where arteries may be felt pulsating, but these are sufficient to illustrate the fact that arteries, although mainly lying deep in the tissues, at certain points appear near the surface.

4. The presence of valves in the veins may be proven on the back of the hand in some persons. Find a place where the vein stands out prominently; wet the finger and rub along the course of the vein in a direction opposite to that in which the blood flows, or away from the heart, and keep the finger firmly pressed on the vein. The finger will push the blood out of that part of the vein over which it passes, and if there be a valve in its course, the blood will be seen coming back up to that point but no further. This shows that blood may flow backward; that is, away from the heart, but only to a point where a valve occurs.

LESSON 19.

The Blood and its Circulation.

1. The blood in the human body amounts to about one-eighth of the weight of the body, or in a person of average size, to about 2½ gallons.

2. **Physical Properties.** — Blood is a little heavier than water, and is of a bright scarlet color in the systemic arteries, and a very little darker in the systemic veins. It is salty to the taste, and has an odor peculiar to itself. Shortly after being drawn from the body it *coagulates*, or clots, and becomes thick like jelly.

3. **Composition of Fresh Blood.** — To the unaided eye, or in quantity, the blood appears to be a simple liquid of a red color, but if a little be spread very thinly on a glass slide, and examined with high power of the microscope, it is seen to consist of a clear liquid in which numbers of little roundish bodies are floating. These are usually called blood **corpuscles** (little bodies). The greater proportion of the corpuscles appear faintly red or yellowish when seen singly, but when many are together the mass appears red. A few of the corpuscles are whitish, or nearly colorless.

The colorless liquid in which the red and white corpuscles float is called **plasma,** or **liquor sanguinis.** It is the nourishing part of the blood, but also contains waste matter of the body. It is composed of proteid, or albuminous matter, mineral salts, and water. Also a small proportion of certain gases. The red corpuscles contain a substance which gives them their characteristic color. It is called **hemaglobin.** It is a complex chemical substance, containing iron in combination. The white corpuscles are supposed to be simply masses of protoplasm. (See Introduction.)

4. **The Corpuscles.** — These are interesting little bodies, and deserve further notice in this connection. The red ones when lying flat appear as circular discs, but when seen in profile are slightly concave on both sides, bearing no little resemblance to

a biscuit or cracker. They are about $\frac{1}{3500}$ of an inch in diameter in man, but many times larger in some of the lower animals. In the proteus, a species of salamander resembling a lizard, they are large enough to be seen by a common pocket magnifying glass, being more than sixty times as large as in man. In a few animals they are smaller than in man. In the reptiles and frogs they are oval in shape and have a distinct nucleus. Some notion of the minute size of the corpuscles in

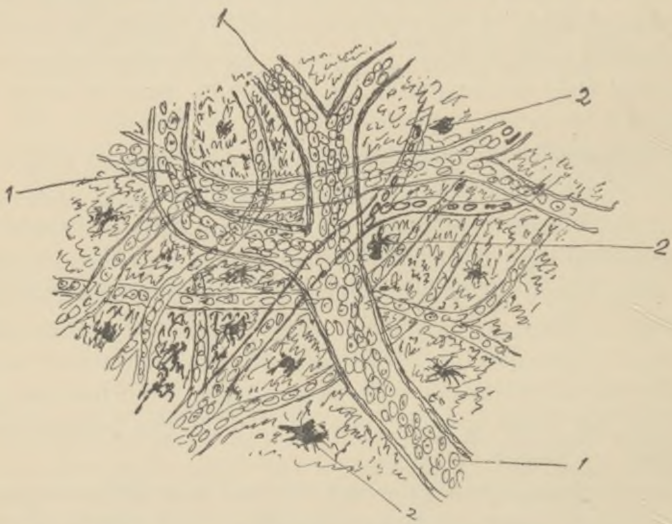


Fig. 14.—The Circulation in the Capillaries of the Web of a Frog's Foot, as seen under the Microscope.

1, Blood corpuscles; 2, Pigment matter.

man may be had when we say that were they laid closely side by side, it would take twelve millions of them to cover a square inch of surface. When spread upon the glass they often collect in rows appearing like so many coins leaning against each other.

The white corpuscles vary in proportion to the red. Sometimes there are only $\frac{1}{300}$ as many white as red ones, and again there are $\frac{1}{50}$ as many. The white corpuscles, unlike the red, have no definite shape; in fact, they may be seen to change their shape apparently at will. In their motions they resemble one of the lowest forms of animals, called the **amœba**. This animal is a mere shapeless mass of living matter (protoplasm). When it wants to move it merely pushes out a part of itself, and the remainder of the body slowly draws up to it. It may push out parts of itself in several directions at the same time, and assume a great variety of irregular forms. Exactly similar actions have been observed in the white corpuscle, and its movements are therefore called *amœboid movements*. Under certain conditions they actually pass through the capillary walls, although no openings discernible by the highest powers of the microscope exist. A minute, thread-like portion appears on the opposite side, and this enlarges while that on the other side diminishes, until the entire mass has passed through. This is called *diapedesis*, or *migration of the white corpuscles*.

5. The Origin, Destiny, and Use of Corpuscles. — We know nothing definite as to the origin of the corpuscles. That they are formed in the spleen, lymphatic glands, and in the red marrow of the bones is an opinion which has not been proven a fact. It is thought that the white are simply an earlier stage in the formation of the red ones, but this is not settled. As to their destiny we are also in the dark. From fragments having been found in the spleen, it was thought that they were destroyed in that organ, and the spleen has been designated "the grave of the red corpuscles."

As to their use, we have more definite knowledge, especially of the red ones. The hemaglobin of the red corpuscles unites with oxygen in the lungs, and again gives it up throughout the tissues of the body. They are therefore carriers of oxygen gas which is necessary in the vital processes. The white corpuscles are always found to be more abundant near a wound which is in the process of healing, and they are identical in appearance and actions with the corpuscles found in chyle and lymph. It is a reasonable supposition that they are early stages of living cells, and are closely connected with the processes of growth and repair of the tissues.

6. Coagulation. — If blood be drawn from the living body and allowed to stand in a vessel, in about ten minutes it begins to separate into two distinct parts, one a clear, watery liquid, the other a thick, jelly-like, dark red mass. The watery liquid is called the **serum**. It must not be confounded with the plasma. It is plasma minus corpuscles and a substance called **fibrin**. The **coagulum**, or **clot**, is the name applied to the jelly-like portion. It consists of fibrin, which has entangled in its meshes the corpuscles. By repeated washing in clean water the corpuscles may be dissolved out, leaving the fibrin a white, stringy substance. Blood may be kept from coagulating for a time by the addition of certain chemical substances, or by a certain degree of cold. In this case the corpuscles prove themselves to be slightly heavier than the plasma by slowly settling to the bottom of the vessel. If fresh blood be beaten with twigs in the same manner as one would beat an egg, the fibrin will collect on the twigs as a stringy substance. If a portion of a large blood-vessel be tied in two places, while full of blood, and then separated from the animal, the blood will remain for an indefinite time in this tube, uncoagulated. If needles be thrust into a living blood-vessel, the fibrin will form and gather on them. These and other experiments have been tried on animals to discover the cause of coagulation, but as yet nothing very satisfactory is known. It has been proven that the blood contains three elements, all of which are necessary for its coagulation.

But whatever the cause of coagulation may be, its importance to the animal being is undoubted, for it is nature's method of arresting hemorrhage. When blood-vessels are cut or torn so that blood begins to escape, coagulation soon closes the openings in the vessels, unless the vessel be a very large one, in which case, unless artificial means are applied to stop the flow of blood, the animal will die of hemorrhage. In some of the lower animals coagulation takes place much more quickly than in man, and bleeding is seldom fatal among them. In birds the blood coagulates almost instantly after leaving the vessels.

7. The General Course of the Blood. — Starting with the capillaries throughout the body, let us trace the blood in the round of the circulation. From the capillaries it passes into the veins, which grow larger and fewer until the heart is reached by two main trunks, already described. These empty the blood into the right auricle. From here it passes into the right ventricle. By the contraction of its walls it is forced into the pulmonary artery, which, by its numerous branches, conveys it to the capillaries of the lungs. Thus far it is dark colored, or *venous blood.* In the capillaries of the lungs it receives oxygen and parts with carbon dioxide, and appears in the branches of the pulmonary veins of a brighter red color. It is now arterial blood, although the vessels containing it are called veins. The pulmonary veins convey the blood to the left auricle, from whence it descends into the left ventricle. By the contractions of the powerful muscular walls of the left ventricle, it is sent with great force into the aorta, and through it into its branches, until it reaches again the capillaries of the body, the place from which we started. In the capillaries it becomes dark again by the loss of oxygen and the gain of carbon dioxide.

It must be remembered that the veins are those vessels which carry blood *to* the heart, and the arteries are those vessels which carry blood *from* the heart. The veins, with the exception of the pulmonary, carry dark, or venous blood; the arteries, with the exception of the pulmonary, carry bright red, or arterial, blood.

8. Special Circulations. — The course of the blood, from the left ventricle through the body and back to the right ventricle, is called the **systemic circulation.** The flow from the right ventricle to the lungs and back to the left ventricle is called the **pulmonary circulation.** The passage of the blood through the capillaries is sometimes distinguished as the **capillary circulation.** The blood which is distributed to the stomach, spleen, and intestines, is carried by the portal vein to the liver and spread through its tissues, to be gathered up again by the hepatic veins and returned to the vena cava. This is called the **portal circulation.**

9. Causes of Circulation. — The primary cause of circulation is the muscular contraction of the heart. When the heart stops beating the blood soon ceases to move in the vessels. The heart acts like an engine or force-pump, sending a constant supply of blood into the vessels and keeping it there under pressure. That the heart exerts an influence beyond that of merely throwing the blood into the aorta, is shown by the fact that the arteries, down to the smallest, can be felt and seen to throb and pulsate with every beat of the heart. This "pulse," as it is called, may be felt under certain circumstances, even in the veins. With every contraction of the heart, a wave-like motion is started in the blood and becomes less and less perceptible, the farther away and the smaller the artery. It is somewhat like the ripple produced upon a pond by dropping a stone in the water. Thus by feeling the pulse at the wrist, or on the temples, the physician can tell how rapidly and how strong the heart is contracting. If the heart is beating feebly and slow,

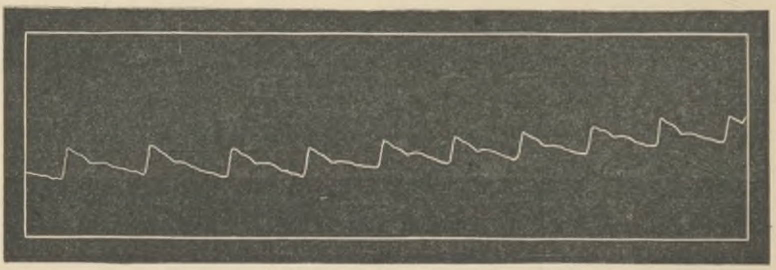


FIG. 15.—SPHYGMOGRAPH TRACING OF PULSE.

the pulse will feel weak against the finger, and the number of beats per minute will correspond exactly to the number of heart-beats in the same time.

There are other circumstances which modify and aid in the circulation. Among these may be mentioned: (1) the elasticity of the arteries; (2) the muscular contractions in the coats of the arteries; (3) the pressure caused by the movements of the muscles upon the veins, aided by their valves; and (4) possibly *capillary attraction* in the smallest vessels, and *osmose*, or the force which causes the flow of fluids and gases through the walls of the capillaries, both into and out of the vessels.

10. The Sphygmograph.—This is a strange looking word, but it means simply the "pulse-writer." It consists of a lever so arranged that the pulse in the wrist can move it up and down freely, and at the same time its point is made to press upon a piece of smoked paper, made to move at a regular rate by clockwork. When applied to the wrist and set in motion, the lever writes a wavy line as shown in the cut, which is an accurate copy of the writing made by the pulse of the author of this book. This instrument shows the condition of the Circulatory System, for marked differences exist between the pulse of health and that of disease. It is therefore a valuable aid to the physician. The highest part of the line represents the contraction of the ventricles, and the wavy slope shows their dilation and the resistance to the flow in the arteries. The variations in these curves show the variations in force, frequency, and regularity of the heart-beats and the degree of arterial resistance, points of great value in determining disease and its treatment.

11. Rate of Circulation. — A given portion of the blood may make the complete circuit of the body; that is, from the veins to the right side of the heart, thence to the lungs, back to the left side of the heart, thence to the arteries, and through the capillaries to the veins again, in the short space of twenty-four seconds. Experiments on various animals have been made to ascertain this. Certain chemicals which can be easily detected by a test are introduced into a vein on one side of the neck, then blood is drawn at different intervals of time from a vein on the other side of the neck, and tested for the chemical. It is estimated that the entire amount of blood in a man makes a complete circuit of the body every two minutes.

PRACTICAL ILLUSTRATIONS.

1. Procure from a slaughter-house a small quantity of the fresh blood of an animal. It will very probably have coagulated before you reach the schoolroom. Place a little of the clot in a clear glass bottle, and add water. Shake vigorously, and observe that the water becomes intensely red. Then pour out the water and add more. Shake again and pour off the reddened water. Repeat this process many times. Observe that the clot becomes smaller and the edges become white. This white substance is fibrin. By repeated washings a small quantity of pure fibrin may be obtained. The water has been made red by the corpuscles which have separated themselves from the clot.

2. The principle of the *sphygmograph* may be shown by laying the hand and arm palm upward on the table and balancing a pencil on the radial artery in the wrist. Observe that the pencil moves up and down with every pulsation. This motion may be magnified so that it can be seen by a large audience. Fasten a bit of looking-glass to one end of the pencil and balance it on the pulse, holding the hand in the sunlight in such a position that the mirror will reflect a spot of light on the wall or ceiling. The spot will vibrate back and forth through a considerable space with every beat of the heart. It may not be possible to perform this experiment with every person, as in some the artery lies too deep to move the pencil.

3. To show the corpuscles of the blood requires a microscope such as the majority of teachers or schools are not likely to be provided with. To those teachers who are fortunate enough to possess or have access to a good microscope, the following hints may be of value: —

Tie a string tightly around the finger. In a moment the finger swells and becomes red. Prick with a needle slightly. Touch the drop of blood which appears lightly with the surface of a glass slide. Blow off or shake off the superfluous blood so as to leave only a stain on the glass. Place at once under the microscope, turning on a good light. The red corpuscles will be seen in great numbers, and probably a few white corpuscles may be seen. They will be known by the white appearance and generally irregular form. If possible procure a live frog, turtle, or salamander, and place a drop of its blood under the microscope. Note the oval shape, the great size, and the nucleus.

The circulation of the blood in the web of a frog's foot is a very interesting and instructive sight. The frog may be placed in a box along with a cloth saturated in chloroform. As soon as he shows signs of unconsciousness he should be removed and placed on a thin board with a small hole cut in one corner. Fasten the board to the stage of the microscope so that the hole comes under the lens. Spread out the web of the frog's foot over the hole, and fasten by pins placed against, not through, the toes. Keep the body of the frog covered with a wet cloth.

An instructive and beautiful object is the egg of a carp just about to hatch. They may be procured frequently from artificial fish ponds, adhering to weeds and sticks in May. If procured at the proper time, the young fish may be seen curled up in the egg, the whole being so nearly transparent that the blood may be seen flowing from the heart to all parts of the body and back again to the heart.

LESSON 20.

The Lymphatic System.

1. The Lymphatic System, sometimes called the *Absorptive System*, is accessory to the Circulatory System, and consists of:

(1) *lymphatic vessels* with their contents, lymph, and chyle and (2) *lymphatic glands.*

2. Lymphatic Vessels. — These are a series of minute, delicate, transparent tubes of nearly uniform thickness, but having a knotted appearance, due to valves in their interior. They are found in nearly every part of the body, except the brain, spinal cord, eyeballs, tendons, cartilages, nails, epidermis, and hair. They are divided into: (1) *superficial*, lying just beneath the skin and near the surfaces of the great cavities of the body; (2) *deep*, accompanying the deep blood-vessels. They are more numerous than the veins and anastomose more frequently.

3. Thoracic Duct and Right Lymphatic Duct. — All the lymphatic vessels except those of the right side of the head, neck, and chest, right arm, lung, and upper surface of the liver, empty into one common trunk, called the **thoracic duct.** It is from eighteen to twenty inches long, one-quarter of an inch thick, and extends from the second lumbar vertebra to the seventh cervical, where it empties into the left subclavian vein. At its lower extremity is a bag-like enlargement, called the *receptaculum chyli* (receptacle of the chyle). Those lymphatic vessels which do not empty into the thoracic duct, empty into a short trunk, one inch in length and about one line in thickness, called the **right lymphatic duct.** It empties into the right subclavian vein.

4. The Lacteals. — Although described with the digestive organs, they should be mentioned here as a part of the Lymphatic System. They consist of those lymphatics which are distributed to the small intestine, and end in the villi already described. They differ from the other lymphatics only in that they carry chyle instead of lymph.

5. Lymphatic Glands. — These are small bodies, varying from the size of a grain of wheat to the size of an almond, and are pinkish gray in color. They are found in the course of the lymphatic vessels, in various parts of the body, but more numerous in the neck, armpits, space behind the knee, groins, and in the folds of peritoneum which hold the intestines in place.

We are often made aware of their existence by their becoming swollen and enlarged. The lymphatic vessels pass into the glands, divide into branches, and unite again as they pass out. Their function is not certainly known. They have been supposed to be concerned in the production of blood corpuscles.

6. **Lymph, Chyle, Blood, Plasma, Serum.** — Five fluids of importance which the pupil should understand. The **lymph** is the clear fluid found in all the lymphatics (except the lacteals, during digestion). It is poured into and becomes a part of the blood in the manner already described. It contains some white corpuscles, but rarely, if ever, red ones. The **chyle** differs in no way from lymph except that it contains fat globules, which give it a milky white appearance. It is found in the lacteals and thoracic duct, during and after the digestion of a meal. When emptied into the blood-vessels it loses its identity and becomes a part of the blood. The blood in the living vessels consists of **plasma** and corpuscles. Plasma and lymph are scarcely distinguishable. Plasma will coagulate, producing *fibrin* and *serum*. **Serum** in any considerable quantity is not found as a normal constituent of the body. It is a result of coagulation of the blood, or some morbid change. It is the fluid of dropsy. When a blister is raised on the skin by heat or pressure or medicine, the clear fluid beneath the epidermis, or in the blister, is serum. It bathes the surfaces of all serous membranes. The term serum is used by some authors synonymous with plasma, but a distinction should be made. The following formulated statements will assist the memory: —

Lymph equals *chyle* minus fat.
Chyle equals *lymph* plus fat.
Plasma equals *blood* minus corpuscles.
Fresh blood equals *plasma* plus corpuscles.
Coagulated blood equals *serum* plus fibrin and corpuscles.
Serum equals *blood* minus fibrin and corpuscles.

7. **Function of the Lymphatic System.** — The tissues, as we have learned, are constantly being torn down and rebuilt, and while the body is increasing in size, new tissues are forming

in addition to those which replace the old. The material for this building and rebuilding is the plasma of the blood. It passes by the process known as *osmosis* through the capillary walls. The material of the old tissue, or a part of it at least, passes back through the capillary walls by the same process, and produces the change from arterial, or red blood, to venous, or dark blood. But in this flow of plasma through the capillary wall there is a surplus which the tissues cannot use. This, with possibly a part of the waste material which is not returned to the blood in the capillaries, passes into the lymphatic vessels and constitutes the fluid known as lymph, which, as we have seen, is returned again to the blood through the two main channels, the thoracic and right lymphatic ducts. The lymphatics proper, therefore, are for the collection of the overflow of the blood-vessels, and possibly, to a certain degree, for the return of waste material to the veins. The function of the lacteals has been given under the Digestive System. The function of the lymphatic glands is not certainly known. As the lymph all passes through them, we suppose that they produce some change in it which prepares it for nourishing the system.

8. The Thymus and Thyroid Glands. — In this connection we may mention two peculiar bodies which have received the name of glands, although their use is not known. They are regarded as appendages of the Lymphatic System. The *thymus gland* is a small body found just above the heart. It reaches its greatest size at about the age of two years, and then becomes smaller and almost disappears in the adult. The *thyroid gland* lies in front of the neck just beneath the skin, in front of the windpipe. It becomes greatly enlarged in the disease known as big neck, Derbyshire neck, or goitre. This disease is occasionally seen in this country, but in certain mountainous portions of Europe it is exceedingly common. The gland becomes sometimes as large as one's head, and may interfere with breathing.

LESSON 21.

Hygiene of the Circulation.

1. **Wounds and Bleeding.** — A very slight wound may bleed profusely and appear to be very serious, and again, a wound may be deep and severe and appear to be but slight. Examine a wound carefully. Observe if the blood flows steadily and is dark in color. If so, only veins are injured, and the danger is not so great from hemorrhage. Should the blood flow very rapidly try to stop it by tying a bandage (a handkerchief will do) loosely around the limb, pass a stick through the loop and twist the bandage until it is drawn tightly to the part. It must be remembered that the blood in the veins flows toward the heart, and the bandage must be put on the side of the wound furthest from the heart. Should the blood flow in *spurts* or *jets*, and be bright red in color, an artery is injured, and no time should be lost in placing a bandage on the side nearest to the heart. If the flow of blood is considerable, send at once for a physician, but keep trying to stop the flow of blood by the bandage and stick. In some cases, as in the palm of the hand, it will be best to place a piece of wood, a cork, or a wad of cotton or rags in the wound, then pass the bandage directly over this and apply the pressure by twisting. Where many small blood-vessels are injured, some astringent substance, as powdered alum, may be applied to the wound, or cotton, lint scraped from a towel, cobwebs, or some similar substance, may be applied to the wound. Many a soldier on the battlefield has saved his life, or at least prevented serious loss of blood, by applying dry earth to the wound. Bleeding from slight wounds may often be arrested by plunging the part in cold water or by tying a bandage tightly over it.

FIG. 16. — HANDKERCHIEF AND STICK BANDAGE.

When a person spits or vomits blood, it is important to know if it come from the lungs or from the stomach. If from the latter it will be dark and probably mingled with food. If from the former it will be lighter in color and frothy. In either case, give some vinegar or lemon juice, and consult a physician. Bleeding from the nose is often quite serious with some persons, and it is difficult to check it. Bathing the face and neck in cold water and holding the arms high above the head for a few minutes will often succeed. If these do not, pour a solution of alum into the nostrils. If not stopped soon send for the physician.

2. **Effects of Nervous Shocks on Circulation.** — The circulation of the blood is controlled entirely by the Nervous System, and as a general rule the action is automatic; that is, an unconscious stimulus passes from the brain, causing the heart to beat with a certain degree of regularity and force; but strong emotions, as of fear, anger, etc., cause special stimuli to pass along the nerves to the heart, and induce irregularities in its action. Certain mental states affect also the small arteries and the capillaries. Blushing and pallor are due to relaxations and contractions in the muscular fibers of the blood-vessels, caused by mental conditions.

Frequent disturbances of the regularity of the circulation cannot occur without injury to the system. Causes of shocks and nervous excitements should be avoided.

3. **Effects of Cold and Heat on the Circulation.** — Cold temporarily increases the circulation, but if continued tends to check it unless counteracted by exercise and stimulants, which may keep it up for a time. Heat also increases the circulation within certain limits only. Coldness of the feet and hands is generally due to insufficient circulation of blood through them, and this deficiency of circulation is often brought on by external cold in the first place. Hence the importance of keeping the extremities properly clothed in cold weather.

4. **Exercise and the Circulation.** — Count your pulse when at rest; then exercise vigorously for a few minutes and count it again. You will observe a perceptible increase in the number

of beats per minute. Every part of the body should have exercise, that the blood may flow more freely to all parts. When the feet begin to get cold a vigorous and constant working of the toes will soon make them warm, because the exercise increases the flow of blood to the parts.

5. Alcohol and Tobacco and the Circulation. — The first effect of alcohol upon the circulation is to increase it generally. The heart beats more rapidly and with greater force, the arteries expand, and more blood is sent to the capillaries. A sensation of warmth and an increase apparently of strength throughout the system is the result. There is, however, no actual gain of strength, but rather a loss. It has caused strength to be expended, and like a fever is followed by corresponding depression and weakness. Frequent stimulations of this kind cause permanent dilation of the arteries and capillaries. It is this enlargement of the capillaries of the face that cause the red nose and face of the habitual drinker. It is true that under some circumstances of disease an artificial stimulus of the circulatory organs is a good thing, and the wise physician often makes use of alcohol to the great advantage of the patient, but in a state of health this undue excitement is injurious. Long-continued use of alcoholic drinks may cause fatty degeneration of the heart. Many men who are supposed to be temperate users of alcoholic drinks appear to be healthy until about the age of fifty, when they suddenly decline, the cause being a weakness of the Circulatory System in many cases. The heart has reached the limit of the unnatural strain put upon it. This weakness of the Circulatory System, due to alcohol, explains in the main why drinking men generally succumb to the attacks of epidemic diseases like cholera. The circulatory forces are not sufficient to expel the poisons from the blood.

Excessive use of tobacco is apt to produce a form of palpitation of the heart. This condition is often spoken of by doctors as the "tobacco heart" or the "smoker's heart."

EXERCISES FOR REVIEW.

1. What is the probable amount of blood in your body ?

2. How does fresh blood differ from blood which has been drawn from the vessels for some time ?

3. What is the use of the red corpuscles ? What gives color to the blood ?

4. Name and classify the cavities of the heart. Name and locate the valves of the heart.

5. What are the motions of the heart ?

6. In what is the heart enclosed ?

7. What holds the heart in its position ?

8. If you were to tie a string very tightly around an artery, what coats would be severed ?

9. What is the sphygmograph ? What is its value ?

10. Trace a particle of blood from the little finger of the right hand until it reaches the capillaries of the lungs, naming the principal parts through which it must pass. Trace in a similar manner a particle of blood from the capillaries of the lungs to the great toe of the left foot. [The teacher may assign other routes for the pupils to trace out.]

11. Name some points of resemblance and some of difference between arteries and veins.

12. What is the use of the pericardium ? Of the mitral valve ? Of the semilunar valves ? Of the tricuspid valves ? Of the valves in the veins ?

13. What are *vasa vasorum ?*

14. Describe the portal circulation. Compare with Functions of the Liver.

15. How do chyle and lymph differ from each other ? Compare plasma and serum.

16. What advantage does the animal derive from coagulation of the blood ?

17. Where place the bandage in case you wish to stop the flow of blood from a wounded artery ? In case of a wounded vein ?

18. Explain the red nose of the drunkard.

19. How do the muscles aid in the circulation ?

20. What is meant by anastomosing of the blood-vessels ? What advantage is there in it to the individual ?

21. How is the Circulatory System related to the Digestive System ?

22. Can human blood be distinguished from the blood of an animal ? It can by the microscope be distinguished from the blood of reptiles, fishes, birds, and some mammals by the difference in size and shape of the corpuscles, but it cannot be distinguished from that of the dog, pig, and some other mammals. This is an interesting medico-legal question.

CHAPTER III.

HOW GASES ARE EXCHANGED IN THE BODY, OR THE RESPIRATORY SYSTEM.

LESSON 22.

Organs of Voice and Respiration.

1. **Oxygen** is necessary to the existence of all animals. As this gas exists free in the air there must be some mechanism whereby air can be taken into the body. In the lower forms of animal life very little oxygen is needed, and the quantity found dissolved in water is sufficient for many species. In some cases it passes through the skin directly into the blood, in others it goes in with the water which circulates through the animal or mingles with its blood. In others again, little openings in various parts of the body admit air to tubes which ramify through the body. In fishes and some others the oxygen is absorbed from the air contained in the water by means of gills which are similar to lungs. All higher animals have lungs more or less perfect. Yet a variable quantity of oxygen is taken in through the skin in all animals, even in man. Those animals which make sounds by means of a modification of the respiratory organs are said to have *voice*. The organs of voice and respiration are therefore necessarily closely connected.

2. **The Larynx.** — The air is received from the nasal passages or mouth into the pharynx, which has already been described. From this chamber it passes into the larynx, a short tube or box composed of cartilage and membrane. It forms the lump in the neck so prominent in lean persons, called "Adam's Apple." The cartilaginous portion is in nine pieces. The largest is called the *thyroid* (shield-like) cartilage. It may be

felt in the neck as the prominent point of the Adam's Apple. It forms the main part of the larynx. It is largest above and unites below with the *cricoid* (ring-like) cartilage. This is somewhat like a seal ring, having the broad portion behind. The *arytenoid* cartilages, two in number, are small, triangular pieces placed upon the broad part of the cricoid. To each of the arytenoid cartilages is attached a very small cartilage called *cornicula laryngis.* The *cuneiform* are two small cartilages, one on each side of the arytenoid. The **epiglottis** is a single cartilage just behind the tongue, attached to the thyroid somewhat like a trap-door. When the air is passing through the larynx, the epiglottis stands vertically, its free extremity curving forward toward the base of the tongue. During the act of swallowing it is carried downward and backward so as to completely close the *glottis*, or upper opening of the larynx.

The **vocal cords** are two ligaments covered with mucous membrane passing from the fixed thyroid cartilage in front to the movable arytenoids behind, across the sides of the cavity of the larynx, leaving a space of varying size between them, called the *rima glottidis.* A little above the vocal cords are two ridges or elevations, which have received the name of the *false* or *superior vocal cords.* Little muscles passing from the thyroid and cricoid cartilages to the arytenoid are capable of separating and approximating the points to which the cords are attached, and thus altering the size of the rima glottidis and changing the tension of the cords.

3. The Trachea, or *wind-pipe*, extends from the larynx downward about four inches and divides to form the bronchial tubes, or bronchi. The trachea is a peculiar tube, so constructed as to combine the proper amount of flexibility with sufficient rigidity to remain an open tube under all circumstances. It is composed of incomplete rings of cartilage, from sixteen to twenty in number, and held together by fibrous membrane. The rings surround about two-thirds of the tube, leaving a space at the back composed entirely of fibrous tissue with a few muscular fibers. Its diameter is about three-fourths of an inch.

4. The Bronchi. — The right *bronchus*, or branch of the trachea, is a little shorter and wider and is placed more horizontal than the left *bronchus.* Each bronchus divides and subdivides many times, exactly like the branches of a tree, and thus penetrates every portion of the lungs. In structure the bronchi are somewhat similar to the trachea, being made up of fibrous membrane and cartilaginous imperfect rings.

5. A continuous layer of **mucous membrane** lines the larynx, trachea, and bronchial tubes. The mucous membrane of the trachea and bronchial tubes is thickly set with what the anatomist calls *ciliated epithelium;* that is, a layer of cells, each of

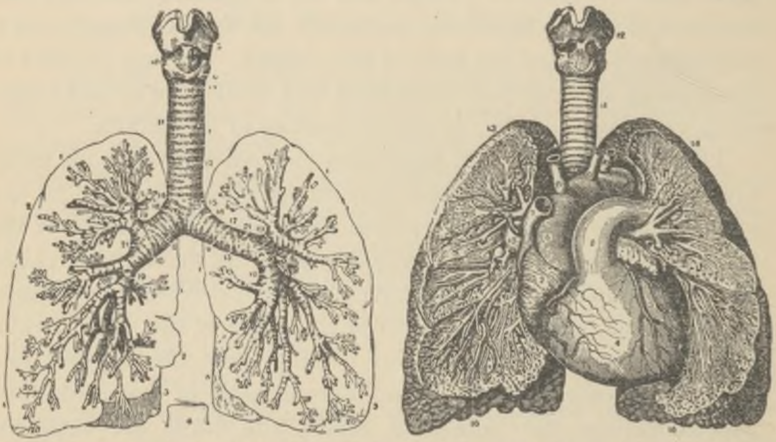


FIG. 17.—MAIN ORGANS OF CIRCULATION AND RESPIRATION.

1. The Larynx, Trachea, and Bronchi, deprived of their fibrous covering, and with the outline of the lungs. 2. A view of the Bronchi and Blood-vessels of the Lungs, as shown by dissection, as well as the relative position of the lungs to the heart.

which has several exceedingly fine, hair-like projections. These projections are called **cilia.** They have the peculiar power of moving all at the same time and in one direction, so that if small particles be placed on them they are carried along like a boat in the current. This motion is always toward the mouth. In this way foreign particles, as dust, taken in with the air, are expelled. This motion is distinct from muscular movement. In many of the lower animals cilia play an important part in their life history. The oyster, and many other species of marine animals, swim about in the water by means of cilia when in a very young state, and when fixed for life in the adult stage currents, created by cilia, bring them their food.

It must be remembered that **mucous membrane** *lines all cavities* in the human body *accessible to air.* The mucus secreted acts as a protection from the irritating influences of the air.

6. The Lungs. — The entire cavity of the chest, with the exception of the comparatively small space occupied by the heart and its blood-vessels, and the esophagus, is filled by the two lungs. They even extend a little way into the neck. When the cavity of the chest is increased by the elevation of the ribs and lowering of the diaphragm, the lung-tissue expands and fills the enlarged space. They are in the shape of irregular cones with the apices above. The right lung has three lobes or divisions below, and the left two lobes.

The lungs are a rose color, or light pink, in early life, but get darker as age advances. This dark color is more marked in persons who dwell in large cities or near factories, where the atmosphere contains much coal smoke. The color is due to particles of carbon inhaled during life.

The lungs are very light in weight by reason of the air in the cells. When once air has entered the air-cells a certain portion always remains, so that the lungs of an animal which has once breathed will always float in water.

7. Structure of the Lungs. — Following out the bronchial tubes, which are really a part of the lungs, we come to the smallest branches which are from $\frac{1}{120}$ to $\frac{1}{75}$ of an inch in diameter. These branches open into a collection of oblong vesicles, or tiny bags of membrane, called **air-cells.** These collections of air-cells are called lobules (little lobes). Hales estimated the combined surface of the air-cells at 289 square feet, and Lieberkühn at 1500 square feet. Professor Flint thinks we cannot tell how near the truth these estimates are, but it is simply evident that the extent of surface is very great. Around each lobule is a fine net-work of capillaries, the terminations of the branches of the pulmonary artery, the beginnings of the pulmonary veins. A fine connective tissue holds all these vessels and air-cells and tubes together, and among them ramify arteries which supply the lung-tissue with blood, and lymphatic vessels permeate every part.

8. The Pleura. — The cavity of the chest is lined, and the lungs are covered with a continuous, delicate, serous membrane called the *pleura*. It thus forms a complete sac, and its inner surfaces secrete a fluid which lubricates them and prevents chafing when the lungs move in the chest. When this membrane is inflamed, the disease is known as *pleurisy*. This disease is liable to be brought on by exposure to cold and dampness.

PRACTICAL ILLUSTRATIONS.

1. Get a live mussel shell from a stream or lake. Place it in clear water in a shallow dish with a little sand in the bottom. Leave it undisturbed for an hour, then drop a little powdered indigo into the water close to the shell. You will soon observe two openings at one end of the shell, and a current of water, as shown by the particles of indigo, going into one and out of the other. With a small magnifying glass you may be able to see the *cilia*, which surround the openings and produce the currents.

2. Get the lungs of any animal from a butcher. The trachea and larynx will usually be attached. The larynx differs so much in size and shape in different animals that only a general idea of the human larynx can be obtained. Its general construction of pieces of cartilage and membrane may be shown, and the epiglottis and vocal cords may be seen, but they differ considerably in different animals. The trachea differs mainly in size from that in man, and a good idea may be formed. Cut it through lengthwise and show the cartilaginous rings.

3. Place a tube in the trachea and blow into the lungs. Observe their increase in bulk as the air passes into the cells. Cut off a portion of lung-tissue and throw it into water to show its extreme lightness. Cut through the mass of a lung to observe the cut ends of the bronchial tubes and arteries of different sizes. With a narrow knife-blade slit open a bronchial tube, following it as far as possible into the minute branches.

4. Make an artificial larynx to illustrate the action of the vocal cords thus: Over the end of a short tube about an inch in diameter tie two pieces of sheet rubber or gutta-percha so as to leave a narrow slit between them. By properly adjusting these bands and blowing in the other end of the tube, you will be able to produce a sound, which will be caused by the vibration of the bands and the column of air passing through the narrow slit.

LESSON 23.

Respiratory Processes.

1. **Respiration.** — Breathing, or respiration, is the process of taking air into the lungs (inspiration) and expelling it again (expiration). Respiration is mainly an involuntary or automatic process. We can voluntarily hold our breath for a time, but in a few seconds an uncomfortable feeling compels us to take in and expel air. An animal cannot live long after respiration has ceased. In cases of suspended animation, where the person is supposed to be dead, respiration seems to have entirely ceased, but a small amount of air is exchanged and breathing really goes on, although unperceived.

2. **The Mechanism of Inspiration** is as follows: The air enters the lungs through the nose or mouth (or through an artificial opening in the trachea) by atmospheric pressure caused by enlargement of the cavity of the chest. When you lift one board of a pair of bellows you enlarge the cavity and the air is forced in at the opening by its pressure, just as water enters a bottle when it is thrust into the water. The chest is a piece of mechanism very similar to a pair of bellows. There are two chief means of enlarging the chest cavity: (1) *By the descent of the diaphragm.* This is a muscular partition across the cavity of the body, dividing it into two principal cavities, the thorax and abdomen. When at rest the diaphragm is convex on the upper side. It has a tendon in the central portion, and the fibers radiate from it to the walls of the chest. When these fibers contract they cause the diaphragm to become much flatter by pulling the central portion down. This has the effect of lowering the general level of the floor of the chest cavity. (2) *By the elevation of the ribs.* In the cuts of the skeleton you will observe that the ribs at rest have a general slope downward from the spinal column. In inspiration all of the ribs are raised a little, and the general effect is to throw them forward and spread them out, and thus the cavity of the chest is enlarged

both from before, backward, and from side to side. The ribs are raised by the contraction of the external intercostal muscles, assisted by certain muscles of the back, neck, and shoulders. In forced, or labored, inspiration still other muscles come into action, but all have a tendency to elevate the ribs.

3. **Mechanism of Expiration.** — In ordinary breathing expiration is mainly the elastic reaction of tissues. The diaphragm returns to its state of rest in a convex position by the reaction of the abdominal organs which have been compressed and pushed against the abdominal walls. The ribs are returned to their position by the elasticity of the sternum and costal cartilages which they have bulged out. Likewise the tissues of the lungs, which have been stretched by the inrushing air, resume their original condition and aid in expelling the air. In forced and labored expiration the abdominal muscles come into play by forcing the contents of the abdomen up against the diaphragm, and the internal intercostals tend to pull the ribs down.

4. **Rate of Respiration.** — A healthy adult breathes on an average eighteen times per minute. The rate of respiration is *increased* by food, exercise, moderate cold, stimulating medicines, and in certain conditions of disease; and is *diminished* by moderate heat, inactivity, depressing medicines, starvation, and in certain diseased conditions. The respirations are more frequent in children than in adults, and more frequent in women than in men. The rate rarely exceeds twenty-five per minute or falls below fourteen. A man breathes about nine million times in a year.

5. **Lung Capacity.** — The lungs are capable of holding from 300 to 320 cubic inches of air. There is always a portion of air which *cannot* be expelled by the most forcible expiration. This is called *residual* air. There is a large quantity which *can* be expelled by a forced expiration. This is called *reserve* air. A like quantity can also be taken in by a forced inspiration. This is called *complemental* air. The quantity actually moved in ordinary respiration is comparatively small and is called *tidal* air. The following table shows the relations of these various quantities: —

Total Lung Capacity	300 to 320 cubic inches.
Residual Air	100 " 130 " "
Reserve Air	90 " 100 " "
Complemental Air	90 " 100 " "
Tidal Air	20 " 30 " "

The residual air slowly diffuses with the reserve air, and while it remains the same in quantity its quality does not deteriorate. The presence of the residual air prevents sudden variations in the temperature, kind, and amount of air inhaled. About every fifth respiration is more forcible than the others.

6. **Exchange of Gases.** — Atmospheric air contains about four parts **nitrogen** to one part **oxygen**. The nitrogen is almost, if not completely inert, and serves only to dilute the oxygen, which is the great life-sustaining element in nature. The expired air contains about four or five per cent less oxygen than the inspired air, and about four per cent more carbon dioxide (carbonic acid gas), or to be more exact: —

		Oxygen.	Nitrogen.	Carbon dioxide.
Inspired Air	=	20.81 parts.	79.15 parts.	.04 parts.
Expired Air	=	16.033 "	79.557 "	4.38 "

Thus we see that the lungs have taken oxygen from the air and given back carbon dioxide. Now this latter gas is produced by the union of carbon and oxygen. This takes place in all ordinary combustion of fuel, since nearly all fuel is mainly carbon. We must not conclude, however, that the process of combustion in the body is exactly the same as in ordinary burning of fuel. We know that outside of a living body it requires a temperature of more than 200 degrees to cause oxygen and carbon to unite, and that the temperature of the animal body seldom goes above 100 degrees. The carbon dioxide must be produced not by direct union of oxygen with carbon but by the breaking up of tissues of the body which contain carbon and oxygen. The oxygen which is taken in is probably used with the carbon and nitrogen of the food to form new tissues.

7. **Effects of Respiration on the Air.** — We have observed elsewhere that the blood after passing through the capillaries of the lungs, and coming in contact with the air-cells, is returned to

the heart much brighter in color. This is due to the oxygen which it has absorbed. A similar effect may be produced on venous blood by shaking it in a vessel containing pure oxygen gas.

Besides carbon dioxide, the expired air contains various other ingredients which it did not before possess. Ammonia gas, which exists in ordinary atmosphere in only minute quantities, is found to be present in a greater proportion in air that has been breathed. Also various organic matters, which are believed to be highly poisonous, when again inhaled in considerable quantities, are given off at each breath. It is not the carbon dioxide thrown off in breathing that is poisonous, but these organic matters, as is shown by the experiment of breathing an atmosphere containing one per cent of carbon dioxide with a corresponding diminution of oxygen, as compared to breathing atmosphere in which the carbon dioxide has been raised to one per cent by breathing. In the first case no perceptible effect is produced, but in the second much depression and uneasiness follows.

8. Modified Respiratory Movements. — There are several common phenomena connected with breathing which should be explained in this connection. These are as follows: —

Sighing, a long, deep inspiration, chiefly through the nose, followed by a shorter expiration.

Yawning, similar to sighing, but longer continued, and the air drawn through the widely opened mouth.

Hiccough, or *hickup*, a sudden inspiration caused by spasmodic contraction of the diaphragm and sudden closure of the glottis, the well-known sound being caused by the column of air striking the closed glottis. It is sometimes difficult to control and becomes an alarming symptom, requiring medical skill.

Sobbing, a series of short, convulsive inspirations with closure of the glottis.

Coughing, a deep and long-drawn inspiration, followed by a closure of the glottis, and then by its sudden and forcible opening, allowing a blast of air to be driven through the mouth. It is sometimes an effort to expel some irritating foreign substance in the air-passages, sometimes caused by an accumulation of mucus, and again by an irritation in some remote part of the body, being an example of pure **reflex action**, which will be explained in the chapter on the Nervous System. It is sometimes partly contagious, as in schoolrooms and assemblies the coughing of a few persons will be followed by that of a large number. To a certain degree only it is under control of the will.

Sneezing, the same as coughing, except that the air is driven through the nasal passages instead of through the mouth. It is generally caused by some irritation in the nose, but it may be produced through the nerves of the eye by strong light.

Laughing, an inspiration followed by a series of short expirations which set the vocal cords in vibration.

Crying, similar to laughing, but with different facial expressions, and generally caused by opposite emotions.

Hawking, a voluntary forced expiration directed towards the larynx and pharynx to clear them of some obstruction.

Grunting, a short, voluntary expiration causing vibration of the vocal cords. **Groaning** is similar, but more or less involuntary.

9. The Vocal Sounds are made by expiratory efforts modified by the tongue, teeth, lips, larynx, and palate.

PRACTICAL ILLUSTRATIONS.

1. To illustrate how raising the ribs enlarges the chest cavity, get a flexible twig or piece of whalebone and form a hoop which will just encircle the chest closely, when placed somewhat diagonally, that is, with the front part lower than the back part. Then let some one hold the hoop against the body at the back, while you raise the front part so as to bring it on a level with the back part. Observe the increase of space between the front part of the hoop and the body.

2. Procure a large pail nearly full of water, a common glass fruit-jar, a piece of rubber tube about two feet long, a bit of candle, and some lime-water. (The lime-water must be made by immersing a lump of quick or unslaked lime in water and allowing it to remain until it has settled. Then pour off the clear solution into a separate bottle.) With this material the following interesting experiments may be made: —

a. Fill a glass fruit-jar with water by immersing it in a pail of water, and without taking it out invert it, and hold it so that only the mouth will be under water. The atmospheric pressure will sustain the water in the jar above the level of that in the pail. Now put one end of the rubber tube beneath the mouth of the jar, and the other end in your mouth, and slowly expel the air from your lungs until you have caught a jar full of expired air. In this way you get the expired air free from any mixture with the atmospheric air. Now place the palm of your hand under the jar and, holding it tightly (keeping the palm flat), place the jar right end up on the table, and keep the hand firmly pressed on the mouth until an assistant can hand you a piece of lighted candle fixed on a piece of wire. Then quickly remove the hand and slowly lower the candle into the jar. The candle will cease to burn in the expired air, since it has been deprived of much of its oxygen.

To make this experiment a success you must take in a good breath and hold it for several seconds, and then exhale slowly through the rubber tube; otherwise the air will not have been sufficiently deoxygenated.

b. Fill the jar with expired air as in *a.* On removing the hand pour in a little lime-water. Then replacing the hand shake vigorously for a minute. Observe that the clear lime-water becomes milky white. This is due to the carbon dioxide of the breath uniting with the lime to form carbonate of lime, which gives the milky precipitate. (Lime-water is thus a test for carbon dioxide.)

c. Allow a bit of candle to burn for a minute or two in the bottom of a clean jar. Then remove it and pour in a little lime-water and shake as in experiment *b.* The clear lime-water becomes milky, showing that the product of combustion is the same (carbon dioxide) as the product of breathing.

d. Modify experiment *b* by placing one end of the rubber tube in a bottle of clear lime-water, and breathing slowly through the other end. Result, a white precipitate of carbonate of lime same as in the other experiments.

LESSON 24.

Hygiene of Respiratory System.

1. Necessity for Pure Air. — The blood needs oxygen. Pure air contains a sufficient quantity and the blood absorbs it in the lungs. If the air be mixed with other gases the amount of oxygen will be to that extent lessened. But unless these other gases be considerable in quantity the effect will not be perceptible. The greater danger lies not in the displacing of a small amount of oxygen, but in the substitution of gases injurious in themselves. Carbon dioxide, which is given off in the breathing of animals and in combustion and decay of organic matter, seems not to be injurious in itself, but displaces a certain amount of oxygen, yet the amount ordinarily displaced would hardly do any harm. Ammonia sometimes exists in considerable quantity in the air. It is irritating and injurious. So are some of the gases thrown into the air from factories of various kinds. Carbon monoxide is a poisonous gas, sometimes produced in badly constructed cast-iron stoves, and when thrown into the atmosphere of improperly ventilated rooms produces headache and dizziness.

Air which has once been breathed is unfit for immediate respiration because it contains certain organic substances which are poisonous. This exhaled air becomes purified by mingling with the mass of the atmosphere in various ways. Water and other liquids absorb some of the impurities. Plants take up a certain amount of the carbon dioxide, and all becomes so diluted by the atmosphere that only infinitely small quantities can be again inhaled where ventilation is perfect.

By **pure air**, then, we mean air containing the average amount of oxygen, nitrogen, carbon dioxide, and watery vapor, and the absence of injurious gases and solids in the form of dust.

2. Moisture in the Air. — All air contains more or less water in a state of invisible vapor. This can be shown by the simple experiment of filling a dry glass tumbler with ice-cold water and allowing it to stand for a few minutes in a warm atmosphere. Moisture soon collects in drops on the outside of the vessel, being condensed from the atmosphere. When air contains a very large amount of watery vapor it contains correspondingly less oxygen, hence the air seems heavy (although it is really lighter), because the respiratory apparatus must make greater effort to get the proper amount of oxygen for the blood. On the other hand, air which is too dry irritates the delicate structures of the lungs and air-passages. The air of rooms becomes frequently too dry when heated by stoves. A vessel of water placed where it will evaporate rather rapidly will improve the quality of the air in such cases, but care must be taken to see that the water and the vessel containing it are clean.

3. Dust and Disease. — Although we cannot see it always, the air contains at all times solid matter in the form of fine particles. When the sun shines through a small opening into a room we can see this dust, which is illuminated and appears as a bright band. Tyndall showed by illuminating the air by electric light that no air is free from dust. The dust consists of sand, clay, particles of carbon from smoke, fibers from clothing, hairs and epidermal scales from animals, particles of dried expectorated matter, and other objects. But the worst matter held in suspension is the minute germs or seeds of low orders of plants. These germs (generally called **bacteria**) are now shown to be the causes of most of the diseases which affect mankind. They find their way into the blood, and if they be numerous enough and the system in a proper condition for them, they grow and multiply, and this constitutes the disease, the different diseases being produced by different species of germs. The coarse particles, when numerous, are also injurious, as they irritate the delicate membranes of the air-passages. Wherever air is known to be unusually full of dust and where disease germs are suspected, a filter of cotton wool placed over the mouth should be used. This will almost completely arrest particles and germs. This arrangement is particularly useful in the sick-room where contagious disease exists.[1]

4. Danger of Draughts. — While it is important to secure fresh and pure air, in our efforts to do so we frequently subject ourselves to greater dangers. When the body is heated by exercise and weakened by fatigue, and we remain quiet in a place where a strong current of cold or cool air exists, we take great risk of "catching cold." A "cold" is a condition of the mucous membranes caused by a sudden or great lowering of the temperature

[1] Modern physicians and surgeons have gained great control over diseases by what is known as *antiseptic* treatment. In all operations of the surgeon every precaution is now taken to prevent germs entering the system through wounds and openings, and to destroy those which may already have come in contact with a denuded surface. The hands of the surgeon and assistants, all the instruments, bandages, and appliances are treated with certain chemicals which are known to destroy bacteria. In typhoid fever, consumption, diphtheria, scarlet fever, and other diseases due to germs the physician takes every precaution to destroy and prevent the spreading of these germs, and the result is that these diseases have lost much of their fearful nature. Babies fed upon artificial food, under the skillful physician's care, now have their food *sterilized*, that is, subjected to a certain degree of heat for a certain time until all germs are destroyed.

of the body. It usually affects the mucous membrane of the respiratory passages, but it may in many cases affect the alimentary canal, so that various disturbances of the digestive function will result. Diarrhea and dysentery are frequently brought on by being exposed to draughts. One is scarcely liable to take cold when exercising in a draught, because the exercise keeps up the body temperature, but when at rest there is danger, more especially if the person be of delicate organization and accustomed to an indoor life. Long exposure to severe cold and to cold winds frequently causes severe colds and internal inflammations. We do not always take cold even under the same external circumstances, because the system has greater power of resistance at some times than at others. It is not well to take risks of this kind. Rooms should be so ventilated that while a constant supply of fresh air is secured, no draughts will strike the inmates.

5. Proper and Improper Ventilation. — The common method of ventilating a room is by opening windows at top or bottom, or at both places. This in many cases exposes one or more of the inmates to dangerous draughts. In very warm weather it matters little, as a draught is not liable to be dangerous; but when the temperature is higher inside than outside of the room, it is risking too much to sit still near an open window or door. Air that has just been breathed, and air of a room sustaining a fire, is warmer and consequently lighter than the air outside, and when a window is opened at only one place, a double current is established — one of cold air coming in, and one of warm air going out; the colder one always being below. If a window is opened at both top and bottom the cold current flows in at the lower opening, and the warm one out at the upper opening.

Where there is no other way to ventilate than by opening windows, a good plan is to fix a board to the upper sash so inclined that the air-current is directed against the ceiling, and thus spread out through the room. Another good plan is to fix a strip of board to the window-sill so that the lower sash will not come quite all the way down. Then a space will be left between the upper and lower sash opening upwards and not directly towards the inmates.

In a properly ventilated room there should always be an opening for fresh air near the stove or other source of heat, and another opening for the exit of foul air at a point farthest from the source of heat. Then the cold air enters, becomes warmed, and circulates through the room, while the foul air is by it forced out.

This is an important subject. Statistics show that fully one-fourth of all the deaths in the United States are from consumption, and a very large per cent of the rest from pneumonia and other diseases of the respiratory passages. These diseases are generally due, it is true, to specific germs, which in most cases cannot be prevented from entering the system; but those with vigorous constitutions are able to resist the encroaches of the germs, while those whose organs have been weakened by colds and other troubles brought on by draughts and foul air, are the ones who succumb to the deadly germs.

6. Air of Sick-rooms. — Nowhere is proper ventilation more important than where persons are lying sick. Every effort should be made to secure a constant change of air without exposure to draughts. Much may be done in the way of removing gaseous impurities in the air of sick-rooms by keeping vessels of water standing open. The water absorbs the gases to a considerable extent. The water should be changed every few hours.

7. Exercise and Respiration. — Judicious exercise, especially of the muscles of the chest and arms, is greatly beneficial to the respiratory organs. Young persons should take frequent drills in arm movements, raising and lowering the shoulders, at the same time standing erect with the shoulders well drawn back. Those occupations which bring into use the muscles of the chest, without overworking them, are conducive to a healthy respiratory system. Many a man hastens to his death from consumption by an indoor life and want of judicious exercise. Walking is a good exercise for the digestive system and the circulation; but for the better development of the respiratory organs, more exercise of the muscles of the upper part of the body is needed.

Breathing exercises, if carefully carried on, are excellent. Stand erect, throw the shoulders well back, and slowly inhale; then slowly exhale. Repeat this several times in succession. Do this every day in the open air. *Always inhale through the nose; never through the mouth.* Observe this at all times. The nasal passages modify the temperature of the air and catch a great deal of the dust which otherwise would pass into the trachea and lungs. Keep the mouth closed except when eating or talking.

8. Effects of Alcohol on Respiration. — Alcohol causes at first an increased warmth on the surface of the body, because the capillaries are dilated and more blood flows to the surface. This is true of the lungs also. In fact the lungs and mucous membranes are simply arrangements to secure a vast amount of internal surface accessible to air. Respiration is at first increased also. But soon a reaction occurs. The surfaces lose heat by radiation and evaporation, and the respiratory apparatus fails to keep up its usual work, and general depression follows. Frequent repetition of this causes in time permanent enlargement of the capillaries of skin and lungs. Respiration cannot be perfect when the capillaries of the lungs are engorged, as the air-space is correspondingly diminished.

Inebriates frequently succumb to lung diseases, but it is often indirectly due to their carelessness in protecting themselves from cold and dampness, the alcohol blunting their sensitive nerves.

9. Effects of Tobacco on Respiration. — Tobacco exerts no direct effect on the respiratory organs, except in some cases it produces much irritation of the mucous membranes. But by its effect on the nervous system, digestion, and circulation, it indirectly affects the respiration and is especially injurious to young and nervous persons.

EXERCISES FOR REVIEW.

1. What is oxygen? State the composition of pure air. What effect has nitrogen in respiration? Carbon dioxide? Ammonia?

2. If a solid body were dropped into the trachea, which one of the bronchi would it enter?

3. What is the use of the cartilaginous rings of the trachea?

4. What is the use of the epiglottis? Describe the vocal cords. What change in tone would be produced by increasing the tension of the vocal cords? What would be the effect of enlarging the rima glottidis?

5. What is the pleura? What organ or part of the circulatory system is similar in structure and function to the pleura?

6. Comparing the respiratory apparatus to a pair of bellows, what is analogous to the valve of the bellows? What causes the air to enter the lungs?

7. What has the air lost by respiration? What gained?

8. How many times do you breathe in a minute? What is reserve air?

9. What relation have *bacteria* to the respiratory system?

10. Why is a draught injurious? What is meant by "taking cold"?

11. What are *cilia?*

12. Where do we find mucous membranes?

13. Why should we not breathe through the mouth?

14. How may we strengthen and deepen the voice? By forming the habit of *full and deep breathing.*

15. How may we acquire flexibility, grace, and melody in utterance? By constant practice upon suitable exercises under the criticism of a master of vocal expression.

CHAPTER IV.

WASTE AND REPAIR OF THE BODY, OR THE SECRETORY SYSTEM.

LESSON 25.

The Skin.

1. The skin is that layer of tissue which covers all parts of the body exposed to the air, except that which is covered with mucous membrane. It is a very important part of the body in many ways. It not only protects the deeper parts and gives beauty to the individual, but with its appendages it is an important secreting and excreting organ. It is like an elastic and tight-fitting garment which is easily kept clean and renews itself as fast as it wears out. It consists of two principal layers: (*a*) the *epidermis*, *cuticle*, or *scarf skin;* (*b*) and the *cutis vera*, or *true skin.*

2. The Epidermis. — This is the external layer, and is composed of what is called horny tissue, entirely destitute of blood-vessels and nerves. It consists of two layers, the outer, of hard, flattened, nearly transparent cells which are continually coming off in the form of minute scales. These scales on the scalp constitute the so-called "*dandruff*." The deep layer consists of cells more or less rounded and softer than those of the outer layer. They contain a *pigment*, or coloring matter, which gives the different races of men their peculiar color and complexion. These cells become flattened and elevated and replace those of the outer layer, which are constantly coming off.

The epidermis is an important part of the skin, as it affords protection from irritating objects, prevents the too rapid escape of heat, and limits the amount of evaporation of water. Were it removed from the entire body we would suffer acutely from the irritating effects of the air, from the cold, and from contact with objects. Indeed, the irritation produced by the air alone, if the entire epidermis were removed, would probably be so great as to cause nervous collapse and death. A blister is simply a portion of the epidermis raised by the accumulation of serum under it. This outpouring of serum may be produced by heat, by pressure, and by certain chemicals.

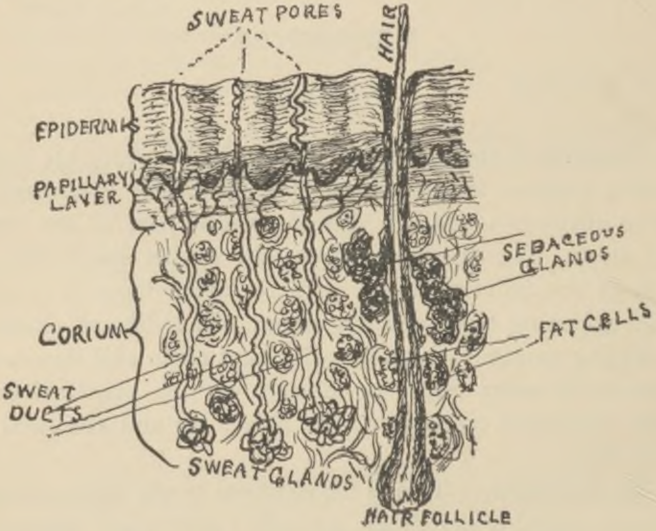


FIG. 18.—VERTICAL SECTION OF THE SKIN.

3. The Derma, or True Skin. — This is also composed of two layers: (*a*) the superficial, or papillary; and (*b*) the deep layer, or corium. The *papillary layer* is composed of numerous conical projections which in the palm of the hand appear in rows, forming those peculiar little ridges we see. These projections, or papillæ, are extremely sensitive and vascular, containing terminations of nerves and capillaries. The *corium*, or deep layer, is dense, tough, and elastic, and consists mainly of bundles of white fibrous tissue and some yellow elastic fibers and muscular fibers, so arranged as to form spaces called *areolæ*. These spaces contain fat, hair-follicles, and the glands of the skin. The corium of the skin of animals, when thickened and hardened by chemicals, constitutes leather.

4. **Muscles of the Skin.** — If the surface of the body be suddenly exposed to cold air the skin raises in little lumps, producing what is familiarly known as "gooseflesh." This is caused by the contraction of tiny muscles which run in a slanting direction through the corium. They cause, to a slight extent in man, the hair to "stand on end." In the skin of the back of a dog and the tail of a cat, they are capable of making the hairs to stand almost at right angles with the surface. These muscles also aid probably in throwing out the oil from the sebaceous glands.

5. **Peculiarities of the Skin.** — The skin varies in thickness in different parts of the body, and slightly in different individuals. On the nose and some other parts it is not much more than one-sixteenth of an inch, while on the sole of the foot it is frequently a half inch or more. The increased thickness on parts that receive pressure and friction is mainly due to a thickening of the epidermis. The pigment, or coloring matter, of the skin, hair, and eyes is entirely absent in some rare cases. Such individuals are called **albinos**. This peculiarity is more frequent among the dark races and in hot climates. The Caucasian race is called the white race, but they are really the red or ruddy race, as the small amount of pigment in the epidermis permits the color of the blood to show through the nearly transparent epidermis and walls of the capillaries. *Freckles* are collections of pigment matter in spots or masses.

The skin is connected to the rest of the body by thin layers of fibrous tissue, between which lie the superficial veins and nerves and a variable amount of adipose (fatty) tissue.

6. **Uses of the Skin.** — 1. The insensible epidermis mechanically protects the true skin from the air and external objects, yet does not prevent the necessary escape of waste material. 2. The cutis vera furnishes a bed for the numerous glands which will be described in a succeeding lesson, and affords a support to the numerous capillaries which are necessary to sup-

ply blood to these glands. It also serves in a great measure to protect the superficial veins and nerves and the muscles beneath it. 3. The skin as a whole prevents the rapid radiation of heat from the body. This is aided by the adipose tissue beneath, which always exists in greater or less abundance. With its special glands it is one of the most important secreting and excreting organs. (See the following lessons in this chapter.)

LESSON 26.

The Appendages of the Skin.

1. The hair and nails, and the sweat and oil-glands of the skin, may be conveniently described as appendages, although in a certain sense they are really parts of the skin.

2. The Nails. — The ordinary observer would not think of classifying the nails with the skin, for at a glance they seem totally different. But microscopic and chemical investigations show that they are composed of modified epidermal cells. A nail has a root, body, and free edge. The root is covered by a fold of the skin, and the body is firmly attached to the *matrix*, as the tissue beneath is called. The nail has two layers, a hard, horny, insensible layer above, and a softer, or mucous layer beneath. The nail grows by a continual accession of new cells beneath and at the extremity of the root. The horny layer is thus pushed upward and forward, and worn off or cut off. Nails will grow several inches in length if not cut and care is taken to prevent undue wear and breakage. If a nail is pulled out it will be renewed if the root and matrix be not injured. The entire nail is removed by wear and cutting, and renewed by growth about every four or five months.

The uses of the nails are obvious enough. The ends of the fingers are protected, and we are enabled to pick up small objects with greater facility and to grasp more firmly.

3. The Hair. — The hair, like the nails, consists of modified epidermal tissue. Each hair has a shaft, or stem, a root, and a point. The point of a hair which has not been cut is tapering and ragged. The shaft is a slightly flattened cylinder. The outer portion, or cortex, is composed of cells overlapping each other like shingles on a roof, the free ends towards the point of the hair. Beneath the cortex is the fibrous portion consisting of long cells containing the pigment, which gives hair its characteristic color. When the hair turns gray, the pigment disappears and air takes its place. In the centre is the medulla, or pith, consisting of irregular cells and air-spaces. The root of the hair is slightly enlarged, and is enclosed in a little bag called the hair-follicle. In the bottom of this follicle is a point or germ from which a new hair grows when one is pulled out. The hair-follicle is usually in the corium, but in large hairs it extends beneath it. To stop the growth of hair, the germ at the bottom of the follicle must be destroyed. This is no easy matter.

4. Peculiarities of the Hair. — The hair grows by additions to the root end. When not cut, hair reaches a certain length (varying in individuals and races), and then grows no faster than will make up for the wear at the point. There are some cases of extremely long hair, especially on the heads of women. One woman's hair measured six feet two inches. Men's beards attain great length in some cases. Almost every square inch of surface of the skin is covered with short, thin hair. This has been known in a few cases to attain a remarkable length over almost the entire body.

The immediate cause of hair turning gray is the absorption of the pigment matter and its replacement by air. Why this should take place in some at an early age, and in others not until old age, is not easily explained. Neither can we explain baldness, nor those rare cases where the hair turns gray from great grief or sudden fright in a few hours.

Hair is very durable. That found on Egyptian mummies has remained unchanged through thousands of years. It is elastic, and may be stretched one-third of its length without breaking. It absorbs moisture readily, and is thereby lengthened considerably.

5. Uses of the Hair. — The principal use of the hair is for protection from heat and cold. Being a non-conductor of heat, it keeps in the heat of the body, and keeps out external heat. It also serves as a protection to some degree from blows and pressure. On the body the hair helps to drain off the sweat. A heavy beard protects the throat and face from cold winds, and a thick mustache serves to arrest dust that might be inhaled and modifies slightly the cold of the air before it enters the air-passages.

6. The Sweat-glands. — The *sudoriparous*, or sweat-glands, consist of very fine tubes beginning with a coil in the tissue just beneath the corium, passing in a spiral or wavy course through the skin, and terminate on the surface in the *pores*. They are found in nearly every part of the skin, their total number being estimated at 2,400,000. They are abundantly supplied with blood-vessels and nerves, and are important excretory organs, being the main outlets for the superfluous water of the system, the water carrying in solution certain waste materials. (See Lesson 28.)

7. The Oil-glands. — The sebaceous, or oil-glands, are found over nearly the whole body, but are most abundant on the scalp and face. They are absent on the palms of the hands and soles of the feet. They consist of clusters of little rounded sacs situated in the corium, or just beneath it, with a duct which opens either on the surface or into the upper part of a hair-follicle. They secrete an oily substance which keeps the skin soft and pliable, and protects it from the irritating effects of the perspiration. It is also the natural "hair-oil," keeping the hair from becoming dry and brittle. The oil is carried by capillary attraction along the entire length of the longest hairs. It also flows to the palmer surface of the fingers, so that if you rub your finger on a piece of white paper you will make a grease spot more or less distinct. The sebaceous glands on the nose and cheeks sometimes are quite large, and opening on the surface they gather dust and smoke, and have the appearance of little black dots. By pressure a mass of sebaceous matter may be squeezed out. This mass is supposed by some to be a worm with a black head. There are, however, sometimes parasites, visible only by the aid of a microscope, found in these glands. (See Lesson 28.)

LESSON 27.

Mucous and Serous Membranes.

1. Extent of Mucous Membrane. — All free surfaces, directly or indirectly exposed to the air and not covered with the skin, are covered with mucous membrane. This membrane is much more extensive than one might suppose. It lines the air-passages, which include the nasal cavity, certain cavities in the bones of the face and cranium, the mouth, the pharynx, the Eustachian tube, the larynx, trachea, and bronchial tubes, and the air-cells of the lungs. It lines the entire alimentary canal, which is about thirty feet in length, and the ducts of all glands which pour their secretions into it, as the salivary ducts, the ducts of the liver and pancreas. Also the kidneys and their ducts and the bladder. To sum up, it lines all cavities and passages which have external openings direct or indirect.

Fig. 19.—Ciliated Epithelium from Trachea.

2. Structure. — Mucous membrane consists of one or more layers of cells, sometimes called **epithelium**, arranged on a fibrous tissue. The cells of the different layers differ in shape and size. The cells of the outer layer show a tendency to come off, and their places are taken by cells from the layers beneath, these cells becoming changed in form as they approach the surface. The cells of the outer layer differ in different parts of the body; some are like columns, some rounded, some flattened. Columnar epithelial cells, with fine, hair-like projections called **cilia**, exist in the respiratory passages. The uses of these cilia were explained in the chapter on Respiratory System.

The epithelium has no blood-vessels and, with some exceptions, no nerves. The fibrous tissue beneath is abundantly supplied with blood-vessels and nerves. In this fibrous tissue are found in many places mucous glands and special glands, as those of the stomach and intestines.

3. Uses of the Mucous Membrane. — The mucous membrane serves to protect all internal surfaces exposed to air, which is always an irritant to the delicate tissues of the organs of the body. It is continually kept moist by the secretion of mucus. This acts as the protective agency not only against the air, but against gases and solids which exist in the air as impurities. The membrane is easily injured by sharp or rough bodies, but heals again with remarkable rapidity.

4. Extent of Serous Membranes. — All surfaces not exposed to the air are lined with serous membrane. Such surfaces are not quite so extensive as those lined with mucous membrane, but they are equally necessary and important. In the brain and spinal cord are found certain cavities. These are lined with serous membrane. All the organs of the thoracic cavity are covered with a serous membrane, which is reflected and lines the walls of the cavity also. That which covers the lungs and lines the chest walls is called the pleura. A serous membrane covers the heart and lines the pericardium. That which lines the abdominal cavity and covers all the organs within it is called the **peritoneum.** It has many divisions, which take different names. A serous membrane lines the blood-vessels and lymphatics and the cavities of the heart. It is also found in the internal ear. The synovial membranes of the joints are modified serous membranes.

5. Structure. — Serous membrane resembles mucous membrane somewhat in structure, consisting of layers of cells on a fibrous tissue. These layers of cells are sometimes called **endothelium.** The cells are usually flattened, and form a very smooth and shining surface, which is constantly moistened with a serous fluid. The endothelial cells contain no blood-vessels nor nerves, but the tissue beneath is abundantly supplied with them.

6. Uses of Serous Membranes. — They are mainly for the purpose of preventing friction of one part on another. The organs being covered with this smooth, moist membrane, and the cavities in which they lie being lined with it, they may move freely without injury. This membrane when exposed to the air or to foreign substances is easily irritated, and dangerous inflammations frequently follow such exposure. This explains why a wound through the abdominal cavity so frequently proves fatal. Blood, the contents of the alimentary canal, and the air, containing poisonous germs, are apt to cause *peritonitis*, or inflammation of the peritoneum, which is usually fatal. Surgical operations where it is necessary to expose this membrane were once attended with much risk of life, but modern surgeons take such precautions to preclude the entrance of germs, and to secure absolute cleanliness, that the risks are greatly lessened.

7. The Real Inside of the Body. — When food or a foreign body passes into the stomach we are accustomed to say that it is in the body, but anatomically and physiologically this is not correct. It is on the outside anatomically because the mucous membrane is continuous with the skin, which is the external covering. It is on the outside physiologically because the food must pass through the mucous membrane before it can be assimilated with the tissues of the body. There are some animals low in the scale which are in the form of a bag or flexible cylinder. They may be turned completely inside out and apparently suffer no inconvenience; the external covering becomes a digesting and absorbing surface, as the internal was before. This shows the close relation between the skin and the mucous membrane.

LESSON 28.

Secretion, Excretion, and Absorption.

1. Secretion and Excretion defined. — These terms are sometimes confusing to the student. The following, adapted from

Foster, explains their proper use: "The protoplasm (see Introduction) is continually undergoing chemical change (metabolism), room being made for the new protoplasm by the breaking up of the old protoplasm into products which are cast out of the body and got rid of. These products of metabolic action have, in many cases at all events, subsidiary uses. Some of them, for instance, we have reason to think, are of value for the purpose of dissolving and effecting other preliminary changes in the food introduced into the body; and hence are retained within the body for some little time. Such products are generally spoken of as **secretions**. Others, which pass more rapidly away, are generally called **excretions**. The distinction between the two is an unimportant and frequently an accidental one."

Some of these secretions, as saliva, gastric juice, bile, etc., have been discussed with the Digestive System.

2. Perspiration. — A large amount of the superfluous water of the system is disposed of through the skin in the form of perspiration. We are constantly perspiring, but so long as the perspiration evaporates as fast as it is produced we do not perceive it and call it insensible perspiration. Whenever it becomes so abundant as to collect in drops and appear as moisture we speak of it as sensible perspiration. The proportion of sensible and insensible perspiration varies with the amount of secretion and with the dryness and motion of the atmosphere. When the air is dry and in motion the evaporation is much more rapid and less appears as sensible perspiration. As the evaporation of the perspiration cools the body, this explains why our sensations are not a true index of the temperature of the atmosphere. When the air is dry and in motion we can endure a very high temperature, because evaporation is rapid and the body is parting with its heat at a corresponding rate. On the other hand, when the air is saturated with moisture and no breeze is blowing, we feel very warm, because the heat is retained in the body.

The total amount of perspiration varies with the fluids taken, nature of the food, temperature, amount of exercise, mental condition, and with the amount of secretion by other organs, especially the kidneys. The amount of perspiration is greatly increased in certain diseased conditions, and is affected by certain medicines.

3. **Uses of Perspiration.** — Besides carrying out a large amount of waste material, the perspiration is the main heat-regulating agency of the body. As stated in another place, the temperature of the body varies but little under all circumstances. The heat is constantly being produced by the combustion of the tissues, and the surplus is constantly being expended largely in evaporation of the perspiration. Some heat is lost by direct radiation, and some by warming the other excretions, and a considerable amount by warming the expired air. A cup of hot tea in warm weather, paradoxical as it may seem, is a cooling agent, since it induces copious perspiration, which cools the body by its evaporation.

4. **The Kidneys.** — The kidneys are two excreting glands situated in the "small of the back," behind the intestines. They are about four inches long, two inches wide, and one inch thick, and of the shape of a bean. They consist mainly of a series of minute tubes intermingled with blood-vessels. The secretion is carried to the bladder by two tubes, or ducts, called *ureters*. The use of the kidneys is to remove from the blood certain salts, and a poisonous, organic waste substance called *urea*. If in any way their action is interrupted, the blood becomes poisoned by the accumulation of urea and other waste matter, and serious or fatal results follow.

5. **Absorption from Surfaces.** — It is a well-known experience that bathing quenches thirst, and the body will gain in weight after immersion for some time in water. Medicines, such as liniments, are absorbed when rubbed on the skin. A quantity of mercury sufficient to produce salivation may be introduced into the system by simply rubbing it on the surface. A drop of prussic acid, if placed on the tongue of an animal, will produce death in a few minutes. The poison is evidently absorbed from the mucous membrane. If the epidermis be removed, absorption from the surface is very rapid. The digested food enters the system through the mucous membrane of the alimentary

canal by absorption, passing directly into the blood-vessels, or indirectly by way of the lacteals.

6. **Internal Absorption.** — If a frog be taken in the latter part of the "tadpole" stage and kept in water, in a few days its comparatively large tail will gradually disappear, the body increase in size, and legs appear, although not a particle of food be given it. What has furnished material for the growth of body and legs? Evidently the material of the tail has been absorbed and carried by the circulatory system, and built up into the tissues of the body and limbs. The agents of absorption here are probably the lymphatics. In like manner young snakes increase in length for some days after leaving the egg, the nourishing material being a portion of the yelk retained in the body of the young snake. Tumors and abnormal growths often disappear of themselves, the material being absorbed and carried out doubtless as waste matter.

7. **Waste and Repair.** — All the secreting and excreting glands and surfaces of the body are connected more or less directly with the processes of waste and repair which are constantly going on, and really constitute the life of the body. A dead animal does not secrete nor excrete. In other words, there is no vital activity in the cells of a dead body. The only activity is that of chemical change, which sooner or later results in the complete destruction of the body. The secretory system is intimately blended with all other systems engaged in the nourishment of the body, that is, in **nutrition**. Various glands furnish fluids which dissolve and prepare the food for absorption and assimilation. Other glands separate from the blood certain material thrown into it by the tearing down of old tissue, thus getting rid of material which has served its purpose. The respiratory organs take in oxygen, which is intimately connected with the manufacture of various secretions and the destruction of old tissues.

PRACTICAL ILLUSTRATIONS.

1. With a sharp knife scrape the skin of the arm or back of the hand. A white powder appears. Under the microscope this is seen to consist of flattened epidermal cells. The ordinary contact with clothes and objects keeps the loose cells rubbed off.

2. Take a hair from your head and roll it between thumb and finger, back and forth. Observe that it tends to move at the same time lengthwise, and always in the direction of the root of the hair. The reason of this may be seen if a hair is highly magnified. The cells of the outer part overlap and project like shingles.

3. The experiment (mentioned in the text) of keeping a tadpole until it becomes a frog may be tried. Select the largest specimen you can find. Keep it in a dish of water in the schoolroom and permit the pupils to watch the changes from day to day.

4. The experiment with the egg to illustrate absorption, given in the chapter on Digestive System, may be repeated at this stage, or at least attention should be called to it.

LESSON 29.

Hygiene of the Secretory System.

1. **Cleanliness.** — The excretions of the body act as poisons if again introduced into the system. The skin may absorb any soluble substance which remains for any length of time in contact with its surface. Thus the excretions may prove a source of danger. Again, if excreted material is permitted to remain long on the skin, it, together with the dust and dirt, partially closes the pores and retards the necessary excretion which should be kept up at all times. A dirty skin is also frequently the breeding-place for germs of skin diseases. It is a fact, at least, that the greatest variety and most numerous cases of troublesome skin diseases are found among those who are habitually filthy in their persons. These are sufficient reasons for keeping the surface of the body clean.

2. **Value of Bathing.** — We should bathe the entire body at least as often as once a week for cleanliness' sake. No matter what the occupation and surroundings may be, the skin in that time will have accumulated an amount of excreted matter and foreign dirt which will be injurious if allowed to remain. In warm weather, when the perspiration is more abundant, it is necessary to bathe oftener. Occupations which expose the body to dust and dirt necessitate frequent bathing. Bathing, when

properly done, has often beneficial results, even when not necessary for cleanliness. It is a means of getting rid of surplus heat, and by exciting the skin to increased action often relieves congestion of internal organs. A bad cold may often be cured by taking a warm bath on going to bed. However, if one does not keep warm during the night, or is exposed the following day, a more severe cold may be taken.

3. **Methods of Bathing.** — It is not necessary to immerse the body in water in order to get the full benefit of a bath. A gallon of water in a basin, a sponge or soft cloth, a piece of soap, and a towel are all that are essential. A bath tub, a bathing tank, or a body of water is a luxury rather than a necessity. A thorough drying of the skin by vigorous rubbing with a towel is important in cold weather, as the dampness imparted to the clothes may cause chilliness afterward. Besides, the friction arouses the activity of the blood-vessels, and a thorough circulation near the surface is thus secured and the body fortified against external cold.

4. **Kinds of Baths.** — We read of warm, hot, cold, and lukewarm baths; of salt water baths, of vapor baths, and even of sun and air baths, and all have their particular value in certain cases. For the purpose of cleanliness for which baths should be most frequently taken, the water should be at a temperature agreeable to the sensations. A hot water bath is stimulating to the skin, as also is a vapor bath. They are always followed by a feeling of lassitude or depression, and a good rest should follow such a bath. A cold bath is frequently dangerous, especially to the young and delicate, and to the aged. It gives a shock to the nervous system and drives the blood from the surface to the internal organs, and unless the skin be quickly dried and thoroughly rubbed to get up a reaction, the results are more injurious than beneficial. A cold bath is said to be tonic, or strengthening to the system, and persons in vigorous health soon get used to cold water and quickly recover from the temporary shock. But why should healthy and vigorous persons need a tonic? In our opinion, a cold bath is rarely, if ever, a necessity, and since it is so frequently attended with risks, we

cannot advise it as a hygienic measure. A luke-warm bath in hot weather is cooling and refreshing, the evaporation of the moisture being attended with abstraction of heat. As to salt water baths and medicated baths generally, they are best taken under the advice of a physician.

5. **Too much bathing** may be injurious. The skin is over-excited, and consequently overworked. Boils and other eruptions often result from excessive use of the bath. Two or three times a week is generally often enough to bathe the entire body under any circumstances. One should not remain too long in water during a bath. Ten or fifteen minutes should be the limit.

6. **Clothing.** — The warmest clothing is that which is the poorest conductor of heat, for then the heat of the body is kept in. Fur, wool, and feathers are the poorest conductors of heat; silk is next, and cotton next, linen being the best conductor. Clothes tend to keep an even temperature about the surface of the body. They keep in the body heat, and keep out the heat of the sun when we are in its direct rays. Clothing should be adapted to the season of the year and the climate. It is not wise in our changeable climate to leave off our winter under-clothing too early in the spring. It is better to endure the increased heat for a few days, than to take the risk of getting chilled, and thus taking a cold when a sudden change occurs. Wet or damp clothes should never be worn for a minute, when it is possible to change them for dry ones. If compelled to wear damp clothes for a time, one should keep exercising. Rheumatism, neuralgia, throat and lung diseases, and even diseases of the digestive organs, are frequently caused by neglect in the matter of clothing. For the sake of cleanliness, the underclothing should be frequently changed. It is wise to wear one garment at night and another in the daytime. The one that is not worn should be hung up to air. Bed-clothes should be aired during the day.

7. **Use of Cosmetics.** — If a person has not naturally a beautiful complexion, all the cosmetics in the world cannot make it beautiful. The lady who keeps her complexion on her toilet-

table, and puts it on when she goes out into society, may deceive those at a distance, like the actress on the stage; but she must be skillful indeed who can imitate the bloom and beauty of a healthy skin. But no objection could be made to the use of cosmetics if they were not injurious. They generally contain poisonous substances which may be absorbed. Besides a constant use of the mildest face powders and paints destroys the beauty of the skin by clogging up the pores and interfering with its normal action. A free use of soft water and a mild soap, with attention to the general rules of health, will produce a beautiful complexion if such be possible.

8. **Care of Hair and Nails.** — It adds much to the comfort and health of the body to keep the hair well combed and brushed. An occasional "shampoo" with warm, soft water and some mild soap is good. Do not use oil on the hair unless it be unnaturally dry and harsh. All hair-dyes tend to destroy the natural softness and flexibility of the hair. The upper surface of the nails should be cleaned with a brush and not scraped with a knife, if you would preserve the natural polish.

9. **Handling Poisons.** — As we have learned elsewhere, absorption from the surface is very rapid where the epidermis has been broken or removed. Physicians and medical students have been seriously poisoned in dissecting human bodies; a peculiar poison, developed by the chemical changes in the decay of a body, being absorbed through abrasions on the hands or where a slight wound was made by the dissecting knife. Certain diseases are communicated in a similar manner. Great care should be exercised in handling poisonous substances, as a quantity sufficient to prove serious, if not fatal, may be absorbed.

10. **Chafing and Chapping of the Skin.** — Where the skin is frequently exposed to cold winds, or to water and other liquids, it is apt to crack, and where there is friction and moisture it is apt to chafe and become very irritable. The proper remedy is a substance which will not irritate in itself, but will form an air-tight covering, as the air is the great irritant to a denuded surface. Linseed oil is such a remedy. It may be used in a liquid form,

or mixed with melted paraffine, or spermaceti, and made into an ointment. This is excellent for burned and scalded surfaces also.

11. **Effects of Alcohol on the Secretory System.** — Alcohol has a marked effect on all glands. We have already mentioned its effects on the liver. The kidneys are especially stimulated by alcohol, and in time become diseased in consequence of the overwork. Many men die at about the age of fifty from kidney disease, and in a large percentage of cases these men have been habitual drinkers. The perspiratory glands are overworked, and the body loses heat more rapidly than is natural. The effect of alcohol on the skin is apparently contradictory. A man feels a glow of warmth as the result of a dram or two, and it is a common notion that it warms the body; yet the experience of those who have tried to brave an Arctic climate is, that only those who abstain from alcoholic drinks can endure the intense cold. This is easily explained when we consider the philosophy of its action. Alcohol increases the force and frequency of the heart and dilates the small blood-vessels; hence the warm blood of the interior is rapidly sent to the surface, and there the heat is lost by radiation and by evaporation of the perspiration, which is also increased by the flow of blood to the sudoriparous glands. The general temperature of the body is thus lowered, while the heat on the surface is temporarily increased. Thus if a man is expected to remain in a very cold atmosphere for a very short time, the alcohol would help him endure the cold, but after a few hours his condition would be worse than if he had abstained.

12. **Corns and Bunions** are peculiar thickened indurations of the epidermis, caused by pressure from shoes that are too tight, or rubbing of shoes that are too loose. The only sure remedy is to cut them out with a sharp knife, and avoid pressure on the parts until the normal condition is restored. Even then it is sometimes difficult to get rid of them. The better way is to wear shoes that fit perfectly, and thus avoid the cause.

EXERCISES FOR REVIEW.

1. What are the relations of the skin and mucous membrane? What is the true interior of the body?

2. Uses of serous membrane? of mucous membrane?

3. Epithelium? Endothelium? Cilia?

4. Define secretion and excretion.

5. Uses of perspiration? When is perspiration most copious? Sensible and insensible perspiration?

6. Compare section 3, Lesson 28, with section 4, Lesson 24.

7. Of what use are the muscles of the skin? What is the cause of "goose-flesh"?

8. Use of the oil-glands? Where most numerous?

9. Why bathe? Why keep the body clean?

10. When is the proper time to bathe? If for cleanliness, any time that is convenient; if for any other purpose, advise with a reliable physician.

11. When should we use cosmetics for the complexion?

12. What is the physiological reason for wearing clothes?

13. The temperature being the same, why do we feel warmer in a moist than in a dry atmosphere?

14. Compare section 2, Lesson 27, with section 5, Lesson 22.

15. What is an albino?

16. What causes the "hair to stand on end"?

17. Explain the disappearance of the tadpole's tail.

18. How is the heat of the body regulated?

19. From which end does a hair grow?

Part III.

HOW THE BODY IS GOVERNED, OR THE SENSORY APPARATUS.

CHAPTER I.

HOW ALL PARTS COMMUNICATE WITH ONE ANOTHER, OR THE NERVOUS SYSTEM.

LESSON 30.

The Brain and Spinal Cord.

1. The nervous system may be conveniently divided into (*a*) the encephalo-spinal system and (*b*) the sympathetic, or ganglionic system. The encephalo-spinal system consists of the brain, spinal cord, and nerves branching from them. The sympathetic system consists of a double chain of nerve-knots, or ganglia, which are connected with each other and with the nerves of the encephalo-spinal system by a net-work of nerves.

2. **Size of the Brain.** — The brain is a large mass of nerve-matter completely filling the cranial cavity. In the Caucasian race, the brain averages about ninety cubic inches in bulk. Daniel Webster's brain measured 122 cubic inches. The average weight in males is 49½ oz.; in females, 44 oz. The prevailing weights in males are 46 to 53 oz.; in females, 41 to 47 oz. The greatest weight out of 278 cases of males was 65 oz., and the smallest, 34 oz. In females out of 191 cases the greatest weight was 56 oz. and the smallest, 31 oz. The brain of Cuvier, the great French naturalist, weighed 64 oz. Dr. Aber-

crombie's brain weighed 63 oz. The brains of idiots seldom weigh over 23 oz. One specimen weighed only $8\frac{1}{2}$ oz., the smallest on record. The human brain is absolutely heavier than that of any animal except the elephant and the whale, and relatively to the weight of the body it is heavier than that of most animals.

3. Coverings of the Brain. — The brain has three distinct, membranous coverings or envelopes: (1) the **dura mater** (hard mother), or outer covering, is a dense, inelastic, fibrous membrane which answers also as an internal periosteum to the bones of the cranium. It dips into the large fissures which separate the different parts of the brain, and is continued on the cranial nerves to the outside of the cranium. (2) The **arachnoid** (spider-web like) is the middle covering. It is a thin, delicate, transparent serous membrane. There is a space between it and the dura mater filled with a serous fluid, also a space between it and the pia mater, which also contains a serous fluid. (3) The **pia mater** (soft mother) consists of a net-work of minute blood-vessels held together by fibrous tissue. It dips into all the furrows on the surface of the brain, and lies perfectly close to the brain substance. These membranes are for the threefold purpose of nourishing the bones of the cranium, protecting the brain from injury, and nourishing the substance of the brain. The dura mater furnishes blood to the bones and the pia mater to the brain, while the arachnoid, with its fluids, acts as a cushion to prevent shocks.

4. Divisions of the Brain. — The brain consists of four quite distinct parts, very unequal in size, — the cerebrum, the cerebellum, the pons Varolii, and the medulla oblongata. Each of these is double, having two distinct, lateral, nearly symmetrical portions, united in a central line from before backward.

5. The Cerebrum. — This is the largest part of the brain, being about seven times as large as the other parts taken together. It fills the whole of the cranial cavity above the level of the eyes and ears. Looking at it from above, we see a deep fissure running from before backward and extending entirely through it at the front and back, but only part way through in the center, leaving a mass of matter called the *corpus callosum*, which unites the two hemispheres. The surface of each hemisphere is divided, by winding, irregular furrows about an inch in depth, into folds called **convolutions**. This greatly increases the amount of surface. This is significant when we learn that the surface of the cerebrum is gray nerve-matter and that the center, or source of nerve-power, lies in the gray matter. In the lower animals these convolutions become less and less as we descend in the mental scale until we reach those with perfectly smooth cerebrums. A considerable difference may be noted in the brains of men of intellect, as compared with idiots and men of the lower races.

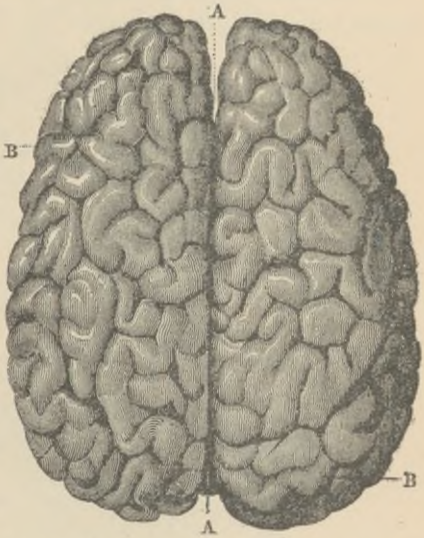


Fig. 20. — Upper Surface of the Cerebrum.
A, Longitudinal fissure; *B*, The hemispheres.

Looking at the cerebrum from below, as many as thirteen different parts may be seen. These have all been minutely described and named by anatomists, although the special uses of all of them are not known. Anatomists also describe five distinct lobes or divisions of each hemisphere, marked off by fissures more or less prominent.

6. The Cerebellum. — The cerebellum, sometimes called "the little brain," is about one-eighth of the size of the cerebrum, and lies in the lower and back part of the cranium. The surface of its hemispheres is marked by many curved furrows.

7. The Pons Varolii. — This term means, "the bridge of Varoli," so named from an Italian anatomist. It seems to connect all of the other parts of the brain together, the cerebrum above, the cerebellum behind, and the medulla oblongata below.

8. The Medulla Oblongata is a pyramidal-shaped mass connecting the spinal cord below with the pons Varolii above. It lies in the lowest part of the cranium, its lowest portion on a level with the outer edge of the foramen magnum, or great opening in the occipital bone. It is the connecting link between the spinal cord and the brain proper.

9. Structure of the Brain. — The intimate structure of nerve-tissue will be given in Lesson 32, but it will be necessary here

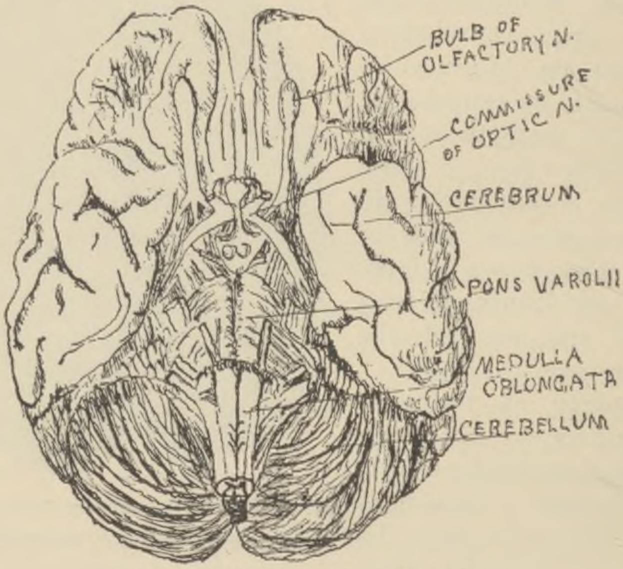


Fig. 21. — The Base of the Brain.

to describe in a general way the interior of the mass of nerve-matter composing the brain. A section made horizontally about an inch from the top shows the upper part of the corpus callosum, and the interior of the hemispheres of the cerebrum. The gray matter is seen to form a layer about a quarter of an inch thick on the outside, and following the convolutions. Inside of the gray matter is a mass of white matter. The whole substance of the brain is very soft, and to make a section it is necessary to harden it by soaking it in alcohol or chromic acid for some days. A section a little lower through the corpus callosum shows two large, curiously shaped cavities, the lateral ventricles, one in each hemisphere. They are lined with serous membrane and contain a fluid. In the septum which separates them is a similar small cavity called the fifth ventricle. A section still lower shows the third ventricle beneath the fifth. The fourth ventricle lies between the cerebrum, the cerebellum, and the pons Varolii.[1] A section of the cerebellum shows white matter in the center and gray on the outside, but the gray matter dips in so deep and in so many places that the whole on section appears like a tree with many branches. This appearance is called the *arbor vitæ*, or "tree of life." The pons Varolii consists of alternate layers of transverse and longitudinal white fibers mingled with gray matter. The upper part of the medulla is a mixture of white and gray matter, and the lower part is like the spinal cord, having gray matter in the center and white on the surface.

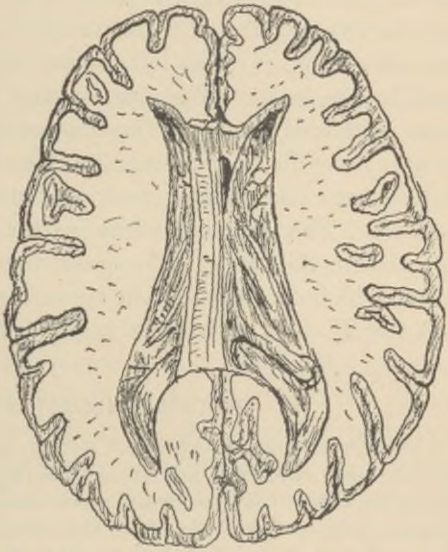


FIG. 22. — HORIZONTAL SECTION OF CEREBRUM.
Showing the lateral ventricle and part of the corpus callosum, also the arrangement of gray and white matter.

10. The Spinal Cord is a continuation of the brain downward through the spinal canal, which is composed, as we learned in

[1] In the very center of each hemisphere of the cerebrum lie two masses of gray matter, the **optic thalamus** and the **corpus striatum**. Fibers of the white matter diverge from them to the gray matter of the cortex, or surface layer. These masses of gray matter, with their connection by means of fibers with the gray cortex, are believed to be of great importance, although their complete functions have not yet been made clear by physiologists.

an earlier chapter, of a succession of openings in the vertebræ. It extends from the foramen magnum of the occipital bone to the lower border of the first lumbar vertebra, about sixteen inches in length. It is about one-half inch in diameter, and weighs about one and one-half ounces. In shape it is nearly cylindrical, terminating in a slender filament. It is partly divided into two lateral portions by two fissures, and each half contains two bundles of fibers, called the anterior and posterior *columns*. It is covered by a continuation of the membranes covering the brain. The dura mater differs from that of the brain, in that it does not form a periosteum for the bone, but lies at a little distance from it, attached by fibrous bands, does not dip into the fissures, and contains no sinuses, or venous channels. The gray and white matter occupy reverse positions from that in the brain. The gray matter forms a mass in the center, which on cross-section appears somewhat in the shape of the letter H. At each vertebra a pair of nerves are given off.

PRACTICAL ILLUSTRATIONS.

1. Procure the head of some small animal, as a cat, dog, rabbit, squirrel, or rat. By means of a chisel and strong knife break and cut away the bones and take out the brain. Care and patience are necessary to get out a brain without injury, as it is so soft and yielding. The dura mater is easily recognized. The other membranes are so delicate that special preparation and care are necessary to demonstrate them. Put the specimen in clear water in a dish and exhibit it to the class. The shape, will differ somewhat from the human brain, but the general arrangement of parts is similar. Before attempting to make a dissection of the specimen, place it in alcohol and let it remain a week or longer. Then with a very sharp, thin knife cut sections as described in the section on "Structure of the Brain." It may be possible to procure a good specimen of the brain of a pig, sheep, or ox from the butcher, but usually the mode of slaughtering the animals results in destroying the structure of the brain.

2. A section of the spinal cord may be shown in its position by sawing through several vertebræ. A good specimen may be obtained from the butcher. Observe the roots of the spinal nerves and the ganglia, to be mentioned in the following lesson.

LESSON 31.

The Nerves and Ganglia.

1. The nerves proper are those white, cord-like extensions of the nervous system which branch to every part of the body. So numerous are the small branches that there is no spot on the surface of the body where a fine needle would not puncture one or more, if inserted to the depth of a quarter of an inch. There are no nerves in the epidermis or hair, and they are more numerous near the surface of the body.

The nerves of the encephalo-spinal system may be divided into: (1) the *cranial*, or those which branch off from the brain; and (2) the *spinal*, or those which branch from the spinal cord.

2. **The Cranial Nerves.** — Some authors describe nine pairs of cranial nerves, others twelve pairs. The reason of this is that several of the nerves are common as to their origin, but separate as to distribution. In the subjoined table, giving the names origin, distribution, uses, etc., they are numbered by both systems. They are all connected with some portion of the surface of the brain, and this is called their superficial origin. All have been traced much deeper into the brain, and the part to which they may be followed is called the deep origin. In the table we have given only the superficial origin. The exact deep origin of all the nerves is not yet a settled question.

3. **The Spinal Nerves.** — In the region of the cervical vertebræ are given off from the spinal cord eight pairs of nerves, which are distributed to the neck and arms. They are called *cervical nerves.* In the back, passing out between the dorsal vertebræ, are twelve pairs called *dorsal nerves.* They are distributed to the trunk. There are five *lumbar* nerves, five *sacral* and one *coccygeal.* They supply the pelvis and lower limbs.

4. **Plexuses.** — The spinal nerves unite in groups and then branch again, forming what are called plexuses. The four upper cervical nerves form the *cervical plexus* in the neck; the four lower cervical and the first dorsal form the *brachial plexus*

TABLE OF CRANIAL NERVES.

NUMBERS.		NAMES.	ORIGIN.	EXIT FROM CRANIUM.	DISTRIBUTION.	FUNCTION.
1.	1.	Olfactory.	Olfactory bulb, frontal lobe of cerebrum.	Through ethmoid bone.	To lining membrane of nose.	Nerve of smell.
2.	2.	Optic.	Optic commissure, anterior part of cerebrum.	Optic foramen in sphenoid bone.	To the eye, its expansion the retina.	Nerve of sight.
3.	3.	Motor oculi.	Front of pons Varolii.	Through sphenoidal fissure.	To all the muscles of the eyeball except two.	Nerve of motion to eyeball.
4.	4.	Pathethic, or trochlear.	Base of brain, front of pons Varolii.	Sphenoidal fissure.	To superior oblique muscle of eyeball.	Nerve of motion to eyeball.
5.	5.	Trifacial, or trigeminus.	By two roots, side of pons Varolii.	Through sphenoidal bone.	To eye, upper and lower jaws, face, and tongue.	Nerve of taste, of sensation and motion.
6.	6.	Abducens.	Near pons Varolii.	Sphenoidal fissure.	To external rectus muscle of eyeball.	Nerve of motion to eyeball.
7.	7.	Facial, or portio dura.	Side of medulla.	Enters with auditory nerve to petrous portion of temporal bone, leaves at stylomastoid foramen.	To muscles of side of face.	Nerve of motion to muscles of expression in face.
	8.	Auditory, or portio mollis.	Side of medulla.	Does not leave cranium.	To internal ear.	Nerve of hearing.
8.	9.	Glosso-pharyngeal.	Medulla.	Jugular foramen.	Tongue and pharynx.	Sensation, motion, and taste.
	10.	Pneumogastric, or par vagum.	Medulla.	Jugular foramen.	Lungs, heart, and stomach.	Motion and sensation.
	11.	Spinal accessory.	Spinal cord.	Enters cranium along with cord, and emerges at jugular foramen.	Muscles of neck.	Motion and sensation.
9.	12.	Hypoglossal	Medulla.	Anterior condyloid foramen of occipital bone.	To tongue.	Nerve of motion to tongue.

near the armpit. The four upper lumbar nerves form the *lumbar plexus* in the small of the back and the last lumbar, and three upper sacral nerves form the *sacral plexus*, lying on the inner surface of the sacrum.

5. **Roots of the Spinal Nerves.** — Each spinal nerve has two roots, a posterior and anterior, arising respectively from the posterior and anterior columns of the cord. The two roots unite in the foramen, which permits their exit from the spinal canal. If the anterior root be severed all power of *motion* is lost in that part to which the nerve is distributed, while *sensation* is not affected. If the posterior root only be severed, the power of sensation is lost, while the power of motion is not affected. Cutting both roots has the same effect as cutting the nerve. On each posterior root is a ganglion, or knot of nerve-matter.

6. **The Sympathetic System.** — Two chains of ganglia, one on either side of the spinal column, with numerous branches and plexuses, constitute the sympathetic system of nerves. It seems to be analogous to the entire nervous system in the invertebrate animals which have no brain or spinal cord. The branches from the ganglia are of three kinds: (1) of communication between ganglia; (2) of communication with cranial and spinal nerves; (3) of distribution to the various internal organs. There are also three great plexuses, the most important of which is the **solar plexus** in the neighborhood of the stomach and intestines. If a person receive a severe blow on the abdomen, even though no tissue be torn or broken, death may follow from the shock received by these sympathetic nerves and transmitted to the brain. The solar plexus has been called the "*abdominal brain.*"

LESSON 32.

Structure and Composition of Nerve-Tissue.

1. Nerve tissue is of two general kinds, gray or vesicular matter, and white or fibrous matter.

2. Gray Matter. — The gray matter is found in the outside or cortex of the brain, in certain large masses in the base of the brain, in the center of the spinal cord, and in the ganglia. As its name implies it is of a grayish or ashy color tinged with red, darker in negroes than in the white races. In consistence it is soft and pulpy, easily broken down by pressure of the finger. In minute structure it is seen to consist of a collection of cells or vesicles embedded in a fine net-work of filaments called **neuroglia** (nerve-glue), with some white fibers intermingled. The nerve-cells, or corpuscles, are of various shapes, generally spheroidal or ovoid, with one or more tail-like processes, and a nucleus and nucleolus, as shown in the cut.

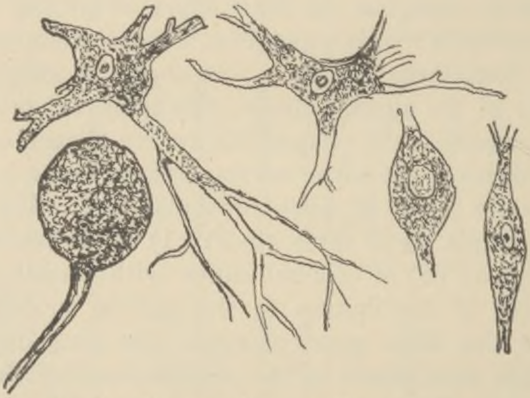


FIG. 23. — VARIOUS FORMS OF NERVE-CELLS.

3. White Matter. — The white or fibrous nerve-substance is found in the central part of the brain, in the outer part of the spinal cord, and composes the entire substance of the nerves. It is, with some exceptions, of a dead-white color. It consists of numerous small fibers united by neuroglia similar to that which unites the cells of the gray matter.

4. Structure of Nerve-Fibers. — Nerve-fibers are of two kinds, medullated or white, and non-medullated or gelatinous. The latter are found in the nerves of the sympathetic system, the olfactory nerve, and to some extent mingled with medullated fibers in the spinal nerves. A medullated nerve-fiber consists of three distinct parts: a sheath, or tube of delicate, transparent membrane, (1) the **neurilemma**; within this a soft, white substance known as (2) the **white substance of Schwann**; in the center of this is a gray, thread-like filament, (3) the **axis cylinder**. At intervals constrictions are seen appearing to be due to thickening of the neurilemma. The non-medullated fibers have no constrictions, are smaller in size, grayish in color, and consist of a sheath containing fine granular filaments.

5. An entire nerve is composed of bundles (funiculi) of fibers held together by neuroglia, and the whole surrounded by a strong fibrous sheath, the **perineurium** (around the nerve), which sends in prolongations of itself between the funiculi, thus giving strength to the nerve and effectually protecting the delicate fibers. The great *sciatic* nerve in the thigh is the largest nerve in the body, is about half an inch in diameter, and is strong enough to support the entire weight of the body.

FIG. 24. — STRUCTURE OF MEDULLATED NERVE-FIBER.

1, Neurilemma; 2, White substance of Schwann; 3, Axis cylinder.

6. Terminations of Nerves. — Some nerve-fibers convey power of motion, others of general sensation, others special sensations, as sight, hearing, etc., and still others, which go to the glands, have the power of causing secretion; but with all this difference of function, neither the microscope nor the chemist's tests can detect any difference of structure or composition of these fibers. Hence physiologists have sought to find differences in the distant extremities or terminations of the nerves and certain "end organs," as they have been called, have been described as characteristic of nerves performing different functions. In the voluntary muscles they terminate in small expansions on the muscle fiber, or "end plates," as they have been termed. In the involuntary muscles they form plexuses, and terminate in the nuclei of the cells. In the glands the axis cylinder is, according to Pflüger, continued into the gland-cell. The terminations of the nerves of smell, sight, hearing, taste, and feeling will be noticed in the description of the special sense organs.

7. Chemical Composition of Nerve-Tissue.—About eighty per cent of nerve-matter is water. The solid constitutents are albumen, fat, and mineral salts. Of the ultimate elements, phosphorus is a characteristic constituent. An increase in mental activity is always accompanied by an increase in the phosphates (salts containing phosphorus) in the excretions of the body, showing that the production of nerve-force is attended with the destruction of nerve-tissue.

PRACTICAL ILLUSTRATIONS.

1. A portion of the sympathetic system may be easily shown in a frog. Make an incision the whole length of the abdomen, and remove the viscera. The two chains of ganglion with their connecting filaments may be seen lying in front of the spinal column.

2. It is a very easy matter to dissect the thigh of a frog and show the great sciatic nerve. If the animal shall have been recently killed, violent contractions of the muscles of the leg will take place when the cut end of this nerve is irritated.

3. It is a very difficult matter to demonstrate the minute structure of nerve-tissue. Patient work, with proper chemical preparation of the material, and high powers of the microscope, are necessary.

LESSON 33.

Functions of the Nervous System.

1. The Governing Power of the Body.—Imagine a large factory in which each laborer worked independently of the others, and on such parts of the work as pleased him, with no rules or plans, no system or division of labor, and the workers had no communication with each other: nothing satisfactory could be accomplished. There must be a plan and a governing head, and all must work in harmony. In the body one organ works in harmony with another. Saliva is secreted in the mouth when the demand for it exists in the stomach. The heart pumps the blood to every organ of the body, and is itself controlled and regulated by the nerve-centers. When we stop breathing the heart stops beating, and *vice versa.* Touch the foot with a hot iron and the muscles of the leg contract and pull it away. Strike at the eye and the lid is quickly drawn down to protect it. When the perspiration is checked by external cold, the kidneys secrete more abundantly. Thus one organ helps another, and all are governed and controlled by the great nerve-centers.

The functions of the nervous system may be stated in general to be: (1) **Originating** a peculiar activity we call *nerve-force.* This power lies in the cells of the gray matter of the brain, spinal cord, and ganglia. If these cells be destroyed all nervous phenomena cease. (2) **Transmitting** *nerve-force.* This is the peculiar function of the white, or fibrous tissue. Sever a nerve and the part to which it is distributed is no longer capable of action. (3) **Receiving** *impressions* from external sources. This power lies mainly in the terminations of the nerves, or "end organs." Thus without the retina of the eye we could get no impressions of the form and color of objects; without the organ of Corti in the internal ear we could not distinguish sounds; and so on through the five special sense organs. We get an impression of temperature through the terminations of the nerves of common sensation in the skin. However, if the optic nerve be severed and the end touched a sensation of light is experienced, and in the same way a noise is heard if the cut end of the auditory nerve be irritated, but there is no perception of objects nor distinguishing of sounds.

The activity of the nervous system, then, consists in *receiving* from *without impressions* which are *transmitted* to certain centers *within*, where other impressions *originate*, prompted by the impressions sent in at the time, or originating from former impressions (memory), and giving rise to certain motions and feelings or sensations.

2. Functions of Special Parts. — The nervous system is a complex apparatus, and we cannot say that all of its details are yet thoroughly understood. Experiments on animals, and observations on insane people and those with wounded and diseased parts, have determined the particular functions of many of the special parts in a more or less satisfactory manner.

3. Function of the Cerebrum. — In general it may be said that the cerebrum is the organ of mind. It is the highest organ of the body, not only in position but in function. Two fundamental characters of mind are the *intellect*, or that which knows or acquires knowledge, and the *will*, or that which determines, decides, and chooses between alternatives. *Consciousness*, or the knowledge the mind has of its own acts, is inseparable from the intellect and the will. The cerebrum is the seat of the intellect, the will, and consciousness. If it be removed from a frog, the animal sits stupid and apparently lifeless wherever it is placed, but if irritated in any way it leaps or crawls. If placed on a board which is made to turn slowly so that it would fall off, it climbs to the upper side. If thrown into water it swims until a support is accidentally touched, and then it climbs upon it and remains at rest. But unless some stimulus is applied it will not move, although respiration and circulation goes on, and if food be introduced into its stomach digestion takes place. It is to all intents and purposes a machine, acting only as it is acted upon by some external force. It has no power of will, or sense to act by itself. When the cerebrum is removed from birds they sit stupidly and only move when stimuli are applied, and act generally like the frog under like circumstances. When a man is asleep, the cerebrum appears to be inactive. He is not conscious of what takes place around him, but may execute all of the acts of a waking individual. A patient under the influence of narcotics acts in a similar manner.

Dr. Courmont, a French investigator, has recently announced his opinion, based on a series of experiments and observations, that the cerebrum is the seat of the higher mental faculties, as thought, judgment, comparison, etc., while the cerebellum is that of the unreasoning mental processes, as love, hatred, joy, sorrow, etc. The cerebrum, he says, is the organ of sense, the cerebellum of sentiment.

4. Functions of the Cerebellum. — When the cerebellum has been removed from a pigeon its gait becomes unsteady, as though the muscles of one side did not act in harmony with those of the other. It will try to eat, but in pecking at the food misses its aim. Similar results have followed when the cerebellum was removed from other animals. Disease of this part in the human being has been accompanied by unsteadiness of gait, yet the evidence here is contradictory, for in some cases extensive disease of the cerebellum was not followed by any disturbance of the harmony of muscular action. Foster says: "Still the experimental evidence is so strong that we must consider the cerebellum as an important organ of co-ordination, though we are unable at present to define its functions more exactly."

5. Functions of the Pons Varolii. — Nothing very definite is known of the special functions of this part of the brain, other than its evident anatomical use in connecting, by means of its fibers, the other parts. It contains a considerable amount of gray matter and is probably an aid to the cerebellum in the function of co-ordinating muscular movements.

6. Functions of the Medulla Oblongata. — This is the great center of centers of the nervous system, a kind of vital telegraphic headquarters. Most of the organic functions of the body are controlled by nerve-centers located in the medulla. Here is found the "*respiratory center*," or a point which, if destroyed, respiration immediately ceases, or if irritated breathing is modified and interrupted. It has been called the "center of life" and the "vital knot," for when respiration ceases all other functions quickly cease and death is the result. The method of executing criminals once in vogue in Spain consisted in forcing a sharp-pointed instrument into this part, through the articulation of the atlas and occipital bone. In ordinary hanging the odontoid process of the axis is forcibly pressed upon this part, and death is instantaneous. Closely connected with the respiratory center is the "*convulsive center*." In the medulla is also found the "*vaso-motor center*," which controls the calibre of the arteries. The phenomena of blushing and turning pale is due to variations in this center, whereby a greater or less amount of blood is permitted to flow to the small vessels. Here also is the "*cardio-inhibitory center*," which controls the force and frequency of the heart's action. The center for deglutition or swallowing is located in the medulla. The entire brain except the medulla may be removed from an animal, and still swallowing will take place if the object be pushed into the pharynx. The center for peristaltic movements of the stomach are found here, and closely related to it the "*vomiting center*." The center for the secretion of saliva, and possibly for all other digestive fluids, lies here also.

It will thus be seen that the medulla oblongata is a very important part of the nervous system, the headquarters as it were of most of the organic or animal functions.

7. **Reflex Action.** — This term, so frequently used in all works on the nervous system, should be clearly understood by the pupil. When we tickle the foot of a sleeping person, he jerks it away without being awakened. If your hand accidentally touches a hot surface or a sharp point, you involuntarily withdraw it at the same instant you feel the pain. Your eyelids involuntarily close when some object suddenly comes near. The pupil of the eye contracts in a strong light. Dust drawn with the air into the nasal passages causes sneezing. A foreign body of any kind in the windpipe produces coughing. The sight and smell, or even the suggestion or recollection of some disgusting object, may cause vomiting. A word or action or a view may cause blushing or pallor. An irritation in the stomach may cause irregular and rapid action of the heart. A foreign body in the ear has been known to cause a troublesome cough. A laceration of the foot may cause rigidity of the muscles of the jaw, or "lock-jaw," as it is called. A crushed finger or toe may cause intense nausea and sickness of the stomach. A chicken jumps about after its head is severed from its body. The snake's tail moves for hours after the body has been cut to pieces. All of these and many others that might be mentioned are examples of reflex action.

Three things are necessary for reflex action: (1) a nerve-center; (2) a nerve-termination; (3) nerve-fibers connecting the two. Reflex action may be defined as an impulse received by a nerve-termination, conveyed to a nerve-center from which another and different kind of impulse is conveyed to a nerve-termination along a nerve-fiber, resulting in motion in the part in which the nerve-fiber terminates. The impulse passing from the nerve-termination to the nerve-center is called an *afferent* impulse and the nerve-fiber conveying it is called a *sensory* nerve-fiber. The impulse passing from the nerve-center to the part moved is called an *efferent* impulse, and the nerve-fiber a *motor* nerve-fiber. The spinal nerves contain both motor and sensory fibers. Some of the cranial nerves contain all motor fibers, others all sensory, and some are mixed like the spinal nerves. (See Table of Cranial Nerves in Lesson 31.)

8. Functions of the Spinal Cord. — From the fact that the spinal cord contains both white and gray matter, one would infer that it acts both as a conductor and a center of nerve-force. Experiments on animals and observations in cases of disease show that it is a great center of reflex action. Many impulses never reach the brain, but are, as it were, reflected by the cord. Thus the brain is relieved of part of its work. When we gently tickle or touch the limbs of a sleeping person the impulse received is conveyed no farther than to the cord, and from there may come back a motor impulse which causes the limb to move. Thus a sleeping person brushes away the flies while the mind is all unconscious of their presence. If, however, the tickling or irritation be more severe or long-continued, the impression goes into the brain and consciousness is aroused, or in other words, the person is awakened.

Pflüger made some experiments on frogs which would seem to prove that to a certain degree the spinal cord possessed intelligence if not consciousness. He removed the brain of the frog and touched the thigh with acetic acid. The animal rubbed the place with the foot of the same side. He then cut off this foot, and after an ineffectual attempt to reach the place with the stump, it rubbed the place with the other foot. These experiments have been repeated by others with the same results. Rattlesnakes in the act of striking have had their heads instantly cut off. The headless trunk would sometimes repeat the stroke. This, however, would appear to be the force of habit, making an otherwise voluntary act a reflex act.

The white matter of the cord acts as a conveyer of impulses to and from the brain. If we will to move a foot, or if something touches the foot, efferent and afferent impulses evidently pass along the whole length of the spinal cord to and from the brain. The anatomical fact that the sum of all the nerve-fibers in the cord is less than the sum of all the fibers of the spinal nerves, would preclude the idea that the impulse is conveyed by one continuous fiber. It is more probable that the gray cells in the cord act as relays which, as it were, strengthen the impulse and pass it on to other cells in succession, and thus the impulse reaches the brain. In this respect it resembles an ordinary telegraphic system, where batteries (called relays) along the route renew the electric current.

9. **Automatic Reflex Action.** — There are many acts performed by men and animals which cannot be attributed to the will, nor to simple reflex action. Thus respiration is a rhythmic action kept up apparently by nerve-cells in the medulla oblongata, without external stimulus and only partially capable of being modified by the will. The beating of the heart is another rhythmic action not due to external stimuli, and entirely independent of the will. The heart will beat a few times after it is severed from the body in higher animals, and in turtles it will beat for two hours, even after all blood is washed out of it and it becomes dry on the surface. Here the action must be due to the ganglia, which are found in the heart-substance. In this class of actions we may place secretion of the glands, although in some cases external influences doubtless provoke them to action. The salivary glands are caused to secrete more abundantly by the presence of food in the mouth, and even by the taste and smell of food. The peristaltic action of the stomach and intestines is also automatic, although modified by the presence of the food.

10. Higher Automatic Action. — A higher form of nerve-activity is that proceeding from the cerebrum. Place an animal on the floor in its natural position when at rest. If its breathing and circulation go on, and it otherwise remains motionless, there is no activity of its cerebrum manifest to the observer. If touched or irritated and it moves, we cannot say it is activity of the cerebrum, for headless animals may do that. But if all causes of irritation be absent and the animal moves, we can say it is from a force proceeding from the cerebrum, and call it volition, or purely *automatic;* that is, *self-action.* If a loud noise be made, or some object be presented to its view, and it then move, it may be from reflex action or from volition, we cannot tell which. The noise or the view may make an impression of fear on the auditory or optic nerve, and this sent to the spinal cord through the brain incite involuntary motion. Examples of this are seen in persons involuntarily jumping from a sudden sound, or when they unexpectedly come upon a strange object. The movements are purely involuntary and therefore reflex. But, on the other hand, in the case of the animal, we do not know but the sound or the view may simply excite the apprehension of the mind of the animal, and its movements be purely voluntary and made for the purpose of getting away from the danger.

Volition, then, seems to come from within and be independent of external stimuli, yet we do not know but that it is a result of impressions *previously* received through the sensory nerves and stored up in the cells of the brain, to be given out later in the form of voluntary motion. Would a being without the senses of smell, touch, taste, hearing, sight, temperature, and common or general sensation (pain) exhibit will power or consciousness? This is a question yet to be answered. Going to sleep is the shutting out of all external impressions, and sound sleep is perfect quiescence of the cerebrum.

This higher automatism to a great extent governs and controls all other forms of nerve-activity. We can by exercise of the will check, or resist, the tendency to motion caused by tickling the extremities. Persons with strong wills resist to a certain degree the encroachment of disease and are enabled to endure great bodily injuries without showing signs of pain.

11. Force of Habit. — Reflex action is of great value to the individual, for it enables him to perform various kinds of movements and carry out different trains of thought at the same time. We walk and work and eat to a great degree automatically. When we are learning to do a certain kind of work, it requires our whole attention, but after we become accustomed to doing it, the work goes on while the mind may be occupied with something else. If the child in learning to walk does not give it the entire attention of its mind, it will lose its balance and fall, but after a while it is enabled to balance itself and move easily without taking a thought. The same is true in learning to read and to write. We must at first give them our entire attention, but after a while it becomes automatic and the words are repeated and the hand forms the letters unconsciously. It is fortunate for us also that breathing and the beating of the heart and other so-called organic movements are independent of our wills, for if they were not we would neglect them when some new activity was demanded. A few moments' neglect of these essential motions would be fatal.

12. Sleep and Dreaming. — Sleep is the cessation more or less complete of cerebral activity. During this period repair of the entire system goes on, and the excess of waste over repair during the waking moments is counterbalanced. Dreams are the result of partial and unco-ordinated activity of the cerebrum. It is believed from some experiments and observations which have been made, that dreaming takes place the very instant of waking. It is strange how in a moment one may dream of occurrences which would occupy days, even years, in their fulfillment. Dreams to a great extent depend upon the nature of the actions and thoughts of the previous waking moments. Different times, places, and individuals are mingled in the strangest confusion in dreams. It is curious to note how external causes may determine the nature of a dream. Thus the firing of a gun, or a clap of thunder may cause one to dream of a battle. Dr. Reid had a blister on his head and dreamed of being scalped by Indians. Complicated mental operations are sometimes performed in sleep, such as the solving of mathematical problems, inventing machines, etc. Coleridge composed a poem while asleep, and on awaking seemed to have a distinct recollection of the whole of it. He instantly began to write it down, but when he had written fifty-four lines he was called away on business, and when he returned he had forgotten the remainder and could never recall it to mind with sufficient distinctness to complete the poem.

Nightmare is an intensified form of dreaming in which the person imagines himself in a distressing situation and unable to help himself. It is a result of imperfect circulation of the blood. *Somnambulism* is a condition in which the person performs, during sleep, the actions naturally belonging to the waking state, as walking, climbing, etc. It is peculiar to certain persons, and it is difficult to trace it to any special cause.

13. Functions of the Sympathetic System. — The sympathetic nerves are distributed mainly to the organs in the thorax, abdomen, and pelvis, and are intimately connected with the functions of digestion, respiration, circulation, secretion and excretion, and nutrition. These are called organic functions because they distinguish a living organism, that is, a plant or animal from inorganic or mineral matter. These nerves are therefore called the nerves of organic life as distinguished from the encephalo-spinal nerves, which are the nerves proper of animal life. It frequently happens that when one organ is diseased or irritated a disturbance in the functions of another organ occurs. Thus an irritation of the stomach may cause labored respiration or palpitation of the heart. One organ is thus said to sympathize with another. The sympathetic nerves were supposed to be the media of these peculiar reflex actions, hence the name *sympathetic system*.

NOTE.

There are a number of experiments which might be performed on living animals, which would illustrate functions of the nervous system, but they are not of a nature to be practicable in an ordinary school. The teacher should call special attention to the experiments alluded to in the text. All pupils will have observed the motions of decapitated fowls, and many will have noticed the movements of frogs, turtles, and snakes when killed. Also the actions of sleeping persons have been observed. By proper questioning the teacher may bring the combined experience of the class on these subjects, and this exercise will be a very good substitute for actual laboratory experiments.

LESSON 34.

Hygiene of the Nervous System.

1. **Healthy Condition of Other Organs.** — The parts of the body are mutually dependent. When one suffers, all must suffer more or less. Good digestion, depending mainly on good food, properly prepared, in proper quantity and taken under proper conditions, tends to produce good blood, and this favors healthy secretions, proper excretion, and proper nourishment of all the tissues. The condition of the nervous system depends largely upon the nourishment of nerve-tissue. But muscular exercise and rest in proper proportion are also necessary for good digestion and perfect circulation and excretion. Proper action of the respiratory system, so that the blood gets the proper amount of oxygen free from injurious admixtures, and proper attention to cleanliness and evacuation of excretions, are also necessary for the general health. Hence, the hygiene of the nervous system demands attention to all other hygienic laws.

2. **Excitement and Emotion.** — The mind and body have a reciprocal action. Anything that disturbs the mind, as paroxysms of anger, excessive fear and grief, even excessive joy, disturbs the functions of digestion, secretion, respiration, and circulation, through the nervous system. The nutrition of the tissues in general is thus impaired, and the nerve-tissue suffers with the others. The nerve-tissue thus changed cannot act in a normal manner, and the mind is disturbed through the body. Insanity is generally the result of unrestrained passions and emotions. Many persons give way to passions and emotions which an educated will would have checked and held in abeyance. Yet

there is often danger in sudden and complete suppression of the expression of emotion. Tears and words are often the safety-valves which relieve the tension of the nervous system. But brooding over misfortunes and stirring up resentment are plain violations of a natural hygienic law.

3. **Work and Worry.** — Some persons can endure without injury much more mental labor than others. Agassiz defined genius as a capacity for an infinite amount of work, and it is generally true that those who have distinguished themselves in any particular field have done it by a vast amount of mental labor. Sometimes it has been at the expense of a broken-down constitution and a shortened life, but we have plenty of instances of men and women living to old age and having labored from youth up almost every minute of their waking existence. It is not mental work simply that kills. It is misdirected mental work, and mental worry. The mind needs a diversity of employment, so that different nerve-cells are called into activity in proper alternation. He who is content to do what he can, properly varying his work, and does not worry over the results, will accomplish the most with the least expenditure of nerve-force. Dr. George M. Beard says: "Worry is the converse of work; the one develops force, the other checks its development and wastes what already exists; work is growth; worry is interference with growth. Worry is to work what the chafing of a plant against the walls of a green-house is to the limitless expansion in the free air. In the successful brain-workers worry is transferred into work."

4. **Rest.** — What has been said in the lesson on Hygiene of Muscles in regard to exercise and rest applies also to the nervous system. It is probably true, however, that nerve-activity can be kept up longer without injury than muscular activity. Except when asleep the mind is ever active. We are always thinking of something, however important or trivial that something may be. It is the constant attention of the mind to one train of thought that tires it. Change is rest. A change of work is frequently a recreation, and the best possible kind of rest. Pure recreation or sport is, however, necessary especially

to some persons. Some of the greatest thinkers and brain-workers have made a habit of resting their brains by indulging in some trivial amusement or occupation. Darwin, one of the most industrious of naturalists, whose labors have revolutionized the study of science, indulged, as a habit, in reading very light fiction. Milton, whose "Paradise Lost" was the greatest intellectual achievement of his age, was accustomed to practicing the sword exercise.

"Rest," says Judge Tourgée, "is that change of occupation; rest is that relaxation of attention; rest is that putting of the mind in a new channel, or in a new course, that gives to the overstrained nerves — that gives to the worn body — that gives to the weary heart, relaxation. A man may rest and work like a horse all the time; a man may do more resting than most people ever dream of, and yet do more work than most of us ever know of."

5. **Sleep.** — "Sleep," says Shakespeare, "knits up the raveled sleeve of care." Young defines it as "Tired nature's sweet restorer." Truth and poetry are here happily commingled. One can scarcely get too much natural sleep. A man gains nothing by robbing himself of sleep. He simply robs himself of vitality. During sleep a man's physiological bank account is increasing, and during waking it is being drawn upon. Physiological bankruptcy will soon follow a continued encroachment of labor or amusement upon the amount of time that should be devoted to sleep. The hours of darkness are the most favorable to sleep. The best time to rise is just at daylight, and the best time to retire is at such an hour as will give a proper amount of sleep before daylight. The proper amount varies with the individual. In adults from six to nine hours is usually enough. Children and very old people require more. The young babe sleeps most of its time and grows and gains strength rapidly.

Persons are often kept from sleep by their minds dwelling upon their business or social affairs. It is not always possible to avoid this, but the best way is to make an effort to fix the mind momentarily on some subject entirely outside of the regular channel of thought, changing from one subject to another as frequently as possible; in other words, make an effort to cause the mind to wander. Try to recall the pleasant incidents of the past, or build air-castles for the future, but do not think about your daily affairs.

6. Effects of Alcohol on the Nervous System. — As alcohol acts on all organs *through* its action on the nervous system, it would naturally be supposed that the nervous matter itself would be injured, and such is the case. One of the first effects of alcohol is a flushing of the face and a feeling of warmth on the surface of the body. This is due to the quickened action of the heart and the dilation of the small blood-vessels from the effects of alcohol on the nerve-centers controlling these organs. The mind is at first more active, because the little vessels of the brain are dilated and blood is sent more freely to that part. A little later the alcohol begins to disturb the reflex and co-ordinating powers of the nervous system, and ordinary muscular movements are performed imperfectly and with difficulty. Still later, the will power and judgment becomes paralyzed and only the emotional and impulsive instincts of human nature are left, and these being no longer under control of the higher faculties of reason and judgment, are liable to cause the individual to act in an irrational manner. In the last stages consciousness and volition are lost, and only that part of the nervous system which governs circulation and respiration remains. In other words, the man is "dead drunk." A large quantity may produce death by paralyzing all nerve-centers, and thus putting an end to all organic functions. This over-action and irregular action of the nerves, when repeatedly occurring, has the effect finally of weakening the nerve-tissue.

Says Dr. George M. Beard: "There is scarcely a nervous disease known to science that excess in the use of alcoholic liquors may not bring on or aggravate. General debility, neuralgia, insomnia, epilepsy, paralysis of every form and type, insanity in all its grades, as well as delirium tremens, may find in alcohol their exciting and predisposing cause." But the worst of all is the moral effect of long-continued excess. The brain degenerates and the mind loses control over the appetite for spirits. "Pledges of total abstinence, fear of disgrace, loss of social position, loss of friends and family, apprehensions for this world or the next, all these considerations have no more weight against this disease [chronic alcoholism] than they would have against smallpox or typhoid fever."

7. Effects of Tobacco on the Nervous System. — While there are many persons, especially among those in adult life, whom tobacco does not apparently injure, there are some who are particularly affected by even a moderate use of the weed. There are persons who have a nervous diathesis, that is, a tendency to nervous diseases. This condition is more prevalent in this country than in Europe, probably an effect of our drier climate. Tobacco is especially injurious to such persons. They become "nervous," suffer from sleeplessness, melancholy spirits, trembling, headaches, and sometimes disturbance of vision.

8. Tea, Coffee, and Chocolate. — These beverages have usually a peculiar soothing and sustaining effect on the nervous system when taken in moderate quantities by adults. Their beneficial effects are more particularly noticeable in persons past the middle age. But there are some organizations which cannot tolerate them in even moderate quantities, and when used to excess they are frequently very injurious. Children should not use them, and adults should observe their effect on themselves and deny themselves if evil results appear to be due to their use. They are inclined to produce wakefulness in some persons, and in others tremblings.

In such cases they should not be used. If a warm drink is needed a harmless substitute for these beverages is found in "Cambric tea," which is simply hot water and milk sweetened to taste. It is a great mistake to drink tea or coffee for the purpose of keeping awake in order to prolong the hours of labor. Their power for evil is thus trebled, for there is combined with the effect of over-stimulation of the nerves the loss of the necessary sleep and excessive labor.

9. Opium and Morphine. — These drugs are valuable agents in the hands of a skillful physician, but anything like an habitual use of them or even a frequent use of them in cases of sickness is exceedingly dangerous. They rapidly gain a powerful hold on the individual, blunting his moral sense and destroying his will power so that he becomes an abject slave to the appetite for them. Those who suffer frequently from neuralgia and other painful affections should be very careful in using these drugs lest a habit of taking them be acquired, a habit which will grow with the indulgence until finally all power to quit their use is lost, and the patient is a helpless victim of a drug which in a few years will make him a mental and physical wreck.

10. The Use and Abuse of Quinine. — This is one of the most valuable of medicines, good in a great variety of cases, and in the hands of a skillful physician one of the greatest of blessings. But of late years many persons are in the habit of prescribing it for themselves in every slight ailment, and many have become slaves to it, taking it as regularly as they would alcoholic liquor or opium, and although the result is not so serious as in case of the latter drugs, it is bad enough.

11. The Effect of Medicines in General on the Nervous System. — The human system is so constituted that it seems to acquire gradually the power of tolerating even very poisonous medicines, the nervous system constantly requiring more and more to produce the same effect, until finally it breaks down under the load, and a general collapse of the whole organization follows. Thus one may begin with the ordinary dose and by gradually increasing it an amount may be taken without immediate danger which would under other circumstances cause death. But the end comes finally in a broken-down constitution. The lesson taught by the victims to the habitual use of narcotic drugs should not be lost on those who are yet free from the bondage of habit. Drug medicines are but necessary evils. He is wise who uses them only in cases of actual necessity.

EXERCISES FOR REVIEW.

1. Is the size of the brain a measure of mental power? What relation has the relatively greater quantity of gray matter to intellect?

2. What are the uses of the membranes covering the brain?

3. Name the divisions of the nervous system; of the brain.

4. What part of the cerebrum is gray matter? of the cerebellum? of the spinal cord?

5. What are the ventricles of the brain? What lines them? Their contents?

6. How does the dura mater of the spinal cord differ from that of the brain?

7. What is the "arbor vitæ"?

8. Where are nerves most numerous?

9. Name the cranial nerves in order, giving the origin, distribution, and function of each.

10. What is the effect of cutting the anterior root of a spinal nerve? the posterior root? both roots? the nerve itself?

11. What is the "abdominal brain"? Explain why a severe blow on the abdomen may cause death without breaking the tissues.

12. What is the structure of gray matter? of white matter? How do they differ in function?

13. Neurilemma? Perineurium? Neuroglia?

14. How do nerves terminate?

15. What is a characteristic chemical element of nerve-substance?

16. State the functions of the nervous system in general terms.

17. Where is the seat of the intellect? of will? of consciousness?

18. Where is the "vital knot"? Why is death by hanging instantaneous and painless?

19. Locate the following centers: the respiratory, vaso-motor, cardio-inhibitory, vomiting center.

20. Define reflex action. What are the functions of the spinal cord?

21. Automatic action.

22. Define sleep and dreaming.

23. What is meant by the "nerves of organic life"?

24. Define rest. Why do so many men succumb to "overwork"?

25. What is the proper amount of sleep for an adult?

26. When is alcohol injurious to the nervous system? Why?

27. *Do not permit yourself to become a slave to habits of eating, drinking, or taking medicines.* Why is this good advice?

CHAPTER II.

HOW THE BODY COMMUNICATES WITH THE EXTERNAL WORLD, OR THE SPECIAL SENSE-ORGANS.

LESSON 35.

The Structure of the Eye.

1. **The Orbits.** — The human eye is peculiarly well protected in its bony socket. Nothing but a well-aimed thrust of a comparatively sharp instrument can injure it. Ordinary blows are sure to be received by the prominent cheek-bone below or the edge of the frontal above. It is also protected from shocks by a cushion of soft material. The cavity of the orbit is conical in shape, and the space not occupied by the eye and its appendages is filled with loose areolar tissue containing fat.

2. **The Eyeball.** — The eyeball is in the shape of a sphere, with the segment of a smaller sphere grafted upon it, making the diameter from before backward a little greater than the lateral diameter, which is about one inch. The eye is apparently set in a slit in the skin of the face, but really this is not the case, for the skin of the eyelids turns over their edge and becomes here a thin, transparent, smooth, and exceedingly sensitive mucous membrane, the **conjunctiva**, which lines the lids and is reflected over the front part of the eyeball itself, so that the eye is really *behind the skin.*

The eyeball is capable of being turned in all directions by six little muscles which have their origin in the back part of the orbit. The *superior rectus* turns the eye upward, the *inferior rectus* turns it downward, the *external rectus* turns it outward, and the *internal rectus* turns it inward. The *superior oblique* muscle passes forward through a loop near the upper, inner front part of the orbit, then turns and passes over the eyeball and is attached to it at its outer side. Contracting, it turns the eye outward and downward and rotates inward. The *inferior oblique* acts as an antagonist of the superior, and turns the eye inward and upward and rotates it outward. "Cross eyes" and "wall eyes" are caused by too great contraction, the former of the internal rectus, and the latter of the external rectus. The defects may be remedied by cutting the proper muscle with a suitable instrument and permitting it to become attached to a new point.

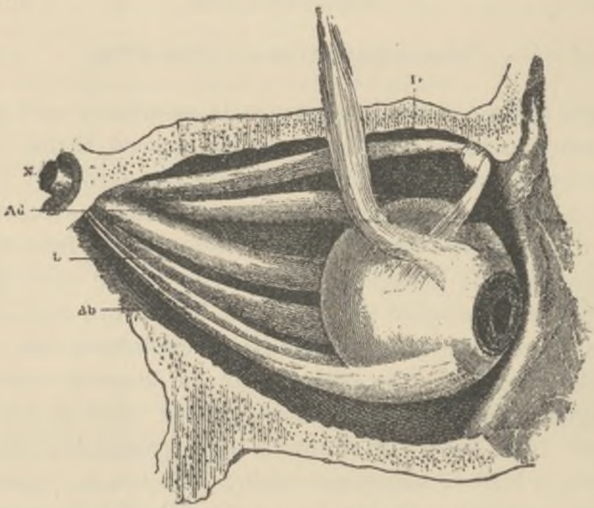


FIG. 25.—MUSCLES OF THE EYEBALL.

3. The Sclerotic Coat. — The eye is a globular receptacle filled with transparent fluids. The walls of the receptacle are three in number, closely attached to each other, and called respectively, the outer or first, the middle or second, and the inner or third *tunic*. The outer tunic is in two parts, one opaque, the other transparent. That part which covers about five-sixths of the eye and is of a pearly white color is called the sclerotic coat. The part of it which we can see is called the "white of the eye." It is a very tough, dense membrane, rigid enough to give shape to the eyeball, yet elastic and yielding to pressure. The muscles of the eye are inserted into it, and it is perforated at the back part for the entrance of the optic nerve. It consists of white fibrous tissue mingled with fine elastic fibers and fusiform nucleated cells. The existence of nerves in it is doubtful, and the blood-vessels are few in number. The veins we see in the white of the eye when it is "blood-shot" are in the conjunctiva, which is so transparent that we do not see it except when its vessels are engorged.

4. **The Cornea.** — The anterior sixth of the first tunic is called the cornea. It is perfectly transparent and fits into the sclerotic coat like the crystal of a watch in its case. In outline it is almost circular. Is is composed of three layers, not including the conjunctiva, which covers it in front. The outer layer is composed of transparent fibers, continuous with those of the sclerotic coat. The middle layer is an elastic membrane which maintains the curvature of the cornea. The inner is a layer of epithelial cells. It contains numerous nerves, but no blood-vessels nor lymphatics. The cornea is the window through which light enters the interior of the eye.

5. **The Choroid Membrane.** — That part of the second tunic which lines the sclerotic coat is called the choroid membrane. It is connected to the sclerotic by fine cellular tissue. It consists mainly of a dense net-work of capillary vessels interspersed with pigment cells, which give it a dark brown appearance. In albinos the pigment, or coloring matter, is absent and the choroid is red from the blood showing through the translucent vessels. Like the sclerotic it is pierced behind for the entrance of the optic nerve.

6. **The Ciliary Processes.** — At the junction of the sclerotic with the cornea the choroid membrane is gathered into a circular, plaited curtain, or series of converging folds from sixty to eighty in number, surrounding the crystalline lens. These folds are called the ciliary processes. Beneath this and attached all around to the sclerotic coat is a muscular ring with radiating fibers called the **ciliary muscle.**

7. The Iris. — We speak of a person's eyes as blue, brown, black, or gray, but all this "color of the eyes" is simply the color of a peculiar circular adjustable curtain with a round hole in its center. This curtain is called the iris, and the hole the **pupil** of the eye. The pupil always appears black because we look through it at the black choroid membrane in the back part of the eye. In the albino it appears red because the choroid membrane is red. The iris lies behind the cornea and in front of the crystalline lens, and is attached to the choroid membrane by its circumference and by the ciliary ligament to the sclerotic coat and cornea. It forms, together with the choroid and ciliary processes, the second, or middle tunic. It consists of a layer of many sided cells, containing a pigment matter in front, behind which is a framework of fibers and cells, and back of this are two sets of involuntary muscular fibers, one running in a circular manner, the other radiating. When the circular fibers contract the diameter of the pupil is lessened; when these fibers are relaxed the diameter of the pupil is increased by the elasticity of the radiating fibers.

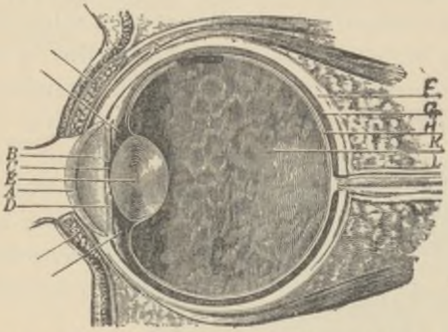


FIG. 26. — A SECTION OF THE HUMAN EYE.

A, Cornea; *B*, Aqueous humor; *C*, Pupil; *D*, Iris; *E*, Crystalline lens; *K*, Vitreous humor; *L*, Optic nerve; *F*, Sclerotic; *G*, Choroid; *H*, Retina.

8. The Retina. — This is the expansion of the optic nerve and constitutes the whole of the inner or third tunic. It is a semi-transparent membrane lying close to the choroid and extending nearly to the ciliary processes in front. It consists of ten layers of variously shaped cells and fibers. The ninth layer, counting from within outward, is called Jacob's membrane, and consists of rod-like and cone-like bodies which appear to be the real termination of the optic nerve. The point where the optic nerve enters is about one-tenth of an inch to the inner or nasal side of the center. Here there are no rods and cones, and experiments have demonstrated this spot to be blind. In the exact center of the retina is a slight elevation with a central depression at its center. As we approach this central spot (the *macula lutea*, or "yellow spot," as it is called) the cones become more numerous and much smaller. Le Conte says they are only $\frac{1}{10000}$ of an inch in diameter, and there are probably a million in a square $\frac{1}{10}$ of an inch. It is at this point that vision is most perfect.

9. The Aqueous Humor. — The cavity of the eye is filled by three transparent bodies, called humors. That occupying mainly the space behind the cornea and in front of the iris is called the aqueous humor. A very little of it lies in the space behind the iris, communicating with that in front through the pupil. It is a clear liquid, consisting mostly of water with alkaline salts in solution. If the cornea be punctured the aqueous humor escapes, the protuberant part of the eye collapses, and the sight is temporarily lost. The wound will, however, heal in a short time and a new supply of liquid will be secreted and sight restored.

10. The Vitreous Humor. — The large cavity enclosed mainly by the retina contains a thick, jelly-like transparent albuminous substance, called the vitreous humor. It is contained in a transparent membrane, called the hyaloid membrane. Meshes of transparent fibers divide the mass into compartments.

11. The Crystalline Lens. — This name is misleading, for although it is really a lens in itself, it forms in the eye only a part of a lens, the other parts being the vitreous and aqueous humors and the cornea. It is described as one of the humors of the eye although it is not a liquid but a solid body, easily compressible and elastic. It is in the shape of a double convex lens, about one-third of an inch in diameter and one-sixth of an inch in thickness in the center. It is enclosed in a transparent bag, called the capsule of the lens. This capsule is attached to the sclerotic coat near the junction of the cornea.

12. The Protectors of the Eye. — Not only is the eye well protected by its location, but it has in addition certain guards and defenders. The **eyebrows** shield it from excessive light and direct the perspiration to one side and possibly catch some particles of dust that otherwise would get into the eye. The **eyelids**, composed of a piece of cartilage covered with skin and lined with the mucous membrane, act both reflexively and voluntarily, closing instantly when danger approaches. Their edges contain small glands (Meibomian glands) which secrete an oily fluid which prevents the tears from overflowing on the face and keeps the lids from growing together. The **cilia**, or **eyelashes**, act as shades to the eye and as feelers to warn of danger in the dark. The **conjunctiva** has already been described. It being highly sensitive, warns us of the danger of permitting particles to remain in contact with the eye.

13. The Lachrymal Apparatus. — This is an additional means of protection to the eye, and consists of the lachrymal gland, with excretory ducts, the lachrymal canals, the lachrymal sac, and nasal duct. The lachrymal gland is located in the upper, outer part of the orbit, and pours its secretion through several ducts upon the eyeball. The constant winking keeps it distributed over the eye. It is prevented from flowing off upon the face, unless in excessive quantity, by the oil from the Meibomian glands. The orifices of the two lachrymal canals open at the inner corner of the eye and receive the fluid. They empty it into the lachrymal sac, and this discharges it into the nasal duct which opens in the nasal cavity. Here it evaporates as fast as discharged. When the secretion is excessive it flows over the lids on the face in the form of tears. The tears consist mostly of water containing salts in solution, common salt, or chloride of sodium, being most abundant. The use of the lachrymal fluid is obvious. It maintains the clearness of the eye by keeping it moist, and washes dust and foreign particles away and protects the delicate mucous membrane from the irritating effect of the air.

PRACTICAL ILLUSTRATIONS.

1. Secure from the butcher the eyes from an ox, pig, or sheep. If possible get several specimens to use in case one is spoiled in dissection, and also that you may try different methods of preparing them for illustration. Place in water until ready for use.

2. After removing the fatty tissue, observe the shape of the eyeball, the firmness and toughness of the sclerotic coat, the size and point of entrance of the optic nerve. Portions of the muscles of the eye will also be seen. With a sharp knife cut through the tissues at the junction of the cornea with the sclerotic coat. A slight squeeze when the opening is made large enough will cause the crystalline lens to come out. The aqueous humor and part or all of the vitreous will also escape, and the eyeball will partially or wholly collapse.

3. Examine the crystalline lens. Observe its form and transparency. Lay it over a letter or word of fine print and observe that it magnifies like a microscopic lens. Put it in water and boil it. Observe that it at once turns white and opaque, and after it has boiled several minutes it will split open in three triangular pieces, and the surface may be peeled off like the coats of an onion.

4. Observe the vitreous humor which will flatten out and resemble very much the fresh white of an egg.

5. Now cut through the tissue further and turn the eye inside out as you would a ball cover. Observe the blackness of the choroid membrane. The ciliary processes will have been partially destroyed perhaps by the rude handling necessary in cutting the tough sclerotic coat, but a partial idea of them can be had. The iris will not show very well, as it is difficult to isolate it.

6. Take another eye and boil it for a quarter of an hour. Then cut it through from before backward. The general relation of the parts may be seen. Try also, if convenient, the method of freezing an eye, and then make sections as before.

LESSON 36.

Phenomena of Vision.

1. **The Eye as an Optical Instrument.** — If you make a pin hole in the end of a box, and throw a dark cloth over your head as you look down into the box so as to exclude all light except that which comes through the pin hole, you will observe an inverted picture of any strongly illuminated object which may be in front of the hole. A box so arranged is a **camera obscura** ("dark room"). A smaller and more distinct image may be made by enlarging the hole and placing in it a convex lens which has the power of converging the rays of light to a point called the *focus*. In this case the surface on which the picture is to be received must be placed in the focus of the converging rays; hence it will be necessary to put in a movable screen which can

be adjusted to the proper distance. The distance of the focus from the lens depends upon the convexity of the latter, the more convex the closer the focus, and *vice versa*. To get the best results the sides of the box should be painted black so that all rays which strike the sides may be absorbed, otherwise they would be reflected upon the picture and obscure it. Such a box, with either an adjustable lens or adjustable screen, is the ordinary camera obscura.

Now let us see how nearly the eye corresponds to a camera obscura. The cornea is the window which first admits the light coming from objects. The pupil is the small hole which admits

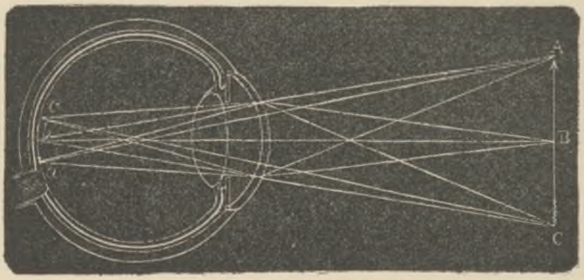


FIG. 27.—THE RETINAL IMAGE.

it to the dark chamber. The retina is the screen on which the picture falls. The choroid membrane answers to the dark colored walls and absorbs the indirect rays. The transparent parts of the eye all combine to form the lens which converges the light. We thus see that **the eye is a perfect camera obscura.**

2. The Picture on the Retina.—As we have seen, the camera obscura produces a miniature picture or image of the objects in front of it, and that the eye is constructed in all essential particulars exactly like such an instrument; hence there must be an image formed on the retina very much reduced in size, but perfect in distinctness. This image is in some way, difficult for us to understand, translated to the mind through the optic nerve and brain, and this translation constitutes the sense of sight. It may be asked, since the image is inverted on the retina, how is it that we see objects in their upright position. It is true it appears inverted to another eye looking at it as a picture, but it does not follow that it is thus translated to the mind. We are not conscious of an image in our own eyes, in fact, we are not conscious of having eyes at all unless we see them in a mirror or have some pain or uneasiness in them, or our attention is called to the fact in some way. The mind refers all sensations to the direction from which they come. All images are, as it were, projected into space outside of ourselves. When you see a horse ten feet away you think of it as a horse at that distance, and not as an image in the eye. The image is inverted on the retina because the rays from the top of the object strike the lower part of the retina, and *vice versa*, but the mind refers them to the place *from which they came;* hence they appear upright, as they really are.

3. **Accommodation.**—In the camera obscura, in order to get a distinct picture the distance between lens and screen must change when the distance between object and lens changes. The same result could be produced without changing the distances if a lens of different degree of convexity, or of different refractive power, could be substituted. The eye has not the power of changing the relative positions of lens and retina, but it has the power of changing the convexity of its principal lens, the crystalline lens. When a near object is observed, the lens becomes more convex than when a distant object is viewed. The mechanical arrangement for this adjustment is a perfect one as to results, but one difficult to understand. Helmholtz explains it as follows: The capsule of the lens is naturally drawn tight by the elastic rigidity of the sclerotic coat and presses on the lens, slightly flattening it. This is the passive condition, as when looking at very distant objects or when the eyes are closed. When the fibers of the ciliary muscle contract they pull the outer part of the capsule of the lens in toward its center. This relaxes the tension in the central part and permits the lens to swell out and become more convex. The normal eye when passive is adjusted to objects at an infinite distance. By increasing the convexity of the lens the eye becomes adjustable

to all distances up to within five inches, which is the limit. It is at comparatively short distances only that the change is great. Beyond twenty feet the change is exceedingly slight. Thus by this beautiful mechanical contrivance we are enabled to see distinctly in a space varying from five inches to millions of miles.

4. Regulating the Light. — The eye has been termed the "window of the soul." This window has a beautiful curtain which is delicately adjustable so as to admit more or less light as needed to form the picture on the retina. Hang a mirror by the side of a door. Darken the room and as you look in the mirror open the door to admit light. You may see the pupil of the eye at first quite large, then as the light becomes stronger it becomes smaller, and if the light be very bright it gets very much smaller. In some animals, as the cat and owl, the range of contraction and expansion of the pupil is much greater than in man, enabling these animals to see after night when the amount of light is very small.

The iris is contracted and the pupil lessened :

1. When the light is increased.
2. When accommodation is made for near objects.
3. When the eyeball is turned inward.
4. When the aqueous humor is deficient in quantity.
5. Under the influence of certain poisons, as opium, and in the early stages of alcohol and chloroform poisoning.

The iris is relaxed and the pupil enlarged :

1. When the light is diminished.
2. When accommodation is made for distant objects.
3. When there is an excess of aqueous humor.
4. During difficult breathing, violent muscular exertion, and strong emotions.
5. Under the influence of poisons, as *Atropa belladonna*, and in later stages of poisoning by chloroform. (See Lesson 35, Sec. 7.)

5. Correction of Chromatism. — In images by an ordinary lens the outlines are edged with rainbow hues. This detracts from the picture. The cause lies in the fact that a ray of light consists of many colors combined, the mixture producing the impression of white light, but the lens acts partially as a prism and refracts some colors more than others, and thus separates them. The optician corrects this by making his lens of two pieces of glass of different refractive power, one in the form of a convex lens, the other in the form of a plano-concave lens, so that the convexity predominates over the concavity and the compound lens is convex. In this way one part of the lens separates the colors and the other corrects it, and the whole lens is *achromatic*, that is, produces no color. Now the lens of the eye consists of three parts of different shapes and different refractive powers and is perfectly achromatic, or in other words, chromatism is corrected by a mechanical arrangement.

6. Correction of Aberration. — Another defect in ordinary lenses is aberration or imperfect convergence of the rays of light, producing a blurred picture. It is due to the fact that the outer part of the lens refracts more than the central portion. This is partially overcome by using a diaphragm, that is, a plate with a hole in it, to shut off the rays coming through the outer part of the lens. In the eye the iris acts as this diaphragm. But a more effectual way is to make the central position of the lens more refractive. This can be done in two ways, by increasing its curvature, or by increasing its density. Art has not succeeded by the latter method, but nature does, for in the eye the crystalline lens is more dense in the central than in the outer portions, and the picture made by it is perfectly clear and distinct.

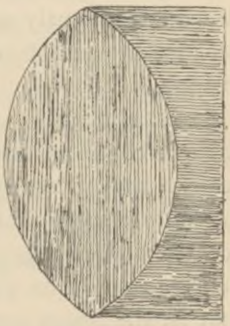


Fig. 28. — Compound Lens for Correction of Chromatism.

7. Single and Double Vision. — If we press the eye to one side by the finger we see objects as double when both eyes are open, but if the eye not pressed upon be closed we see the objects as single. If we hold up a finger of each hand, one about a foot in front of the other, and direct our attention to the near one, the far one appears double; then, if we direct attention to the far one, the near one appears double. Also if we hold up a finger and look at the wall beyond it, we see two images of the finger. If we shut the right eye the left-hand image disappears, and if we shut the left eye the right-hand image disappears. Each eye forms its own image, and when these images fall on corresponding places on the retina they are translated to the mind as one image. When one eyeball is pushed to a side the places of the images do not correspond, and the appearance of two images is the result. When our attention is directed to one point the two eyes are turned so that the two images are projected into space to the same spot and are superimposed and coincide with each other, but images of other objects nearer or farther away are projected to different spots and their images do not coincide. Usually we do not give any attention to these secondary images. With some persons the experiments here given are a failure, they not being able to see the double image. A man frequently sees double under the influence of alcohol, because he cannot control the muscles which direct the line of vision.

8. **Irradiation.** — A white spot on a dark ground appears larger than it really is, and a dark spot on a white ground appears smaller than it really is. For the same reason a person dressed in white appears larger than when dressed in black. This is because the stronger light reflected from the white objects produces an effect on the retina beyond the outlines of its image, that is, the image seems to be spread out on the retina from the greater stimulus of the strong light.

9. **After-images.** — If we look at the sun and then shut the eyes we can see the image of the sun for several seconds. Looking intently at a window from within a room we can shut our eyes and see an outline picture of the window sash and panes. A stick with fire on the end appears as a ring of light when rapidly moved in a circle. A wheel with spokes appears as a solid wheel when rapidly revolving. A spinning top painted in bands with complementary colors appears white from the mingling of the colors. All of these phenomena are due to the fact that the impression on the retina continues for a little

time, that is, the sensation lasts longer than the stimulus that caused it.

After looking steadily at a white patch on a black ground for some time, if the eye be turned to a white ground a gray patch will be seen. After looking at a black patch on a white ground, if the eye be turned to a gray ground a white patch will be seen. This is the result of exhaustion of the retina; the part which received the stimulus becomes tired and ceases to respond for some little time to the stimulus. These are called *negative after-images.*

10. The Yellow Spot and the Blind Spot. — We can see with perfect distinctness only one point of an object at a time. The line of vision must move along the printed line as we read, being fixed successively upon each letter of each word. By practice we are enabled to recognize whole words, and even lines of a dozen words at one glance, but to get an exact and distinct picture of each letter the eye must be fixed upon each in succession. This fixing the eye on one point at a time is simply bringing it in such a position that the image of that point falls on the yellow spot, the only point where vision is completely perfect.

By a simple experiment we can prove the existence of a blind spot on the retina. (See Lesson 35, Sec. 8.) Hold this book on a level with the eye at the distance of a foot. Close the left eye and fix the right steadily on the left hand letter A. Then

A **A**

gradually move the book toward your face. When at a certain distance — about six inches — the right hand A will disappear, to reappear when the book is brought still closer to the face. Similarly the left A will disappear if the gaze be directed to the right A. The letter disappears because its image is thus made to fall on a spot incapable of receiving an impression, that is, the blind spot, or the place where the optic nerve enters. The image of an object does not fall on the blind spots of both eyes at the same time, hence it cuts no figure in ordinary vision.

11. Phosphenes. — If the optic nerve be irritated in any way no pain is felt, but a sensation of light is experienced. Thus a blow on the head produces sometimes by the jarring this sensation, and we call it "seeing stars." It is not real light, as no one else can see it, but simply a sensation the same as would be provoked by light. If we press with the finger upon the inner side of the closed eye a ring of light the size of the end of the finger will be seen. In this case the retina is irritated by the pressure transmitted through the eyelid and sclerotic coat. These rings of light have been called *phosphenes*.

12. **Muscæ Volitantes.** — We sometimes observe indistinct motes or threads floating about apparently in the sky or on the wall. They are due to specks of opaque matter in the transparent vitreous humor. The mind projects the images of these specks out into space. They are called muscæ volitantes ("flying flies").

13. **Myopy, or Near-sightedness.** — The normal eye can adjust itself perfectly for all distances beyond five inches. In those persons whom we call near-sighted the refractive power of the lens in a passive condition is too great and the focus for distant objects is not on the retina, but in front of it. Such eyes have a very small range — from two to six inches, or from four inches to three feet, according to the degree of myopy. The results of this defect are easily overcome by wearing concave glasses which throw the focus back to the retina in the passive state, and then adjustment for near objects becomes possible.

14. **Hypermetropy, or Far-sightedness.** — This is the opposite of myopy. The lens in this case has not sufficient refractive power, and the focus lies behind the retina in the passive state. When young the hypermetropic eye usually sees well at a distance, but not near at hand, because a very slight adjustment only is necessary to adapt the eye to long distances, but as the eye grows older it loses the power of adjustment, and even distant objects cannot be seen distinctly. Such persons should wear convex glasses. When they grow older they need an extra pair with less convexity for distant objects.

15. **Presbyopy, or Old-sightedness.** — This is usually regarded as the reverse of myopy, but, according to Le Conte, it is not.

The presbyopic eye is perfectly normal for distant objects, that is, in a passive state, but it has not the power to adjust itself for near objects, probably from the loss of elasticity of the crystalline lens. Such eyes are corrected by the use of convex glasses, not to be worn habitually, but for near objects, as in reading. Presbyopy is a functional defect, a loss of power to use the instrument. Myopy is a structural defect, a defect of the instrument itself. Myopic persons should use glasses habitually. They may continue to wear glasses of the same curvature until advanced age. Presbyopic persons usually do not become so before middle age.

16. Astigmatism. — A perfect eye has its ..orizontal and vertical diameters equal. But some eyes have one or the other of these diameters greater, and the rays of light instead of being brought to a focus in a *point* are focused in a *line*. Such eyes cannot distinguish horizontal and vertical lines with the same readiness. Most persons have a slight degree of astigmatism, without themselves being aware of it.

17. Color Blindness. — Persons vary much in their power of distinguishing colors. Some regard as the same, colors which to others are very distinct. Such persons are said to be color blind, or are afflicted with "Daltonism," so named because Dalton, the distinguished chemist, was so afflicted. It was said that Dalton could not distinguish a red gown lying on the green grass, or red cherries among the green leaves, except by their form. The inability to distinguish between red and green is the most usual form of it, but there are cases which cannot distinguish between blue, brown, and other colors.

18. Cataract. — This is a not uncommon disease of the eye, producing partial or total blindness, which can be cured by a surgical operation. It consists of an opacity of the crystalline lens. The operation is nothing more nor less than removing the lens by cutting through the coats of the eye. The aqueous humor is thus lost, but will be restored. The loss in refractive power of the eye is compensated for by wearing convex glasses. In some cases the glasses are not needed, as the humors of the eye become more dense and sight is restored.

PRACTICAL ILLUSTRATIONS.

1. The pinhole camera described in the foregoing lesson may be made in another way which is very simple. Make a pinhole in the crown of a stiff hat and fix a piece of greased paper over the mouth of the hat. Now throw a shawl or cloth over your head and shoulders so as to shut out all light except what can come through the pinhole, and direct the crown of the hat toward some strongly illuminated object, as a tree, house or church spire in the sunshine. You will see a picture of the object on the greased paper.

2. The principle of the camera with a lens may be shown with any pocket magnifying lens or burning glass, or even with a pair of ordinary spectacles. Hold the glass between a white wall or piece of paper and a lamp, or a window. By moving the lens back and forth you will find the proper place where it will throw an inverted image of the flame of the lamp or of the window on the screen. By using a piece of white paper for a screen, and a lamp for the object, you will have the three essentials of a camera all movable, and by changing the positions of each you will discover that it is only at *certain* relative distances that you can get a distinct image. By substituting a lens of greater or less magnifying power you can show the necessity of changing the position of the screen, of the object, or of the lens, that is, that a change in the convexity of the lens is the same as a change in the relative distance of object, lens, and screen. By having some person to stand in front of the window you can make the picture more striking, as you will see the outlines of his figure inverted. The brightness of the picture will be heightened if the room be darkened.

3. Try the experiment mentioned in Section 4 of the preceding lesson. Observe the eyes of cats and owls in the bright light, then throw a shadow on them and observe the change.

4. Look through a common magnifying glass at some object as you hold it against the sky. You will observe a border of colors. Chromatism is not corrected in an ordinary lens. When you look into a good compound microscope you see no color on the image not belonging to the object. The best instruments have achromatic lenses.

5. Try all the experiments mentioned in Section 7 of the lesso... They are simple but instructive.

6. Cut out a square or circular piece of white paper and another of black paper exactly the same size. Paste the white one on a piece of black paper and the black one on a piece of white paper, and ask a friend to tell you which is the larger. He will invariably say the white piece is the larger. Prove him wrong by measuring with a rule.

7. Try the experiments described in Section 9. Modify the spinning top experiment as follows. Cut out a word or phrase printed in large plain letters from an advertisement. Cut it in two equal parts lengthwise with the line, that is, so that one piece will contain the upper half of each letter and the other piece will contain the lower half. Paste these pieces on opposite sides of a card, so that the top of one half will come even with the bottom of the other half, letter for letter. Now fasten a string in each end of the card and give it

a rapid rotary motion on its long axis by twisting the string. The whole word will plainly appear as the card revolves, the impression of one half of the letters remaining on the retina until the other half comes into view. The picture of a man, dog, horse, etc., may be cut in two and the halves arranged in a similar manner. An amusing form of the experiment is to draw on one side of the card the picture of a horse, and on the other the picture of a man in the position of one on horseback. The revolving card will show the picture of a man on horseback.

8. Every member of the class should try the "blind spot" experiment. See Section 10. Also the after-images and phosphenes should be demonstrated by each individual.

LESSON 37.

The Structure of the Ear.

1. **The External Ear.** — The ear is usually described as consisting of three parts: the external, middle, and internal ear. The external ear consists of the pinna and the auditory canal. The **pinna** is that portion which projects from the head and is commonly called "the ear," but which is not an essential part, as a man can hear quite well if it be cut off. It is composed of cartilage covered with a thin skin. The outer projecting rim is the *helix*. In front of this is a second ridge, called the *antihelix*. The depression in the center is the *concha*. Between the helix and antihelix is a furrow, the *fossa of the helix*. The antihelix divides in its upper part, and the furrow thus formed is called the *fossa of the antihelix*. Projecting backward over the concha is the *tragus*, and opposite to it is the *antitragus*. The pendulous portion of the ear is called the *lobule*.

2. **The Auditory Canal**, or *meatus auditorius externus*, is a tube leading to the middle ear. The outer portion is membrano-cartilaginous, the inner portion is osseous, formed by the mastoid portion of the temporal bone. It is lined with a thin skin continuous with that of the external ear. In the inner portion are the **ceruminous glands** which secrete the *ear wax*. The outer portion contains sebaceous glands and hairs.

3. The Muscles of the Ear. — In man there are three muscles on the side of the head and attached to the ear. They are functionless, except in some rare cases, and said to be rudi-

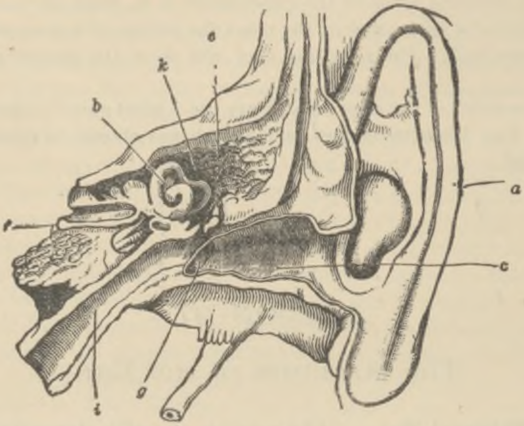


FIG. 29. — SECTIONAL VIEW OF THE EAR.

a, Pinna; *b*, Semicircular canals; *c*, Auditory canal; *e*, Bones of the ear; *f*, Cochlea; *g*, Tympanic membrane; *i*, Eustachian tube; *k*, Tympanum.

mentary, that is, in an undeveloped condition. In lower animals these muscles are particularly active.

4. The Middle Ear, or Tympanum. — This is an irregular cavity in the petrous portion of the temporal bone, and lined with mucous membrane continuous with that of the pharynx, through the **Eustachian tube** which joins the two cavities. Its outer wall is formed by the tympanic membrane, a thin, semitransparent, oval partition which completely separates the middle from the external ear. Some animals have no external ear, and this membrane is on a level with the surface of the body, or nearly so. On the posterior wall of the tympanum are several orifices which open into small cavities in the bone, called the *mastoid cells*. In the internal wall are two small openings in the bone, but covered by the mucous membrane, the *fenestra ovalis* (oval window) and *fenestra rotunda* (round window). They communicate with the labyrinth, or internal ear.

5. The Bones of the Ear. — Extending from the tympanic membrane to the fenestra ovalis, across the cavity of the tympanum, is a chain of minute bones (*ossicles*), three in number. The **malleus** (hammer) is attached by its long projection (handle) to the tympanic membrane and by its large part, or head, to the roof of the tympanum and to the incus. Two tiny muscles are fastened to projections of the malleus; one renders the membrane tense, the other relaxes it. The **incus** (anvil) has a body and two projections, one of which is attached to the back wall of the tympanum, the other to the stapes. The **stapes** (stirrup) extends from the incus to the fenestra ovalis, into which it fits. These bones are exceedingly small, yet each one is articulated to the others by ligaments, cartilage, and synovial membrane the same as other bones in the body, and all are covered with a continuation of the mucous membrane which lines the tympanum. They are so attached to each other and to the walls of the tympanum as to form a series of levers easily moved and communicating motion from the external to the internal ear.

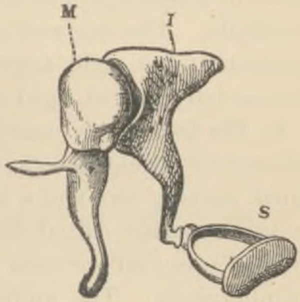


Fig. 30. — Bones of the Ear.
M, Malleus; I, Incus; S, Stapes. Enlarged.

6. The Labyrinth. — The internal ear, or labyrinth, consists (1) of a cavity in the bone of very irregular shape, called the bony labyrinth, and (2) a membraneous sac filled with fluid and floating in a fluid within it. The bony labyrinth consists of three parts, the *vestibule*, the *semicircular canals*, and the *cochlea*.

Fig. 31. — The Labyrinth.

7. The Vestibule. — This chamber serves as a means of communication between the tympanum and the semicircular canals and the cochlea. On the internal wall are minute openings, through which branches of the auditory nerve pass. In the back wall are five openings leading to the semicircular canals. The fenestra ovalis in the bony vestibule opens into the tympanum. In the front wall is an aperture leading to the cochlea.

8. The Semicircular Canals. — These are peculiar channels, three in number, in the form of loops which branch off from the vestibule. The superior and posterior canals stand in a vertical position and at right angles to each other. The third is placed horizontally and at right angles to the other two.

9. The Cochlea, so named from its resemblance to a snail-shell, consists of a central axis, or *modiolus*, around which is a spiral canal, making two and a half turns and terminating at the apex in an expansion called the *infundibulum.* The spiral canal is divided into two portions by a partition partly bony and partly membraneous. The auditory nerve filaments pass along the modiolus and spread upon the partition, finally terminating in the **organ of Corti**, which consists of rows of cells in the form of rods or pillars, called the *rods of Corti.* There are about 2000 of these minute bodies.

10. The Membraneous Labyrinth. — The bony labyrinth already described is lined throughout with a serous membrane which secretes a fluid, the *perilymph.* Floating in this is a completely closed sac of membrane containing a fluid, the *endolymph.* This sac fills the semicircular canals, and is of the same form. The portion which is contained in the vestibule consists of an expansion called the *utricle*, and a smaller expansion called the *saccule.* In the walls of the vestibular portion of the sac are two calcareous bodies called *otoliths* (ear-stones). The membraneous labyrinth fills only the duct or entrance to the cochlea. Portions of the auditory nerve ramify on the membraneous sac in the vestibule and semicircular canals.

PRACTICAL ILLUSTRATIONS.

1. Some idea of the tympanum and its membrane may be formed by a rough dissection of the ear of a cat or dog. The bone may be sawn or broken with a chisel sufficiently to expose the cavity of the tympanum. The little bones of the ear may be seen, and it is possible to get some idea of the cochlea or semicircular canals by breaking open the portion of bone nearer the center of the

head. The parts are all so small and so well protected by strong bone that anything like a perfect idea is difficult to get by dissection.

2. From the interior of the skull the foramen which admits the auditory nerve to the internal ear may be seen near the apex of the petrous portion of the temporal bone.

LESSON 38.

Phenomena of Hearing.

1. **Sound** is a vibration, or wave-motion of matter, which is capable of producing a special sensation through the auditory nerve. Usually the vibration is conveyed from objects to the ear through the air, but air is not essential to sound. Lay a watch on the forehead and you can hear the ticking distinctly. Move it an inch away from the head and although it be nearer the ear than before the ticking is scarcely audible. The sound-waves are conveyed to the internal ear through the bones of the head. But as sound-vibrations pass with difficulty from air to solids and liquids, a special apparatus is needed to transfer the vibrations to the fluid of the internal ear, where it may influence the terminations of the auditory nerve. This special apparatus is the external and middle ear.

2. **Functions of the External Ear.** — The concha serves to catch and concentrate the waves of sound and transmit them to the auditory canal, which conveys them to the tympanic membrane. In man the concha serves but little purpose, but in many of the lower animals it is very important.

3. **The Use of the Tympanic Membrane.** — It is a property of stretched membranes to vibrate easily by atmospheric waves. The tympanic membrane readily responds to very slight vibrations in the atmosphere. These vibrations it transmits to the chain of bones attached to its inner surface. The *tenser tympani* muscle serves to regulate the tension of the membrane and prevents it being pushed too far out. Some persons can at will produce a peculiar cracking noise in their ears. This is

supposed to be due to the contraction of this muscle. The tympanic membrane is exactly analogous to the diaphragm in an acoustic telephone, which vibrates by impulses of air and communicates these impulses to the wire or string attached to it.

4. **The Eustachian Tube** serves an important purpose. It is well known that if the air be removed from a cavity the pressure on the outside of its walls will be great. The air at sea level presses with a force of fifteen pounds to the square inch of surface. As we ascend above sea level it becomes less and increases as we go below sea level. The cavity of the tympanum contains air. If there were no means of communication with the outside air there would be a variation in its comparative density every time we changed our level and a consequent pressure either in or out upon the tympanic membrane. The Eustachian tube permits air to pass from the pharynx to the tympanum, and thus keeps the air on both sides of the membrane in equilibrium. When loud sounds are produced the violent impulse of air against the tympanic membrane is somewhat relieved by the Eustachian tube acting as a valve to permit some of the air to pass out of the tympanum. In this respect it acts like the hole in the side of a drum. When cannon are fired, if a person stands on tiptoe, so that the body will be swayed by the air-wave, and holds the mouth open so that air will escape through the Eustachian tube, the danger of rupture of the tympanic membrane is very much lessened.

5. **The Function of the Ossicles.** — The bones of the ear are so placed as to act as a series of levers multiplying the force of the vibration of the tympanic membrane, and every movement of this membrane is by them transmitted with increased power to the perilymph through the fenestra ovalis.

6. **The Functions of the Vestibule.** — It is believed that the branches of the auditory nerve, which spread in the membraneous labyrinth in the vestibule, are capable of transmitting the sensation of *noise* simply, and cannot translate musical sounds or distinguish pitch and quality of sounds. The otoliths are supposed by some to intensify the vibrations, by others to act as dampers of the sound.

7. **The Semicircular Canals** have, it is believed, a function somewhat aside from hearing. When the vertical canal was destroyed in a pigeon the bird continued to move its head up and down, and when the horizontal canal was destroyed it moved its head from side to side. When a person is made to rotate rapidly dizziness and inability to stand erect is the result. These facts seem to point to the conclusion that in some way the semicircular canals are concerned in maintaining the upright position of the body, probably by sending impulses to the brain which inform it of the body's relation to surrounding objects. This question is involved in much obscurity.

8. **The Cochlea** is the most important part of the internal ear. Here, doubtless, the distinction between sounds of different pitch, quality, and intensity is made by sympathetic vibrations of the rods of Corti, communicated to them by the perilymph. We may say that the cochlea hears music and differentiates sounds, and the vestibule simply conveys the sensation of sound in general.

9. **Auditory Sensations.** — Sound, as before stated, is a vibration capable of affecting the auditory nerve. This vibration usually starts by the setting in motion of some object, this motion being communicated to the air as a wave which passes into the auditory canal, shakes the tympanic membrane, which in turn shakes the chain of bones, the last one of which, as it pushes the membrane across the fenestra ovalis, produces a wave-motion in the perilymph, part of which is conveyed to the endolymph of the vestibule and semicircular canals, and part passes to the cochlea and affects the organ of Corti. The effect of the vibration on the nerve endings in the cochlea and vestibule is to produce nervous impulses, which pass along the auditory nerve to the brain, where they give rise to the auditory sensation. These sensations may be classed as *noises* and *musical sounds*. A noise is an irregular sound, or one without periodicity. A musical sound is one which occurs and recurs at regular intervals. There are, however, all grades between these two.

In both musical sound and noise we recognize *loudness* or *intensity*. This is determined by the amplitude of the vibration, in other words, by the amount of matter set in vibration. In musical sounds we recognize: (1) *pitch*, which is determined by the rapidity of the vibrations. The more rapid they follow in succession, the higher the pitch. (2) *Quality, or timbre.* This is due to the sounds being not simple, but compound vibrations. A body vibrates as a whole, also in parts. The vibrations of the parts are either slightly higher or slightly lower in pitch, and these "over-tones" and "under-tones," mingling in varying proportion with the "fundamental tone," produces the different qualities of different sounds.

In order to produce a sensation of sound, the vibrations of a body must have a certain degree of rapidity. If less than about sixteen vibrations per second no sound is heard. If over 38,000 vibrations per second no ear can hear a sound. These limits vary, however, in different individuals. It has been conjectured that there are sounds in nature, which are heard by insects and not by the human ear, that these animals may be able to communicate with each other by sounds inaudible to the human being.

10. **Auditory Judgments.** — The auditory sensation is always referred to the external world, that is, projected into space, just as visual sensations are. The judgment of distance of sounds is very imperfect. A loud sound with high pitch seems far away, and a faint sound with low pitch seems near. This is the secret of the ventriloquist, who, by adroitly varying his tones and calling attention by words or gestures to distant, or near objects, succeeds in making his hearers believe that the words come from different persons in different places.

11. **The Audiphone.** — Defects in hearing are sometimes remedied by using an instrument by which advantage is taken of the fact that the bones of the head will convey vibrations. The instrument is placed in contact with the teeth, and is so arranged as to vibrate by receiving the wave-motion from the air. In case of injury or destruction of the tympanic membrane this instrument is useful.

12. In ordinary subjects there is no direct communication between the auditory canal and the tympanum, but we occasionally see a person who can take tobacco smoke into his

mouth and cause it to come out at his ears. Such persons have a perforated tympanic membrane. A slight perforation may not materially interfere with hearing.

13. The Ear-wax. — This is a peculiar, sticky, and very bitter substance, which is for the purpose of keeping out dust and insects. The dust is caught and adheres to the outer layer of the wax, which on exposure to the air hardens and falls off in scales, and thus the ear is self-cleaning. The insects are repelled by the bitter and adhesive nature of the wax.

PRACTICAL ILLUSTRATIONS.

1. Lay a watch on the table. Hold a stick or a ruler a foot or more in length with one end on the watch and the other between the teeth. The ticking of the watch will be distinctly heard although it may not be otherwise when at the same distance. This illustrates the fact that the air is not necessary to the production of sound.

2. Make an acoustic telephone thus: Take two old tin cans. Melt or cut out the bottoms. Tie over the end of each a piece of strong paper tightly stretched. Pass a string through this paper diaphragm on one can, securing it on the inside by a knot. This string may be forty of fifty feet long, and the other end passed through the paper of the other can and secured in the same manner. In using the string should not come in contact with anything solid. Let one person hold the open end of one can to his mouth and speak into it while another holds the other can to his ear. A conversation may thus be carried on at a distance. In a rough way we may liken the paper diaphragm of one can to the tympanic membrane, the string to the chain of bones, and the other diaphragm to the perilymph of the internal ear, and the person hearing the words to the nerve-terminations. The vibration of one diaphragm is communicated to the string and thus to the other diaphragm, and this again to the air, causing waves exactly similar to the waves started by the voice of the person at the other end.

3. Shout or sing a syllable loudly into an open piano. A sound of the same pitch will be heard coming from the strings. The vibrations of air of your voice has set a string vibrating, and its vibration is given to the air again. It will be found that the only string of the piano which vibrated is that one which is capable of producing a sound of the same pitch as your voice. Such vibrations are called *sympathetic vibrations*. The rods of Corti have been supposed to vibrate in sympathy with the different sounds and thus the different notes are distinguished by the brain.

4. The Eustachian tube opens when an effort is made to swallow and a little air passes up into the tympanum. This may be proven by closing the nostrils and making an effort to swallow. A peculiar sensation is felt in the ear, caused by the air entering the tympanum.

5. Take a walking-stick in both hands, place one end on the floor, and turn

round rapidly four or five times; then quickly aim with the point of the stick at a point on the wall three or four feet distant. The whirling motion will have so disturbed the brain, probably through the semicircular canals, that it will be next to impossible to touch the point aimed at.

LESSON 39.

Smell, Taste, and Touch.

1. **The Nasal Fossæ.** — These are two irregular cavities in the nose. The openings in front are called *anterior nares*, or *nostrils*, and the openings into the pharynx behind, the *posterior nares*. The interior contains a great deal of surface caused by the irregular nature of the inferior turbinated bone and the superior maxillary. The septum between the fossæ is formed mainly by the vomer and a triangular piece of cartilage. The interior is lined with a continuation of the mucous membrane of the pharynx and here called the Schneiderian membrane. That portion of it in which is distributed the filaments of the olfactory nerve is much thicker, contains more blood-vessels, and many brown pigment cells. The remaining portion contains ciliated epithelium. Numerous mucous glands are distributed throughout the membrane.

2. **The Olfactory Nerve** arises from three roots in the cerebrum which unite in a cord ending in a bulb-like expansion, called the olfactory ganglion. This bulb lies on the upper surface of the ethmoid bone and from it branch off about twenty nerve-filaments which pass through holes in this bone and thus reach the Schneiderian membrane. The nerve-filaments terminate in long, delicate threads with a number of expansions in their course; these threads are called the olfactory cells.

3. **The Sensation of Smell.** — Odorous particles of matter in the inspired air passing through the nasal fossæ affect the terminations of the olfactory nerve and give rise to the sensation of smell. The odorous particles must be in a gaseous medium,

as is shown by the experiment of filling the nasal fossæ with rosewater or other perfumed liquid, when no odor is perceived. As with sight and hearing we project the sensation into the external world. The smell does not seem to be in the nose but somewhere in the air outside of it.

4. **The Organs of Taste.** — The mucous membrane covering the upper surface of the tongue, the back part of the mouth, the soft palate and uvula, and possibly a portion of the upper part of the pharynx, contains the nerve-endings which give rise to the sense of taste.

5. The **tongue** is the principal part concerned in taste. It is composed of several sets of muscular fibers, the whole covered with mucous membrane. On the upper surface are a number of little elevations called papillæ, which give the tongue its characteristic roughened appearance. These papillæ are of two kinds, simple and compound. The simple papillæ are similar to those of the skin. The compound papillæ are of three kinds: (1) The *circumvallate* are the largest, about eight or ten in number, forming a V-shaped row at back of the tongue. (2) The *fungiform* papillæ are mostly on the tip and edges of the tongue. They are smaller and ovoid in shape. (3) The *filiform* papillæ are the most numerous, covering the whole surface of the front and middle parts of the tongue. They are small, and conical in shape. The epidermis covering them is in the form of hair-like processes having a general inclination backward. In many animals these processes are large and horny and serve as hooks to help securing food. In animals of the cat kind they form a rasp which is used in removing the flesh, which forms their food, from the bones. The filiform papillæ are supposed to act as organs of touch rather than taste.

6. **The "Taste Buds."** — According to some authorities the nerves of taste terminate in flask-shaped organs which are called "taste buds," or "gustatory bulbs." They are found principally in the circumvallate papillæ, and less numerous in the fungi form. (See Lesson 31, Sec. 2, Table of Cranial Nerves.)

7. We recognize several distinct tastes as sweet, sour, bitter, salty, and pungent or peppery. The latter is probably not a

real taste-sensation, but an effect on the nerves of general sensation similar to that produced by heat. Bitter substances produce the greatest sensation when placed on the back part of the tongue, and sweet substances on the tip of the tongue. Sour substances are said to be most effectual on the edges of the tongue. No substance can be tasted unless it is in a liquid form or capable of solution in the saliva. Syrup of sugar tastes sweeter than the crystalline sugar, because more readily soluble in the secretions of the mouth.

8. The Sense of Touch. — If you place the palm or surface of your fingers on a substance of any kind at the ordinary temperature, you can tell by the contact of the fingers alone whether it be solid or liquid, hard or soft, smooth or rough, and can gain a fairly good conception of its shape. This knowledge can be obtained, but in a much smaller degree, by contact with any other part of the skin and even by the tongue and mucous membrane of the mouth.

9. The Sensation of Temperature. — The skin is capable within certain limits of giving sensations which vary with the temperature, and we recognize them as warm or hot, cool or cold. Intense heat and intense cold produce the sensation of pain only. A good conductor of heat, when colder than the skin, feels colder than a poor conductor of the same temperature because it rapidly abstracts the heat from the skin. A good conductor, when warmer than the skin, feels warmer than a poor one of the same temperature, because it imparts its own heat to the skin. Thus a piece of silver, unless it be of the same temperature as the body, always feels either warmer or cooler than a piece of wood of the same temperature.

10. The Muscular Sense. — When we press our hands on an object we are sensible of the amount of pressure we exert, but when we hold an object in our hand and lift it up and down we are conscious, not only of the pressure of the object on the hand, but also of the amount of muscular exertion required to hold it up. We are thus enabled to form a judgment of the weight of the object. This is called the muscular sense, and by some has been regarded as a sixth sense, co-ordinate with sight, hearing, taste, smell, and touch.

11. The Sensations of Hunger and Thirst, and of Fatigue. — These are distinct sensations, but are difficult to locate. In extreme hunger there is a painful sensation in the stomach, and in great thirst the mouth and throat are the seats of disagreeable sensations. Fatigue may be of the mind or of the body, or of some particular part of the body.

12. General Sensation. — The sensations of temperature, of weight and pressure, of hunger and thirst, of fatigue and pain, and some others that we can scarcely designate with a name, may all be grouped together as general sensations produced by stimulation of the terminations of the nerves of common sensation, which are distributed throughout the whole body, but are most numerous in the skin. There are but few sensory nerve-fibers in the body of large muscles, as is shown by the comparative absence of pain when they are cut. Boys sometimes drive a pin its entire length into the thigh. After passing through the skin there is scarcely any pain. In the days before anæsthetics were used, those who submitted to amputations of limbs said they suffered very little or no pain when the knife was passing through the muscles.

The stimulation of the trunk of a nerve of general sensation gives rise to a sensation of pain at the extremity of the nerve. Thus if we press on the ulnar nerve where it lies near the skin at the point of the elbow, we feel a painful sensation in the third and little fingers where this nerve is distributed. Sensations started in the stump of an amputated limb are referred to the absent member. (See Lesson 3, Sec. 1.)

13. The Special Sense of Touch seems to reside mainly in the palmar surface of the fingers. In the papillary layer of the corium certain bodies have been described as the terminations of the nerves. These are called tactile corpuscles and are supposed to be the special organs of touch.

PRACTICAL ILLUSTRATIONS.

1. The sense of taste and of smell are sometimes confused. To test this tell some person to shut his eyes, open his mouth, and close his nostrils, and having previously, and unknown to the person, procured a small piece of onion, place it in his mouth and ask him to eat it and tell you what it is. The probability

is that he will be unable to tell until his nose is relieved and he gets the odor. We smell an onion and imagine we taste it.

2. Judgments formed by the sense of touch alone may be misleading, as is shown by an experiment familiar to many and said to be as old as Aristotle. It is this: Shut the eyes and cross the fore and middle fingers, and place between them a small round object, as a pea or a bullet, so that it will come in contact with the radial side of the forefinger and the ulnar side of the middle finger. We will seem to be touching two objects instead of one.

LESSON 40.

Hygiene of the Special Sense-Organs.

1. **The Eye** is a very delicate and sensitive organ, easily irritated by any foreign body or substance, as dust, smoke, or irritating gases. The delicately adjusted parts are easily strained and wearied by improper use. Hence an avoidance of all irritating substances and excessive and improper use of them is of great importance.

2. When a **foreign object** gets into the eye do not rub it, for this only causes greater irritation. By a strong effort of the will you may keep from winking for several seconds, during which time the tears will accumulate in quantity sufficient often to wash out the offending body. If this fails, close the nostril on the opposite side and blow the nose forcibly. This may create a suction in the nasal duct which will draw the object to the inner corner of the eye. If these means fail, let some one roll the eyelid over a pencil and look for the object. If found, remove by touching with the twisted corner of a handkerchief.

3. Use **no medicine** or salve for the eyes without the advice of a physician. You may do more harm than good. Bathing the eye in cool or tepid water can do no harm, and is often better than any medicine to allay irritation from any cause.

4. The **light** in reading, sewing, or other work requiring special exercise of the eye, should not fall on the eye, but on the work. Do not sit facing the light, but so that it will come over the left shoulder; then it will not shine in the eyes,

but on the work, and no shadows will interfere. Artificial light is hard on the eyes unless it be bright and steady. It may be too bright, as the electric arc light. A very bright lamp mellowed by a porcelain shade is perhaps the best.

5. Small type, poor printing, and paper of an ashen gray or dirty tint are frequent causes of diseased eyes. So is reading or sewing in the twilight, or by a poor artificial light. Reading in a jolting car or carriage is also injurious if indulged in to any great extent. Reading in a recumbent position is not advisable. In all these cases the eyes are put on a strain, and they soon become tired and finally weak from exhaustion.

6. Perhaps the most frequent cause of **weak eyes** is the constant use of them upon objects at the same distance. Every two or three minutes the eyes should be **rested** by looking for a few seconds at some distant object. This gives rest to the muscle concerned in accommodation. Remember that when looking at a distant object the eye is in a passive condition, or at rest, and that it is put on a strain when looking at near objects.

7. The eyes are often weak when recovering from a spell of sickness. This is especially the case in convalescence from eruptive diseases, as measles, small-pox, and scarlet fever. The utmost care should be then taken or the eyes may be permanently injured.

8. Never purchase spectacles from a pedlar or ordinary dealer in them. Go to an oculist and let him examine your eyes and select the proper glasses for you, and don't postpone it too long.

9. **Cigarette smoking** is said to be injurious to the eyes. Tobacco smoke can certainly do the eyes no good, and the bad effect of tobacco on the nervous system of some persons may be manifested in the form of weak eyes.

10. The eyes of the drunkard are bloodshot and bleared from the excessive blood pressure in the capillaries, caused by the alcohol affecting the circulatory system.

11. **The Ear** is perhaps not so easily injured as the eye, but it is important to observe certain rules of hygiene bearing on this organ.

12. Very **loud sounds**, as the firing of cannon, may cause rup-

ture of the tympanic membrane. The danger is lessened, as has been elsewhere noted, by standing on tiptoe and keeping the mouth open.

13. The **ear-wax** should not be removed with an ear spoon or other instrument unless unnatural in quantity or nature. The finger will penetrate the auditory canal far enough for ordinary cleansing purposes. A wet cloth over the finger's end is usually sufficient to keep the ear clean. *Never pick the ear with a pin, knitting needle, or anything of the kind.* You may let go of the pin, or some one may accidentally jostle your arm and cause the instrument to penetrate the tympanum.

14. The ear should be protected from cold winds, but not by compact material, such as ear-muffs are made of. Ear-muffs keep the ear too warm, and make it more sensitive to the cold when they happen to be left off on going out. A very little cotton placed in the ear is a good thing when riding in the cold wind, or a shawl thrown loosely over the head to break the force of the wind.

15. If a child gets a small object, as a pea, bean, or cherry stone, into the ear, do not make frantic efforts to extract it. The auditory canal is wider at the inner end, and an object pushed far in is very difficult to extract. First, turn the ear down and tap gently on the other side of the head. If this does not dislodge it, use a syringe and a little warm water, keeping that side of the head down. If this fail, send for a physician and do not permit any one to touch the object until he arrives. Cherry stones have been known to remain in the ear for years without serious results, so do not become alarmed.

16. If an **insect** gets into the ear, pour in a little oil of any kind. This will kill the insect and not injure the ear. A syringe and warm water will then generally remove the dead insect.

17. Throwing snowballs is dangerous sport. Permanent deafness has been caused by snow being forcibly driven into the ear.

18. In ascending or descending a mountain it is necessary to make frequent efforts to swallow, as this permits air to pass up the Eustachian tube and maintains the equal pressure on both sides of the tympanic membrane.

19. Very highly seasoned and very hot foods and drink temporarily blunt the sense of taste, and possibly have a permanent injurious effect on the nerves of taste.

EXERCISES FOR REVIEW.

1. What bones form mainly the orbits of the eye?
2. What is the conjunctiva? Can you see it?
3. What are the parts of the outer tunic of the eye?
4. Are there any nerves in the sclerotic coat? In the cornea?
5. What is the condition know as a "blood shot" eye?
6. What gives the choroid membrane its dark color? What is its color in albinos?
7. Where is the "color of the eyes"?
8. What relation does the pupil of the eye bear to light?
9. What are the terminations of the optic nerve called? Where are optical elements the most numerous?
10. Which is the thinnest of the humors of the eye?
11. What is the use of the lachrymal fluid? When is it called "tears"?
12. What kind of an optical instrument is the eye?
13. Explain accommodations. When is the eye at rest?
14. What use is the iris besides regulating the amount of light?
15. Explain why the eye is a perfect optical instrument.
16. When do we see double?
17. Why do persons look larger dressed in white than when they are dressed in dark clothes?
18. What is the blind spot? Phosphenes?
19. What kind of glasses should a myopic person use? A presbyopic? A hypermetropic?
20. Why does a plus sign look like a minus sign to some persons? See Section 16, Lesson 36.
21. What is the matter with a person who cannot tell green from red?
22. How may cataract be cured?
23. The use of the bones of the ear.
24. What are the semicircular canals? Their use?
25. What separates the endolymph from the perilymph?
26. Otoliths? Organ of Corti?
27. What is sound? Is air necessary for the producing of sound?
28. What is the use of the Eustachian tube?
29. Classify sounds. Name the properties of sound.
30. Explain the "throwing the voice" by the ventriloquist.
31. The audiphone. What does it prove?

32. How does the olfactory nerve reach the nasal cavity? What is the Schneiderian membrane?

33. What is taste? Where is it located?

34. What is the muscular sense?

35. Do you taste or smell an onion?

36. What should be the position of the light in reading or writing?

37. How should one take care of the ear?

HINTS TO TEACHERS.

The different parts of the human body are so closely related that the anatomy and physiology of no one part can be clearly understood until the other parts have been studied. In this respect this study differs from some others in which the different branches are more or less independent. From this fact it is evident that frequent reference from one part of the work to another is necessary, and frequent reviews, in which the *relations* the different systems sustain to each other are discussed, should be given.

The pupil should constantly be urged to make frequent use of the index of the book, and to compare one part with another. Occasional lessons, consisting of a given number of questions, to answer which the pupil will be obliged to search the entire book, should be assigned. He will then be compelled to use the index, and thus become accustomed to the true method of study in general, which is to *use* books as means of acquiring knowledge, not as so many pages to be "gone over."

PART IV.

GENERAL INFORMATION ON FOODS AND STIMULANTS.

CHAPTER I.

HOW TO SELECT PROPER FOODS AND DRINKS.

LESSON 41.

Heat-making Foods.

1. IN Lesson 15 we gave a classification of foods as to composition and nutritive value. We would advise the pupil before beginning the study of this lesson to read that lesson again.

2. **Wheat.** — This is the most important vegetable production of temperate climates. It is an almost perfect food, as it contains a large per cent of tissue-making material, although the greater part of its weight and bulk is starch, which is a heat-making food. The outer layer of a grain of wheat is largely silica, a substance destitute of nutriment. This is separated with the coarsest bran. Next to this is a layer of *aleurone grains*, so called by the botanist, but usually called *gluten* from its adhesive properties. This is highly nitrogenous and therefore tissue-making. The main part of the kernel is almost pure starch. In ordinary white flour a large part of the gluten goes with the starch. It is what makes the bread spongy when raised by the escape of gases in baking. A great deal has been written about the value of graham flour, or whole wheat flour; but most writers overlook the fact that the stimulating effect of

the coarse bran causes the food to pass on too rapidly in the stomach and intestines, and a considerable portion of the nutriment is not absorbed; so that while it contains more tissue-making ingredients than white flour, the system does not appropriate as much of it. Graham bread and cracked wheat are valuable for the variety they afford rather than for their intrinsic merits.

Macaroni, which forms the chief food of the people of Southern Italy, and is used to a considerable extent in this country, is made from the finest wheat flour, formed into a paste and dried. *Vermicelli*, much used in soups, is similarly made. They are richer in nitrogenous material than our white bread, as the wheat of Italy and Southern Russia, from which these articles are made, contains more gluten than our wheat.

3. **Corn**, or maize, contains eleven per cent nitrogenous matter, sixty-four of starch, eight of fat, and a little sugar. It is, taken altogether, a valuable heat-making food. It is liable to be irritating to the intestines of some persons. It should be used more in winter than in summer. Green ears of corn, or "roasting ears," are palatable and wholesome if well cooked. Corn-starch, used frequently in puddings and other dishes, is almost pure starch.

4. **Oatmeal** contains about fifty-eight per cent of starch, twelve of nitrogenous matter, five of sugar, five of fat, and is a valuable food material. It should be thoroughly cooked.

5. **Barley.** — This is a valuable food, but not used to any great extent in this country for bread. It contains sixty-nine per cent of starch, four or five of sugar, and about six per cent of nitrogenous matter. Pearl barley is simply the grain with the husk removed. It is a palatable and nutritious food when well cooked.

6. **Rye.** — This grain is not much used in this country for bread, although in nourishing qualities it is not much inferior to wheat. It contains sixty-nine per cent of starch, and eight per cent of nitrogenous matter, with some sugar and fat. Rye flour mixed with wheat flour and made into bread is palatable and affords a good variety.

7. **Rice.** — This grain is rich in carbonaceous, or heat-forming material, being about seventy-nine per cent starch, and but six of albuminous matter, and a small proportion of fat and sugar. It is easily digested, and forms a valuable addition to our food-stuffs. It forms almost the entire food of millions of people in eastern countries.

8. **Arrow-root.** — Obtained from the root of a tropical plant. It is almost pure starch. A great many preparations are sold under the name of arrow-root which are simply starch prepared from different plants. English arrow-root, it is said, is made chiefly from potatoes. It is often recommended as a food for the sick, but as it is not palatable unless sweetened, it would be better to use some other substance rich in starch, and which is palatable in itself.

9. **Tapioca.** — This substance is also nearly pure starch, and is prepared from the root of a tropical plant. It is often used in puddings and is useful in its place.

10. **Sago.** — This is another form of starch produced from various species of palm trees. It is very similar to arrow-root.

11. **Potatoes.** — Irish potatoes contain eighteen per cent of starch, two per cent of albuminous matter, three per cent of sugar, the remainder being mostly water. The sweet potato contains more sugar, but in other respects is similar. Potatoes should be thoroughly cooked. When boiled they should be put in boiling water and kept at that temperature until soft. Then they should be exposed to dry heat until they appear mealy. If roasted, the oven should be hot when put in. If fried, the fat should be very hot when they are put in. Otherwise potatoes become soggy, unpalatable, and unwholesome. They should not be eaten when very young nor when diseased.

12. **Buckwheat** contains about eighty per cent of starch, and about two and a half of albuminous matter. Buckwheat cakes have been known to produce an eruption on the skin when eaten frequently.

13. **Beans and Peas.** — These vegetables contain so much albuminous, or tissue-making material, that they might be placed

in that class, but the starch predominates, being about fifty per cent of the latter to twenty per cent of the former. When ripe and hard they should be boiled at least five hours. Beans are among the most economical articles of diet in use in this country, as they contain much nourishment (both heat-making and tissue-making material) in proportion to the price.

14. Sugar. — The principal ingredient in the foods we have mentioned is starch. Another form of carbonaceous or heat-making food is sugar. It is found in most all vegetables and fruits to a greater or less extent. Beets contain about ten per cent, and are largely used in France and Germany as a source of sugar of commerce. Bananas contain twenty per cent of sugar. Cabbage, turnips, carrots, and potatoes contain a small per cent of sugar. Dates are nearly half sugar. All fruits contain some sugar. Honey is almost pure sugar.

There are two varieties of sugar commonly used for food, cane sugar, or *saccharose*, and grape sugar, or *glucose*. The former is obtained mostly from the sugar cane, but also from sorghum, beets, corn stalks, maple trees, and some other vegetable substances. Grape sugar is found in many kinds of fruits, and exists along with cane sugar in maple trees, and in many plants it is found in small quantities. It is usually produced, however, by boiling starch for a long time with weak sulphuric acid. This process converts the starch to sugar. Grape sugar is largely employed as an adulterant of cane sugar and in the manufacture of candy and syrups. It is less soluble than cane sugar, and not nearly so sweet to the taste, but is equally valuable and wholesome as a food.

15. Fats and Oils. — The only difference between fat and oil is that the former is solid and the latter liquid at ordinary temperatures. They are carbonaceous and mainly heat-making. All animal food contains more or less fat. The ordinary grains contain a small per cent of oil. Nuts are rich in oil. Cocoanuts form the principal food of many people in tropical countries. The ill effects that are often ascribed to eating nuts are mainly because they are eaten between meals and as an addition to, rather than a part of, the regular food. Butter is the fat of milk, and is generally regarded as more palatable than other forms of fat. The substitute for butter known as oleomargarine is one of the triumphs of the chemist's art. It is prepared from beef tallow, and that of the best grade is a perfect imitation in flavor of real butter, and is pronounced equally wholesome by good authorities. Eggs contain about eleven per cent of oil.

PRACTICAL ILLUSTRATIONS.

1. The presence of starch in any article is very easily shown even when it exists in minute quantities. Heat a little of the substance supposed to contain starch in clear water, and when cool add a few drops of tincture of iodine. The mixture immediately turns blue if starch be present. If in considerable quantity the color will be black. As the test is delicate, to get a beautiful blue color use but very little of the material to be tested in a large amount of water.

2. If a microscope is accessible, the teacher may show the starch grains in potatoes, beans, or grain, by making a very thin section with a razor, or by scraping a minute portion from the mass, placing it on a glass slide, and adding a drop of water. By adding a little tincture of iodine much diluted with water, the grains take on a beautiful blue color. The starch grains vary much in size, and are of different shapes in different vegetables.

3. If starch, flour, or corn meal be used as an adulterant of any article of food or condiment, its presence is easily detected by the methods above given.

LESSON 42.

Tissue-making Foods.

1. The tissue-making foods are nitrogenous, or albuminous. Many of the articles mentioned in Lesson 41 contain a large per cent of tissue-making material, but the following are mainly of this nature.

2. Beef. — There is no better nitrogenous food than beef. The lean meat contains about twenty per cent of albuminous matter, the remainder being water and a small amount of salts. When of good quality and properly cooked it is easily digested. It is usually most wholesome and palatable when fresh. It should never be eaten raw, as there is a possibility that it may contain germs which will produce tape worms or trichina. When fried the fat should be very hot when it is put in, as otherwise the meat will absorb the fat and become tough and indigestible.

3. **Pork.** — Not quite so nutritious as beef and not so easily digested. The fibers are firmer and require a longer time to dissolve in the gastric juice. There is a great deal of prejudice against the use of pork, much of which is unfounded. If the animals be in a healthy condition and the meat well cooked no harm can result from the use of pork. It should under no circumstances be eaten raw. Thorough cooking and thorough mastication are required. Ham is best when thoroughly boiled and eaten cold. Bacon is regarded as a luxury by the rich and as a necessity by the poor. Such food should be eaten in the morning when the digestive powers are at their highest.

4. **Mutton.** — "Although an agreeable and valuable food for all classes, it is not so well fitted as beef to sustain great exertion, but is rather a food for those of sedentary and quiet habits, including women and the sick." — *Dr. Edward Smith.*

5. **Poultry.** — The flesh of chickens, turkeys, geese, and ducks is generally regarded as lighter food than beef, mutton, and pork. This is not because of inferior nourishing qualities, but rather because they have a more delicate flavor and are more easily digested. They contain nearly as much nutriment as beef.

6. **Game.** — This includes all wild quadrupeds and birds used for food. As a rule only those animals that live on purely vegetable food are fit to eat. The flesh of wild animals is generally easy of digestion and almost as nutritious as beef.

7. **Eggs.** — Contain all the elements required by the body and in about the proper proportion, hence are a perfect food. When raw or soft boiled they are more easily digested than when boiled hard. However, when long boiled they become again easily digested. The proper way to cook an egg in the shell is to put it in boiling water and set it off of the fire, allowing it to remain a few minutes in the hot water. In this way the heat

penetrates to the center of the yolk and the white is merely turned to a milky condition, which makes them more palatable and easy of digestion. A pound of eggs contains more nourishment than a pound of meat, hence at average prices they are cheaper than meat.

8. Fish. — Fish contain much less nutriment than meat. Fresh fish are easily digested, and for a variety form a palatable addition to the list of nitrogenous foods. Fish with red meat, as the salmon, are more nutritious than those with white meat. Fish contain a larger per cent of phosphorus than the flesh of higher animals, and are said on that account to be good food for brain-workers. It must be remembered, however, that the human system appropriates only a certain amount of material in building up the tissues, and that there is probably more phosphorus in ordinary meat and in the nitrogenous parts of vegetables than is needed by the system. A fish diet increases the amount of phosphates (salts containing phosphorus) in the excretions, showing that only a part of the phosphorus is appropriated.

9. Cheese. — This is the albuminous part of milk, the remainder being water, sugar, and fat. It is strong food and does not agree with many persons. Fresh milk from healthy cows is a wholesome article, and like eggs a perfect food, as it contains the nitrogenous, or tissue-making elements in the caseine (cheese), and the carbonaceous, or heat-making, in the butter (fat) and sugar.

10. Oysters and Clams. — These, and other mollusks which are sometimes eaten, contain a large per cent of water, hence are not of high nutritive value. Raw oysters are, perhaps, the most easily digested of all articles. This is especially true of the greenish or dark part (the liver) of the animal. For sick persons, or those who have weak digestive powers, they are a valuable food.

11. The quantity of heat-making food should be in excess of the tissue-making. The body is constantly losing heat which must be supplied by the consumption of fuel. This fuel comes indirectly as carbonaceous food. It has been computed from many careful experiments and observations, that a man doing ordinary work requires daily 4.59 ounces of nitrogenous and 17.22 ounces of carbonaceous food. This means solid food. In addition he requires from seventy to ninety ounces of water, partly in the form of drink and partly as a constituent of the food. It will be observed that we find in nature a larger per cent of carbonaceous food. The supply of starch, sugar, and fat far exceeds that of albuminous substances.

LESSON 43.

Relishes and Condiments.

1. There are many articles in our daily dietary which are usually classed as foods, but their nutritive value is so small that they may be regarded more as relishes, and as aids to digestion, serving to dilute the more highly nutritious foods. Many fruits and vegetables belong to this class, some of which will be noticed in this lesson.

2. Apples. — Contain over eighty per cent water, some sugar, starch, and acid. They form a valuable addition to more nutritious foods. They should be well cooked or thoroughly ripe, and not eaten in large quantities at one time. The skin and seeds with their horny coverings are indigestible and should not be eaten.

3. Peaches, Plums, and Apricots. — Very wholesome, but not more nutritious than apples. The seeds are poisonous if eaten in any considerable quantity.

4. Pears. — More nutritious than apples, but more difficult of digestion.

5. Cherries. — Very wholesome and agreeable acid fruit. They contain from eight to thirteen per cent of sugar and a small amount of albuminous matter. The seeds have been known to lodge in the vermiform appendix and cause serious trouble.

6. Blackberries, Raspberries, and Strawberries. — Similar in composition, contain sugar and acid, wholesome and agreeable to most persons. The seeds are indigestible, but so small that they do no injury.

7. Grapes. — Contain from nine to fifteen per cent of sugar, about one per cent of albuminous matter, and over eighty per cent water, with some tartaric acid. The skins and seeds are indigestible. The latter have been known to lodge in the vermiform appendix. They should not be eaten. When grapes are perfectly ripe there is no fruit more agreeable to the system.

8. Oranges and Lemons. — Contain a large amount of citric acid, especially lemons. Wholesome fruits. Lemonade is one of the most agreeable of drinks and the least harmful.

9. Cabbage. — Consists of ninety-four per cent water, a small amount of sugar and albuminous matter. Could never be used alone for food, as the amount of nourishment is too small. If not well cooked is difficult of digestion. Cauliflower and kale are very similar.

10. Turnips. — Contain ninety-one per cent water, some sugar, and a very little nitrogenous matter. Afford a good variety as a relish and addition to more substantial foods.

11. Carrots, Parsnips, and Celery. — More nutritious than cabbage or turnips. Disliked by many persons. Wild parsnips are said to be poisonous, but it is probable that in the cases reported another plant was mistaken for the parsnip.

12. Melons. — The pulp of watermelons is almost entirely composed of water and a little sugar. Muskmelons contain a little more solid matter. Melons are valuable for their cooling and refreshing properties. They should be perfectly ripe and fresh to be wholesome.

13. Cucumbers. — Are regarded by some as very indigestible, but when eaten in moderate quantities do not appear to be injurious to healthy stomachs.

14. Pumpkins and Squashes. — Wholesome and moderately nutritious.

15. Rhubarb. — Contains much acid and cannot be used in great quantity.

16. Gooseberries, Currants, and Cranberries. — These very strongly acid fruits afford a good relish, especially when eaten with meats. They should be used in moderation.

17. Tomatoes. — An agreeable acid vegetable, formerly not supposed to be eatable, but becoming more popular every year.

18. Onions. — Contain a stimulating oil which gives them their pungency and peculiar odor. In cooking this oil is largely evaporated. They are moderately nutritious, containing more nitrogenous matter than the potato but only one-fourth as much carbonaceous matter.

19. "Greens." — This includes a great number of succulent vegetables which are eaten when young. Persons are often poisoned by eating plants for "greens" which they suppose are harmless. Young rhubarb leaves and poke leaves are said to be poisonous. "Greens" afford but little nourishment, water being the principal constituent.

20. Gelatine. — The skins of animals, the tendons and bones when boiled yield a substance called gelatine. When dry it forms glue. It is a much disputed question as to whether gelatine is nutritious. Dr. Whittaker says, "Though the gastric juice will attack and dissolve gelatine it has very little if any nutritive properties, and should never in any of its forms (jellies, isinglass, Iceland moss) be relied upon as an article of food." Professor Flint arrives at about the same conclusion. But Dr. Edward Smith says, "My experiments, and those of others, have proved that it is a valuable food, since it increases vital action in the same direction, if not in the same degree, as albumen." The "jelly" of fruits is called *pectin*. It is very similar to the gelatine of animal bodies. Much that is put on the market as fruit jelly is simply the gelatine of animals flavored and sweetened in imitation of the jelly of various fruits. Whether nutritious or not jellies and soups are very agreeable additions to our dietary, and seem to be harmless.

21. Mushrooms. — There are many species of fungi which may be eaten, but few persons are able to distinguish the wholesome from the poisonous kinds. Two well-known edible species grow quite abundantly in this country, one generally appearing in early spring, the other late in the summer. We cannot enter into a description of these species here, but will say that those who are not able to recognize them and do not relish their taste miss one of the luxuries of life. Mushrooms contain about ninety per cent water, and are therefore more to be regarded as a relish than as a food, although of the solid constituents nitrogenous matter forms a considerable part.

22. Condiments. — This term includes certain substances which do not supply material for the growth or warmth of the body, but in some way not well understood render food more palatable, stimulate our appetite, and in some cases supply certain necessary elements to the fluids of the body. The condiments may be grouped as salt, vinegar, and spices.

23. Salt. — Common salt, or chloride of sodium, has been in use from the earliest times. Enough, perhaps, exists naturally in ordinary foods for the purposes of the system, and the principal reason for putting an additional quantity in our food is to give it taste and to stimulate the salivary glands to action. Where there is a continued use of salted meats and the absence of fresh fruits and vegetables, as is sometimes the case on board vessels, or in armies, a disease known as scurvy appears. This disease is not due to the use of salt, or salty food, as some may suppose, but to a deficiency of certain acids and their chemical salts, such acids being found in fresh vegetables and fruits.

24. Vinegar. — This is acetic acid diluted with water and mixed with flavoring extracts of whatever it be made from. Acetic acid is a product of fermentation. By a certain kind of fermentative process starch is changed to sugar; by another fermentation sugar is changed to alcohol; and by still another kind of fermentation alcohol is changed to acetic acid. The first is called the *saccharine*, the second, *vinous*, the third, *acetic* fermentation. Any substance, then, containing starch, sugar, or alcohol can be used as a source of vinegar. The best vinegar is that made by the fermentation of fruits, as it is agreeably flavored by certain extracts from the fruits. Apple, or cider vinegar is the most commonly made in this country. A writer in the *Popular Science Monthly* says: "The value of vinegar as a condiment depends on the fact that acetic acid dissolves gelatine, fibrine, and albumen; hence it aids in digesting young meats, fish, lobsters, and hard-boiled eggs. The acid assists also in the conversion of cellulose (woody fiber) into sugar, which is the first stage in the digestion of green leaves used in salads. It is a mistake to use vinegar on beans, for it renders insoluble the legumen, which is their chief nutritive constituent."

Vinegar will cure scurvy, hence it is inferred that some acid of vegetable origin is lacking in the dietary which produces scurvy.

25. **Spices.** — Spices have been held in high esteem from the earliest times. They are frequently mentioned in the Bible. It is recorded that "Neither was there any such spice as the Queen of Sheba gave Solomon." One of the most commonly used spices is *black pepper*. It imparts a flavor to certain foods, and used in moderation is not injurious, except to sensitive stomachs. Red, or Cayenne pepper is from an entirely different species of plant, but differs but little in its effect on the system. *Mustard* is another spice in common use. It is not objectionable unless used in excessive quantities. *Cloves*, *cinnamon*, *nutmegs*, and *allspice* are aromatic spices, and milder in their action than the peppers and mustard. They impart delicate flavors to fruits. *Ginger* is a strong spice, more useful perhaps as a medicine than as a condiment. In its native country it is made when young and fresh into a delicious preserve, which is gently stimulating.

LESSON 44.

Water and Non-alcoholic Beverages.

1. **The Use of Water in the Body.** — Without water there could be no life. Water is the transporting agent in nature. Material must be conveyed from one place to another in all building processes. Organic growth is a building process. The parts of

a vegetable or animal body which are the most active contain the most water. The bones and teeth when fully grown are comparatively inactive and contain less water in their composition. The muscles and nerves are active parts and are largely composed of water. As we learned in the introduction, fully three-fourths of the body is water. Dr. Edward Smith thus sums up the uses of water in the body: "*First*, to soften and dissolve solid foods so as to facilitate their mastication and digestion; *second*, to maintain a due bulk of blood and the structures of the body; *third*, to keep substances in solution or suspension whilst moving in the body; *fourth*, to supply elements in the chemical changes of the body; *fifth*, to enable the waste material to be carried away from the body; *sixth*, to discharge superfluous heat by transpiration through the skin, and by emission through other outlets; and *seventh*, to supply in convenient form heat to, or to abstract heat from, the body. Some of these functions are performed by water in its liquid state, and others in a state of vapor."

2. **Water in the Food.** — The amount of water existing naturally in food varies from five to ninty-five per cent or more. Sugar contains the least, only five per cent, while milk, eggs, lean meats of all kinds, fish, potatoes, turnips, cabbage, and parsnips all contain over seventy per cent. Wheat flour contains fifteen, and rice thirteen per cent of water. On an average each adult takes from twenty to thirty ounces of water daily in his food, and requires from seventy to one hundred ounces in all for the purposes of nutrition. There are wide ranges, however, from this average. In a warm atmosphere and while exercising much more water is required. Women drink less water than men, and children more than adults in proportion to their size.

3. **Composition of Water.** — Pure water, that is, water simply, consists of two gases, hydrogen and oxygen, chemically combined in the proportion of two parts by volume of the former to one of the latter, or by weight two parts hydrogen to sixteen parts oxygen. But pure water in this sense does not exist except in the chemist's laboratory. Water so readily absorbs

gases and dissolves solids that as soon as exposed to the air it begins to acquire impurities. The question for the hygienist is what of these impurities are injurious and what harmless. The water of one section of country differs from that of another on account of differences of soil and rock, and differences in the gases existing in the atmosphere. In limestone regions the water contains a large amount of carbonate of lime in solution, and we say the water is hard because it does not mix with soap readily and dissolve and remove dirt so easily as soft water, that is, water comparatively free from salts of lime. In sandstone regions, or where there is but little calcareous matter in the soil, the water is soft, but it may contain other minerals than carbonate of lime. Just how much of these inorganic salts water should have to give it flavor and not be injurious is a difficult question to determine.

4. Dangers from Unwholesome Water. — (1) Diseases of the alimentary canal from the irritation produced by water containing an excess of mineral matter are recorded. These mineral substances are sometimes dissolved in the water and again partly dissolved and partly suspended. When dissolved the water is perfectly clear, but will have a peculiar taste. Persons may become accustomed to such water when it will no longer influence them injuriously. When the matter is suspended, the water is muddy or discolored. This matter may be removed by filtering or by settling with alum and other chemicals. Dissolved and suspended vegetable and animal matter may also produce diseases of the digestive tract. Boiling the water before using will remedy this. Water which has stood in lead, zinc, or copper vessels or pipes becomes poisoned, and injuriously affects the digestive organs. In this case the only remedy is to avoid the use of such water.

(2) *Malarial fever* is supposed to be caused in some instances by use of water which has stood in contact with decaying vegetable matter, a specific poison being developed in the water. (3) *Typhoid fever* is readily communicated from one person to another through the excretions of the body getting

into the drinking water. Other contagious diseases, as *yellow fever* and *Asiatic cholera*, are said to be propagated by means of contaminated water. Boiling or filtering the water does not destroy or remove the germs of these diseases. (4) The eggs and embryos of human internal parasites, as tape worms and other intestinal worms, are believed to be introduced into the body by means of water. Boiling the water will destroy these germs.

5. **How to Test Water.** — Wholesome drinking water should have no decided taste nor odor, and be at least moderately clear. The water generally used in large cities comes from rivers or lakes and is frequently quite muddy looking, so much so that the person drinking it for the first time is inclined to think it very unwholesome, but the color is due to suspended clay and sand in a very fine state of division and is rarely injurious. But clearness is no test of wholesomeness. Water may be perfectly wholesome, especially to those accustomed to its use, when it is almost black with sediment, and on the other hand may be as clear and sparkling as a drop of dew and yet be loaded with deadly germs and wholly unfit for use. The senses, then, are not to be trusted in selecting wholesome water. There is no easy way to test for the presence of germs of contagious diseases, but we can always know whether the excretions from persons diseased can possibly contaminate the water we use. Water from wells near vaults or open sewers or graveyards, is liable to be contaminated and should be avoided. The percolation of the water through the earth does not remove all impurities, as is sometimes supposed.

Water containing a large amount of dissolved animal or vegetable matter is injurious. This cannot be detected by the senses, as it may be clear and have no disagreeable taste. But if let stand in a vessel for a day or two in a warm place it will acquire a decided foul odor. This is a rough test. A more delicate one is as follows: Get the druggist to dissolve a few grains of permanganate of potassium in an ounce of distilled water. Add enough of this solution to a tumblerful of the water to give it a decided pink tinge. A few drops will be sufficient. If organic matter be present this pink color will fade out in a few hours. If the water be free from organic matter the color will remain.

6. **Non-alcoholic Drinks.** — There are a number of drinks which are harmless in any reasonable quantities that may be substituted for water. In hot weather such drinks are usually beneficial and for occasional use to be preferred to water. There is no drink, however, which may not be used in excessive quantities and prove injurious to the digestive organs.

7. **Buttermilk.** — This is peculiarly grateful to many persons in hot weather. It is slightly nutritious and rarely does harm.

8. **Lemonade.** — There is no drink, perhaps, less liable to be injurious than this. It should, however, be drunk slowly and be made only moderately cold. If the ice be grated or pounded fine it may be made exceedingly cold and thus prove injurious by rapidly lowering the temperature of the body.

9. **Unfermented Cider.** — The juice of apples contains no alcohol until it has begun to taste "sharp," and shows numerous minute bubbles when held to the light. Then fermentation has begun and alcohol is being manufactured from the sugar which it contains. Cider may be kept from fermenting by boiling a certain time, or by the addition of ground mustard. Boiling changes its flavor and makes it disagreeable to many persons. Sweet or unfermented cider is a wholesome drink when used in moderation.

10. **"Soda Water."** — This is a very inappropriate name, as it contains no soda nor any compound of sodium, nor is soda used in its manufacture. It consists of water in which a large amount of carbonic acid gas has been forced under pressure. When it is drawn from the fountain it mixes with the syrup previously placed in the glass. This syrup is a solution of sugar containing certain flavoring extracts. Sometimes these flavoring extracts are made from fruits, again they are made from a class of substances called "ethers," which are obtained from coal tar. In any case they are not injurious and the only harm that may usually come from drinking soda water is from the excessive coldness of the mixture. The carbonic acid gas

rapidly escapes as you drink, and gives a peculiarly agreeable sensation in the stomach and mouth.

11. "Ginger Ale." — This is not strictly a non-alcoholic drink, as it contains, usually at least, a very small per cent of alcohol, so small, however, that it can scarcely be said to produce any physiological effect. The drink is gently stimulating from the ginger and sometimes peculiarly grateful to the stomach in hot weather. "*Sarsaparilla*," "*phos-ferrone*," "*orange phosphate*," and many other special drinks are prepared and sold alongside of soda water and lemonade. They may all be classed with ginger ale as comparatively harmless beverages.

12. Warm and Hot Drinks. — The use of some kind of warm or hot drink is almost universal, some races and nations preferring one kind and some another exclusively, others using a variety of them. The United States contains more persons who are exclusive cold water drinkers than any other country in the world. In Europe and Asia many people would sooner think of going without food than without their accustomed beverage. The substances most commonly used in the form of warm or hot drinks are Chinese tea, Paraguay tea, Abyssinian tea, coffee, cocoa (chocolate), and chicory.

13. Chinese Tea. — The tea plant is a small shrub and is chiefly cultivated in China and Japan. It has probably been in use in China for 1200 years. It was introduced into England in the seventeenth century. In 1678 a book on tea was published in England which described it as "the infallible cause of health," and recommended it as a cure for every disease. The writer thought that 200 cups a day would not be excess. At present more than 600,000,000 people use tea. Green tea differs from black only in the mode of preparation, both kinds being made from the same plant. More tea is consumed in northern than in southern countries. The Russians are great tea drinkers. The active ingredients of tea are a *volatile oil*, *theine*, and *tannic acid*. The combination of these three produce the peculiar effects of tea on the system. Tea is turned black by the addition of any substance containing iron in a soluble state. This explains why brown sugar and molasses blacken the tea. The iron forms ink by combining with the tannic acid. Tea should be steeped, not boiled, as the volatile oil is driven off in boiling.

Paraguay tea is the leaves of a species of holly growing in South America. It is much more powerful than Chinese tea and is in use in South America by 10,000,000 people. *Abyssinian tea* is a substitute for Chinese tea and is used to a great extent in Asia. When the leaves are fresh it is very intoxicating.

14. Coffee. — Coffee is the seed of a tree growing in tropical countries. Although it does not resemble tea in taste, its chemical composition and physiological effects are very similar. Coffee is in use in almost every country in the world, but is more extensively used in southern countries. Coffee should be both boiled and steeped, or what is better, although not always practicable, made by raising it to a temperature above the boiling point in a closed vessel without permitting it to boil.

15. Cocoa. — This is the seed of a tropical or semi-tropical tree. Chocolate is prepared from the cocoa beans by grinding and mixing it with sugar, and forming into cakes. Chocolate is one of the safest of the mild drinks. It seems to have peculiar sustaining properties whose effects are not followed by depression. It is in use by at least 200,000,000 people. The reason many persons do not like it is because they make it too strong, the peculiar oil which it contains making it disagreeable to those not accustomed to it. It contains an appreciable amount of nutriment in the form of oil and gluten.

16. Chicory, or Succory. — This is a substitute for coffee which is largely used by poor people in many parts of the world. It is the root of a plant found growing wild in the United States, from New England to Iowa. It is cultivated extensively in Europe for the sake of the root. It has a bitterish taste, but none of the pleasant aroma of coffee. It contains an oil which has similar properties to tea and coffee. It is often used to adulterate coffee. It may be detected by putting the ground mixture in cold water. The chicory gives color to the water while the coffee does not.

17. As we have stated in former lessons, a moderate use of these mild drinks, as tea, coffee, and chocolate, is not injurious to the majority of adults, and in old age are in many cases positively beneficial. One should not become a slave to them. A proper exercise of reason and judgment in their use and a use of our will power in abstaining from them when we are convinced that they are doing us injury, is possible with all persons who have arrived at mature age. Children should not be permitted to use them. Milk and water are proper drinks for the growing period of life. It should be a part of school instruction and training that all drinks of the nature of tea, coffee, and chocolate, and all alcoholic drinks, and tobacco, are dangerous articles during the period of growth.

EXERCISES FOR REVIEW.

1. Read carefully Lesson 15 and compare it with Lessons 41 and 42.
2. Why is wheat a valuable food ?
3. What part of the wheat kernel contains heat-making food ?
4. On what does the food value of macaroni depend ?
5. Why should potatoes be cooked rapidly ? Because the walls of the cells which contain the starch burst and the potatoes are made dry, mealy, and the saliva and gastric juice can more readily penetrate and act upon the nutritious portions. When put in cold water or slowly cooked, the cell walls absorb water and are stretched without bursting.
6. Why are beans economical as food ? In what respect do they resemble animal food ?
7. Glucose ? What kind of sugar is found in beets ? In maple trees ?
8. To what class of foods do fats and oils belong ?
9. What is the test for starch ?
10. Compare beef and pork as to nutritive value ; as to digestibility.
11. Why are eggs perfect food ?
12. What element is characteristic of the flesh of fishes ?
13. Caseine ? Its value as a nutriment ?
14. What class of foods is required in greatest quantity ?
15. Why are fruits valuable additions to more substantial food ?
16. What is gelatine ? Its food value ?
17. What are condiments ? Compare Lesson 43, sec. 22, with Lesson 16, sec. 10.

CHAPTER II.

DANGERS OF STIMULANTS AND NARCOTICS.

LESSON 45.

Alcohol.

1. Origin and Composition. — Alcohol does not exist in nature, except in very minute quantities in some natural waters, where it is doubtless formed from fermentation of the sugar of vegetable matter. It is a result of a destructive process we call fermentation. Common alcohol comes from sugar, and all sugar from starch, which is a special product of growing plants. The vinous fermentation, or that chemical change whereby sugar is split up into alcohol and carbon dioxide, is the result of a growing plant of a low order, generally known as the yeast plant. Under the proper conditions of temperature and moisture, the germs of the yeast plant grow and reproduce themselves, and in some way are the cause of the decomposition of the sugar. Sugar consists of a certain proportion of carbon, hydrogen, and oxygen, and alcohol consists of another proportion of the same elements. There are several varieties of alcohol known to the chemist, but only one, ethyl alcohol, is used as a beverage. Any substance containing sugar may be a source of alcohol; also any substance containing starch, since starch can be converted into sugar.

2. Uses in the Arts and Medicine. — Alcohol is a most useful substance in a great many arts. It burns without smoke, making a very hot flame, and is used by artisans in a variety of ways. It is a solvent for resins and other substances which are insoluble in water, thus making it useful in varnishes and paints. It hardens and preserves tissues, and is indispensable in the study of the minute structure of plants and animals. In medicine its uses are numerous. The properties of many plants could never be extracted without the use of alcohol. It is used in dissolving out and separating the medicinal properties of plants in many cases where the alcohol itself forms no part of the finished product. To sum up, the researches of the scientist and the work of the artisan would be set back hundreds of years were the world to be deprived of alcohol.

3. Action on Vegetable and Animal Substances. — Alcohol hardens and preserves all animal and vegetable tissues. It preserves by abstracting the water and destroying the germs of putrefaction. It hardens by abstracting water and coagulating albumen. Add a little alcohol to the white of an egg and observe that it turns it white and solidifies it at once.

4. Summary of its Physiological Effects. — In the foregoing pages we have had much to say of the physiological effects of alcohol. It is proper here to make a summary of these effects.

1. *On the Osseous System.* — No direct effect, only through the digestive and circulatory systems, whereby the nutrition of bone is affected. This is shown in stunting and checking growth when given to children.

2. *On the Muscular System.* — Impairs the functions of the muscles, destroying their power of co-ordination. Of course, this is brought about by its action on the nerve-centers which control muscular action. This is shown in the unsteady gait, the want of precision of touch, the double vision and "thick tongue" of the inebriate.

3. *On the Digestive System.* — Abstracts water from the mucous membrane, inflames and thickens it, lessening its sensibility, thus diminishing power of absorption; weakens the blood-vessels of the stomach by distending them; hardens the liver and causes disease of this and other glandular organs.

4. *On the Circulatory System.* — Weakens the circulatory organs by overworking them and distending them.

5. *On the Respiratory System.* — Engorges the capillaries of the lungs and mucous membrane of respiratory tract, thus diminishing the power of oxygenating the blood and increasing the tendency to disease of these parts.

6. *On the Secretory System.* — Affects all glands, overworking them at first, hardening them afterward. By sending the blood to the surface causes rapid loss of the heat of the body.

7. *On the Nervous System.* — Impairs the power of all nerve-centers properly to control the various organs. Hardens the albuminous constituents of nerve-tissue and leads to insanity.

8. *On the Special Sense-Organs.* — By its effects on the nervous system it must necessarily affect injuriously all special sense-functions.

Dr. N. S. Davis, in a paper read before the International Congress, July 14, 1891, thus sums up the effects of alcohol: —

By all chemists, and other scientific men, it is classed as an active poison capable of speedily destroying life when taken in sufficient doses; and if taken pure or undiluted, it destroys the vitality of the tissues with which it comes in contact as readily as creosote or pure carbolic acid. When largely diluted with water, as it is in all the varieties of fermented and distilled liquids, and taken into the stomach, it is rapidly imbibed or taken up by the capillary vessels and carried into the venous blood, without having undergone any digestion or change in the stomach. With the blood it is carried to every part, and made to penetrate every tissue of the living body, where it has been detected by proper chemical tests as unchanged alcohol, until it has been removed through the natural process of elimination, or lost its identity by molecular combination with the albuminous elements of the blood and tissues for which it has a strong affinity.

The most varied and painstaking experiments of chemists and physiologists, both in this country and Europe, have shown conclusively that the presence of alcohol in the blood diminishes the amount of oxygen taken up through the air-cells of the lungs, retards the molecular or metabolic changes of both nutrition and waste throughout the whole system, and diminishes the sensibility and action of nervous structures, in direct proportion to the quantity of the alcohol present. By its strong affinity for water and albumen, with which it readily unites in all proportions, it so alters the hemaglobin of the blood as to lessen its power to take the oxygen from the air-cells of the lungs, and carry it as oxyhemaglobin to all the tissues of the body; and by the same affinity it retards all atomic or molecular changes in the muscular, secretory, and nervous structures; and in the same ratio it diminishes the elimination of carbon-dioxide, urea, phosphates, heat, and nerve-force. In other words, its presence diminishes all the physical phenomena of life.

5. **Social and Moral Effects.** — In a community where the drinking habits have full sway, the social and moral condition of the people is of a low grade. Drunken men are generally quarrelsome, and fights and murders are common where there is no

check upon this vice. A love of drink, and its attendant sports and amusements, excludes higher and more intellectual amusements and occupations. It is true we occasionally see a man of genius who at the same time is a "hale fellow well met," and who frequently succumbs to the effects of alcoholic beverages, but such cases are to be pitied and not admired. Robert Burns and Edgar A. Poe will always be pitied in the same breath that expresses admiration of their works.

Alcohol, moreover, actually blunts the moral sense, by its effects on the brain-tissue. Many a man has committed crime under the influence of alcohol who would have been under other circumstances only moderately immoral. We may all recall instances in our own experience of fathers and husbands who, when sober, are kind and affectionate to their families, but under the influence of liquor are transformed into demons whose very presence is dreaded. It is curious to note that there are some cases where a man is more generous and affectionate when drunk than when sober. Very few confirmed drunkards really reform. They may sign a pledge of total abstinence, exhort and lecture others to reform, and then in spite of all efforts of friends and relatives resort again to their cups, having no moral strength to control their appetite for drink. This should be a lesson to those who are yet on the safe side, a warning to reform before they have gone too far, and an argument for total abstinence to those who have never begun.

6. Temperance Reform. — This is not the proper place to discuss methods of temperance reform. Men honestly differ as to the means of checking the horrid vice of intemperance, but a word as to the prospects of the temperance cause, and a hint regarding the part the teachers and pupils of our public schools may play in the work of reform will not be out of place.

We are safe in saying that more has been done in the United States towards checking intemperance than in any other country in the world. This does not mean that our people are more temperate than other nations. It seems to be an universal rule that the people of cold and dry climates are, other things being equal, more inclined to intemperance in the use of alcohol than those of warm and moist climates. There is more drunkenness in Russia than in any other country in the world. Sweden, Norway, and Scotland are also notorious for the drinking habits of the people. On the other hand, in Italy and Greece there is very little drunkenness, although almost every individual, from the child in the cradle to the tottering gray-beard, drinks mild wines which contain very little alcohol. The people of the United States have a strong natural tendency to drink alcoholic liquors to excess, but this tendency is held in check by the moral and intellectual force of the people. There are more total abstainers from all kinds of intoxicants in this country than anywhere else, and this is due largely to the work of temperance societies, temperance lecturers, and the influences of teachers, ministers, and the public press. We have made intemperance unfashionable to a great degree, and confined it to the lower strata of society. This is not so much the case in other countries.

Whatever may be done in other ways, one thing is certain, that a more general diffusion of a knowledge of physiology and the effects of alcohol on the system, and a knowledge of its real nature, will do much towards temperance reform. Every school boy and girl who studies physiology can contribute something towards this reform. A love of knowledge in general will also contribute much towards the desired end; for the young person who loves to read and takes delight in acquiring knowledge, whether of science, history, language, or literature, will care little for the so-called pleasures of indulging the appetite.

LESSON 46.

Alcoholic Beverages.

1. **Fermented Liquors.**—In a proper sense all alcoholic liquors are fermented liquors, that is, the alcohol which they contain

is produced by fermentation; but what is here meant by fermented liquors are those which at first consist of water, sugar (or starch), and flavoring substances, and subject to conditions under which the sugar is converted to alcohol (or the starch to sugar and this sugar to alcohol), and the whole used as a drink without further change, except it may be the addition of other flavoring substances or narcotic drugs. Fermented liquors may be again divided into two classes, the **beers** and the **wines.**

2. The Beers. — Beers differ from wines chiefly in containing a small amount of nutritious material; contain a bitter or narcotic substance, usually *hops;* are fermented by the addition of yeast, and do not contain acids except sometimes, as in the case of sour beer, acetic acid. Ordinary beer is prepared from barley somewhat as follows: the barley is first moistened with water and placed where it is warm enough to cause it to germinate. At a certain stage the germination is stopped by heat. This substance is called *malt.* The germination of the seed produces a substance called **diastase**, which has the power of converting starch to sugar; the malt is then bruised, or ground, and mixed with water. The water dissolves the sugar already formed by the action of the diastase, and the latter goes on to convert the balance of the starch to sugar. The liquid thus formed is called *the wort.* The wort is then boiled, which kills the diastase and stops its action. Yeast is next added to the liquid, and the vinous fermentation begins, and the sugar is changed to alcohol. Before all of the sugar is converted into alcohol the liquid is put into strong kegs and kept from the air and in a cool place, otherwise the beer would sour, or the vinous fermentation would be completed and followed by the acetous fermentation. The sparkle and foam of beer is due to the carbonic acid gas, which is always produced in vinous fermentation. The bitter taste of the beer is given by the addition of hops, which contain a narcotic principle and add to the intoxicating properties of the liquor. Beers contain from three to eight per cent of alcohol, and are among the mild alcoholic beverages.

Other grains are used for making beer, but barley is the principal one in this country. In South America *chica*, or maize beer, is made from Indian corn, and is a common drink among the natives. In the valleys of the Sierra it is made in a peculiar way. A description of the process is given here because of its bearing on a physiological fact. The natives gather around a large vessel and each one chews corn and throws the pulp into the vessel. The mass thus obtained is mixed with water and allowed to ferment. Can the student of physiology guess what converts the starch to sugar in this case? It is the ferment, **ptyalin**, of the saliva.

Quass, or rye beer, is a favorite drink in Russia, and *Bouza*, or millet beer, in Tartary. *Koumiss*, or milk beer, made from mare's milk which is peculiarly rich in sugar, is also largely used in Tartary. *Saki*, or rice beer, is used largely in Japan and other eastern countries. *Ale* and *porter* are modified beers.

3. The Danger in Beer. — Immense quantities of beer are consumed in the United States. It does more harm here than in European countries, first, because of the more sensitive nature of the nervous systems of Americans it produces more effect, and second, because our customs of drinking are different. In Europe men and women will sit down at a table and sip their beer slowly while they chat, and it is largely used with their food also. Here it is the custom for two or more persons to "treat" each other, and each one drinks in rapid succession one glass after another, and excess is thus much sooner reached. Besides, the beer made in this country usually contains more alcohol and hops than that of other countries.

Is beer nourishing? The amount of nutriment in it is so small that it is not worth considering. Liebig, the great German chemist, said, "If a man drinks daily eight or ten quarts of the best Bavarian beer, in the course of twelve months he will have taken into his system the nutritive constituents contained in a five-pound loaf of bread." Think of a man drinking over twenty barrels of beer in order to get as much nourishment as he would from five ordinary loaves of bread.

The use of beer leads to stronger alcoholic drinks. Many a drunkard began as a boy to drink an occasional glass of beer which he was told would not hurt him.

4. The Wines. — Wines differ from beers chiefly in their containing less nutritious matter, in being free from narcotic ingredients other than alcohol, in being fermented without the addition of yeast, and in containing various acids belonging to the fruits from which they are usually made. The general method of making wine is to expose the juice of fruits or vegetables to air in a warm place until it has reached a proper degree of fermentation, when it is barrelled or bottled. The alcohol comes from the fermentation of the sugar contained in the juice. Sometimes sugar is added, there not being enough in the fruit juice. The fermentation is said to be spontaneous, because no yeast or other substance is added. But the germs of yeast are everywhere present in the air, and falling into the *must*, as the liquid before fermentation is called, it grows and multiplies and converts the sugar to alcohol. If air be excluded from sugar solutions and no yeast is added, fermentation will never take place. If the juice of fruits be first heated to destroy all yeast germs which may be in it, and then excluded from air to prevent their entrance, it will keep for an indefinite time without change. This explains why canning preserves fruits. If the exclusion of air be not perfect the canned article spoils, that is, ferments.

Wine is made from a great variety of substances. Fermented or "hard" cider is wine of apples. The so-called wines in the market contain from three to twenty-five per cent of alcohol. They are frequently vile adulterations, or imitation mixtures, being made from raisins, with the addition of alcohol, flavoring extracts of coal-tar, sugar, and coloring matter, and sold under fictitious names. More wine is sold in civilized countries than could be made from all the grapes in the world.

Palm wine, or *toddy*, is made from the sap of palm trees and is largely used in tropical countries. *Date wine*, or *sechar*, was known to the Hebrews and is referred to as "strong drink" in the Old Testament. (See Lev. x. 9 and Deut. xiv. 26.)

Guarapo, or *sugar-cane wine*, is largely used also in tropical countries. In Mexico the national drink is *pulque*, a wine made from the juice of the *maguey*, a species of *agave* (century plant).

5. The Danger in Wine. — If it were possible for all persons to control their appetites, and if wines were simply fermented juice of the grape with not more than five per cent of alcohol, an occasional moderate use of them could do but little harm. But much of the wine that is in use is strong in alcohol and contains other injurious ingredients, and the number who can use moderation in this respect is exceedingly small. The wise man who said, "Wine is a mocker, strong drink is raging, and whosoever is deceived thereby is not wise," understood the danger of tampering with such dangerous substances. A little creates a desire for more, and this still more, and the senses become blunted, the man's judgment concerning the degree of its effect is impaired, and thus he is deceived by the mocker and is not wise. It must be borne in mind always that there is a great difference between the people of Italy and Greece in their non-stimulating climate, drinking, as a part of their daily food, wines made from the pure blood of the grape and containing but three or four per cent of alcohol, and the active, nervous American in our irritable atmosphere, drinking vile mixtures containing from twenty to twenty-five per cent alcohol.

There may be poetry in the allusions made by literary men in all ages to wine and its influence upon humanity, but the ancient sage stated a pure scientific fact when he said, "Wine is a mocker." Modern physiologists and chemists confirm the statement, and all experience bears it out.

6. Distilled Liquors. — These are the "strong drinks" of modern times. The ancients knew nothing of the process of distilling and the weaker wines, those made from fruits with a moderate amount of sugar, were called *wines*, and those from fruits containing much sugar, and therefore richer in alcohol, they called "*strong drink*."

Alcohol is more volatile than water, that is, it is converted into vapor at a lower temperature. Herein lies the principle of distillation. A liquid containing alcohol is subjected to heat in a close vessel. A pipe connected with the vessel is carried by many coils or turns through cold water. The vapor passing through the pipe is condensed by the cold into liquid. This vapor contains more alcohol in proportion than water, and the condensed liquid discharged is stronger in alcohol than the original liquid. By repeated distillations almost pure alcohol is obtained. To get rid of the last portions of water is a difficult process. It must be redistilled with certain salts which absorb the water. Alcohol thus freed from water is called absolute alcohol. The alcohol usually used in the arts and for making medicine is ninety-five per cent alcohol and five per cent water.

The common distilled liquors are brandy, whiskey, rum, and gin.

7. **Brandy.** — This is the product of the distillation of wine and contains from fifty to sixty per cent of alcohol. It has a peculiar flavor derived from certain oils that distil over with the alcohol. It is a strong and fiery drink, and very little of it produces intoxication.

8. **Whiskey.** — One of the most common forms of strong drink. It is usually made from Indian corn. Malted barley is added to the ground grain and a suitable amount of water. The malt changes the starch of the grain to sugar, which then takes on the vinous fermentation, after which the liquid is distilled. Whiskey is frequently made from wheat, rye, potatoes, and other vegetable substances containing starch. Its peculiar flavor is due to *fusel oil*, which is formed in the process and distils over with the alcohol. Whiskey contains from forty-five to sixty per cent or more of alcohol. The fusel oil gives it the peculiar burning effect when taken in the mouth.

9. **Gin and Rum.** — Gin is produced in the same manner as whiskey, except that juniper berries are distilled with the grain. This gives its characteristic flavor. Rum is distilled from fermented molasses.

10. **Influence of Distilled Liquors.** — All that has been said concerning the dangers of alcohol, applies to these strong liquors. They are the form in which alcohol is generally used when intoxication is desired. Alcohol alone cannot be used as a drink. It is too strong and the flavor is not pleasant to the majority of persons. Even when diluted with water it is seldom

used, because not palatable, but when combined with the flavors of whiskey, brandy, gin, and rum or other distilled liquors, or in the form of wines and beers, it produces its evil effects. The confirmed drunkard, when he can get no other liquor, will drink alcohol, or, in fact, any mixture which which will intoxicate, for it is the intoxication that he desires. In fact, the inebriate has very little sense of taste, his nerves having been blunted by the use of alcohol. Men drink for two reasons, because they love the taste and because they love the effect of the drinks. Were there no liquids but alcohol and water there would be fewer drunkards, because there would then be but one inducement instead of two.

11. Adulteration of Liquors. — All kinds of beverages are largely adulterated in this country. Were the adulterations in use always harmless substances, as sugar, caramel, and water, the final effect would be for the better; but this is not the case. Some very poisonous substances are used in adulterating alcoholic drinks. Among the most common is *cocculus indicus*, a very poisonous vegetable substance which produces a kind of intoxication which is more injurious than that produced by alcohol.

LESSON 47.

Narcotic Drugs.

1. Stimulants and Narcotics. — Stimulants are those agents which increase or intensify the forces of the system. Narcotics are those agents which paralyze or depress the forces of the system. These opposite effects are produced by the same agents, modified by the quantity, the age, the sex, the temperament, and the condition of health, the general law being that small quantities stimulate and large quantities depress, other things being equal, and that large quantities at first stimulate then depress. Large and small are relative terms, and what would be a large quantity for one person may be a small quantity for another. An stimulants, then, are narcotics when pushed to an extreme in quantity or continued in time. All narcotics are stimulants in small quantities and when first taken. This may be illustrated by a simple mechanical action. Gentle rubbing or tapping of the skin causes an increased flow of blood to the part and an agreeable sensation. This is stimulation. Let the pressure be very strong and the nerves are paralyzed and the blood driven away from the part. Or let the gentle action be kept up continuously for a long time, and there is a shock or paralysis of the nerves. This is narcotism. Some drugs are so powerful that but minute quantities produce the stimulating effect. Others are mild, and it requires a large quantity to produce the narcotic effect.

2. Opium. — One of the most seductive and dangerous of drugs, yet when properly used one of the most valuable. It is in the form of a gum, being the dried and thickened juice or milk of a species of poppy. The pods of the plant are cut in several places with a knife, which allows the milk to flow. In twenty-four hours it has dried and thickened on the pod and is scraped off and formed into balls. It is grown chiefly in Persia, Turkey, and India. It is bitter and disagreeable to the taste, and it is only for its effects that people use it. It is usually either eaten or smoked in a pipe. It is soluble in alcohol, the solution being known as *laudanum*. Sometimes it is taken in this form.

The first effect of a dose of opium is an exhilaration of mind and a pleasurable or comfortable condition of the entire system, thus somewhat resembling the first effects of alcohol. Then a period of stupor and depression follows. A desire to sleep comes on, a sleep in which sometimes most extravagant dreams occur. On recovering from the stupor the body is weak, the head aches, and a miserable feeling makes the victim pay dearly for the pleasurable sensations experienced at first. When the habit of taking it is formed the person is the most abject slave imaginable. It is almost impossible for him to break off the habit. When deprived of the stimulant he is in a terrible torment and has no rest until he indulges again. Every time it requires a little more to produce the intoxication effect. After awhile he becomes subject to pains which opium will not relieve, digestion is impaired, the skin becomes yellow, the eyes sunken and glassy, there is a bending of the spinal column and emaciation of the body, and the victim is a hopeless wreck of humanity, both mentally and physically. More so than alcohol it seems to destroy the moral sense. The confirmed opium-user, if he desires to be cured of the habit, must put himself under the closest kind of restraint, for while he may have been a conscientious man in other respects he will not hesitate to lie and steal to get the drug.

There have been two remarkable cases of opium eating among men of genius, Thomas De Quincey and Samuel T. Coleridge. The former was an eminent English writer who had acquired the habit and after a long struggle succeeded in freeing himself. His "Confessions of an Opium-Eater" is interesting reading. Coleridge was one of England's greatest poets, who in like manner became a victim and succeeded in breaking off the habit. These men are remarkable exceptions to the rule that whoever forms the habit is hopelessly lost.

The people of Turkey, India, China, and other eastern countries are much addicted to this habit. It is a worse evil among them than the alcohol habit is in our country. The habit is on the increase in the United States. It is believed by good authorities that the checking of the alcohol habit has led to an increase in the use of opium. If this be true it shows that we must strike deeper than prohibiting the manufacture and sale of alcoholic drinks. *We must educate the people to see the evils of stimulants and narcotics of all kinds.*

Johnston's "Chemistry of Common Life" thus sums up the effects of opium: —

1. It is certain that opium, like spirituous liquors, produces most melancholy body-and-soul-destroying effects upon those who give themselves up to its use as a narcotic indulgence. If day brings them the bliss of heaven, night brings with it the torments of hell.

2. It is certain, also, that some can continue for years to use it in small doses as a narcotic indulgence, without becoming slaves to it, or without appearing to be sensibly affected by it in their general health.

3. But it is of all indulgences the most wonderfully seductive, and is therefore a most dangerous substance to become familiar with. The infatuation sometimes reaches such a point that the certainty of death, and all of the fearful infirmities which in this case precede death, have no influence on the victim.

4. To give up the indulgence produces tortures of mind and body, which makes cowards and recreants of the most resolute. To this fact, the testimony of Coleridge and De Quincey has been already quoted.

3. **Morphine.** — This is simply an extract of opium, a concentrated principle of the gum, having all its active narcotic properties in a much smaller bulk. It is a more convenient form for use in medicine, and many in our civilized countries are using it instead of opium for the intoxicating effect. It acts much more quickly and powerfully when dissolved and injected beneath the skin by an instrument called the hypodermic syringe. Not a few are using it in this manner as a constant habit.

4. **Indian Hemp.** — Our common hemp plant, which is cultivated in parts of this country for its fiber, contains a resinous substance which is strongly narcotic. In India this plant develops this resin in much greater quantities, and it is there gathered and used as a substitute for opium. The Arabians prepare from it a substance they call *hasheesh*. Immense quantities of this hemp resin are consumed, in Turkey, Arabia, and India. It is estimated that 300,000,000 people use it habitually. Its intoxicating effects differ considerably from opium, both in kind and degree. It induces a peculiar kind of temporary insanity, but does not affect the circulation and digestion as opium does.

5. **Coca.** — This must not be confounded with the cocoa from which chocolate is made. It is an entirely different plant and possesses narcotic properties in the highest degree. It is the leaves of a bush six or eight feet high which grows in South America. The leaves are chewed or a tea is made from them and drank. Most extraordinary virtues are assigned to it by the natives who use it. They claim that by chewing the leaves they are enabled to endure the greatest fatigue and perform an immense amount of physical exertion without the need of food. The observations of many travellers confirm these re-

ports, but a scientific man will regard them as exaggerations. There is scarcely an article in use as a medicine but at sometime in its history has been lauded to the skies for its extraordinary virtues. Opium when first introduced to the medical profession was called "*Magnum Dei donum*," the great gift of God. Cinchona bark, from which quinine is made, was also attributed with extraordinary powers. *Cocaine*, an extract of coca, is now much employed in medicine.

Coca is probably less dangerous as a narcotic indulgence than opium, hemp, and alcohol. It is in use by about 10,000,000 people in South America.

6. Betel-nut. — This is the seed of a species of palm tree, growing in India and on the islands of the Indian Ocean. It is chewed like tobacco, and it is estimated that not less than 50,000,000 people so use it. It gives a red color to the saliva and to the lips and teeth. This is considered very ornamental by the natives who use it. It seems to have narcotic effects somewhat similar to coca.

7. Chloroform and Ether. — Perhaps no discovery of modern times has contributed more to human happiness than the discovery of the use of these substances as *anæsthetics*. An anæsthetic is a substance which produces unconsciousness to such à degree that any operation may be performed on the body without pain and without the knowledge of the patient. Previous to the use of anæsthetics in surgery, when it was necessary to amputate a limb or remove a tumor or growth, the patient was obliged to suffer extreme torment; and it required a number of assistants to hold him still long enough to perform the operation, which under such circumstances had to be done hurriedly, and necessarily in an imperfect manner. Now the patient lies down and inhales for a few minutes the vapor of chloroform or ether, and passes into a sleep as sound, and apparently as natural, as that of a child when undisturbed, and awakes in a few hours, knowing nothing whatever of what has been done. It is true that in some rare cases death results from the use of these substances, yet the chances for recovery from the operation are so much greater, that there are few that are not willing to take the risk.

Surgery has made wonderful advances since the introduction of anæsthetics, and hospitals which once were filled with shrieks and groans of the suffering patients are now transformed into a paradise in comparison.

But there is no good thing that is not abused. There is growing tendency among civilized people to use these substances for every ache and pain, and while it is not likely they will come into such habitual use as alcohol and opium, yet the danger is such as to call for warning. It is a safe rule never to use chloroform or ether without the advice of a competent physician.

8. **Tobacco.** — This is too well known to need description. The extent of its use is simply enormous. It is in use in all countries and by all races of men. Thirty years ago it was estimated that not less than 4,480,000,000 pounds were consumed annually, and since then it has been increasing. Its effects have been stated in the foregoing pages. We shall say here only that it is an injurious habit to all young persons, and to many adults, that to those past the middle age a moderate indulgence is generally beneficial, and that in many cases its use satisfies the longing for some kind of a stimulant, and doubtless saves many persons from the alcohol and opium habits. It is an expensive and filthy luxury, and if for no other reason it should be abstained from by the young.

9. **Other Narcotics.** — There are numerous substances in use, taking the world over, which produce intoxicating effects in a greater or less degree. Thus various species of pepper which are known to possess narcotic properties are used in tropical countries. In Siberia a species of mushroom is largely used as a narcotic. Species of our common jimson weed are used in South America for the same purpose. The milky juice of lettuce has been collected and dried and used as a substitute for opium in Europe. In Jamaica a plant called bull-hoof is used for its narcotic effect.

TEST QUESTIONS FOR GENERAL REVIEW.

NOTE.—The teacher who desires to hold an examination in Physiology may select ten or more of these questions as tests of the pupil's knowledge. He may assign the whole list for study, and then select a given number and require the pupils, without access to books, to write out answers to them, the pupils not to know what the test questions are until required to answer them. It must be remembered that examinations are only partial tests of knowledge. As a general rule, examinations should be more of the nature of a general review of the subject.

1. Who discovered the circulation of the blood? When? Read a sketch of his life in any encyclopædia or biographical dictionary. What can be said of the importance of this discovery?

2. Why is disease now less dreaded than in the Middle Ages?

3. What is a cell? What is life?

4. What do you mean by the word *tissue?* Can we speak of the blood as "tissue"?

5. What organs constitute the Digestive System? What is the use, stated in a few words, of the Digestive System?

6. What three elements compose in great part the human body?

7. Write an essay on Bones, using the following outline of points to be discussed: 1. Number; 2. Sizes and shapes; 3. Structure and composition; 4. How joined together; 5. Properties and uses; 6. Growth and repair; 7. How to care for them.

8. Suppose a man's arm to be amputated half-way between elbow and shoulder, what structures can you name that would be severed? In like manner name the parts severed in cutting off the head; in cutting the body through at the lower point of the sternum. [Similar questions should be proposed. It is an excellent method of testing the pupil's knowledge of the *relation* of bones, muscles, arteries, and nerves.]

9. Write an essay on Digestion, discussing briefly the organs, processes, results, uses, and hygiene of digestion.

10. Name the heat-making element in each of the following articles: Wheat, bread, rice, potatoes, dates, cocoanuts, bacon.

11. Name the tissue-making element in beans, bacon, milk, and wheat bread.

12. What is the hardest and most durable substance in an animal body?

13. Describe a proper method of ventilating a room.

14. What are the advantages of full and deep breathing?

15. What would be the probable effect of a removal of the entire epidermis?

16. What is protoplasm?

17. What is the function of the red corpuscles?

18. What are cilia, and what is their use?

19. What is the office of the Eustachian tube? Of the tympanum?

20. Where is the organ of Corti? What is its supposed function?

21. What is the remedy for near-sightedness?

INDEX AND GLOSSARY.

A HINT TO THE STUDENT.

The most valuable part of any book is the index. Study the subject and not the book. *Use* the book in studying the subject. You cannot use a book with economy of time without using the index. The more practice you have in looking up words in the index the quicker you will find them. Do not pass over words in the text which you do not understand. If the word is not defined in its connection, or not made clear by the context, look for it at once in the index. It will either be defined there or the figures will refer you to the part of the text where it is made clear. A teacher can help you much, but you need not depend on a teacher. This book is a self-instructor, if used as here directed. Where several page numbers are given, look for each of them.

A.

B.

C.

D.

E.

O.

P.

U.

V.

W.

X.

Y.

CONTENTS OF THE APPENDIX.

APPENDIX.

TO THE TEACHER.

The teacher should always be in advance of the pupil, both in general grasp of the subject and in a knowledge of details. The former is, however, of more importance than the latter. It is always possible for some of the pupils, at least, to be better posted in some of the details of a subject than the teacher; but in general knowledge, and in the comprehension of fundamental principles and a knowledge of leading facts, the teacher should be much in advance of those he assumes to instruct.

Few teachers have access to libraries rich in the literature of physiology, and no single text-book can contain that which will place the teacher in advance of the diligent pupil. This College Edition, containing matter in addition to the "Lessons in Physiology," has been prepared to meet, in part, the wants of the teacher. If possible, however, the teacher should possess at least one more comprehensive work. The author can confidently recommend as a valuable book for the teacher "The Human Body," by Prof. H. Newell Martin. It is not an expensive work, and will be found exceedingly helpful.

A copy of the latest edition of Gray's "Anatomy" would be a valuable reference book for the teacher. This, with Landois & Sterling's "Physiology" and Parke's "Practical Hygiene," would form a very complete library of reference in this line, but the expense of such books is considerable. Yet, many teachers can well afford them.

The microscope is a valuable aid in the study of physiology. There are a great many teachers who could afford a microscope of sufficient powers to demonstrate all the important points of the subject. It must be remembered that microscopes range in price from 25 cents to hundreds of dollars. A simple lens, or common magnifying glass, costing no more than 25 cents, is of some value. It will answer in demonstrating adjustment of the eye, as shown in the text. The Excelsior pocket and dissecting microscope, costing only $2.50, will, under good management, show the individual corpuscles in the blood of the frog, and will easily show the circulation in the web of the frog's foot. The lenses of this microscope can be used singly, and thus answer the purpose of a common magnifying glass. The Student's microscope, with powers ranging from 80 to 375 diameters, can be had for $30.00. This will answer all purposes of the ordinary teacher, show structure of bone and teeth when sections are made thin enough, show human blood-corpuscles quite well, structure of muscles, epithelial cells, etc. There are other instruments that may answer the teacher's purpose equally as well, but the price will not differ much from that we have named. The teacher should write for catalogues of microscopes of different houses, and compare prices and statements, or consult some reliable dealer in microscopes.

WHAT IS PROTOPLASM?

In all modern works on plants and animals the term protoplasm is of frequent occurrence. Huxley called it "the physical basis of life." It is the first step in the organization of inorganic matter. It is living matter without definite shape. It is a very convenient term to use, but we really know but little about the substance it is the name of. We can say that protoplasm reproduces itself, drawing, in the case of the plant, from the inorganic world for its new material, and, in the case of the animal, from previously organized matter. All protoplasm comes from some pre-existing protoplasm, which is equivalent to saying that all living things come from pre-existing living things. All tissues of plants and animals, with the exception of certain crystalline and other mineral deposits between and in cells, are produced from protoplasm.

"A small lump of protoplasm may in itself represent an independent, living being, exhibiting vital phenomena of such a kind that it is impossible to refuse to call it an 'animal.' It moves by its own force, and, as it would seem, voluntarily; it imbibes matter for its own nutrition from the surrounding liquid; it grows, it multiplies its kind, and it dies. The most evident motion in this case occurs in two ways. Sometimes single processes are seen to protrude from the whole mass; these processes gradually affect the whole granular mass, so that the whole body is displaced, and a genuine change of position happens to the animal; or the processes being again retracted, other similar processes are protruded from another part of the body in such a way that the direction of motion is changed; in short, the animal creeps about on the glass plate on which it is observed by means of these processes. Meanwhile currents of granules can be seen within the mass; closer observation, however, shows that the motion in this case is only passive, and that it is the result of a continuous wave-like displacement of the protoplasm. Movements entirely similar to those in these independent animals (*Amœbæ*) occur in more highly organized beings, vegetable as well as animal. *All living beings are fundamentally composed of just such lumps of protoplasm as we see in the Amœbæ.* Most of these lumps of protoplasm have, however, essentially changed their appearance, and, at the same time, their qualities, so that it is only from the evolution of the parts that we know them to have originated from such lumps. Moreover, even in developed organisms separate parts always occur which are in all respects similar to such lumps of protoplasm as the *Amœbæ*, and which move like the latter. It is a well-known fact, that when a drop of blood is placed under the microscope, a very large number of small red bodies, to which the red color of the blood is due, are seen within it. And scattered about among these red blood-corpuscles are seen colorless or white blood-corpuscles, round or jagged in form, and containing granular protoplasm with a kernel or nucleus. If the blood has been placed on a warmed glass, and if it is observed at a temperature of from 35 to 40 degrees C., these blood-corpuscles exhibit active movements entirely similar to those of the *Amœbæ*, and which have, therefore, been called *Amœboid movements.* The corpuscles send out processes and again retract them; they creep about on the glass; and, in short, they behave exactly like *Amœbæ*, and like the latter they even absorb matter, such as granules of any coloring substance which may have been added, from the blood-fluid — they eat, that is, — and after a time they again reject this matter."—*Dr. I. Rosenthal.*

Of plant protoplasm, Bessey, in his admirable work on Botany, thus speaks: "If we examine a thin slice of any growing part of a plant under a microscope of a moderate power (400 to 500 diameters), there may be seen large numbers of cavities which are more or less filled with an almost transparent semi-fluid substance. In very young parts, as in buds and tips of roots, this substance entirely fills the cavities, and makes up almost the whole mass, while in older parts it occurs in less quantity, and usually disappears in quite old tissues. This substance is the *living portion of the plant*, the active, vital thing which gives to it its sensibility to heat, cold, and other agents, and the power of moving, of appropriating food, and of increasing in size; it is, in fact, *that which is sensitive, which moves, appropriates food, and increases in size*. This sensitive, moving, assimilating, and growing substance is named **Protoplasm**.

"It is a fact of great biological interest that in animals the essential constituent of all living parts is a substance similar to the protoplasm of plants. We cannot distinguish the two by any chemical or physical tests, and can only say that, taken as a whole, the protoplasm of plants differs from that of animals in its secretion. And yet these secretions are not strictly confined to plants; cellulose, starch, chlorophyll, and other products of vegetable protoplasm, formerly regarded as peculiar to plants, are now known to occur in undoubted animals. Botanists and zoölogists have labored long in vain to discover absolute differences between the animal and the vegetable kingdoms; between the higher plants and the higher animals there are great and constant differences; in none of the higher animals, for instance, is chlorophyll produced, but in the lower orders of both kingdoms not one of the differences observed to hold between the higher plants and animals exists."

Geddes, a recent investigator, thus defines protoplasm: —

"Protoplasm is regarded as an exceedingly complex and unstable compound, undergoing continual molecular change or metabolism. On the one hand, more or less simple dead matter or food passes into life by a series of assimilative ascending changes, with each of which it becomes molecularly more complex and unstable. On the other hand, the resulting protoplasm is continually breaking down into more and more simple compounds, and finally into waste products. The ascending synthetic constructive series of changes are termed *anabolic*, and the descending disruptive series *katabolic*."

CLASSIFICATION OF THE TISSUES.

The following classification of tissues is based on that of William Turner, M.B., Professor of Anatomy, University of Edinburgh: —

THE TISSUES.

I. Cells suspended in Fluids.

1. **Blood.**
2. **Lymph.**
3. **Chyle.**

II. Cells placed on Free Surfaces.

("By a free surface is meant a surface which is not blended with or attached to adjacent structures, but is free or separable from them without dissection. Every free surface is covered by one or more layers of cells.")

1. **Epithelium.** — ("By the term epithelium is meant the cells situated on free surfaces which are exposed directly or indirectly to the air.")

(1) *Tessellated, pavement, scaly, or squamous.* — Nucleated, flattened cells, varying in diameter from $\frac{1}{500}$th to $\frac{1}{1000}$th of an inch. Found in mucous lining of mouth, pharynx, esophagus, conjunctiva, entrance to nasal cavity, and under the special name of epidermis forms the external layer of the skin.

(2) *Columnar, or Cylindrical.* — Elongated, cylindrical cells, about $\frac{1}{500}$th of an inch long, placed side by side like palings, with their long axis perpendicular to the surface on which they rest. Found in mucous lining of alimentary canal, and in the ducts of various glands.

(3) *Ciliated.* — Columnar cells with hair-like processes or cilia, not more than $\frac{1}{2500}$th to $\frac{1}{4000}$th of an inch in length. Found in mucous lining of air passages, in ventricles of the brain, and canal of spinal cord, and some other places.[1]

(4) *Spheroidal, or Glandular.* — Cells spheroidal or polyhedral in form. Found in glands and the commencement of gland ducts.

(5) *Transitional.* — Forms of cells resembling both columnar and tessellated, or columnar and spheroidal. The cells of the mucous membrane of the bladder are of this nature.

2. **Endothelium.** — ("By the term endothelium is meant the cells situated on free surfaces which are not exposed directly or indirectly to the air.") Generally flattened, scale-like cells, arranged like the cells of tessellated epithelium. Found in all serous membranes.

III. CELLS EMBEDDED IN SOLID TISSUES.

1. **Connective Tissue.** — Those tissues which, though differing in various respects from each other, agree in having the property of binding together other tissues or parts of the body, and in serving as a supporting framework for more delicate tissues.

(1) *Neuroglia.* — "Small round or ovoid corpuscles, embedded in a soft undifferentiated protoplasm." Connects the nerve-cells and nerve-fibers.

(2) *Retiform Tissue.* — Star-shaped, branching cells. It constitutes the supporting framework of the lymphatic and some other glands, also in the enamel of the teeth.

(3) *Gelatinous or Mucous Tissue.* — The framework of the vitreous humor of the eye. Rounded or star-shaped cells, embedded in a gelatinous substance.

(4) *Fibrous Tissue.* — Consisting of threads or fibers.

a. Areolar Tissue. — Loose, fine fibers, running in all directions. Found just below the skin and in part of the peritoneum.

b. White Fibrous Tissue. — Makes up the great bulk of most ligaments, tendons, and fibrous membranes. The fibers are extremely delicate, $\frac{1}{25000}$th to $\frac{1}{50000}$th of an inch in thickness.

c. Yellow Fibrous Tissue. — Elastic fibers, certain ligaments as the strong ligament in the back of the neck (*ligamentum nuchæ*), and in the elastic coats of the arteries. In some places mingled with the white fibrous tissue.

2. **Adipose Tissue.** — Collections of ovoid or spherical cells containing fat.

3. **Pigmentary Tissue.** — Cells containing coloring-matter. Found in the skin and choroid coat of the eye.

4. **Cartilaginous Tissue.** — ("By the term cartilage or cartilaginous tissue is meant a group of tissues which, although usually found in the form

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[1] The ciliated cells of the ventricles of the brain and spinal cord would properly come under the head of *endothelium*, as they are not exposed to air.

of plates or bars, yet differ in various aspects from each other, both in naked eye and microscopic characters. They agree, however, in forming solid textures, opaque when seen in mass, but in thin slices translucent, pearly, or bluish white, firm in consistence, but easily cut with a knife, endowed with considerable elasticity, and yielding *chondrine* on boiling.")

(1) *Cellular Cartilage.* — The original form of bone, the growth of bone being the change or modification of the cartilage cells into bone cells.

(2) *Hyaline Cartilage.* — Cells embedded in semi-transparent, solid mass. The costal cartilages, the layer at ends of bones, those of the nose and trachea and part of those in the larynx, also the temporary cartilage.

(3) *Fibro-cartilage.* — Cartilage cells and fibrous tissue commingled. The epiglottis, framework of the external ear, Eustachian tube, etc.

5. **Osseous Tissue.**
6. **Muscular Tissue.** } Have been sufficiently described.
7. **Nervous Tissue.**

CHEMICAL COMPOSITION OF THE HUMAN BODY.

Note. — The teacher who has some knowledge of chemistry may make the following outline the basis of an hour's lecture or talk on this subject. If possible, specimens of some of the elements should be exhibited. The following may be obtained without cost in a state nearly pure: — *Carbon* in the form of charcoal, black lead, and gas carbon (the latter is used in electric batteries and electric lights); *sulphur*, *iron*, fibrin, glucose, gelatine, calcium carbonate in the form of limestone and marble, sodium chloride (common salt). The following may be purchased at a small cost: — Phosphorus, magnesium, sodium, potassium, dextrin, calcium phosphate, calcium fluoride. The following may be manufactured by the teacher who has studied chemistry, and their peculiar properties illustrated by experiments: — Hydrogen, oxygen, nitrogen, chlorine.

I. Ultimate Elements. — By these, we mean those elements which cannot be further divided or separated into two or more elements.

1. **Carbon.** — Found in all the tissues of the body. Found pure in nature as the diamond, and nearly so as charcoal, anthracite coal, graphite, or black lead. Produced in the manufacture of illuminating gas from coal. Combined in limestone, marble, and chalk, and in all animal and vegetable substances.

2. **Hydrogen.** — In all the tissues. When free and uncombined it is an invisible, inflammable gas, the lightest of all known substances. One of the elements of water and consequently of all animal and vegetable substances.

3. **Oxygen.** — In all the tissues. When uncombined it is a gas sixteen times as heavy as hydrogen, a little heavier than air. Does not burn but most substances burn readily in it; in fact, nearly all combustion or burning is simply the union of oxygen with some other substances so rapidly that great heat is produced. Nearly all decay is also the union of oxygen with some of the elements of a substance, but more slowly than in combustion. Found in the air simply mixed, not chemically combined with nitrogen. One of the elements of water. It is combined in nearly every substance in nature.

4. **Nitrogen.** — In most all of the tissues. When uncombined, it is a gas which will not burn nor support combustion nor life. It is free in the air. Combined with hydrogen it forms ammonia, and with hydrogen and

oxygen, nitric acid and numerous acids and salts, including a number of highly explosive substances.

5. **Sulphur.** — One of the elements of albumen and fibrin. Also found in the hair, epidermis, and nails. Hair is dyed black by salts of silver, because the sulphur in the hair unites with the silver to form silver sulphide, a black substance. For the same reason a drop of nitrate of silver makes a black spot on the skin which will not wash out, but remains until the epidermis is cast off and replaced by new. Eggs blacken silver spoons on the same principle. Sulphur is found in nature in an uncombined state in volcanic regions, and is widely diffused in the form of combinations with iron and copper.

6. **Phosphorus.** — Found in bones and nerves. When uncombined is a solid, waxy substance, which takes fire at a temperature a little higher than that of the body. Must be handled with extreme care, as a little friction will cause it to ignite. Does not exist uncombined in nature. Is manufactured mainly from the bones of animals.

7. **Calcium.** — Found in the bones. In nature it is never found uncombined, but is very abundant and widely diffused, being one of the elements of limestone, which is the commonest of rocks. It is a light yellow metal.

8. **Magnesium.** — In the bones in small quantities. In nature combined with other elements in various rocks and soils. When uncombined it is a white metal, which takes fire at a red heat, and burns with the most brilliant and intense light.

9. **Sodium.** — Found in minute proportions in every tissue of the body, and in almost every substance in nature. When separated from its combinations by the chemist it is a white metal, soft as wax, and when it comes in contact with water it appears to take fire and burn with a yellow flame. In reality it unites with the oxygen of the water, releasing the hydrogen, which burns as it is released.

10. **Potassium.** — Found in muscles and some other parts of the body. Abundant in the ashes of plants. Resembles sodium in its properties, behaving when thrown on water in a similar manner, except that the flame is violet.

11. **Chlorine.** — Found generally combined with sodium in the form of chloride of sodium, or common salt, in nearly all the tissues. When uncombined it is a heavy, greenish gas, very irritating and poisonous.

12. **Fluorine.** — In minute quantities in bones and teeth. Sparingly distributed in nature. It is the only element which will not unite with oxygen. Until recently chemists did not succeed in isolating it.

13. **Silicon.** — Exists in minute quantities in the brain. Found more abundantly in plants, and exceedingly abundant in nature in the form of silica or quartz, which is a compound of oxygen and silicon.

14. **Iron.** — Sparingly in the hemaglobin of the red corpuscles of the blood.

15. **Manganese.** — In minute quantity in bones. When uncombined it is a hard, white metal.

II. Proximate Elements.

By proximate elements is meant those compounds produced by the chemical union of two or more ultimate elements. For example, water is a proximate element consisting of hydrogen and oxygen; common salt is a proximate element consisting of chlorine and sodium. We can give a brief notice of only the most important ones here. It must be remembered that when we speak of a proximate element of the body we mean one that is found in the living tissues, or may be separated from them immediately after the death of the part. There are many compounds formed, as we observed in the introduction to this volume, during the decay of the body. These must not be considered as normal constituents of the tissues. We cannot say that alcohol exists in corn or apples, but it is produced from the elements contained in these vegetables during their decomposition. The important proximate elements may be classified as follows:

1. **Nitrogenous or Albuminous Substances.**

(1) *Proteids or Albuminoids.* — Under this head are grouped various substances which contain carbon, oxygen, hydrogen, and nitrogen (with sometimes other elements, as phosphorus), in varying proportion.

a. Serum-Albumen. — The principal form of albumen in the body. Found in the blood and in the muscles.

b. Casein. — In milk.

c. Myosin. — The principal part of dead muscle.

d. Fibrin. — May be separated from fresh blood by whipping it with twigs. Is formed in coagulation of the blood; in fact, coagulation is nothing more nor less than the formation of fibrin from the elements of living blood.

e. Peptone or Albuminose. — The various albuminous substances which are taken as food are converted into a soluble form by the action of the digestive fluids, this soluble form being called peptones. (See Discussion of Processes of Digestion.)

(2) *Substances resembling Proteids.*

a. Mucine. — The active principle of mucus.

b. Chondrin. — The principal basis of cartilage.

c. Gelatine. — Obtained by boiling fibrous tissue, as tendons and ligaments; also from the skin and bones. The jelly of pigs' feet is pure gelatine. Glue is dried gelatine.

2. **Carbonaceous Substances.** — Substances which contain carbon, hydrogen, and oxygen, but no nitrogen. They differ from nitrogenous substances in being less liable to decay.

(1) *Carbo-hydrates.* — Those in which the carbon predominates.

a. Glucose, or *Grape-sugar.* — Produced in the liver from glycogen. Found in the blood. An excess of glucose in the body forms the disease known as *diabetes.*

b. Lactose, or *Milk-sugar.* — Found in milk.

c. Dextrin. — A substance produced from starch by the action of ferments. It is a step in the process of converting starch to glucose. It is found in the alimentary canal after a meal containing starch, and has also been found in the blood.

d. Glycogen. — Found in the liver if examined immediately after death; but if much delay, it is all converted into glucose. See Functions of the Liver.

(2) *Hydro-carbons.* — Those substances in which the hydrogen predominates. They are represented by the *fat* of the body.

3. **Inorganic Substances.** — This includes all substances which are not peculiar to animal and vegetable bodies, but found in the mineral kingdom also.

(1) *Water.* — This has been sufficiently described. See Index to body of book for the various places in which it is discussed.

(2) *Calcium Phosphate.* — More commonly known as phosphate of lime, a principal constituent of bones.

(3) *Calcium Carbonate.* — Known in the mineral kingdom as limestone, marble, and carbonate of lime. Found in bones.

(4) *Calcium Fluoride.* — Known in the mineral kingdom as fluor-spar. It is found only in small quantities in bones and in teeth.

(5) *Sodium Chloride.* — Commonly known as common salt. In the blood and perspiration; also in nearly all the tissues of the body in small proportion.

TABLE OF BONES OF THE CRANIUM.

NAME.	ARTICULATES WITH.	MUSCLES ATTACHED.	USES, ETC.
Occipital	Two parietal Two temporal Sphenoid Atlas	Twelve pairs—Occipito-frontalis, trapezius, and others	Forms back and base of skull
Frontal	Two malar Two parietal Sphenoid Ethmoid Two nasal Two superior maxillary Two lachrymal	Three pairs — Corrugator supercilii, orbicularis palpebrarum, temporal	Forms forehead. In two pieces at birth, which usually unite afterward
Temporal	Occipital Parietal Sphenoid Inferior maxillary Malar	Fifteen pairs — Temporal, masseter, occipito-frontalis, and others	Forms side and base of skull, and contains internal ear
Parietal	Opposite parietal Occipital Frontal Temporal Sphenoid	Only one — The temporal	Forms side and top of skull
Sphenoid	All others of cranium, and — Two malar Two palate Vomer	Twelve pairs — Temporal, external and internal pterygoid, muscles of eyeball, and others	Forms base of skull, holds others together
Ethmoid	Sphenoid Frontal Two nasal Two superior maxillary Two lachrymal Two inferior turbinated Vomer	No muscles attached	Helps to form orbits, transmits olfactory nerve

TABLE OF BONES OF THE FACE.

Name.	Articulates with.	Muscles attached.	Uses, etc.
Nasal	Frontal Ethmoid Opposite nasal superior maxillary	No muscles attached	Forms bridge of nose
Superior maxillary	Frontal Ethmoid Nasal Malar Lachrymal Inferior turbinated Palate Vomer Opposite superior maxillary	Twelve pairs — Orbicularis palpebrarum, buccinnator, masseter, and others	Forms upper jaw. Contains upper teeth
Palate	Sphenoid Ethmoid Superior maxillary Inferior turbinated Vomer Opposite palate	Five — Internal and external pterygoid, superior constrictor of pharynx, tensor palati,and azygos uvulæ	Forms back part of roof of mouth
Lachrymal	Frontal Ethmoid Superior maxillary Inferior turbinated	One muscle — Tensor tarsi	Helps to form orbit
Malar	Frontal Sphenoid Temporal Superior maxillary	Five — Masseter, temporal, and others	Helps form orbit and prominence of cheek
Inferior turbinated	Ethmoid Superior maxillary Lachrymal Palate	No muscles attached	Furnishes surface for spread of olfactory nerve
Inferior maxillary	Two temporal	Fifteen pairs — Buccinnator, masseter, digastric, temporal, internal and external pterygoid, and others	Lower jaw. Contains lower teeth. Largest bone of face
Vomer	Sphenoid Ethmoid Two superior maxillary Two palate	No muscles attached	Forms septum of nasal cavity

TABLE OF BONES OF THE TRUNK.

Name.	Articulates with.	Muscles attached.	Uses, etc.
Sternum	Clavicles Seven costal cartilages on each side	Nine pairs and one single muscle—Pectoralis major, sterno-cleido-mastoid, diaphragm, and others	Forms part of front wall of thorax. Holds ribs in place
Ribs	Each with one or a part of two vertebræ, and all except 11th and 12th with costal cartilages	Twenty — Internal and external pterygoid, pectoralis major, diaphragm, and others	Form the main part of the thorax. Aid in breathing
Clavicle	Sternum Scapula Cartilage of 1st rib	Seven—Trapezius, sterno-cleido-mastoid, deltoid, and others	Acts as a brace to shoulder
Scapula	Humerus Clavicle	Eighteen — Trapezius, deltoid, biceps, triceps, and others	Forms the shoulder. Attaches arm to body
Atlas	Occipital axis	Nine pairs — Longus colli, levator anguli scapulæ, and others	Supports the head
Axis	Atlas Third cervical vertebra	Eleven pairs — Muscles of neck and back	The pivot on which the head rotates
Other vertebræ	Axis Sacrum Ribs	Thirty-five pairs and one single muscle	Form the axis of the body and protect spinal cord
Sacrum	Last lumbar vertebra Coccyx Two innominata	Eight pairs — Gluteus maximus, latissimus dorsi, and others	Forms back wall of pelvis
Coccyx	Sacrum	Four pairs and one single muscle — Gluteus maximus and others	Gives attachment to muscles — not important in man
Os innominatum	Its fellow Sacrum Femur	Forty-five muscles of abdomen, back, thigh, and pelvis	Forms main part of pelvis. Attaches lower limb to trunk

TABLE OF BONES OF THE LIMBS.

Name.	Articulates with.	Muscles attached.	Uses, etc.
Humerus	Scapula Ulna Radius	Twenty-five — Pectoralis major, latissimus dorsi, deltoid, flexors and extensors of the forearm, and others	The axis of the upper arm
Ulna	Humerus Radius	Sixteen — Triceps, anconeus, flexors and extensors of fingers, and others	Forms main joint at elbow. With radius makes forearm
Radius	Humerus Ulna Scaphoid Semilunar	Nine — Biceps, flexors, extensors, pronators and supinators of hand	Forms main joint at wrist. With ulna makes forearm
Carpal bones	Radius Metacarpal bones	Seven — Short flexors of the fingers	Form an elastic union of hand to arm, by the aid of ligaments
Metacarpal bones	Carpal bones Phalanges	Twenty-one — Flexors and extensors of the hand	Form the framework of the hand
Phalanges of hand	Metacarpal bones Fellows	Twenty-one — Flexors and extensors of the fingers	The axes of the fingers
Femur	Os innominatum Tibia Patella	Twenty-three —Gluteus maximus, crureus, gastrocnemius, plantaris, and others	The axis of the thigh
Patella	Femur	Four muscles having one common tendon — Rectus, crureus, vastus internus, vastus externus	Protects knee joint
Tibia	Femur Fibula Astragalus	Twelve — Tibialis anticus, sartorius, gracilis, and others	The main axis of the leg
Fibula	Tibia Astragalus	Nine — Biceps femoris, soleus, and others	An aid to the tibia
Astragalus	Tibia Fibula Os calcis Scaphoid	No muscles attached	Supports the tibia. Main part of ankle joint
Os calcis or calcaneum	Astragalus Cuboid	Eight — Tendo Achillis, plantaris, and others	Forms the support of the heel

TABLE OF BONES OF THE LIMBS. — *Continued.*

Name.	Articulates with.	Muscles attached.	Uses, etc.
Cuboid	Os calcis External cuneiform 4th metatarsal bone 5th metatarsal bone Sometimes with scaphoid.	Part of the flexor brevis pollicis	Helps form the instep
Scaphoid	Astragalus Three cuneiform Sometimes with cuboid	Part of tibialis posticus	Helps to form instep
Three cuneiform bones	Scaphoid Cuboid 1st, 2d, 3d, and 4th metatarsal bones	Tibialis posticus and anticus, flexor brevis pollicis	Help form instep
Metatarsal bones	Tarsal bones Phalanges	Twenty-one muscles	Form the framework of the front part of foot
Phalanges	Metatarsal bones Fellows	Twenty-four muscles — Flexors and extensors of the toes	Axes of the toes

ARTICULATIONS.

The following outline is adapted from Gray's "Anatomy."

I. Kinds of Joints.

1. **Synarthrosis, or Immovable Joint.** — Surfaces separated by fibrous membrane, without any intervening synovial cavity, and immovably connected with each other, as in joints of cranium and face (except lower jaw).

(1) *Sutura.* — Articulation by processes and indentations interlocked together.

a. *Sutura vera* (true). — Articulate by indented borders.

(*a*) *Dentata.* — Having tooth-like processes, as in interparietal suture.

(*b*) *Serrata.* — Having serrated edges, like the teeth of a saw, as in interfrontal suture.

(*c*) *Limbosa.* — Having bevelled margins and dentated processes, as in fronto-parietal suture.

b. *Sutura notha* (false). — Articulate by rough surfaces.

(*a*) *Squamosa.* — Formed by their bevelled margins overlapping each other, as in squamo-parietal suture.

(*b*) *Harmonia.* — Formed by the apposition of contiguous rough surfaces, as in intermaxillary suture.

(2) *Schindylesis.* — Articulation formed by the reception of a thin plate of one bone into a fissure of another, as in articulation of sphenoid with vomer.

(3) *Gomphosis.* — Articulation formed by the insertion of a conical process into a socket, as the teeth.

2. **Amphiarthrosis, or Mixed Articulations.**

(1) Surfaces connected by fibro-cartilage, not separated by synovial membrane, and having limited motion, as in joints between bodies of vertebrae.

(2) Surfaces covered by fibro-cartilage, lined by a partial synovial membrane, as in sacro-iliac and pubic joints.

3. **Diarthrosis, or Movable Joint.**

(1) *Arthrodia, or Gliding Joint.* — Articulation by plane surfaces, which glide upon each other, as in sterno-clavicular joint.

(2) *Enarthrosis, or Ball-and-Socket Joint.* — Articulations by a globular head received into a cup-like cavity, as in hip and shoulder joints.

(3) *Ginglymus, or Hinge Joint.* — Articulation surfaces fitted together so as to permit motion in one plane, as in elbow, ankle, and knee.

(4) *Diarthrosis Rotatorius, or Lateral Ginglymus.* — Articulation by a pivot process, turning within a ring or ring round a pivot, as between upper end of radius and ulna and the atlo-axoid joint.

(5) *Condyloid.* — Ovoid head received into elliptical cavity, as the wrist joint.

(6) *Reciprocal Reception.* — Articular surfaces inversely convex in one direction and concave in the other, as in the metacarpo-phalangeal joint of the thumb.

II. Kinds of Movement admitted in Joints.

1. **Gliding.** — Common to all movable joints; but in some, as in the carpus and tarsus, it is the only motion permitted.

2. **Angular.** — Occurs only in long bones, and by it the angle between the two bones is increased or diminished. It may take place in four directions, — forward and backward, constituting *flexion* and *extension*, or inward and outward, constituting *adduction* and *abduction*. The ginglymoid joints admit of motion in two directions only.

3. **Circumduction.** — Where the extremity of the bone is made to describe a circle, or the whole length of the limb describes a conical space, having the joint as the apex; the shoulder and hip joints are capable of this motion.

4. **Rotation.** — The movement of a bone on its own axis, as in the atlas and axis, and the radius and humerus.

TABLE OF SOME IMPORTANT MUSCLES.

NOTE. — "In the description of a muscle the term *origin* is meant to imply its more [usually] fixed or central attachment, and the term *insertion* the movable point to which the force of the muscle is directed; but the origin is absolutely fixed in only a very small number of muscles, such as those of the face, which are attached by one extremity to the bone, and by the other to the movable integument. In the greater number the muscle can be made to act *from either extremity*." — *Gray's "Anatomy."*

NAME.	ORIGIN.	INSERTION.	ACTION.	SHAPE, ETC.
Occipito-frontalis	Occipital bone	Skin of forehead	Raises the eyebrows and moves scalp	Broad, thin, and tendinous
Orbicularis palpebrarum	Interior angle of frontal bone mainly	Makes complete ring and blends with other muscles	Closes the eyes	Sphincter muscle
Corrugator supercilii	Interior angle of frontal bone	Into the orbicularis palpebrarum	Draws eyebrow down and in. "The frowning muscle"	Pyramidal, small
Temporal	Temporal, parietal, and frontal bones	Lower jaw	Raises lower jaw	Radiating
Masseter	Superior maxillary and malar bones	Lower jaw	Raises lower jaw	Short, thick, quadrilateral
External and internal pterygoid	Sphenoid and palate bones	Lower jaw	Give side motion to lower jaw. "Food-grinders"	Short and thick
Platysma myoides	Clavicle and scapula	Lower jaw	Draws jaw, lip, and corner of mouth down. Expresses melancholy	Very thin and broad
Sterno-cleido-mastoid	Sternum and clavicle	Mastoid process of temporal bone	One turns head to one side. Both together bend head down. Shortening of it produces "wry-neck"	Thick in the middle, flattened at ends
Digastric	Temporal bone, front of mastoid process	Lower jaw at chin	Lowers the jaw and raises hyoid bone in swallowing	Two parts. Tendon in middle, which perforates stylo-hyoid
Stylo-hyoid	Styloid process of temporal bone	Hyoid bone	Raises hyoid bone in swallowing	Slender, perforated by digastric
Pectoralis major	Clavicle, sternum, and costal cartilages	Humerus	Draws arm across chest. The "flying muscle" in birds	Triangular, radiating
Trapezius	Occipital bone and spinal column	Clavicle and scapula	Raises shoulder and draws it back	Triangular, broad
Latissimus dorsi	Dorsal, lumbar, and sacral vertebræ	Humerus	Draws arm back and down	Broad and flat

TABLE OF SOME IMPORTANT MUSCLES. — *Continued.*

NAME.	ORIGIN.	INSERTION.	ACTION.	SHAPE, ETC.
Serratus posticus superior	Cervical and dorsal vertebræ	2d, 3d, 4th, and 5th ribs	Elevates the ribs. An inspiratory muscle	Thin, flat, quadrilateral
Serratus posticus inferior	Dorsal and lumbar vertebræ	9th, 10th, 11th, and 12th ribs	Draws ribs down	Quadrilateral
Erector spinæ	Sacral, lumbar, and dorsal vertebræ	Ribs and cervical vertebræ	Maintains erect position of spinal column	Large mass below, several divisions above
Deltoid	Scapula and clavicle	Humerus	Raises the arm	Thick, triangular
Teres major	Scapula	Humerus	Lowers the arm	Slightly flattened
Subscapularis	Scapula	Humerus	Rotates the arm inward	Triangular
Biceps (of arm)	Scapula	Radius	Bends the arm at elbow	Fusiform
Triceps	Scapula and upper end of humerus	Ulna	Straightens the arm. Antagonist of biceps	Three-parted at upper end
Psoas magnus	Last dorsal and all the lumbar vertebræ	Upper end of the femur	Bends the thigh on the body	Fusiform
Gluteus maximus	Ilium, back part	Upper end of femur	Straightens and rotates the thigh outward	Quadrilateral. One of the largest in the body
Biceps (of leg)	Ischium and femur	Fibula and tibia	Bends the leg at knee	Fusiform
Quadriceps extensor	Ilium and femur	Patella	Straightens the leg. The antagonist of biceps	Four muscles with one tendon at lower end
Gastrocnemius	Lower end of femur	Os calcis	Raises the heel and with it the entire body	"Calf of leg." Its tendon is the "tendon of Achilles"
The diaphragm	Lumbar vertebræ, ribs, and sternum	A flat tendon in the center	Principal agent in breathing	Flat and thin

THE GENERAL EFFECT OF EXERCISE ON THE BODY.

The main effect of exercise is to increase oxidation of carbon and perhaps also of hydrogen. It also eliminates water from the body; and this action continues, as seen from Pettenkofer and Voit's experiments, for some time. After exercise, therefore, the body is poorer in water, especially the blood. It increases the rapidity of circulation everywhere, as well as the pressure on the vessels; and therefore it causes in all organs a more rapid outflow of plasma and absorption, — in other words, a quicker renewal. In this way also it removes the products of their action to the various parts of the body. It increases the outflow of warmth from the body by increasing perspiration. It therefore strengthens all parts. It must be combined with increased supply, both of nitrogen and carbon (the latter possibly in the form of fat), otherwise the absorption of oxygen, the molecular changes in the nitrogenous tissues, and the elimination of carbon will be checked. There must be also an increased supply of salts, certainly of chloride of sodium, probably of potassium phosphate and chloride. There must be proper intervals of rest, or the store of oxygen, and the material in the muscles which is to be metamorphosed during contraction, cannot take place. The integrity and perfect freedom of action, both of the lungs and heart, are essential; otherwise neither absorption of oxygen nor elimination of carbon can go on, nor can the necessary increased supply of blood be given to the acting muscles without injury. — *Parkes's "Practical Hygiene."*

EFFECTS OF OVER-EXERCISE OF THE MUSCLES.

Physiology teaches us that the contraction of the muscle is attended with the production of various chemical substances, such as carbonic acid, lactic acid, urea, creatin, sugar, phosphates, etc. In the normal state these waste matters — the ashes of the fire of life — are easily got rid of by the kidneys, lungs, and other organs, which play the part of dustmen to the economy.

The greater the work done, the larger naturally is the amount of waste matter produced; and, if the work is increased beyond a certain point, the physiological dust-bin becomes full faster than it can be emptied. In that case the waste matters accumulate in the muscles and give rise to the feeling of fatigue; indeed, fatigue can be artificially induced by injecting into the muscles of a perfectly fresh animal an "extract" of the muscles of another that is tired out. In healthy persons a comparatively short period of rest suffices for the removal of the waste matters, and fatigue disappears.

It may be said here that this happy result is much assisted by allowing young athletes a sufficient amount of sleep, as in addition to the repose afforded to the muscles thereby during sleep there is much less formation of poisonous material that causes fatigue than in the waking state. Hence sleep is a particularly favorable condition for the "working off" of the poisons generated during exercise.

If, however, the work to be done is too severe or too prolonged, the elimination of waste matters cannot keep pace with their production, the system becomes saturated with them, and "auto-intoxication" results, the man being in truth poisoned by materials of his own manufacture. The dose may be sufficient to cause death, as in the case, reported by Dr. Bertherand, of two native runners in Algiers, who died immediately after having run respectively 192 kilometers in forty-five hours, and 252 kilometers in sixty-two hours. On examination of the bodies nothing was found beyond the ordinary signs of excessive fatigue (intense blackness of the blood, owing to deficient aeration, great softening and discoloration of the muscles, extravasation of blood in various parts of the skin and mucous membrane with extremely rapid decomposition).

It is now coming to be recognized that many of the cases of so-called "sunstroke" among soldiers on the march are really due to the "auto-intoxication" by waste products which I have described. — *Sir Morell Mackenzie, M.D.*

AMOUNT OF WORK A MAN MAY DO.

The external work which can be done by a man daily has been estimated at one-seventh of the work of the horse; but if the work of a horse is considered to be equal to the one-horse power of a steam-engine (viz., 33,000 lbs. raised one foot high per minute, or 8839 tons raised one foot high in ten hours), this must be an over-estimate, as one-seventh of this would be 1263 tons raised one foot in a day's work of ten hours. In some works on physiology a man's work of eight hours has been put as high as 1020 tons lifted a foot; but this is far too much. The hardest day's work of twelve hours noted by Dr. Parkes was in the case of a workman in a copper rolling mill. He stated that he occasionally raised a weight of 90 lbs. to a height of eighteen inches 12,000 times a day. Supposing this to be correct, he would raise 723 tons one foot high. But this much overpasses the usual amount. The same man's ordinary day's work, which he considered extremely hard, was raising a weight of 124 lbs. sixteen inches, 5000 or 6000 times in a day. Adopting the larger number, this would make his work equivalent to 442.8 tons lifted a foot, and this was a hard day's work for a powerful man. Some of the puddlers in the iron country and the glass-blowers probably worked harder than this, but there are no calculations recorded. From the statement of a pedler, his ordinary day's work was to carry 28 lbs. twenty miles daily. The weight is balanced over the shoulder — 14 lbs. behind and 14 lbs. in front. The work is equal to 419.5 tons lifted one foot. It would, therefore, seem certain that an amount of work equal to 500 tons lifted a foot is an extremely hard day's work, which perhaps few men could continue to do. Four hundred tons lifted a foot is a hard day's work, and 300 tons lifted a foot is an average day's work for a healthy, strong adult.

The external work is thus 300 to 500 tons on an average; the internal work of the heart, muscles of respiration, digestion, etc., has been variously estimated; the estimates for the heart alone vary from 122 to 277 tons lifted a foot. The former is that given by Haughton, who estimates the respiratory movements as about 11 tons lifted a foot in twenty-four hours. Adopting a mean number of 260 tons for all the internal mechanical work, and the external work of a mechanic being 300 to 500 tons, this will amount to one-seventh to one-eighth of all the force obtainable from food. — *Parkes's "Practical Hygiene."*

TURNING OUT THE TOES.

The practice of turning out the toes, so much insisted on by dancing-masters, when it becomes habitual is a deformity. Although in standing in an easy position the whole limb may be rotated outward from the hip, so as to give a broader basis of support, in walking or running the hip, knee, ankle, and joints of the foot are simple hinges, and it is essential for the proper co-ordination of their actions that they should all work in the same plane, which can only be the case when the toes are pointed directly forward and the feet nearly parallel to one another. Any deviation from this position must interfere with the true action of the foot when raising and propelling the body. Turning out the toes is, moreover, a common cause of weak ankles, as it throws the weight of the body chiefly on the inside, instead of distributing it equally over all parts of the joint. — *William Henry Flower, LL.D., F.R.S.*

THE FOOT AND HOW IT SHOULD BE TREATED.

The human foot is an instrument admirably adapted to all the various uses it has to serve, which fashion has done its best to spoil by improper treatment. The bones of the instep are so adjusted as to form an arrangement which combines in exquisite perfection the resistance of the arch with as much elasticity as enables it to bear safely the prodigious strain to which it is subjected. The whole frame of the foot is kept in position and made capable of its proper range of movement by means of muscles and tendons, constituting a living and sensitive bandage, increasing or relaxing its pull or pressure in the most exact obedience to our will. In a sound, free foot each part of the machinery is in constant readiness to bring it into the required position, whether to lift the body, to bound, or to sustain the shock of the whole weight in coming down again, or to perform any other of a number of complications of movement.

How perfectly the foot is adapted for these purposes and is protected against too great pressure and sudden shock is shown by the fact that such violent actions as leaping, or the being burdened by a weight twice or thrice that of the whole body, causes no uneasiness to a sound foot; the injury, if any, resulting from such exertions being usually felt elsewhere. The skin, very thin and delicate on the upper part of the foot, is thick and tough, though soft and pliable, on the sole. Beneath it is a layer of fat, strengthened by strong fibers crossing it and binding it to the muscles and ligaments. The sole can endure great pressure and even violent shocks, but is at the same time curiously sensitive, especially to the touch. It is very easily tickled. This property serves a very important purpose in walking, for the pressure on the ground stimulates the muscles of the foot to their required activity without any effort of the will, and, indeed, without one being conscious of the operation. This spontaneous alertness of the muscles, on which the energy and grace of movement depend, can be secured only by their being kept uncramped, free, and well exercised.

How much the shoemaker's shoes, cramping the foot, jamming the toes upon each other, destroying the shape of the organ, and lifting the heel up so that the weight of the body is thrown upon the toes, prevent this needs no elaboration. The lesson of these observations is that the shoe should give plenty of room all around to the foot, that the sole should be thinnest and narrowest at the "waist," where elasticity is wanted, broad and thick at the tread, where protection is most required, and that no one should be ashamed of the size of his foot. "A well-formed, large one is a far pleasanter sight than the smallest one distorted." — *The Popular Science Monthly.*

RELATIVE STRENGTH OF MEN AND WOMEN.

A French experimenter has tested the strength of 50 robust men and 50 healthy women, all of the middle class of society, and between 25 and 45 years of age. He used an apparatus recording the greatest downward pressure with the palm of the hand. The strongest man was able to give, with the right hand, a pressure equivalent to 187 pounds, and the weakest one of 88 pounds. The short men were nearly as strong as the tall, the average difference being less than 7 pounds. The force exerted by the strongest woman was only 97 pounds, and that by the weakest was but 35 pounds, while the average was 72 pounds. — *Medical Journal.*

THE USE OF LIQUIDS AT MEALS.

Dr. Tev. O. Stratievsky, of St. Petersburg, after elaborate trials, has found that fluids materially assist the assimilation of proteids, and announces the following conclusion, which it is to be hoped no future experiments will controvert: "On the whole, the widely spread custom of taking fluids during or just before one's meals, proves to be rational and fully justified on strict scientific grounds. To take fluids with the meals is almost as important an adjunct to digestion as is the mastication of solid food preparatory to swallowing it. It is obvious, however, that there is a limit to the amount of fluid one can swallow with impunity — not to speak of comfort — just as much with meals as at other times." It would be dangerous to create a general impression that the fluid is good with food irrespective of quantity. It is, moreover, a well-ascertained clinical fact that an excess of cumprandial fluid does not retard digestion in certain people, and gives rise to discomfort in most. A little attention to one's sensations in such matters will far better fix the desirable limit than all the "data" in the world. — *Medical Journal.*

SCIENCE AND ECONOMY IN COOKING.

If the true way were comprehended, the right way made use of, the tougher but equally nutritious pieces of meat would be placed in suitable crockery dishes, these dishes or vessels would be placed in a suitable oven, a small oil lamp lighted at night, and in the morning a nutritious meat stew, soup stock, oatmeal, or salt fish cooked in milk, would be found ready either to be eaten at breakfast with the bread baked over the evening lamp all night; or it would be ready to be warmed over for the noonday meal. If a hot dish were desired without the expenditure of any of the noontide hour for the preparation of the meal, then the tougher portions of the meat would be put into the pan immediately after breakfast, treated with suitable relishes and flavorings, many vegetables placed in other vessels, the lamp lighted and left burning five hours, when the dinner would be found ready to be served; tender, nutritious, and appetizing, without any attention having been required in the interval.

Both the real waste of food and the true waste of time are to be found in the attempt to cook quickly, which almost invariably results in cooking badly. Both the true saving of time and the true saving of food are to be found in learning the right way of preparing the material, then putting it under the right conditions, and there leaving it where the regulated measure of right heat may work upon it a certain number of hours.

This is the art which can be learned from those who have mastered the science of cooking. It can be learned in a single week, perhaps in a day, by those who can read intelligently and comprehend what is printed, with a little practice. — *Edward Atkinson.*

COFFEE: A PHYSICIAN'S VIEW.

I venture the opinion that there is no beverage on earth to-day which, used in moderation, expresses more comfort, contentment, and calmness to the cerebral centers than coffee. But in excess it is undoubtedly most dangerous. . . . The infusion of coffee in proper quantities aids digestion, and is a safe cerebro-spinal stimulant, which is not followed by perceptible reactions. Leibig drew attention first to the fact that this beverage contains the elements which stimulate the flow of bile. It is a decided laxative; a pronounced diuretic. The fact that the coffee belt of the world is also the "bilious belt" and the malarial belt, as well as the field where noxious germs and suppurative processes most abound, is evidence of the fitness of things. No one knows better than the citizens of the hot regions of the world the value of coffee to open up the secretions which have been checked by excessive heat or the malarial influence. They know well, and have known for centuries, that which has recently been receiving much attention by the medical world, particularly in Germany, viz. the *antiseptic qualities* of coffee. — *I. N. Love, M.D., St. Louis.*

HEREDITARY EFFECTS OF ALCOHOL.

Demme studied 10 families of drinkers and 10 families of temperate persons. The direct posterity of the 10 families of drinkers included 57 children. Of these 25 died in the first weeks and months of their life, 6 were idiots, in 5 children a striking backwardness of their longitudinal growth was observed, 5 were affected with epilepsy, 5 with inborn diseases. One boy was taken with chorea and became idiotic. Thus of the 57 children of drinkers only 10, or 17.5 per cent, showed a normal constitution and development. The 10 sober families had 61 children, 5 only dying in the first weeks; 4 were affected with curable diseases of the nervous system; 2 only presented inborn defects. The remaining 50 — 81.9 per cent — were normal in their constitution and development. From this series of investigations we derive the sad truth that among the children of drinkers the prevailing mortality is fearful, that the survivors represent a pitiful crowd, afflicted with unsoundness of mind, idiocy, epilepsy, and other disturbances of their nervous system, and that only a very small proportion of the descendants grow up as useful members of society. — *Herald of Health.*

BLOOD CORPUSCLES.

The blood globules of all warm-blooded quadrupeds, with the exception of the camel family, resemble those of the human species in shape and structure. They differ somewhat in size, being generally smaller than in man. There are but two species in which they are known to be larger than in man; viz. the Indian elephant, in which they are $\frac{1}{2700}$ of an inch, and the two-toothed sloth (*Bradypus didactylus*), in which they are $\frac{1}{2800}$ of an inch in diameter. In the musk deer of Java they are smaller than in any known species, measuring less than $\frac{1}{12000}$ of an inch. According to the best authority, the comparative size of the red globules of blood in the principal mammalian species may be shown in the following list: —

Ape . . .	$\frac{1}{3400}$	of an inch.	Cat . . .	$\frac{1}{4400}$	of an inch.
Horse . .	$\frac{1}{4600}$	"	Fox . . .	$\frac{1}{4100}$	"
Ox . . .	$\frac{1}{4200}$	"	Wolf . .	$\frac{1}{3600}$	"
Sheep . .	$\frac{1}{5300}$	"	Elephant .	$\frac{1}{2700}$	"
Goat . . .	$\frac{1}{6300}$	"	Red Deer .	$\frac{1}{3000}$	"
Dog . . .	$\frac{1}{3500}$	"	Musk Deer	$\frac{1}{12000}$	"

According to the estimate of Vierodt, five millions of red globules are present in every cubic millimeter of healthy human blood. As the red globules or corpuscles are circular, biconcave disks in all mammals, except the camel tribe, so in all birds, reptiles, and amphibia they are either oval or elliptical. — *Popular Science News.*

BLOOD-PLAQUES.

There is a "third corpuscle" in the blood, known variously as "hematoblasts" and by other names, but best by the name given them by Bizzozero, "blood-plates," or "blood-plaques." They are colorless, protoplasmic disks, constant in mammalian blood, measuring 1.5 to 3.5 micromillimeters, and about the ratio of one to eighteen or twenty red ones, as a rule. They are colorless, homogeneous, or finely granular, probably without a nucleus. They are increased in number in a large number of diseases, and bear an important relation to the coagulation of the blood, and especially to the formation of thrombi. — *Gray's "Anatomy."*

CARBON DIOXIDE IN THE AIR.

The amount of carbon dioxide in the expired air may be taken as a gauge or index of its impurity, even though this gas in itself be not injurious, for the more carbon dioxide present, the more poisonous organic exhalations from the lungs. Waller's "Introduction to Human Physiology" says that when the carbon dioxide does not exceed 2 parts in 10,000 the air may be considered "fresh"; when between 2 and 4 parts in 10,000, it begins to feel "close"; between 4 and 6 parts per 10,000, it is "decidedly close"; and between 8 and 10 parts per 10,000, the air is "foul"; and beyond this limit intolerable for any length of time.

THE FINGER NAILS.

There is a common belief that the finger nails are poisonous, which idea is natural enough, considering the fact that scratches made by them are generally quite irritable and much inclined to unusual inflammation. The reasoning is erroneous, however, for, as far as is known, the nails themselves do not have any poisonous properties. The trouble excited by them is due to the foreign deposits under them. In other words, if one keeps his nails clean, scratches caused by them will be no more irritable than those produced by any like instrument that is considered innocent. The results of the examinations made in Vienna show that it is more important that the finger nails be kept clean than is supposed. Seventy-eight were made, and there were found thirty kinds of micrococci, eighteen different bacilli, and three kinds of sarcinæ; besides common mould spores were present in many instances. It would seem from this that the spaces under the finger nails were favorable hiding-places for minute organisms which are more or less prejudicial to health, and that therein lies the poisonous element attributed to nails; furthermore, that cleanliness of the nails is a very important essential. It is not sufficient to use merely a knife blade, but at the toilet a nail brush and plenty of soap and water should be called into service.

Surgeons long ago learned that deposits under the nails were a menace, and that through them wounds were easily poisoned. This led to extreme care in the matter of personal cleanliness on their own part and on the part of all their assistants. Before an operation is performed all who touch the patient or the instruments must first clean their hands thoroughly with soap and water, being especially careful to have the spaces under the nails absolutely clean; then the hands are put into disinfectant solutions. — *Hall's "Journal of Health."*

THE SUDORIPAROUS GLANDS.

Their number varies. They are most numerous on the palm of the hand, presenting, according to Krause, 2800 orifices on a square inch of the integument, and are rather less numerous on the sole of the foot. In both these situations the orifices of the ducts are exceedingly regular, and correspond to the small, transverse grooves which intersect the ridges of papillæ. In other situations they are more irregularly scattered, but in nearly equal numbers, over parts including the same extent of surface. In the neck and back they are least numerous, their number amounting to 417 on the square inch (Krause). Their total number is estimated by the same writer at 2,381,248, and supposing the aperture of each gland to represent a surface of $\frac{1}{56}$ of a line in diameter, he calculates that the whole of these glands would present an evaporating surface of about eight square inches. Each gland consists of a single tube, intricately convoluted, terminating at one end by a blind extremity, and opening at the other end upon the surface of the skin. — *Gray's "Anatomy."*

DISTRIBUTION OF FUNCTIONS IN THE CEREBRUM.

Until recently but little was known of the special functions of special parts of the gray matter of the surface of the brain. Of late years many experiments have been made upon dogs and monkeys, and a great deal of information has been obtained from observations of the actions of human beings with disease in different portions of the brain, so that at present a tolerably accurate knowledge of the localization of functions of the brain has been obtained.

The following quotations from an article by Ambrose L. Ranney, M.D., sum up our present knowledge of the functions of the cerebral cortex, or the shell of gray matter on the surface of the brain: —

In summary we are justified in drawing the following conclusions respecting the cells of the cerebral cortex from the results obtained by experimentation, clinical experience, and pathological data.

1. The **surface of the brain** is the seat of all conscious mental action. It is the receptacle of all impressions made upon the organs of smell, sight, taste, hearing, and the tactile organs of the skin. Here, and only here, do such impressions become transformed into a conscious appreciation of external objects.

2. The **mental powers** are the result of different combinations of memories of past events and the activity of groups of cells that are probably situated in the frontal lobes. Although the integrity of the entire organ is necessary to the unimpeded action of the higher mental faculties (such as judgment,

will, self-control, reason, etc.), the cells of that portion of the frontal lobes that lies in front of the motor centers are perhaps more closely associated with these faculties than those of any other area.

3. The **central convolutions** of the brain (a part of the frontal and parietal lobes of each hemisphere) preside exclusively over motion. The upper part governs the legs chiefly, the middle part controls the upper extremity, while the lower part presides over the complex movements of the tongue and lips necessary to speech. The memories of muscular acts are probably stored within the cells of the motor area.

4. The **occipital lobes** preside over the sense of sight and the memory of sight pictures. The recognition of familiar objects by the eye depends on the activity of the cells of the cortex of these lobes. Hallucinations of vision point strongly toward a disturbance of the function of these cells. An inability to recognize familiar objects, such as faces, letters, words, etc., is one of the prominent symptoms of disease of the occipital region, provided the eyes are capable of performing their normal functions. Colored perceptions of objects and other ocular spectra often accompany irritation of these lobes. If the whole of the occipital lobes be not destroyed, the unimpaired part may slowly accumulate new sight memories, and the sense of vision may thus be slowly regained. This has been proven upon the dog by Professor Munk.

5. That part of the **parietal lobes** which is not occupied by special centers of motion is probably associated with the conscious perceptions of various tactile impressions, and the associated memories of touch, temperature, degrees of pressure, and pain.

6. The **temporal lobes** are the seat of our conscious appreciation of sounds, odors, and taste. When these lobes are diseased, the memory of spoken words may be obliterated, and hallucinations of hearing, or deafness, may be developed. I once encountered an interesting case where hallucinations of smell (imaginary odors) existed in consequence of disease involving the apex of this lobe. Cases of persons who were suddenly deprived of their ability to appreciate a question when spoken, but who would reply promptly to the same question if written before their eyes, have been reported. In such the memories of sound have been obliterated by disease of the temporal lobe, but the memories of the form and meaning of letters have remained intact, because the occipital lobes were not involved. These patients can often be made to repeat mechanically word upon word, in a parrot-like way, but the memory of their meaning has gone forever.

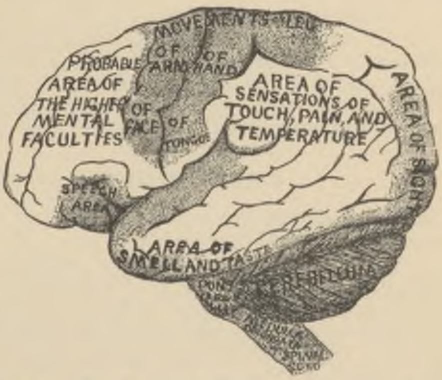


Fig. 32. — Dr. Ranney's Diagram showing Functions of Different Areas of the Cerebral Cortex.

7. The **power of speech** (when regarded as a mere mechanical perform-

ance) seems to be governed by the inferior frontal convolution and the area adjacent to it around the lower part of the fissure of Sylvius. But it must be remembered that our remarks are usually called forth by some form of excitation, such as a spoken question, an impression upon the eye, or some form of irritation of the sensory nerves, as in the case of pain, tickling, etc., for example. Disease of this limited area of the brain's surface causes patients to frequently interpolate wrong words in conversation, in spite of the fact that they grasp the meaning of all that transpires about them and have the memories of past events perfectly at their command. Such a subject could write a reply to any spoken or written question with perfect accuracy, although he might speak it incorrectly. If he were asked to repeat words selected as a test of co-ordinate movements of the tongue and lips he would probably fail to do so with his accustomed facility.

8. That we are endowed with **memories of muscular movements** is well illustrated by a case observed by Professor Charcot of a gentleman who was rendered incapable, by disease of the brain, of recognizing either printed or written language, but who could grasp the meaning of both with ease by tracing out the curves with his fingers. The habit of writing had impressed the mind with the symbols of thought through the agency of the muscles.

9. Some collections of cells within the deeper parts of the brain (the corpus striatum and optic thalamus of each cerebral hemisphere) are probably **distributing centers** for all impulses that pass either to or from the cerebral cortex. They act as middlemen as it were. They are capable of an automatic control over movements; but, as far as we know, there is no reason to think that they are associated in any way with the attribute of consciousness.

10. The functions of the cerebellum, the pons Varolii, and the medulla oblongata are too complex to be discussed here. Their cells are called into action in a reflex manner rather than by volition. There is reason to believe that the cerebellum is an "informing depot" for the cerebrum, and a "storehouse for nerve force." The medulla presides over acts that are chiefly outside of the domain of the will, such as the beating of the heart, the worm-like movement of the intestine, the regulation of the caliber of the blood-vessels to the wants of the different organs, the modifications of blood pressure, and other functions that are essentially vital.

BRAIN WORK AND INSANITY.

Does excessive brain work tend to produce insanity? The best authorities are generally agreed that mental labor of itself does not have this tendency. It is gratifying, however, to have statistical evidence bearing upon the question, and we see that Dr. O. Evart, in the "American Practitioner," gives the results of his large experience. From 1870 to 1876 he admitted into the general insane asylum in Ohio 1204 patients. Of these but 17 had received an academic education. Only 25 professed to be professional men. As we have more than once said in the "News," a man in good health seems to be able to do an almost unlimited amount of mental work, provided it is not attended with anxiety. It is *worry*, not *work*, that generally breaks him down. — *Popular Science News.*

RELATIONS OF MIND AND BODY.

It must be distinctly understood that our mental condition is most extensively influenced by corporeal states. Certain conditions of the nervous centers modify their workings and mould their products, thought amongst the rest. When the nutrition of the brain, and especially those tiny, microscopic cells upon whose activity thought, or at any rate the manifestations of thought, depends, is modified or interfered with by any physical condition, a distinct effect is produced, viz. a condition of mental pain, otherwise unhappiness and depression, is induced. The brain feels as pain intensified sensations from other parts, but it is insensitive to pain itself. The condition which produces neuralgia in the peripheral nerves is mental pain in the cells of the brain itself. When they are well fed and unexhausted, they endow the individual with a sense of well-being, of comfort, and of energy; when ill-fed and exhausted, this condition expresses itself in a feeling of discomfort, of wretchedness, and apprehension. The thoughts are steeped in misery during such periods, and the affairs of life assume a different hue and complexion according as these physical conditions vary. When the brain is well supplied by a powerful circulation, and a rich blood supply from a good digestion furnishes it with an abundance of pabulum, the cares of life are borne with cheerfulness and sustained with equanimity. But when the physical condition becomes affected a total and complete change may be, and commonly is, induced. The change is as great as is that betwixt a bright, sunny May morning with a cheering breeze and the sultry, oppressive electrical condition which ushers in the violence of a black, darkening thunderstorm. Things look very differently in the light of a bright morning to what they appear during the dark gloom of the impending thundercloud. But, after all, the *things* are the same, however much in appearance they may seem altered.—*J. Milner Fothergill, M.D., M.R.C.P.*

THE RATE OF NERVE FORCE.

In the "Nineteenth Century" Dr. J. McK. Cattell gives an account of the time-measurements of thought made by means of the line drawn on a rapidly moving surface by a pen attached to the prong of a tuning fork vibrating at a constant rate, by means of electricity. By a delicate apparatus constructed on this principle, duration of time may be measured to the $\frac{1}{10000}$ of a second. The writer above named has found that the process of thought varies in its degree of rapidity in different individuals, children and old persons thinking slower than people of middle age, ignorant persons thinking more slowly than educated persons. In this way he also found that he could measure the time it takes to perceive, that is, the time which passes from the moment when the impression reaches consciousness until the moment at which we know what it is. In his own case he found that it took $\frac{1}{20}$ second to see white light, $\frac{1}{10}$ second to see a picture, $\frac{1}{8}$ to see a letter, and $\frac{1}{7}$ to see a word. It takes longer to see a rare word than a common word, or a word in a foreign language than in our native tongue. It even takes longer to see some letters than others. "Will time," or time taken up in choosing can be measured. It takes $\frac{1}{13}$ second to judge between blue and red. To recall the name of a printed word takes $\frac{1}{9}$ second, to a letter $\frac{1}{6}$ second, to a picture $\frac{1}{4}$ second. It takes less time to remember the name of a familiar word than of a letter, though it takes less time to see the letter. The time of remembering can be measured. It takes $\frac{1}{4}$ second to translate a word from one language to another when one is familiar with both. It takes $\frac{1}{20}$ second longer to translate a word from a foreign language to one's native tongue than it does in the other direction. We can think of the name of the next month in half the time we can think of the last month. It has been demonstrated that sensation does not travel through the nerves to the brain so fast as has been supposed. Its speed is not much greater than sixty miles an hour. — *Scientific Journal.*

The following, from "General Physiology of Muscles and Nerves, by Rosenthal," bears on the same point: —

Let us suppose that an observer sitting in complete darkness suddenly sees a spark, and thereupon gives a signal. By a suitable apparatus both the time at which the spark really appeared and that at which the signal was given are recorded. The difference between the two can be measured, and it is called the *physiological time* for the sense of sight; the physiological time for the sense of hearing and for that of touch may be determined in the same way. Thus Professor Hirsch, of Neufchâtel, found —

In the case of the sense of sight	0.1974to 0.2083	sec.
" " " " hearing	0.194	"
" " " " touch	0.1733	"

When the impression which was to be recorded was not unexpected, but was known beforehand, the physiological time proved to be much shorter; in the case of the sense of sight it was only from 0.07 to 0.11 of a second. From this it follows that, in the case of excitement, the advent of which is expected, the brain fulfills its work much more quickly.

Certain experiments made by Donders are yet more interesting. A person was instructed to make a signal, sometimes with the right hand, sometimes with the left, according as a gentle irritant applied to the skin was felt in one place or the other. If the place was known the signal succeeded the irritant after an interval of 0.205 of a second, but if the place was not known only after an interval of 0.272 of a second. The psychological act of reflection as to where the irritant occurred, and that of the corresponding choice of the hand, occupied, therefore, a period of 0.067 of a second.

The physiological time in the case of the sense of sight was somewhat dependent on color; white light was always noticed somewhat sooner than red. If the observer knew the color which he was to see he gave the signal sooner than when this was not the case, and he had first to reflect as to what he had seen before he gave the signal. In such experiments the observer always forms a preconception of the color which he expects to see. If the color when it becomes observable corresponds with that which he expected, the reaction in the observer takes place sooner than when this is not the case.

Similar observations were made in the case of the sense of hearing. The recognition of any sound heard follows sooner when it is known beforehand what sound is to be heard than when this is not the case.

Dr. Alexander Bain says: "The example is put by M. Du Bois Raymond of a whale, 90 feet long, struck in the tail by a harpoon; one second would be occupied in transmitting the impression to the brain, a fraction of a second, say $\frac{1}{10}$ in traversing the brain, a full second in returning the motor impulse, so that the boat would have upward of two seconds for escaping the danger." Some one has estimated that if a child had an arm long enough to reach to the sun it would die of old age long before it would know that its fingers were burned.

THE NUMBER OF NERVE CELLS AND FIBERS IN THE BRAIN.

The thin cake of gray substance surrounding the hemispheres of the brain, and extending into its many doublings by the furrowed or convoluted structure, is somewhat difficult to measure. It has been estimated at upwards of 300 square inches, or as nearly equal to a square surface of 18 inches in the side. Its thickness is variable, but, on an average, it may be stated at $\frac{1}{10}$ of an inch. It is the largest accumulation of gray matter in the body. It is made up of several layers of gray substance, divided by layers of white substance. The gray substance is a very nearly compact mass of corpuscles of variable size. The large caudate nerve cells are mingled with very small corpuscles, less than the thousandth of an inch in diameter. Allowing for intervals, we may suppose that a linear row of 500 cells occupies an inch, thus giving a quarter of a million to the square inch for 300 inches. If one half of the thickness of the layer is made up of fibers, the corpuscles, or cells, taken by themselves would be a mass $\frac{1}{30}$ of an inch thick, say 16 cells in depth. Multiplying these numbers together we should reach a total of 1,200,000,000 of cells in the gray covering of the hemispheres. As every cell is united with at least two fibers, often many more, we may multiply this number by 4 for the number of connecting fibers attached to the mass, which gives 4,800,000,000 of fibers. —*Alexander Bain, LL.D.*

THE COLOR SENSE.

We may suppose that all over the surface of the retina nervous terminations are closely packed, belonging to three orders which correspond to three classes of fibers and their connected central organs. Each order of terminations vibrates in sympathy with a system of ether waves possessing a limited though widely varying rate of oscillation only. From the stimulation of those in sympathy with the *slowest* (visible) waves arises the sensation of *red*. From the stimulation of those in sympathy with waves having a *medium rate* of oscillation arises the sensation of *green*. From the stimulation of those in sympathy with the *quickest* (visible) waves arises the sensation of *violet*. *All other sensations of color* are due to combinations of these in different degrees of intensity. Stimulation of all three simultaneously produces the feeling [sensation] of *whiteness*. Stimulation of the red and green produces the sensation called *yellow;* of the green and violet, that called *blue;* of the violet and red, that called *purple*. Hence, the visible shape of any object depends upon the number and position of the points in the retina affected by it; its color depends upon the class of nervous terminations stimulated; and this last point again depends upon the rapidity of the ether waves which infringe upon that particular portion. So that, in the eye as in the ear, differences of sensation are ultimately explicable as due to differences in the several structures involved.— *Grant Allen*, "*Physiological Æsthetics.*"

THE ARBORESCENT FIGURE OF PURKINJE.

One of the most interesting entoptic phenomena is the *Arborescent Figure*, discovered by Purkinje. If, towards evening, we place ourselves opposite a dark wall in a dark room and move a lighted candle to and fro before our eyes, looking, however, fixedly at the wall beyond, we shall then, after a little practice, see this arborescent figure, whose intersecting branches cover the whole of the dark space, and which is unmistakably caused by the blood-vessels in the interior of the eye. The field of vision assumes a reddish appearance, upon which the veins stand out in dark shadows. The trunk of the figure rises a little on one side of the center, where the optic nerve enters the eye, and thence branches out after the manner of blood-vessels, which is undoubtedly a proof that in this experiment we see the blood-vessels of the retina itself. One spot alone is free from vessels: the yellow spot, which is the most sensitive to light of all parts of the retina. If now the candle is moved to and fro, the figure will also move and follow the direction of the light. That these vessels cast a shadow behind them is clear, but that the shadow should be sufficient to cause a perception leads to the very important and interesting fact that the elements of the retina which receive the impression of light must lie behind the blood-vessels. — "*The Five Senses of Man*," *Bernstein.*

HEARING WITHOUT AIR.

There is a well-known children's game, which depends chiefly upon the conveyance of sound to the ear through bone. A metallic spoon is fastened to a string which is wound round the first finger, and the finger pressed firmly into the auditory canal. The spoon is then struck against the edge of the table, and the sound produced resembles that of a large bell, for the vibrations of the spoon are communicated to the labyrinth through the thread, the finger, and the bones of the skull with increased intensity.

The communication of sound through bone is of no value to man under ordinary circumstances, since we do not generally bring the head into close contact with the sounding body. In fishes, however, it plays a very important part, for they possess neither external ear, auditory canal, nor ear-bones, but only a labyrinth, which is entirely closed by walls of bone, or is only covered with membrane on its outer surface. The sound-waves of the water, therefore, are transferred directly to the fluid of the labyrinth through the bone. This is possible because the sound-waves of water, which is well known to be incompressible, are similar to those of a solid body, and do not, like those of the air, consist of expansions and condensations. Sound-waves of the air, on the contrary, are transferred to solid bodies and to liquids with great difficulty; and to effect this ingenious contrivances are required, which are found in their greatest perfection in our ears. Such contrivances are not required by fishes, for they have only to hear in water; indeed, an apparatus filled with air, if placed between the water and the labyrinth of their ear, would considerably diminish their power of hearing. In cases of illness the communication of sound through the bones can be of considerable importance to us. If the apparatus for the communication of sound is diseased, and can no longer perform its duties, in spite of deafness sound can still be communicated by means of bone, which then gives the physician a very important diagnostic sign that the labyrinth and the auditory nerve are in a sound condition. — *Bernstein.*

THE GERM THEORY.

The contagious or infectious principle, unlike all other causes of disease, accumulates after it enters the system. We can account for this accumulation in no other way than that it is a living, growing germ, capable of reproducing itself. A drop of matter taken from the pustule of a small-pox patient and introduced into the body of another produces small-pox. Here, again, are multiplied hundreds of pustules, each of which contains many drops of matter identical with that first introduced. That it has not lost any of its virulence or potency is evidenced by the fact that it will produce the disease in a third person as surely and quickly as the original drop did in the second. From the first drop there has been a prodigious increase in quantity; and thus it has been throughout the ages. No other cause, whether it be animal, mineral, or vegetable in its nature, if not endowed with life and the power of procreation, will perpetuate a disease of unabated intensity through successive individuals. Strychnine given to an animal will produce its characteristic effects, but these effects cannot be maintained by transmission from one animal to another. So it is with the mineral poisons and the non-contagious animal poisons. The experiment has often been made of submitting a fowl to be bitten by a venomous reptile and establishing therefrom a series of inoculations. The fowl bitten speedily succumbs to the virulence of the poison introduced into its system. A second one, inoculated from the blood of this, may die, but less speedily. A third, inoculated from the second, is much less profoundly affected, and so on continually, the poison losing its strength as it becomes diluted by dissemination through different bodies, until it finally becomes practically inert. So it is with all other known substances, except such as consist of living elements.

Every contagious disease has its own special contagium, which differs from that of all others, and which imparts to the disease its distinguishing characters. Thus, the contagium of small-pox differs from that of scarlet fever, cholera, or any other contagious disease, and always produces small-pox. So it is with other contagia; each produces its kind and nothing else.

The ordinary parasites of the body are the grosser representatives of the minute organisms which we call *contagia*. Fleas, lice, and ticks infest the surface of the body; they grow and multiply, pass from individual to individual, and produce their characteristic effects on each. They are contagious. The same may be said of the intestinal worms, and by the aid of the microscope numerous other parasites are revealed. These are too small to be detected by the naked eye, yet none the less certainly the producers of disease.

As familiar examples, we may mention the itch mite, the trichina spiralis, and the filaria medinensis, each of which gives rise to its characteristic disease. Lowly organisms have been found in most of the contagious and infectious diseases; notably in cholera, typhoid fever, diphtheria, small-pox, erysipelas, relapsing fever, and the septic diseases. It can hardly be claimed that for the present the specific contagium for either of the above has been affixed beyond question, though the field is being cleared for subsequent investigations. — *D. Tod Gilliam, M.D.*

LONGEVITY.

Much evidence has accumulated to show that the average duration of human life has been increasing for some years past. Formerly it was set down as 33 years; it is now 35 years. The gain in longevity is greatest among educated men familiar with the laws of hygiene. Among Yale College graduates the records show that, from 1701 to 1745, 32 out of every 100 lived beyond 70; between 1875 and 1885, 40 out of every 100 lived beyond 70. Similar records in England show like results.

We frequently see newspaper accounts of men and women who have lived to the age of 110 and even 120 years. These accounts are set down by physiologists and medical men as pure fictions. Mr. Thoms, who has written a work on longevity, says: "Any evidence that can be produced of any human being having attained the age, not of 130 or 140, but of 110 will be found on examination to be perfectly worthless." Dr. Gardner says:

"The historical evidence up to the present time fails in proof of any person's having reached even 105 years."

"The longevity of stagnant villages and country parsons proves how infinitely *health* outweighs all other means of happiness. The peasants of Southern Russia live almost as frugally as the Hebrew patriarchs, on milk, bread and honey, with a bit of cheese now and then, or a drop of hydromel (half-fermented honey-water); their climate is dry and favorable to outdoor life, and, in spite of official tyranny, war and rumors of war, feudalism, and outrageous over-taxation, they outlive the free-born British yeoman, with his strong ales and daily beefsteaks. But the coincidence of dietetic and administrative abuses cuts the thread of life with a two-edged knife, and in Northern Russia the average duration of life is 10 years less than among the equally intemperate but less misgoverned natives of Northern Germany, and almost 20 years less than in the equally despotic but less poison-cursed territories of the Shah." — *Felix L. Oswald, M.D.*

THE HUMAN FORM.

The Greek sculptors, it is said, used the following rules in making their statues: —

1. From the crown of the head to the nape of the neck is *one-twelfth* of the height.
2. The face from the point on the forehead where the hair begins to the tip of the chin is *one-tenth* of the height.
3. The length of the right foot is *one-sixth* of the height.
4. The distance between the finger tips of each hand when the arms are extended in opposite directions is exactly *equal* to the height.
5. The distance from the wrist to the tip of the middle finger is *one-tenth* of the height.
6. From the place where the hair begins on the forehead to the place of meeting of the eyebrows, from this point to the nostrils, and from the latter to the tip of the chin are *equal* distances.

SEAT OF THE GREATEST GROWTH.

The entire body from birth to adult life increases 3.37 times. The entire leg increases 4.49 times, but the lower end of the femur increases 7.30 times, so we may say that we grow in height mainly by lengthening of the lower end of the femur.

DIFFERENCES IN THE MALE AND FEMALE SKELETON.

All the parts of the female skeleton are lighter and more frail; the general contour is more soft and graceful; the eminences, processes, or tubercles are smaller and less marked. If there is one well-established physiological fact it is this: that the asperities which serve for the insertion of muscles are developed in proportion to the activity of those muscles. Less marked in the studious man than in the laborer, these asperities are still less so in the woman, especially in women residing in towns. This law is so exact that we can tell by the degree of prominence of the crests and processes what muscles the individual was most in the habit of using, and hence judge as to his profession or calling. As a sequence of these prominences, the depressions, grooves, and marks are more distinct in the man. So the temporal ridge, which serves superiorly for the insertion of the temporal muscle, and the transverse ridges, which divide the internal surface of the scapula and serve for the insertion of the subscapularis muscle, are more marked in the male; the groove of torsion of the humerus is more visible, and the two S-like curvatures of the clavicle are stronger.

In the woman, on the contrary, the external protuberance of the occipital and the two subjacent curved lines, which serve for the insertion of the muscles of the nucha; the anterior tubercle of the tibia, to which the triceps femoris is attached; the tuberosity of the radius, which gives insertion to the biceps of the humerus — are less prominent. The curved alveolar borders are more regular, the borders of the malar bone are less thick, the canine fossa is less deep. In a word, it is tolerably easy to determine the sex by the appearance of a bone: in the case of a long bone we are rarely in doubt; in a short bone, as the calcaneum, it is still more possible to do so. But we must not be surprised if we are occasionally at fault. . . . On the skeleton, a woman who had worked hard all her life would have the bony prominences and the processes for the attachment of muscles more developed probably than a man who had not worked at all. . . . The head of the woman is smaller and lighter, its contours more delicate, the surfaces smoother, the ridges and processes not so marked. The superciliary arches are but little prominent; the external half of the superior orbital border is thin and sharp. The forehead is vertical below, projecting above. The occipital condyles are small, as also the styloid and mastoid processes. . . . The inferior maxillary is smaller, its posterior angles having no projecting roughnesses. The frontal sinus is less developed. — *Dr. Paul Topinard.*

COMPRESSION OF THE INTERVERTEBRAL CARTILAGES.

A person is taller in the morning than at night. The reason is that he is pressed down during the day by the weight of the atmosphere, and by the pressure of the upper parts of his body and such burdens as he may carry. These weights press down the cartilages at the joints, and especially those in the spinal column, so that the height of the man is reduced. When the weights are removed and he lies down at night the cartilages act like cushions and gradually return to their original size. M. Robert reports measurements of 287 persons, showing a difference in height between morning and night measurements of 6 to 20 millimeters ($\frac{1}{5}$ to $\frac{4}{5}$ of an inch). This fact is well understood among French conscripts, and M. Paul Topinard reports that some of them, who are just upon or very slightly above the minimum limit as to height, walk about with heavy weights upon their shoulders for several days and during the night immediately preceding the final measurements, in order to reduce their heights. This practice has been so successful that in some extreme cases, according to the same authority, the height of a man has been reduced by it more than an inch. As men advance in age the cartilages do not fully recover during the night from the effects of the day's compression. The result of this is that men are commonly not so tall at an advanced age as in middle life. Extreme cases of this, reported by M. Tenon, are of a man who had lost $1\frac{1}{2}$ inches at the age of 70, and another who had lost $1\frac{9}{16}$ inches at the age of 85. — *Medical Journal.*

ANATOMICAL LANDMARKS.

By this term we mean points on the surface of the body, such as lines, ridges, prominences, furrows, etc., which are guides to the location of important parts that are deeper seated.

1. **Supra-orbital Arch and Notch.** — Commence at the angle of the nose and forehead and pass your finger along the eyebrows, pressing firmly. You feel a sharp ridge of bone. This is the *supra-orbital arch*. In some persons a depression may be felt at the inner side of the middle of this arch. This is the *supra-orbital notch*, through which passes the supra-orbital artery, vein, and nerve. In others, there is a foramen or hole through the bone instead of a notch, and it cannot be felt. The artery may generally be felt pulsating just above the arch. It is a branch of the ophthalmic, which is a branch of the internal carotid artery. The nerve is a branch of the fifth cranial nerve.

2. **The Mastoid Process.** — This is the prominence behind the ear. The cavities in this process probably act as a sounding-board, and increase the resonant properties of the middle ear. The portion of bone between these cells and the brain is sometimes very thin, and inflammation of the mucous membrane lining them may spread to the brain and result seriously.

3. **The Occipital Protuberance.** — The bump which may easily be felt on the back of the head is the occipital protuberance. The skull is very thick at this point, there being an elevation on the inner side of the bone also. It is more prominent in very muscular persons. It gives attachment to the *ligamentum nuchæ*, a strong elastic ligament which unites the spinous processes of the seven cervical vertebræ. "In man it is merely the rudiment of an important elastic ligament which sustains the weight of the head." — *Gray's "Anatomy."*

4. The **Pulley for the Superior Oblique Muscle of the Eye** may be felt by pressing the finger against the frontal bone in the inner and upper part of the orbit of the eye.

5. The **Thyroid and Cricoid Cartilages** are easily felt. As your finger passes down from the point of the thyroid cartilage a slight depression is felt before you reach the cricoid. This is the *crico-thyroid space*. Here there is no cartilage, nothing but the skin and a membrane between the interior of the larynx and the exterior of the body. At this point an incision may be made by the surgeon and a tube inserted in cases of croup or other obstruction of the air passages. The operation is not likely to be dangerous and has often saved lives. The ignorance of many people concerning the anatomy of the body often stands in the way of surgical operations that might be the means of saving life. Many persons regard any operation about the throat as exceedingly dangerous and will not trust the surgeon to make them.

6. **The Subclavian Artery.** — By standing behind a person and pressing with the thumb in the hollow above the clavicle, near the sternum, the pulsation of the subclavian artery may be felt. It can be compressed against the first rib by pushing downward and a little inward. In case of wounds about the shoulders and chest it might some time be of importance to know how to stop the flow of blood in this vessel by pressure of the thumb until surgical assistance could be brought.

7. **Parts behind the First Bone of the Sternum.** — "There is little or no lung behind the first bone of the sternum, the space being occupied by the trachea and large vessels, as follows: —

"The left vena innominata crosses the sternum just below the upper border. Next come the great primary branches of the arch of the aorta. Deeper still is the trachea, dividing into its two bronchi opposite the junction of the first and second bones of the sternum. Deepest of all is the esophagus. About one inch from the upper border of the sternum is the highest part of the aorta, which lies on the bifurcation of the trachea." — *Gray's "Anatomy."*

8. **The Heart.** — "A needle passed through the second intercostal space to the right side of the sternum would pass through the lung, enter the pericardium and the most prominent part of the bulge of the aorta. A needle passed through the *first* intercostal space close to the right side of the sternum would pass through the lung and enter the superior vena cava above the pericardium. The *aortic valves* lie behind the third intercostal space, close to the left side of the sternum. The *pulmonary* valves lie in front of the aortic, behind the junction of the third intercostal cartilage on the left side of the sternum. The *tricuspid* valves lie behind the middle of the sternum, about the level of the fourth costal cartilage. The *mitral* valves (the deepest of all) lie behind the third intercostal space, about one inch to the left of the sternum." — *Gray's "Anatomy."*

9. **Liver and Spleen.** — There are three areas on the abdomen and chest where a tapping with the fingers will give a dull sound. All other places will give a hollow or drum-like sound. First, a small area over the heart; second, a larger area over the spleen; and third, a still larger over the liver. In this way one can locate tolerably well these organs.

10. **The Knee Joint.** — The patella can easily be outlined with the fingers when the limb is extended. It can also be made to slide back and forth beneath the skin in this position of the limb, but when the leg is bent it is fixed by the stretching of the tendons attached above and below it. The enlarged heads (condyles) of the femur may be felt as prominences on either side of the knee joint; also the enlarged portions (tuberosities) of the tibia. The patella lies over the middle of the joint when the knee is bent, thus protecting it when kneeling. When the leg is extended it is drawn above the joint.

11. **The "Hamstrings."** — On either side of the hollow behind the knee (popliteal space) may be felt strong cords beneath the skin. They are popularly known as hamstrings, and are the tendons of the following muscles: The outer hamstring is the tendon of the *biceps* of the leg. The inner hamstring is composed of the tendons of the *semitendonosus*, *semimembranosus*, and *gracilis*.

12. **The Ankle Joint.** — The prominent points on the outer and inner sides of the ankle are the *external malleolus*, or projection of the fibula, and the *internal malleolus*, or projection of the tibia.

13. **The Shoulder Joint.** — The highest prominence of the shoulder is the *acromion process* of the scapula. The prominent ridge, or *spine*, of the scapula can always be distinctly felt.

14. **The Elbow Joint.** — The tip of the elbow is the *olecranon process* of the ulna. The two other bony points which can be felt are the *external* and *internal condyles* of the humerus. In the depression between the olecranon process and the inner condyle lies the *ulnar nerve*. You may press the nerve with the thumb here sufficiently hard to produce a peculiar sensation in the third and little fingers.

DISINFECTANTS AND THEIR USE.

A disinfectant as generally understood is any substance which will destroy or remove bad odors or poisonous gases from the atmosphere. As we propose to use the term it includes all means of destroying and removing injurious gases, liquids, and solids which may in any way injure animal life by contact either through breathing, through food, or by direct contact with the surface of the body.

A convenient classification of disinfectants is here given, with a brief description of the more important ones.

1. **Antiseptics, or Decay-preventers.** — Many substances are powerfully antiseptic, but at the same time are injurious of themselves and cannot be used in every case. Modern physicians regard corrosive sublimate (mercuric chloride) as the best antiseptic. It is a deadly poison if introduced into the system or applied to the surface in any ordinary quantity, but it has the peculiar power of destroying *bacteria* and other germs when used in an extremely diluted form. It can be used externally in solutions so weak that no injurious effect will be produced and yet destroy all germs of disease. We will not attempt to prescribe the form of its use here, but advise all to consult with a physician in regard to its proper use. Says Remington, "It is undoubtedly the most powerful antiseptic available, the only serious disadvantage being the necessity for great care on account of its poisonous properties."

Carbolic acid is also much used as an antiseptic. It should also be used with caution, as it is a powerful poison. *Iodoform* is a substance lately much employed as an antiseptic. It is also a poison when used too freely.

Antiseptics, from their necessary poisonous character, cannot be used to destroy bacteria when the latter have gained access to the blood and tissues, but when properly used externally and upon instruments and appliances which come in contact with the body they are a means of preventing disease which should not be ignored.

2. **Deodorizers, or Smell-destroyers.** — It must be held in mind that all disagreeable odors are not injurious to health, and that many very poisonous gases have no disagreeable odor and that air may be laden with disease germs and have no perceptible indication of it in the way of odor or appearance; yet, as a general rule, wherever there is a foul smell dangerous gases and bacteria-laden atmosphere exist also.

One must distinguish also between smell-destroyers and mere smell-disguisers. Perfumes frequently so disguise the disagreeable odor by their more powerful agreeable smell that one does not recognize the bad odor; yet it still exists, and if dangerous at all is still dangerous.

Water and other liquids, especially milk, are smell-removers to a great extent. They act by absorbing the gaseous substance, and thus take it from the atmosphere; but if exposed to warm air these liquids evaporate and give off the odors again to the air. In the same manner many porous solid substances act, as dry earth, charcoal, chalk, etc. Dry earth can be used to great advantage, as it not only absorbs gases, but liquids, and holds them an indefinite time. Earth thus saturated with gases and liquids that are dangerous can be disinfected by adding chemicals which will neutralize and destroy the dangerous substances.

There are, however, several substances which actually destroy bad-smelling gases by chemically combining with them. The most effectual of these is *chlorine gas*. The best way to use it is in the form of **chloride of lime** (bleaching powder). This, when exposed to the air, slowly gives off chlorine gas. It can be made to give it off rapidly by adding a little acid of any kind. Strong vinegar will answer. Chlorine gas is in itself dangerous when in any considerable quantities. It irritates the mucous membrane when inhaled, and if very strong will cause death. It also destroys most colors, and when strong will corrode clothing, paper, etc. It is best to remove clothing, books, and such like articles from a room which is to be disinfected. Johnston says of chlorine as a disinfectant: "It is probably the most generally efficient for this purpose of any gaseous substance with which we are acquainted. And, besides its efficiency, it is further recommended by being easily and cheaply prepared; by producing its good effects even when so diluted with air as to be breathable without injurious effects. It can thus be used within a building without displacing its inhabitants, and with little inconvenience even in the chambers of delicate invalids. In this diluted state, also, its use is free from almost every other objection. For, though it does corrode metallic substances, its evil effects in this way are much less sensible than those of any of the other gases already mentioned."

Quick-lime is a valuable and cheap disinfectant to be used upon solid or liquid substances and prevent the formation of injurious gases, but it has comparatively little effect on gases already in the atmosphere.

Many an epidemic of disease may be cut short by a thorough and free use of disinfectants. It should be the duty of every one to contribute something toward work of this kind. The student of physiology can use his advice, backed up by his knowledge of the human body and its liability to be affected by impure physical surroundings.

COMPARATIVE ANATOMY.

This is an extensive subject. We can only give here a few points of resemblance and difference in the structure of man and the lower animals. They are mainly condensed from Topinard's "Anthropology."

All mammals have 7 cervical vertebræ, except the sloth, which has 9, and the sea-cow, which has 8. The long neck of the giraffe is due, not to increase in number of vertebræ, but to their individual length. The dorsal vertebræ vary much in number. The bat has 11, the elephant 20. The number of lumbar vertebræ varies little, generally from 4 to 7. The sea-cow, however, has but 1, and the dolphin 18. The ribs vary as the dorsal vertebræ. The divisions of the coccyx vary greatly, this bone corresponding to the bones of the tail in those mammals possessing one. The number of caudal vertebræ, or, in other words, divisions of the coccyx, varies from 2 in the tapir to 60 in the Cape rorqual.

The bones of the head are in the main similar in the lower mammals to those of man. The principal differences being in the shape of the bones, and the consolidation of two or more into one in some cases, and their division by sutures in others. We see similar variations in man; for example, the frontal bone often remains in two pieces through life, and again the nasal bones frequently unite into one.

If a line be drawn on a skull from the opening of the ear to the base of the nose, and another from the most prominent part of the forehead to the most projecting point of the upper jaw, the space between the lines forms an angle which is found to vary considerably in man, and to be much greater than in the highest mammals. There is also apparently a regular gradation from the most intelligent man down through the lower races, and from them through the lower animals, until we reach the fishes, which are the lowest of the backboned animals. The angle in fishes and snakes is very small, in birds a little greater, in the lower mammals still greater, until we reach one species of ape which has an angle of 42 degrees, and another an angle of 50 degrees. Then comes the African with an angle of 70 degrees, while in the European it is 80 degrees or more. The painters and sculptors among the Greeks and Romans represented their highest ideal men and women with faces having an angle of 90 degrees, while their gods they represented with angles of 100 degrees.

The angle made by lines forming axes of the orbits of the eyes varies also greatly in man and lower animals. It varies from 40 to 50 degrees in different men, from 30 to 62 in the monkeys, is 73 in the lemur, and 143 in the rabbit.

The higher apes have the same number of teeth as man, but some monkeys have as many as 38. The number and shape vary greatly in other lower animals. Man is the only creature that can be said properly to have a chin, that is, a projection of the jaw in front of the insertion of the teeth. The foramen magnum in man is in the center of the base of the skull, and the head is poised upon the trunk, a condition not found in any of the lower animals.

The innominata bones in man are broader in proportion to their length in consequence of the upright posture. They come into use to support the abdominal organs.

The thorax is more developed transversely in man, and more so from before backward in quadrupeds.

The clavicles are wanting in many animals as the cow, horse, etc. The sternum is broader in man than in quadrupeds.

Man is the only animal that can "oppose" the thumb to the fingers separately, as in picking up small objects.

The pupil of the eye in man is perfectly circular. In many mammals which are preyed upon by others it is elongated horizontally. In many which seek their prey it is elongated vertically.

All other mammals have a more perfect development of the muscles of the jaw, since the jaws alone are used in dividing the food.

POISONS AND ANTIDOTES.

When convinced that a poison has been swallowed, send for a doctor at once. But in the meantime something may be done which may save the patient's life. If the nature of the poison be known, of course the thing to do is to administer the proper antidote if there be one. But you may not know what the antidote is, or if you do it may not be at hand. In these cases, and also where it is impossible to know what has been swallowed, the proper thing to do is to administer an emetic, that is, something that will incite immediate vomiting. A quick and harmless emetic is a teaspoonful of ground mustard in half a pint of lukewarm water. Salt and warm water, soapsuds, or simply large quantities of lukewarm water will also act as an emetic. In case none of these articles be obtainable, vomiting may often be induced by pushing the finger down the throat.

Some poisons have no special antidote. In such cases any oily or mucilaginous substance should be given, such as oil or grease of any kind, cream, milk, white of egg, flour and water, or starch and water. These substances prevent rapid absorption of the poison by spreading over the mucous coat of the stomach. There is only one kind of poisoning in which oil or grease should not be used, and that is by phosphorus.

Antidotes may be chemical or physiological. A *chemical antidote* acts by forming with the poison a harmless compound; in other words, it neutralizes the poison. A *physiological antidote* acts by producing an opposite physiological effect on the body, thus neutralizing the effect of the poison, and not the poison itself.

In the following list will be found the names, both common and chemical, of most of the common poisons and their recognized antidotes, the names being arranged alphabetically for ready reference: —

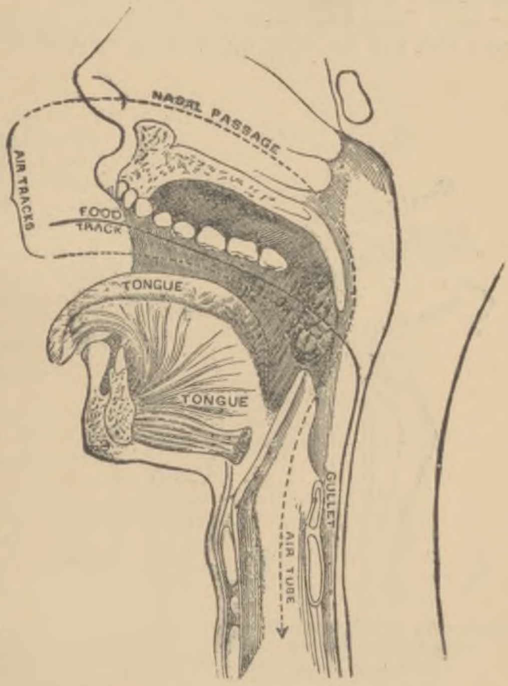
Acetic Acid. — See *Acids.*
Acetate of Lead. — See *Lead.*
Acids. — A class of substances known generally by a sour taste and chemically opposed to alkalies. The common dangerous acids are sulphuric acid (oil of vitriol), nitric acid (aqua fortis), hydrochloric acid (muriatic acid), acetic acid, and oxalic acid. The antidotes are the harmless alkalies, as powdered chalk, magnesia, soap, and lime water. If nothing else be at hand, scrape the plastered wall and mix the scrapings with water and drink the mixture. Cream, milk, and flour and water will help to allay the burning sensation produced in the mouth and throat by the acid. If these acids have been swallowed in an undiluted state in any considerable quantity, it will be impossible to save the life of the patient, as they are intensely corrosive, destroying the mucous membrane almost the instant of contact. Such substances often get by accident on clothes or on the skin. A little aqua ammonia if immediately applied will in great measure neutralize their effects. If this be not at hand, use strong soap, lye, potash, baking soda, or even ashes from the stove will help to neutralize the effect.
Alkalies. — A class of substances known by their acrid or bitter taste, soapy feel, and chemically opposed to acids. The common poisonous alkalies are concentrated lye, potash, sal-soda, and ammonia (hartshorn). Acids are the chemical antidotes, but, as most of the acids themselves are dangerous, only certain ones should be given. Vinegar, lemon juice, sour milk, and sour cider are about the only available harmless antidotes. Use these freely.
Ammonia. — See *Alkalies.*
Antimony. — May have been swallowed in the form of *tartar emetic*, or of *black antimony*. Give plenty of strong tea of oak bark, elm bark, currant or blackberry leaves.
Aqua Fortis. — See *Acids.*
Arsenic. — May have been taken in the form of *Paris green*, or rat poison (white arsenic, "ratsbane"). Iron is its chemical antidote, but no convenient form of it will probably be at hand. Give milk and raw egg, or lime water, or flour and water, until the doctor comes. Give emetics if possible.
Bateman's Drops. — See *Opium.*
Bed-bug Poison. — See *Mercury.*
Blue-mass or Blue-pill. — See *Mercury.*
Calomel. — See *Mercury.*
Carbolic Acid and Creosote. — Differing from the common acids. Give sweet oil, or castor oil and a mixture of lime, sugar, and water.
Chloral. — See *Chloroform.*
Chloride of Zinc. — See *Zinc.*
Chloroform, Ether, and Chloral. — The first two are generally inhaled. Dash cold water in the face. Suspend patient by the legs for a few moments; practice artificial respiration, as for drowned persons.
Concentrated Lye. — See *Alkalies.*
Copper. — May have been taken in the form of *blue vitriol (blue-stone)*, *verdigris*, food cooked in copper vessels, "greened pickles." Give milk and white of eggs, and strong tea. Do not give acids.
Copperas. — See *Iron.*
Creosote. — See *Carbolic Acid.*
Cyanide of Potassium. — See *Prussic Acid.*
Dog Button. — See *Strychnia.*
Green Vitriol. — See *Iron.*
Greened Pickles. — See *Copper.*
Hartshorn. — See *Alkalies.*
Hydrochloric Acid. — See *Acids.*
Iodine. — Give large quantities of starch and water, or flour and water.
Iron. — May have been taken in the form of *sulphate of iron* (*copperas*, or *green vitriol*). Give magnesia, or baking soda and water.
Laudanum. — See *Opium.*

Lead. — In the forms of *acetate of lead* (*sugar of lead*), *white lead* or *white paint*, *red lead* or *red paint*. Give Epsom salts, 2 ounces in a pint of water, a wineglassful every ten minutes, until several doses have been taken. Painters and others who work with these substances are often slowly poisoned, causing what is called "lead colic," attended with loss of power in the limbs, noticeable in the wrists. Consult a physician.
Lunar Caustic. — See *Silver*.
Lye. — See *Alkalies*.
Matches. — Children sometimes eat lucifer matches. See *Phosphorus*.
Mercury. — In the form of *calomel*, *corrosive sublimate*, or *bed-bug poison*, *red precipitate*, *vermilion*, *blue-mass*, or *blue-pill*. Give white of eggs freely, or flour and water, or milk, or linseed oil.
Morphine. — See *Opium*.
Muriatic Acid. — See *Acids*.
Nitrate of Silver. — See *Silver*.
Nitric Acid. — See *Acids*.
Opium. — In the form of *laudanum* or *tincture of opium*, *paregoric*, *Bateman's drops*, *soothing sirups*, *poppy seeds*, *morphine*. Give plenty of strong coffee, which is a physiological antidote; put mustard plasters on the calves of the legs; keep patient roused by dashing cold water in the face and beating the soles of the feet.
Oxalic Acid. — Is a solid and resembles Epsom salts, for which it may be mistaken. See *Acids*.
Oxide of Zinc. — See *Zinc*.
Paregoric. — See *Opium*.
Paris Green. — See *Arsenic*.
Phosphorus. — In the form of *matches* and *rat poison*. Give magnesia, chalk, or whiting with warm water. Give oil or fat of any kind.
Poppy Seeds. — See *Opium*.
Potash. — See *Alkalies*.
Prussic Acid and Cyanide of Potassium. — Very powerful poisons. Little hope of saving the patient. Give a teaspoonful of hartshorn in a pint of water. Dash water in face.
Rat Poison. — See *Phosphorus* and *Strychnia*.
Ratsbane. — See *Arsenic*.
Red Lead. — See *Lead*.
Red Precipitate. — See *Mercury*.
Sal-soda or Washing Soda. — See *Alkalies*.
Saltpeter. — Give flour and water or linseed oil.
Soothing Sirups. — See *Opium*.
Silver. — In the form of *nitrate of silver* or *lunar caustic*. Give salt and water freely, then castor oil and flaxseed tea.
Strychnia. — In the form of *rat poison*, *nux vomica*, or *dog button*, or *strychnia*. Convulsions are produced and the body bent backward. Give flaxseed tea. Keep quiet and darken the room. Give belladonna or opium under medical advice.
Sugar of Lead. — See *Lead*.
Sulphate of Iron. — See *Iron*.
Sulphate of Copper. — See *Copper*.
Sulphate of Zinc. — See *Zinc*.
Sulphuric Acid. — See *Acids*. Give very little water, as great heat is produced when water and sulphuric acid come together.
Tartar Emetic. — See *Antimony*.
Verdigris. — See *Copper*.
Vermilion. — See *Mercury*.
Vitriol, Blue. — See *Copper*.
Vitriol, Green. — See *Iron*.
Vitriol, Oil of. — (Same as sulphuric acid.) See *Acids*.
Vitriol, White. — See *Zinc*.
White Lead or White Paint. — See *Lead*.
Zinc. — In the form of *chloride of zinc*, *white vitriol*, or *sulphate of zinc*, or *oxide of zinc*. Give milk, or magnesia, or chalk and raw eggs.
All poisons should be plainly labeled and kept out of the reach of children.

ANATOMY AND PHYSIOLOGY OF THE VOCAL ORGANS.

The following is a modified extract from a lecture by Dr. Edward B. Gray of Oxford, England, before the London district of the National Phonographic Society, December 16, 1891: —

I will deal first with the general anatomy of the vocal organs, and trust that by the help of these diagrams I may be able to present to you an intelligible outline of it. Allow me to draw attention first to this diagram representing a longitudinal section down through the middle of a man's head and neck, from the under surface of the skull to the top of the windpipe, the section passing a trifle to the left of the central division of the nostrils. The part marked "nasal passage" is the irregular cavity of the left nostril. The pharynx is the expanded portion at the top of the gullet. The cavity of the mouth is separated from that of the nostrils by a vaulted partition called the palate. These several cavities here represented will henceforth be spoken of as the nasal, oral, and pharyngeal cavities.

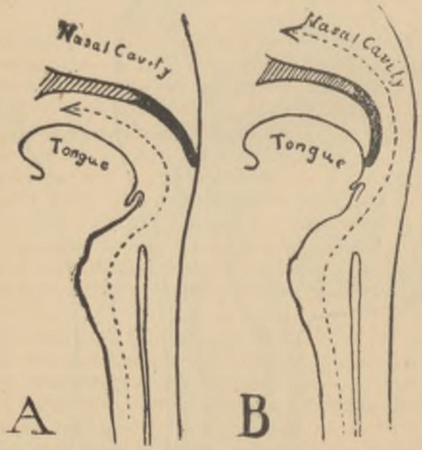


About the palate I must pause to say a few words. The word "palate" in ordinary parlance is rather vaguely used. When a man says his palate is out of order, he means the surface of his tongue, and inside of his mouth generally. But remember that in medical parlance the word has always a restricted meaning, being used *only* of this vaulted partition between the nasal cavity above and the oral cavity below.

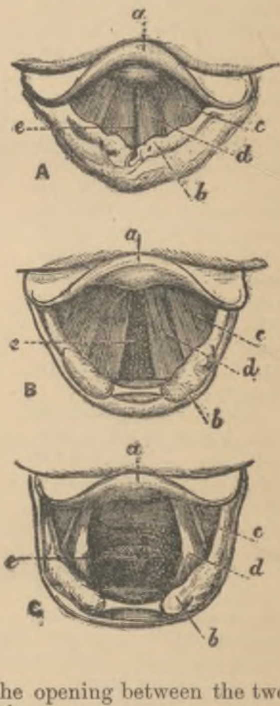
This partition is not of the same substance throughout. Its anterior two-thirds, called the hard palate, is firmly fixed solid bone; its posterior one-third, called the soft palate, has no bone in it; it is a soft, fleshy swinging curtain, with its free edge downwards, and the uvula, like a small, short tassel, dangling from its middle. You see it here in section. A full front view of it can always be had by looking at the back of your own mouth in the looking-glass.

This soft palate has a great deal to do with speech. Its real use is that of a self-acting valve; and according as it is drawn back against the wall of the pharynx behind, or forward against this part of the tongue in front, so will the outgoing current of air from the lungs escape by two very different channels — in the one case by the mouth, in the other by the nose, of course with corresponding modification of sound.

We must now leave the nose, mouth, and pharynx for a moment, and carry our eyes downwards to the lower part of the first diagram, namely, the air tube or larynx. As with the term palate, so the term throat in ordinary parlance is employed in a very ill-defined sort of way. A layman almost always means by throat the top of his gullet, that is the region between and behind the two tonsils. But in medical language, whenever we talk of the throat as an organ of speech, we mean, not this part, but the larynx or voice box. This is simply an expansion of the upper end of the windpipe, and, like the windpipe, made of cartilage or gristle. It opens behind



Diagrams to illustrate the play of the soft palate (shaded black) in determining the direction of the outgoing air stream.



into the upper part of the pharynx or gullet, the opening between the two being guarded by a flap-valve, called the epiglottis.

Food, when swallowed, pushes this flap down before it, and the flap effectually prevents any of the food entering the larynx. When food goes the wrong way, as the saying is, what happens is this: The perfect closure of this valve has been somehow prevented, and some of the food has slipped into the sensitive larynx, which immediately makes violent and spasmodic efforts to expel the intruder. Inside this voice box are the so-called vocal cords. Imagine yourselves to be looking down into the larynx from above, and you will see the cords stretching across the cavity like a pair of broad, thin, white parallel india-rubber bands. By a special and most elaborate machinery of fine muscles these cords can be rendered more or less slack or tense, or brought more or less near together, or separated more or less widely apart. This play of the vocal cords is represented in the annexed diagrams, and can be actually seen and studied by placing a little mirror called a laryngoscope at the back of the throat, throwing a strong light upon it, and then getting the patient to sing a few notes.

So much for a rough outline of the anatomy of the parts concerned in the production of speech. I must now try to make clear to you the function of these several parts, and show how they co-operate in the production of speech.

To understand this you must first remember that all articulate sound depends primarily on respiration. The several modulations of voice which constitute speech depend upon the play of the various structures just described on the outgoing stream of air. The lungs do for our vocal machinery just what the bellows does for the church organ. The importance of respiration as a factor in speech comes out strikingly, when, instead of being calm and even, the expiratory act is hurried, jerky, and spasmodic. We then have one of the commonest forms of stammering.

The *first* factor, then, in the production of speech is the act of expiration, giving rise to an outgoing stream of air from the lungs. The *second* factor is the partial or complete stoppage of that air stream by the interposition of a series of barriers in the oral and laryngeal cavities. The *third* factor is the direction of that air stream into the oral or nasal cavity through the valvular action of the soft palate.

A *fourth* and most important factor is the action of the brain, for before a man can utter a single articulate sound the brain has to settle what that sound shall be and to put in motion the machinery necessary to produce it. Note, therefore, what a very complex matter speech is; for the utterance of each sound involves the exercise of (1) cerebration, (2) respiration, (3) phonation and articulation, and not only the exercise of each of these highly complex functions, but also their harmonious co-operation.

In pronouncing the several elementary sounds of the English language, if you watch closely you will note the fact that, while in the articulation of some the outgoing air stream is momentarily blocked, in the articulation of others it is merely narrowed. In the utterance of the following four pairs of consonants, *p*, *b*; *t*, *d*; *ch*, *j*; *k*, *g*, there is momentary complete arrest, then sudden liberation of the air stream at different points in its passage through the mouth. Hence these four pairs of consonants are called **explodents**.

Observe that the order from before backwards in which the several barriers to the air stream are placed, determines the order in which these consonants stand in the Phonetic Alphabet. Thus, when the explosion takes place between the lips, *p* and *b* are formed. When it takes place at the teeth, or (to speak more accurately) between the tip of the tongue and the gums behind the upper front teeth, *t* and *d* are formed. When the explosion takes place yet further back, between the tip of the tongue and the fore part of the roof of the mouth, *ch* and *j* are formed. Lastly, when it takes place between the root of the tongue and the back part of the roof of the mouth, *k* and *g* are formed. The vocal articulation of each of these pairs of consonants is the same, the second letter in each pair being merely the first letter heavily sounded, or voiced.

Then there are four other pairs of consonants, *f*, *v*; *th*, *th*; *s*, *z*; *sh*, *zh*. The difference between these and explodents is simply this, that whereas explodents are produced by forcing the air stream in a sudden gust through openings momentarily *closed*, these are produced by forcing the air in a slowed, continuous stream through similar (but slightly modified) openings merely *narrowed*. Hence they are called **continuants**. They stand in the order in which they are placed, because this is the order of the successive barriers formed in the mouth from before backwards, at which the outgoing air stream becomes narrowed. Like explodents, the continuants go in pairs, and for the same reason.

In the utterance of these eight pairs of consonants, none of the outgoing air stream has made its way out through the nose, that little valve, the soft palate, having shut off the nasal cavity so as to direct the whole air stream through the mouth.

But there are three other consonants, viz. *m*, *n*, *ing*, in which this arrangement is reversed. These three consonants are sounded by the momentary closure in succession (1) of the lips, (2) of the fore part of the tongue against the fore part of the palate, (3) of the back part of the tongue against the back part of the palate. Now it is most important to observe that these three barriers are precisely those which are used for articulating the three explodents *b*, *d*, *g*, and the reason of the difference in the resulting sounds is this, that in the one case the communication between the nasal cavity and the mouth is left open, and in the other case it is closed by the valvular action of the soft palate. In sounding **nasals** the outgoing air stream simply *impinges against* these barriers and escapes into the nasal cavity. In sounding explodents the same air stream *bursts* these barriers, because the closure of the nose by the soft palate leaves the air stream no other mode of escape. Hence it is that in case of nasal obstructions (as in a very heavy "cold in the head") our attempted nasals become explodents, *i.e.* *m*, *n*, *ing* become *b*, *d*, *g*.

A good illustration of this fact, that is, the fact that in nasal obstruction attempted nasals become explodents, occurs in "Oliver Twist." The wide-awake doorkeeper of old Fagin's den at the "Three Cripples" was a certain youth named Barney. For some reason or other not determined by Dickens, Barney was never able to breathe through his nose. When Noah Claypole first knocks at the door of the "Three Cripples" Barney says "Cub id," and in answer to Noah's inquiry, "Is this the 'Three Cripples?'" he informs him "That is the dabe of this 'ouse." Again, when Toby Crackitt, spying Oliver in the Jew's den, asks Barney who he is, Barney says, "Wud of Bister Fagid's boys." Barney always spoke of Fagin as "Bister Fagid," and Nancy as "Biss Dadsy."

So much for the articulation of explodents, continuants, and nasals.

The only consonants now remaining are the **liquids**, *l* and *r*, and aspirate *h*. *L* and *r* are sounded by forcing the outgoing air stream between the tip of the tongue and the roof of the mouth. In point of articulation, therefore, *l* and *r* are voiced continuants; but, like the nasals, not having in our language corresponding breath consonants to pair with them, they form a special group. They are called liquids from the ease with which in pronunciation they follow other consonants, and, as it were, melt with them into combinations such as the *pl* and *pr* series.

The only other remaining consonant is the aspirate *h*. This calls for no remark; its production being, as its name indicates, a mere sigh, or expiratory effort. So much for consonants.

Now, following our plan of proceeding from before backwards and downwards, we come to the last barrier in the way of the expired air, and that is the vocal cords. It is the rush of the air stream through the varying width of the chink between the cords — in sufficient force to make them vibrate —

which primarily gives rise to the simple long vowels — *ah*, *eh*, *ee*, *aw*, *oh*, *oo*, and their corresponding short sounds — *ă*, *ĕ*, *ĭ*, *ŏ*, *ŭ*, *ŏŏ*.

Now, observe that in the mechanism of their production vowels are by no means as simple as they may at first appear. Books will tell you summarily that vowels are formed in the larynx and consonants in the mouth. This is by no means a correct representation of the case. It is true that vowels are primarily formed at the vocal cords in the larynx, but they are, one and all, more or less modified by simultaneous adaptations of the aperture of the lips and the position of the tongue. In the sounding of each vowel both these agencies are at work, but in unequal degrees, *ah*, *eh*, *ee* depending mainly on the position of the tongue as regards the palate, while *aw*, *oh*, *oo* depend mainly on the regulation of the aperture of the mouth by the lips. In *ah*, *eh*, *ee*, there is gradual *protrusion* and *elevation;* in *aw*, *oh*, *oo* gradual *retraction* and *depression* of tongue. On this natural law is based Mr. Pitman's classification of simple vowels into palatal and labial, each series commencing with the most open and ending with the most closed sound.

The main principle of this classification is unassailable, but I venture to think that the palatal group would be more appropriately named lingual, for this simple reason, that in the oral modification of *ah*, *eh*, *ee* the tongue does all the work, while the palate remains passive. If the one group of vowels is called labial because the lips play the chief part in their production, the other group for similar reason should be called lingual.