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Elementary Physiology

HYGIENE

ALCOHOL

NARCOTICS

DUNGLISON

MUSCLES.

AN

Elementary Physiology

WITH SPECIAL REFERENCE TO

Hygiene, Alcohol and Narcotics

BY

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ELE'NT'Y PHYS.

PREFACE.

THE importance of instilling into the youthful mind, in its very earliest search after knowledge, a wholesome sense of the terrible consequences of any form of indulgence in the use of alcohol, tobacco, and narcotics seems to be universally appreciated at the present day.

The child, when once taught the formation of its own body, and how necessary it is to observe all the laws of health, cannot fail to regard the use of these poisons, and the vicious habits resulting from them, as fertile sources of disease, and will be able to convince its parents and friends, by its knowledge of Physiology, of the folly and wickedness of indulgence in such intoxicating agents. By their injurious influences these undermine the mental and physical health of individuals and communities, and lead by paths of crime and suffering to lives of poverty and wretchedness.

The author has endeavored in these pages to present as full a statement as is possible in an elementary work of all the main facts in Physiology which may interest and instruct the young, and at the same time, interwoven with each subject, to make prominent mention of the action of alcohol, tobacco, and narcotics generally, believing that the study of Physiology will be prosecuted with increased vigor when taught from the standpoint of temperance and morality. The physiological facts and the general laws of hygiene, or the preservation of health, herein offered, will, it is hoped, lead naturally and instinctively to a just appreciation of such violations of the laws of health as are caused by the use of alcohol and other narcotics. The author believes that the correct method of teaching these subjects is by simultaneous instruction in the great principles of Physiology, Hygiene, and Temperance.

As the author has made it a rule to explain and divide for proper pronunciation all the technical terms as they occur in the text, it has not been deemed necessary to add a glossary at the end of the work.

RICHARD J. DUNGLISON.

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PHYSIOLOGY AND HYGIENE.

Physiology.—When we look at the world around us, we see that it is made up of bodies of various kinds, some of which have life and grow from day to day and from year to year, and then die, and others which have no life or movement, such as the stones in the street or the bricks of the houses. Those which have life, such as the people, the trees and plants, are called animals or vegetables. When we study physiology, we do not concern ourselves with the lifeless things around us or with living vegetables or plants, but we study the life of animals only. Man is the most perfect animal of all; and when we study his physiology we do so that we may learn how he breathes, how the blood passes through his body to keep him in good health, and what he must eat to give him strength and prolong life; and we must also learn something about his brain, and how it is that he can move about from place to place at his own will. We must also study his eye and his ear, and try to learn in what way they are formed so that he can see and hear so well.

The word *Physiol′ogy* means a study of nature, or of the living things around us. *Vegetable Physiology* is a study of the life of plants only.

In that kind of ancient story, which is sometimes called mythology, there were said to be gods and goddesses whose business it was to look after the good and bad things of this world. Health, one of the best of Nature's gifts, was said to be presided over by the Goddess of Health, and the name *Hyge'ia* was given to her, from a Greek word meaning health. So when writers or others now speak of the rules for preserving health they give the name *Hy'giene* to this subject.

There cannot be any higher study of nature than that which we have of our own bodies, for we can there see how wonderful a work of creation we are, and how all our organs act together to keep us alive and in good health. We can learn much about ourselves by merely examining our bodies; we can feel our hearts beat, can study our own breathing, know that our joints are movable, and learn what hunger and appetite are, and so be able to understand much that is taught us in the study of physiology. If we understand all this, we will soon learn that we should take the best of care of our bodies, so that we may enjoy good health and avoid all such things as will cause sickness.

Some writers speak of the human body as a machine, and they describe it just as they would a clock or a steam-engine, telling what each part is used for and how it is made, and how all the different parts of the machine work together. This is the best way of studying our own bodies, and of learning the uses of all the different parts, which are so closely connected that if anything should get out of order in one portion of the body all the other portions may suffer also.

Animals and Vegetables.—Before studying physiology it would be well to notice in what way the bodies which have life, such as animals and vegetables, differ from one another. They are all made up of parts, or organs, as they have been called. An animal has, for example, eyes, ears, and stomach, which are its organs; while a plant or a tree has leaves, flowers, bark, etc., which are the organs of the plant. A bird has wings, which are its organs with which to fly. Each of these organs, in the plant as well as in the animal, has certain work to do to help keep it alive and to enable it to grow. If any of these organs be injured, the animal or the plant may droop and die. A mineral, having no organs, cannot have life, and cannot grow, as animals or plants do. A child may grow to be a man, and a seed, planted in the ground, may become a large bush or a tree, but a stone will never get to be of larger size, except by the addition of other things to it, such as particles of dust or dirt. The parts of a living body differ from one another: the leaves are not like the flower; the bones are not like the flesh; but any part of a stone is like any other part.

When we speak of animals, we of course include man, and all the beasts, birds, fishes, insects, or reptiles which we see or read about. It is not necessary that we should know the physiology of all these animals before we can understand that of man, but it is well for us to learn how they breathe and move and live, and then we can know how much God has done for man in placing him so high above all the other animals and in giving him such perfect organs for carrying on life.

Anatomy.—When we study physiology, we study the uses of the different organs of the body, but we must also understand their form and what they are made of, as well as their uses; and we have therefore to learn something of their *Anat'omy,* as it is called, for anatomy is that branch of study which describes the appearance and structure of the different parts of the body. When we say that the teeth are so many in number, and that they are arranged in the mouth in a certain way, and that the jaw has spaces in it in which the teeth fit, we are speaking of the anatomy of the teeth; but when we say that our teeth are used to break up the food after it is placed in the mouth, and that some of the teeth crush it while other teeth cut it, we speak of the physiology of the teeth.

Animals have the power of moving from place to place of their own will. Vegetables or plants have not this power, for they are fixed to the earth, and must get their food from the ground and from the moisture contained in it. A vegetable cannot feel, and has no brain to guide its movements as an animal has. Some of the lowest animals have very little sense or feeling or power to move about.

Divisions of the Human Body.—When we look at a child or a man, we see that the body of each can be divided into four parts—a head, a body or trunk, upper extremities, and lower extremities. The whole body is covered with a very delicate organ called the *Skin,* which protects it from injury, and with the fat beneath it serves as a cushion for the parts which it covers. If we notice any other animals, such as the cat or dog, we will see that they are covered with fur or hair, which have the same wise purpose. Birds have feathers to protect them from the air or from cold; the elephant has a thick hide; the tortoise and oyster have hard shells; fish have scales,—all with the object of keeping their other organs from being injured. So also we find in man such a protection as nails at the ends of the fingers, and hair on the head. If such was not the case, the ends of the fingers would be too tender for the different uses to which they are put in touching and handling objects, and if the head were not covered by a thick growth of hair, it would be exposed to the full force of blows or to the effect of the cold air or of the hot sun.

The *Head* is composed of a front part called the *Face,* and a back part called the *Skull.* In the face are the eyes, nose, and mouth, the cheeks, chin, and forehead. The *Skull* is usually covered with hair. It is a collection of eight bones of various sizes, fitted tightly together, so as to form a cavity in which is placed the brain (Fig. 1). The *Face* is made up of fourteen separate bones united together and firmly fastened to the skull, which is behind it. The lower jaw is the only one of the bones of the face that is movable, and this is made so in order that the mouth may be opened and closed. The bones of the face are hollowed out in some parts and made to stand out in other places, so as to form sockets for the eyes, the bridge of the nose, and other points which give shape to the face.

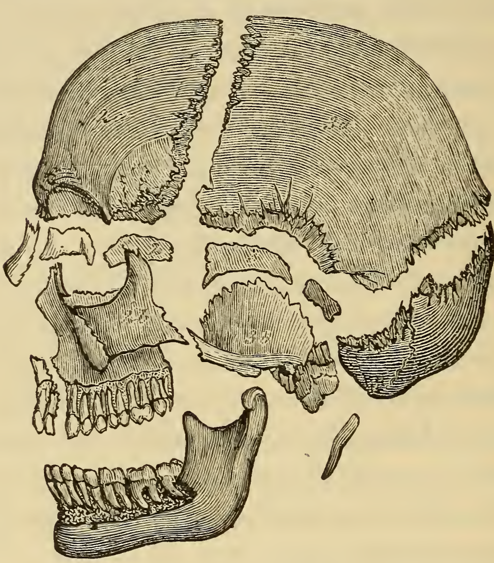

FIG. 1.—BONES OF THE SKULL, SEPARATED FROM ONE ANOTHER.

The *Body* or *Trunk* is divided into the neck, chest, and abdo′men, which most persons wrongly call the stomach. The *Upper Extremities* include the shoulders, arms, hands, and fingers. The *Lower Extremities* include the thighs, legs, feet, and toes. We shall learn the uses of these parts when we come to study the physiology and uses of all these organs.

The Skeleton.—When we study the human body to see of what organs it is made up, we find a great variety, and these are so placed inside the body that they are not likely to be injured. The framework of the body is called the *Skeleton* (Fig. 2), and it is made up of more

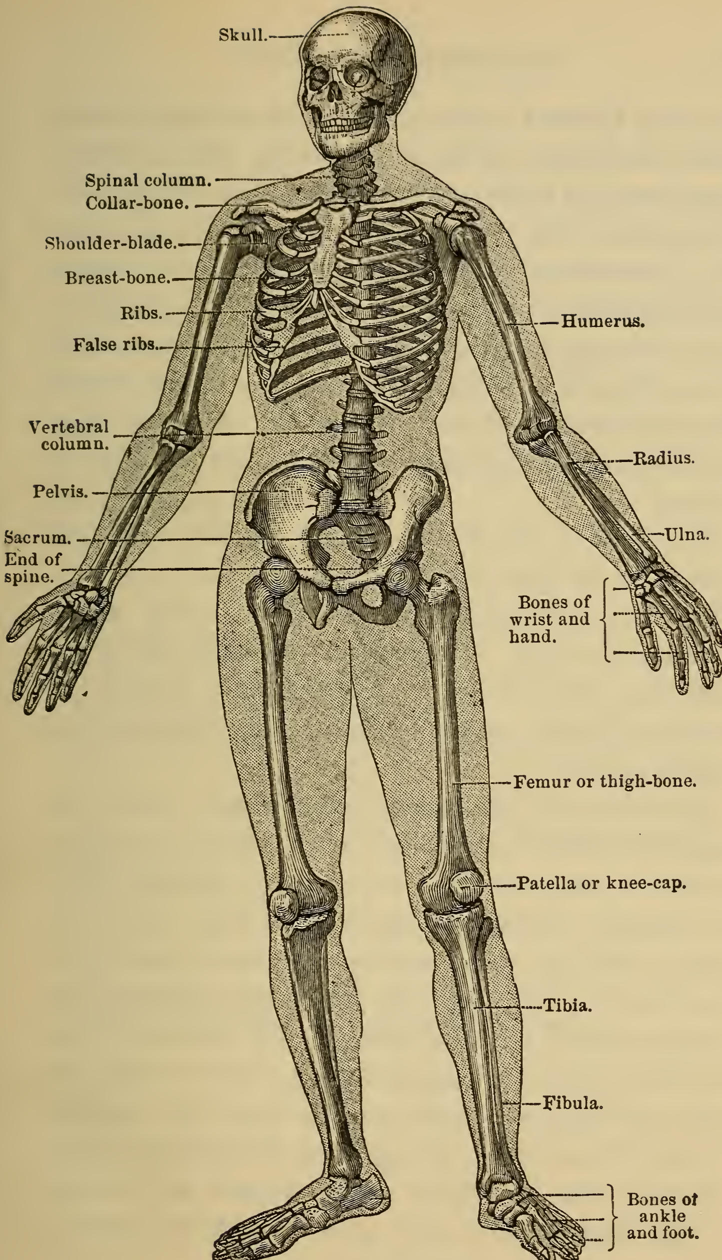

FIG. 2.—THE SKELETON.

than two hundred bones. These are so arranged as to allow of all parts of the body moving easily, and the bones also give a firm and hard base for the various portions of the body to rest upon. It will be seen from Fig. 2 that these bones are of a great variety of shape and size, and the reader will be able to feel many of them on his own person directly under the skin, as in the skull and at the elbow, hands, knee, etc. The names of the largest of these bones are given in the figure, but it is not necessary for the youngest readers to commit them to memory.

The skeleton has the skull at the top, and connected with it is the spine, or spinal column, which is a long row of bones, the sharp points of many of which can be felt along the back. The bones of the upper and lower extremities (Fig. 2) are of different sizes, and are so arranged that the various portions of the limbs can be readily moved.

The bones are all covered with *Muscles,* which are masses of fleshy matter, the use of which is to give motion to the parts which they cover or to which they are fastened. The bones and muscles form cavities or spaces, which are closed and air-tight, and in these cavities the heart and lungs and other organs intended for purposes of life are packed away. The bones and muscles of the chest, for instance, form a cavity in which the heart and lungs are placed, and the bones and muscles of the abdomen are so arranged that a large space is left, which is filled up chiefly by the stomach and bowels. In the chest—one of these great cavities or spaces—

breathing is mainly effected and the blood is sent out from the heart. In the cavity of the abdomen the food is acted upon and absorbed in the stomach and intestines. In the cavity of the skull the brain is stored away, and with it the organs of sight, smell, taste, and hearing.

Besides the bones and muscles and other organs just referred to, there are *Blood-vessels*, which carry the blood from one part of the body to another, and many small cords called *Nerves*, which pass like telegraph-wires all through the body, so that every part seems to know what is going on in other parts.

QUESTIONS.

What kind of bodies do we see around us?

What do we learn from the study of Physiology?

What does the word Physiology mean?

How do animals and vegetables differ from one another?

What do we learn from Anatomy?

Into how many parts do we divide the body?

What is the covering of the body called? What are its uses?

What is the skull?

How is the face made up?

What is the skeleton? How many bones has it?

What are the muscles?

What organs are in the chest? In the abdomen?

What are the uses of the blood-vessels and nerves?

THE BONES AND JOINTS.

The shape of the body depends upon the bones, which we have already seen, serve to protect the other important organs from injury. As already stated, the brain is protected by the skull, and the heart and lungs by the walls of the chest. In the interior of the bones of the spinal column (Fig. 5) is a delicate part of the nervous system, called the spinal cord, which has much to do with the sense of feeling and motion of the body and of the lower extremities.

The bones are very different in size: those of the arms and legs are large, those of the hands small. This is why the hand is so movable and useful for so many purposes, as handling objects, writing, etc. could not be performed unless there were a number of small joints and muscles to bend the fingers in almost every possible position.

When we look at a bone, such as we see it sometimes as it comes with the meat from the butcher, it seems to be a hard, smooth, or solid body. One would hardly think that there was so much that was fluid or delicate inside the bone. If this were not so the bones would be too solid and heavy. Almost all the bones of the body are hard outside, and like a honeycomb inside, resembling a sponge. Inside this is a substance called the *marrow*. To see this we have to saw through the bone lengthwise, and we at once understand why the bones are so strong and at the same time so light, the outside of the bone being solid and the inside so delicate.

Bones are made up of two kinds of matter: one that is like jelly, and called animal matter; the other hard and earthy. Little children have more of the animal matter in their bones, while the bones of older persons have much more of the earthy matter. This is why the bones of old persons are so easily broken, and why the bones of the youngest little folks will sometimes bend before they will break. When the animal part and the earthy part are in the proper quantity the bones are strong and will not easily bend or break. The earthy part makes the bones hard and firm, while the jelly-like part makes them tough and elastic. If we wish to see the earthy part of a bone, we drive off the animal part by heat, and what is left is like chalk and very brittle. If we wish to see the animal part, we place a bone in a weak acid for a few hours, and the earthy part is dissolved, leaving the animal part in the shape of the bone, but so soft and elastic that a knot can be tied in it.

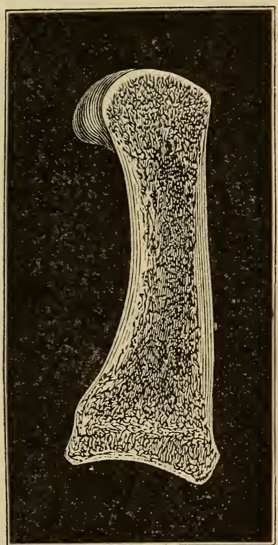

FIG. 3.—INTERIOR OF A BONE.

Bones of the Trunk.—The bones of the trunk or body are made up of those of the spinal column or back-bone, those of the chest, and those of the pelvis or hip (Fig. 4). The spinal column (Fig. 5) is a series of twenty-six bones in a long chain, the bones being smaller at the top of the row and larger at the lower part. The spine is a strong base of support to the chest and abdomen. There is an opening in the centre of each bone of the spine, so that when all the bones come together a canal is formed, in which the spinal cord is placed. This, we shall hereafter see, is one of the great nerve-centres, which has much to do to direct the movements and feelings of the body. Each of these spinal bones is sometimes called a *ver'tebra*, from a Latin word meaning "to turn," and the whole spinal column is therefore called the vertebral column.

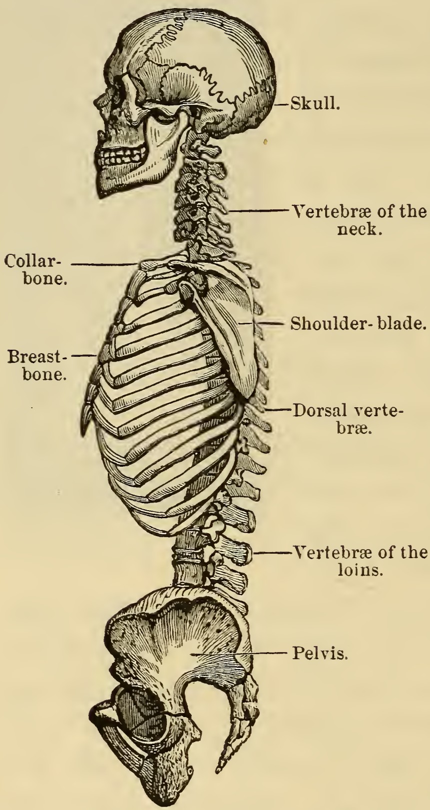

Fig. 4.—Skull and Bones of the Trunk.

The bones of the spinal column do not rub against each other or touch one another. Between all these bones is an elastic matter, which has the effect of making the whole spine slightly movable. If these bones were all placed together, without this elastic matter between them, any fall or blow on the spine would certainly injure the spinal cord, or even hurt the brain itself. The effect of this may be shown by taking several ivory balls and hanging them by strings alongside of one another. Raise up the last one, and let it fall against its neighbor, when the force of the blow will be felt through all the balls, and the first one in the row will fly off. If, however, one, or perhaps two, soft balls be placed in the row, and the last ivory ball be again brought against it as before, the force of the blow will be so broken that the first ball will not move. The elastic matter between the bones of the spine yields so much during the day that

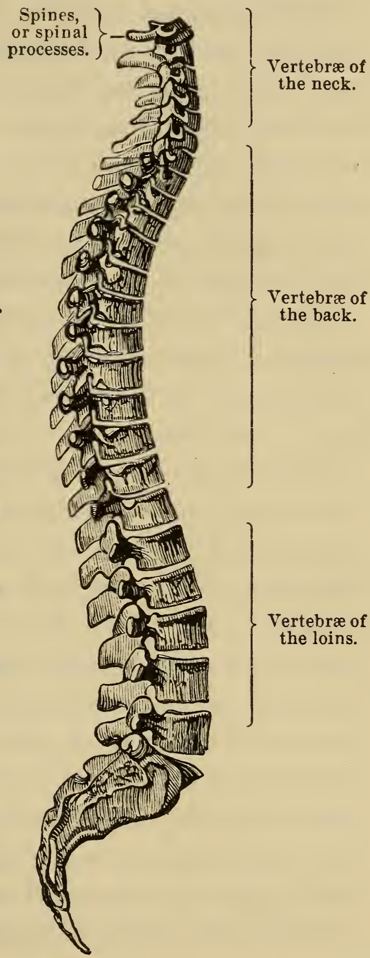

FIG. 5.—SPINAL COLUMN.

we are shorter at night than in the morning after a night's rest has taken part of the pressure off the elastic matter.

The *bones of the chest* (Fig. 4) are arranged like a cage, which is made up by the spine at the back, the breast-bone in front, and the ribs passing between them. There are twenty-four ribs, twelve on each side. They are long and curved, and some of them are fixed to the breast-bone, while others are joined to the other ribs by elastic matter, which allows them to move easily, so that the lower part of the chest yields in the act of breathing.

The *bones of the pelvis* (Fig. 4) are very heavy and shaped like a basin. They act as a support to the parts above, and bear the weight of the whole of the upper part of the body.

Bones of the Lower Extremities (Fig. 2).—These are united to the trunk or body where the thigh-bone fits into the hip-bone. This is what is called the hip-joint. The thigh-bone is connected with two bones of the leg at the knee-joint, and where these come together is another small bone, called the knee-cap, which fits into the hollow space between these bones. At the ankle the two bones of the leg unite with seven small bones, and these bones unite with five other bones to form what is called the arch or instep of the foot. Next to these come a number of small bones, called the phalan′ges, which make up the toes (Fig. 2).

Bones of the Upper Extremities.—One of these bones is the collar-bone (Fig. 4), which is connected with the breast-bone in front and the shoulder-blade behind. With the latter it gives shape to the shoulder. In the shoulder-blade is a hollow space or cavity, in which the arm-bone moves. This is what is generally called the shoulder-joint. There is one bone from the shoulder to the elbow, at which point the two bones of the fore-arm are connected with it. The two bones of the fore-arm are placed side by side, and when the hand is turned, as in writing, grasping, etc., one of these bones twists around over the other. Where these bones meet the bones of the hand the joint is called the wrist. The wrist is made up of eight small bones, which look like small stones or pebbles, and give it motion in various directions. The palm of the hand is made up of five small bones, and the fingers and thumb are composed of fourteen smaller bones called phalanges (Fig. 2).

All the bones have a covering to protect them, through which blood-vessels pass to nourish or feed them.

Other animals have their bones differently arranged from those of man. When they move about from place to place they hold themselves in a very different position from that which a man, or even a child, takes for the same purpose. If we look at the monkeys in the menagerie, we will see that they do not hold their heads erect, and that they are generally stooping and crawling (Fig. 6). Man is the only animal that stands straight with his head erect. The limbs of animals are arranged so as to be adapted to their movements, and they differ from those of man also in the number of bones composing them.

The Joints.—Owing to the large number of bones in the human body, especially in the limbs and in the trunk, it is very movable; but this motion would not be possible to any very great extent if many of the bones were not joined together in some way. Suppose, for instance, that there was only one bone extending all the way from the hip to the ankle or from the ankle to the end of the

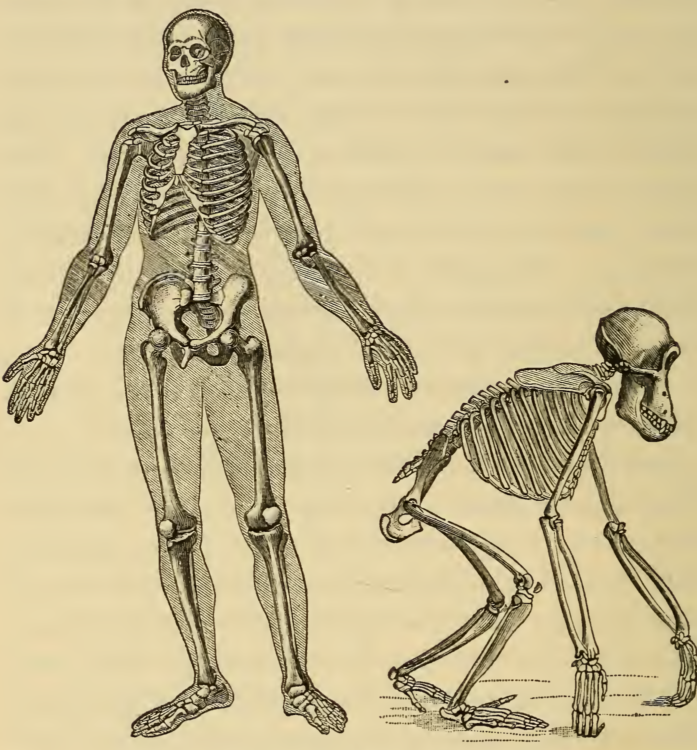

Fig. 6.—Skeletons of Man and Chimpanzee.

toes, what little motion there would be! Bending the leg could not take place, and walking would be a labor. But by having a number of bones placed together or very near each other a certain amount of motion can occur; and this is what is meant by a *Joint*, for a joint is formed by two bones with short white bands passing between them to hold them together. These bands or cords are called *lig'aments*, but a ligament only means something that binds one thing to another.

These cords are very strong, and are in shape like pieces of ribbon of different widths, and they yield a little when the joints are moved. They are strong enough to prevent the joints from being torn apart; and in some parts of the body, as the elbow and the knee, there is quite a number of these ligaments of different sizes, placed all around the ends of the bones where they come together to form a joint. The bones would soon wear away if the ends of them kept rubbing against one another during so many years of life, and so Nature has given them a thick elastic covering called *cart'ilage*, which many persons call gristle; and this comes between the bones and protects them from rubbing against one another, without in any way interfering with the motion of the joint. One would think that so much rubbing as must take place when the large bones of the leg or of the arm are constantly brought against each other in walking or writing or bending the elbow, would wear out the cartilages. But this hardly ever occurs, and most persons do not know from the wear on them that they have any such things as cartilages at all. Perhaps the cartilages would often wear out if the joints were not covered by a very thin, slippery fluid like white of egg, which is being poured over them all the time; and this joint-oil, as it might be called, keeps the bones with their cartilages in proper condition for every movement. This is on the same principle that the engineer oils his machinery to make its joints move easily and without friction.

Some joints are much more readily moved than others. The hip-joint (Fig. 7) is a very movable joint, but the

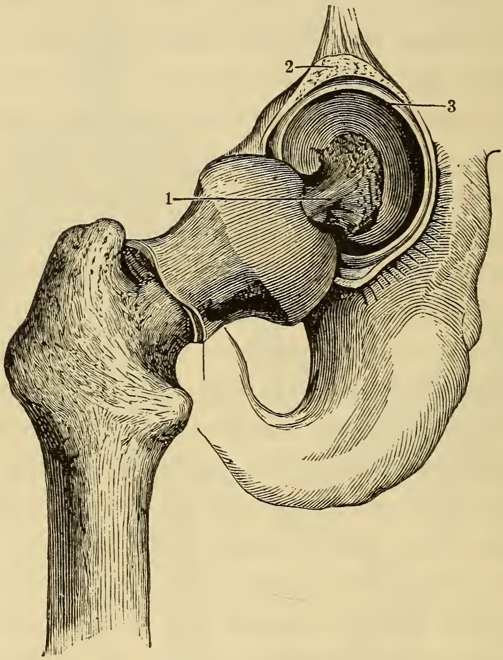

Fig. 7.—Hip-joint.

1, 2, 3, ligaments. The bone in Fig. 7 is represented as moved from its socket, so as to show the cavity. In Fig. 8 the ligaments of the elbow appear as if separated, for the same reason.

shoulder is more so, allowing the arm to be turned in almost all directions; but this is because the thigh-bone goes into a much deeper socket at the hip than the arm-bone does at the shoulder. Some of the joints are movable in several directions; others in one only. The elbow-joint has a movement like a hinge; the hip-joint and shoulder-joint are arranged like a ball and socket. Children will know what this means when they play cup-and-ball, which is itself a sort of ball and socket.

The knee-joint is like a hinge, but the wrist-joint acts not only in the nature of a hinge, but it admits of what is called rotation; that is, the joint turns upon itself. One of the two bones of the forearm turns around the other every time the hand is laid on its back or on its palm. If these bones were not thus movable, the hand would always remain in one of these positions.

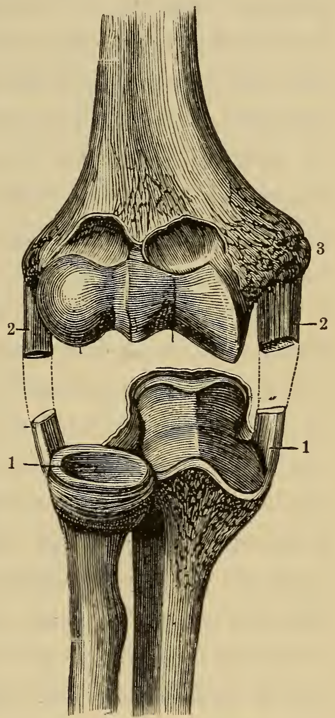

FIG. 8.—ELBOW-JOINT.
1, bones of forearm; 2, ligament; 3, bone of arm. (In the dotted lines the ligaments are shown cut apart, so that the joints may be seen.)

There are no joints in the skull like those of the elbow or hip or wrist. In early life some of the bones are movable, so that the brain may have room in which to grow; but after a while the bones become firmly fixed, so as to be no longer movable. If this were not the case the delicate brain would be pressed on, and perhaps death would result.

The spinal column also has ligaments which hold the bones in place, but the motion between them is very slight. They do turn a little upon one another, and that is the reason, as already stated, that the name *ver'tebræ* is given to them, from a Latin word meaning "to turn." Two of these bones, just where the head is fitted upon the spine, are movable, and this is the reason that we can nod and shake our heads as we choose. One of these bones of the spine is called the *atlas*, because in ancient fable a man called Atlas was said to have carried the whole world on his shoulders; the head being the globe which this spinal bone bears upon it.

There are joints also between the ribs themselves, and between the ribs and the spine.

When the large or small cords, called ligaments, which connect the bones are stretched beyond what they can bear, what is known as a sprain takes place. This is how a sprained ankle results from slipping on a pavement; the ligaments get stretched too far, and almost speak of their own sufferings when they express the feeling of pain. Sometimes the ligaments are torn apart if the force of the fall or of the accident should be great, and, as they do not heal easily or rapidly, the joint remains weak for a long time.

Sometimes bones get out of place, when they are said to be "dislocated," or out of joint, but this accident is more likely to happen in such a joint as the shoulder, because it is so very movable and the socket into which the bone fits is not deep, so that the bone slips out very easily.

Young bones are soft at first and have the proper shape, but they do not become hard, like bone, until the earthy matter is deposited in them, when they become firm and rigid. If a bone be broken, it heals very much in the same way; that is, at first a thin fluid substance is poured out at the broken parts of the bone, and soon after an earthy or mineral matter is deposited, which unites with the other to form bone. In a few weeks, if the bones have been kept at rest and closely bound together by bandages and other means which the ready surgeon has at hand, the broken pieces will be again united, and the bone at that point may be stronger than ever.

Hygiene of the Bones.—We must do all we can to keep ourselves free from sickness, and children can often do this themselves if they understand what are the best rules for keeping well. So far as their bones are concerned, they must remember that when they are very young these are very much more easy to bend than when the child grows to be a man or a woman. They must be particular, therefore, as to their position in school, at home, or wherever they may be. When a baby first begins to walk, if its legs are not strong enough to bear its weight they will become bowed, and what is known as "bow-legs" may result. Children should be very careful as to the position they take in sitting at their desks; they should not get into the habit of leaning over too much or of twisting their bodies, or of sitting in ungraceful attitudes, as they will soon get their backs twisted or their shoulders rounded.

The bones of children sometimes become weak and badly deformed, and almost like wax in softness, from the fact that they have not been fed upon the kind of food to give them plenty of mineral or earthy matter for their bones. Sometimes they may take too much of this kind of matter, and the bones will then become like those of an old person, having too much earthy matter and being very likely to break from the slightest injury. Exercise and fresh air and a good diet will do more than anything else to preserve the good health of the bones.

Effect of Alcohol on the Bones.—Children should know, from the first moment that they learn physiology or hygiene, that every organ of the body may be injured by the use of alcohol or liquor in any form. Sometimes only one organ is affected at first, but gradually all the rest follow, and sooner or later very bad health results, or even death. It is commonly believed that the healthy growth of any part of the body may be checked by the use of alcohol or tobacco, and the bones may therefore be stunted in their growth or affected in their health by the use of these articles. The children of drunken parents may thus inherit a tendency to disease of the bones which may seriously affect those organs in childhood, or even in after life.

QUESTIONS.

How are the eye and the ear and the heart protected from injury?
How is the inside of a bone arranged?
What two kinds of matter is bone made up of?
What effect has each kind on the bone?
What are the bones of the trunk?
How is the spinal column made up?

What is the use of the elastic matter between the bones of the spine?

How can you show this?

Which are the bones of the chest? Describe how the ribs are arranged.

What is the pelvis?

What are the bones of the lower extremity?

How are the thigh-joint and knee-joint formed? The ankle-joint?

Describe the bones of the arm and forearm.

How many bones in the hand?

How are the bones covered?

How are the bones in man different from those of other animals?

What are joints intended for?

What are the ligaments for?

How are the bones covered at the joints?

What is the use of the fluid in the joints?

What are the different kinds of joints? The hip? The elbow?

Are the bones of the skull movable?

Is there anything peculiar in the bones of the spine?

What is a sprain? What is a dislocation?

How do broken bones get well?

Does the kind of food have any effect on the bones?

Has alcohol any effect on the bones?

THE MUSCLES.

When we move the body or any part of it, we do so by means of fleshy matter connected with the bones to which the name *Muscles* has been given. These give shape and fulness to the different parts of the body. There are more than four hundred muscles in the human body. The red meat or flesh we are familiar with in the butcher's shop is muscle. Every action which an animal goes through is produced by the action of a muscle or a set of muscles. When we speak or wink or move a finger to write or to grasp anything we move muscles, as we also do when we laugh or sing. When a dog barks or a horse runs or a bird flies, it has to use a muscle or muscles. We find muscles in every part of the body: some of them are small and hardly to be seen without a magnifying glass; others, like those of the arm or leg, are large and thick.

Many of the muscles are found near the joints, placed in such a way as to move the limbs; some of them are deeply seated in the inner parts of the body. Wherever we find a muscle, no matter how small, it means motion in some shape or other.

When muscles are examined under a microscope they are found to be made up of a large number of fibres or *fi'brils*, as they are called, placed alongside each other in regular parallel lines (Fig. 9). These are so small that they cannot be seen with the naked eye, but they are the portions of the muscle that contract and cause action in the part to which they are fixed. These fibrils are arranged in bundles, and each muscle has a number of these bundles; the fibrils being made up of little round bodies or discs, like coin, placed on top of one another (Fig. 9, A). Every part of these fibrils has the power to shrink upon itself and shorten itself; and when all act together the whole muscle contracts or shortens itself, and the two ends of the muscle are brought nearer one another.

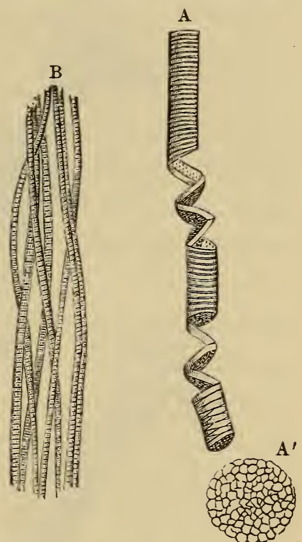

Fig. 9.—Fibrils of Muscle.
A, B, muscular fibrils; A′, cross-section of one of the discs composing them, the fibril being stretched open to show the arrangement of the discs.

One of the best modes of studying this action of a muscle is to grasp the left arm between the elbow and the shoulder, and, while holding it in this position, draw up the left hand so as nearly to touch that shoulder, when a round fleshy mass will be felt under the right hand. This is caused by the muscle or muscles of the arm contracting or shortening, and at the same time drawing up the forearm with them.

As some of the muscles are placed upon the arm or the leg in such a way as to bend the limb upon itself at the elbow or the knee, so other muscles are placed upon the same limbs in such a way as bring the arm or the leg back again to the same position it was in before it was bent.

FIGS. 10, 11.—ACTIONS OF A MUSCLE ILLUSTRATED (the other portions of the arm having been removed to show the action of the muscles more distinctly).

We can move many of the muscles at our own will, but there are many of them, too, that will go on contracting during our whole lives, and we cannot stop them from contracting. The heart is made up entirely of muscles, but it will go on beating as long as we live, without any power on our part to check it; for the beating of the heart is nothing more than a series of contractions of these muscles. When we breathe we move the muscles of the chest up and down, and we also call into use some of the muscles of the abdomen. When we sleep we are still using the same muscles for breathing with; and this is the best proof that muscles can go on contracting when we are not having any will-power in the matter. The blood goes on flowing through the body, and what we have eaten is digested and passes on along the stomach and bowels, all through the action of muscles, whether we are asleep or awake.

All muscles must take a rest after they have been doing their work. After they contract they gradually go back to their former place, and rest until they are called upon to do their duty again. Even the heart after each beat takes a rest or pause for a short moment, until it is ready to give another beat. If we bend the arm or keep it stretched out in a straight line, it will soon feel very tired; and this is because the muscles that bend it or keep it on the stretch want rest.

The bundles of muscular fibres are covered by a thicker membrane, which forms, at the end of the muscle, where it is connected with the bone, a tough substance called a *tendon* (Fig. 12). The muscles are soft and delicate, and would tear away from the bone if the force were exerted upon them alone. The tendon is white and smooth and shiny, and when the muscle contracts the whole force is exerted through it. We can feel a tendon just beneath the skin at the back part of the knee, and a very large one—the largest in the body—behind the ankle. Through this last one the large muscles on the back of the leg act upon the foot, as in walking and other movements of the leg. In ancient fable this was said to be the only part of the body of Achilles, a great Grecian warrior, which was not proof against injury from any weapon of war, and so this tendon has always been called the tendon of Achilles.

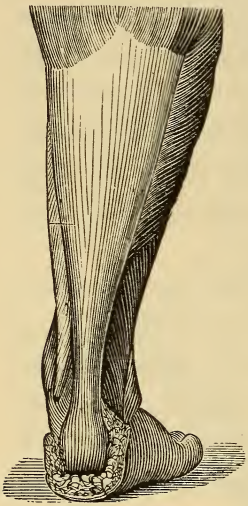

Fig. 12.—Tendon of Achilles at the back part of the leg.

The tendons and the white shining membrane which cover the muscles of the arm and the leg give shape to those limbs and diminish their size (Fig. 13). If they were not so covered the mass of muscles would have an ungraceful effect in their action, and the limbs would be clumsy and awkward.

Some of the most interesting tendons are those which move the fingers. The muscles are attached to the two bones of the forearm, and the tendons of these muscles pass down over the wrist and the palm of the hand, and are fastened to the bones of the fingers. When we bend the fingers we do so through those muscles, which pull upon the tendons connected with the fingers. There are muscles on the back of the forearm which, through other tendons, open the hand in the same general way that the hand is closed by those just mentioned. By placing one hand over the wrist of the other hand, and closing the latter, we will feel some of these tendons in action.

Movements.—When we walk or run or leap or swim, we call the muscles into play in different ways.

In *walking* we use the muscles of the leg to bend the leg or the knee and to bring it back again to a straight position, and we also use the muscles of the thigh, for walking is a series of movements by which we first push forward one limb and then the other, and at the same time the body moves forward.

When we *run*, we raise one foot from the ground before the other reaches it, and we push the body forward at each step. All this is done by the muscles of the leg and thigh.

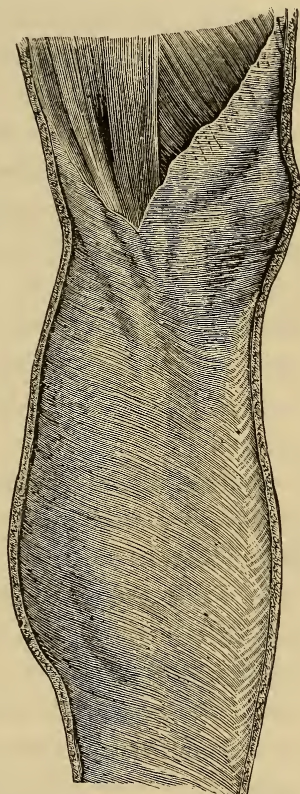

Fig. 13.—Muscles of the Leg, covered with Membrane.

Some Interesting Muscles.—We have mentioned several of the large muscular masses of the body, such as those of the leg and arm; but there are many others that are peculiar and interesting on account of their shape or size or the mode in which they are inserted. There is a muscle, for instance, which gives roundness to the mouth and causes it to assume the O-shape seen in yawning. There are tiny muscles which move little bones in the inside of the ear, as we shall hereafter learn when we study the subject of Hearing. There are strong muscles that help us to chew our food, and when we puff out our cheeks we do so by the aid of a muscle which is sometimes called the trumpeter's muscle. There are muscles connected with the air-tubes through which we breathe which are so small that we must use a microscrope to see them. Some of the muscles are shaped like fans, some are round, others are flat. When we move our eyes we do so by means of half a dozen muscles which turn the eyeball one side or another or raise or lower it at our will.

Hygiene of the Muscles.—As it is the duty of muscles to be moved, they must not be allowed to remain idle. Muscles that are not called upon to do work become weak and unhealthy, and the large ones flabby, especially in young and growing persons whose muscles are not fully developed. Proper exercise is necessary to give the muscles full strength and health, and to cause the blood to flow actively through them. When the muscles are properly exercised, all other parts of the body become fully developed also. The brain then becomes more active, and the blood flows rapidly through the other organs, such as the liver and stomach. The proper exercise of the muscles also gives better shape to the limbs, but exercise must not be carried beyond the strength. Exercise should be taken regularly and in the open air as much as possible, as breathing the pure air is of great importance.

Exercise should not be taken immediately after a full meal, as the stomach is then busy with its own work, and the food will not be properly digested if the blood that is required there be called away to assist in the work that the muscles have to do. Active exercise should not be taken before breakfast, when the body needs food, or in the evening, when it is tired out.

Children, and young persons generally, should not carry their play or exercise beyond their strength. They should stop before they become fairly tired out, for they become unfitted for any other work or for study when so much exhausted. Jumping rope, for instance, or racing, may sometimes bring on bleeding at the lungs or heart disease or headaches, and children often make a great mistake in taxing their strength to see which of them can run the fastest or the farthest, or, in jumping rope, which can count the largest number of times.

Muscles grow in size and become stronger according to the use to which they are put. A brawny blacksmith's right arm is larger than his left, because he uses the muscles of that side regularly and actively. If he were to give up work for a while, his arm would soon grow smaller, for the muscles would not be called upon for their usual exercise.

We have spoken of the muscles as being the cause of motion in every part of the body. When we smile or cry, or become angry or look sorry or grieved, it is because we use some of the muscles of the face to express our feelings of joy or sadness. The face is all made up of muscles fastened to the bony framework beneath it. It would be well for the young reader to compare the

FIG. 14.—MUSCLES OF THE FACE AND NECK.

appearance of the bare skull seen in Fig. 1 or Fig. 5 with the same when it is covered with muscles, as in Fig. 14. It is through all these muscles, with the smaller ones beneath them, that every movement of the face is made and all our pleasant and unpleasant expressions are effected. The muscles of the eyelids, nose, eyebrows, lips, cheeks, and tongue all aid in giving expression to the face. There are about seventy pairs of muscles connected with the face and neck.

Action of Alcohol and Tobacco on the Muscles.—Alcoholic liquors affect the muscles in various ways. Of course the muscles cannot act properly unless the nerves going to them are in a healthy condition. The staggering of the drunkard shows that his muscles are not under proper control, and that the nerves governing the muscles are weakened or perhaps over-excited. As the brain is also affected, he cannot give his attention to such steady or delicate movement of his muscles as would be necessary for fine work. In this way the best workman, although he knows exactly what to do when sober, soon loses his power to do good work, and clumsily tries and fails. In time the voice becomes thick, because he cannot control the muscles of his throat or tongue, and he "sees double," because he cannot move the muscles of his eyes properly together, his mind also being obscured.

In training a person for a race or for active exercise for a prize, he is not allowed either alcohol or tobacco, because they are known to weaken muscular power by acting injuriously upon the nerves supplied to the muscles. It is well for the young to learn as early as possible that tobacco will have this effect on the nerves sooner or later, and will weaken the muscular system, and also the other organs, as the heart and stomach. They should understand that it is wrong for them to do anything that will prevent their muscles or other organs from getting their full strength and health during their years of childhood or youth. The use of alcohol or tobacco in any shape will certainly stunt their growth and development, and make their after-life miserable and unhappy; but we shall learn more about this hereafter, when we come to study the physiology of those organs.

QUESTIONS.

What are muscles, and how many of them are there in the body?

What is the use of the muscles?

What are muscles made of?

How is the action of the muscles of the arm shown?

Show how the muscles act in breathing or in the beating of the heart.

Why do the muscles need rest?

What are tendons? and what are their uses?

What kinds of movements occur in walking and running?

Describe some interesting muscles.

What effect has exercise upon the muscles?

What are the best times and rules for exercise?

What effect have muscles upon the face?

How does alcohol affect the muscles?

How does tobacco affect them?

Why should young persons avoid the use of alcohol and tobacco?

DIGESTION.

THE body is constantly wearing out, and we have to take food to build it up again. As we have said before, the body has been compared to a piece of machinery. If the steam-engine or machine is not regularly supplied with water and with fuel, such as coal or wood, its action will soon stop. So it is with the human body, which without the proper amount of food and drink would soon fail to carry on the work which its various organs have to perform. The muscles and bones, the heart, lungs, and skin, are all built up and nourished by the food taken into the stomach. The food we eat becomes a part of ourselves and keeps us alive. Some waste is going on all the time. Every time we move a muscle we lose some small portion of ourselves, which must be built up again by the food that we take into our mouths. The kind of food we eat must be something that when taken into our bodies will be like the body itself, and must be eaten in such a quantity as to take the place of all that we have lost by the wear of the organs. If the food is not of the right kind, or if it be too small in quantity, the body will soon weigh less than it did before.

The process by which the food which we take into the mouth is changed so as to build up our systems is called

Digestion. The food is changed in the mouth and in the stomach and bowels, and as it passes along everything is taken from it that will be likely to be of use in building up the body.

The Food of Man.—As a rule, the food of man is obtained from animals and vegetables, but some mineral articles are also used for the same purpose. Water, for instance, is one of the necessary articles of our daily food. It is not only drunk as water, but it is part of many of the fruits that we eat. In some parts of the world grain and fruits of all kinds are very abundant, and many of the people of those countries live on that kind of food. In other countries, where there is not much vegetable life, the people live almost entirely on animal food.

As we have already said, the body is always wasting or losing, and food is necessary to make up this loss. While young children are growing the body gains by the taking of food much more than it loses; but after a while, as we grow up to be men, the body does not gain more than it loses, and the weight remains about the same for many months or years. Then, as we get to be very old, perhaps we may lose more by the wear of the different organs than we gain by the food we take, and so we lose in weight.

The kind of food which we ought to take should be such as our systems need. It should be as simple as possible for young children, whose stomachs will not bear as much in quantity or variety as those of older persons. The articles of food should be as much as possible those which do not require much action in the stomach to change them into the kind of material which the body needs for its support. This is why milk is the best article for very young children to take, for it is full of nutritious matters, and, being very much like the blood in its composition, does not require the stomach to do much work in order to make it ready to pass into the blood, and thus go to every part of the body to feed the various organs.

We shall see, after a while, that all these matters which feed and nourish the body do so through the blood as it flows to every part. The milk is like the blood, because it contains fatty matter and sugar and mineral and animal matters, just as the blood does. Flour is also like the blood in having the same kind of materials in it; and this is why bread is correctly spoken of so often as the "staff of life," for we can take nothing, except perhaps milk, which can be better fitted for our wants, and that needs so little change in the stomach to make it like the blood.

There are some articles that are found in almost every part of the body, such as *salts* of iron and lime, common table-salt, etc. Some of these are in the teeth and bones, and others are in almost all the other organs. When we examine the blood and the sweat we find them there, and as the body needs salts so much we must take them with our food; and this we do in many of the articles we eat, without knowing that they are present in them. Even the water we drink has many of them in it. Common table-salt is taken in small quantity by almost everybody, usually to give flavor to the food; but the body needs it, and some writers think it helps to make the digestion of the food go on more actively in the stomach. It should not be taken in large quantities, however, for this mode of using it creates thirst and leads to the taking of such an amount of water as to disturb the action of the stomach or to dilute the other articles of food more than is proper.

Among the other mineral matters in the body is *iron*, which is found in the blood and other parts. It is said that there are about forty-five grains of iron in the whole body. This does not seem a very large quantity when we think that a man of full size usually weighs about one hundred and fifty pounds; but part of the iron is found in the coloring matter of the blood, and when we consider that a drop or two of some chemical substance placed in a tumbler of water will change in a moment the color of the whole quantity of water, we can apply this fact to the presence of iron in the blood, and understand a part of the work the iron has to do in regard to the coloring matter of that fluid. Unless there is a certain amount of iron in the body, the child or man gets pale and unhealthy-looking, and has sometimes to take some form of iron as a medicine to bring back his healthy color.

Gums, Starches, and Sugars.—A great variety of articles of food is taken by the people of all nations, in addition to the usual meats and vegetables which are found in almost all countries. We take starch in some form or other when we eat potatoes, rice, barley, corn, beans, chestnuts, almonds, or arrow-root.

We find about a pound of starch in every seven pounds of potatoes. We take sugar in some form whenever we eat carrots or melons or turnips, and especially when we eat honey or fruits. It seems singular to find sugar in the human body in such organs as the muscles—those of the heart, for example. There is a kind of starch in the liver which is afterward changed into sugar. We take fat into our bodies whenever we eat butter or lard or sweet oil. Gummy matters are sometimes used for food. They generally flow from trees by making cuts into them at the proper season of the year. Gum-arabic is collected in this way. Gums are not good as articles of food, for they are not easily digested in the stomach.

Albu′minous Substances.—In many of the most useful articles we eat there is a substance called *albu′men*, which is so called from the Latin word *albus*, meaning "white," because it is like the white of an egg. If we do not find the albumen itself, we find other articles resembling albumen, which are therefore called *albu′minoid*, or "like albumen." These are the kinds of food that seem to be best adapted for the building up of the body, and also for keeping it warm. White of egg itself contains a large quantity of albumen. The articles that are like albumen are called fi′brin and ca′sein. Lean meat and wheat bread contain both fibrin and casein. The curdy part of milk is casein, for the word casein really means "cheesy." What is called "curds and whey" is only the casein of the milk made into a curd. Fibrin is found in the blood and in the muscles.

Fats.—Fat is found in the body under the skin and in many of the organs, even in the blood. Fatty matters keep the body warm, and also help to nourish it. We therefore take fat or oil in our food when we eat meats or oily grains or seeds, butter, etc. Fats are eaten largely by those who live in very cold regions, such as those in Arctic countries, and they help to keep up the warmth of the body. Even tallow candles and the coarsest oils are used for this purpose.

A mixture of different kinds of food should be taken at each meal, for the simple reason that any one article of diet may not be enough to supply the exact kind that the body may at the time require to build it up. It is better, however, to eat plain food, such as lean meat, eggs, milk, or bread, with nourishing vegetables and perfectly ripe fruits, rather than take fatty or rich articles that give the stomach too much to do or overload it with perfectly useless matters.

Nitrogen.—The air that we breathe is made up of several gaseous matters, the two most important of which are called ni′trogen and ox′ygen. The food which we take into our stomachs contains a certain quantity of both these substances. We need not for the moment consider oxygen as a part of the food, but may briefly say that some writers divide all articles of food into two kinds—those which have nitrogen in them, and those which have not. Vegetables, as a rule, have little or no nitrogen in them; animals have it in large quantity; so when we eat meat we take into our stomachs a certain amount of nitrogen, which the body actually needs for its healthy work. It is better to eat a mixed diet of both animal and vegetable food, however, as the body, with its great variety of organs, needs just such articles as are thus to be obtained, for if they do not contain any nitrogen, they may have other substances in them which will help to meet the wants of the body.

As vegetables contain but little nitrogen, and some of them do not contain any, we would have to eat a much larger quantity of them to get from them the amount of nitrogen that we actually need than if we eat animal food. It is said that a horse must eat three times as much vegetable food, in proportion to its size, as a dog does of animal food, to get the same amount of good from it.

Variety Necessary.—Variety of food is necessary to all animals that are in the habit of taking mixed food. If a dog, for instance, which has been in the habit of eating everything that it could get hold of, were locked up or kept by itself in a place in which it could only eat one kind of food, it would soon begin to droop away and perhaps die. A man who has been in the habit of eating meats and vegetables will soon get sick if he is fed for any length of time on meat alone or vegetables alone. This is the reason that the Government when it arranges what its soldiers and sailors shall eat gives them a variety of different kinds of food, so that they shall keep healthy and strong, and not get a disease called scurvy, which will be very apt to attack them if they eat too much of one kind of food.

We have stated that albuminous articles are the best for the stomach and for the body itself. Meat and milk have albumen in large quantities in some form or other.

The egg contains, besides the yolk, scarcely anything but albumen, and from it the whole chicken—its feathers, claws, blood-vessels, and everything that goes to make up the animal—is formed. This is a good point to show how very important albumen is to the life and growth and health of this animal and of every other animal, for all animals need just such life-giving and health-supporting materials.

Animal Food.—Almost all parts of animals have been used as food, but the portion usually eaten is the flesh, which, we have already stated, is the muscular part. The meat of very young animals should not be eaten, because it is not easily digested, and the fat is not mixed with the fibres of the meat as it is when the animal is older. When fat is well mixed with lean meat, as in the ox, the meat is more digestible. In the very young calf, the veal, as it is called, has fat around it instead of being mixed through it, and it is more jelly-like, and therefore not so easily digested.

Almost all parts of *birds* have been eaten as food, but any part of the animal which is always in use is not so tender. Chickens' legs are not so good for food as the wings. A duck's leg is not used so much, and it is therefore quite as good for eating purposes as its wings. Birds that live in the water, such as the goose or the duck, do not have as tender meat for eating purposes as those which live on the solid ground, such as chickens; the fat mixed with their flesh is more fishy.

The flesh of *fish* is much used as an article of food; it is made up mainly of albuminous materials, but is not so nourishing as the meats usually eaten, although more so than a purely vegetable diet. Oily fishes, as the eel, are not easily digested in the stomach. Tribes are found in various parts of the world who live on fish alone, that being the food which they can easily secure, after floods or heavy rains, with little trouble and expense. Nearly every part of the fish is considered good for food. A fish diet has been recommended to those who are tired out with heavy brain-work, because it contains a chemical substance called phos′phorus, and as this stimulating substance is always present in large quantity in the brain, it has been thought that this organ would receive a fresh supply when this kind of food is taken.

Milk.—As already stated, milk is well adapted to sustain life, being composed of such albuminous matters, fats, and sugars, in water, as will nourish the body. When taken into the stomach it is changed by the fluids of that organ into a solid curd and a fluid or whey. The curd is digested just as any other substance would be digested there, while the fluid portion is taken into the blood-vessels, and soon becomes a part of the blood itself, going to the nourishment of all the living organs. The cheesy part of the milk sometimes disagrees, from its not being digestible, and the curd formed in the stomach may remain there for hours. Generally, milk agrees better than any other kind of food. Boiling makes milk much more digestible, especially if a little lime-water be added to it, if there is an acid state of the stomach.

From milk we get cream, butter, cheese, buttermilk, and whey. *Cream,* carefully skimmed from the milk, contains casein and whey, together with the butter. It is not as digestible as milk, because it has more fat or oil in it. For this reason *butter*, which is the oily part of milk, obtained by churning, is, like other oils, not very digestible. *Cheese*, which is the curd of milk pressed and partially dried, carrying with it a little butter, is very nourishing, but not very digestible. An old proverb says—

> "Cheese is a surly elf,
> Digesting all things but itself,"

because it is thought that it helps to digest other articles of food that may be keeping its company in the stomach. Cottage-cheese or smeer-case—the soft curd of milk—is more easily digested. *Buttermilk* is the fluid left in the churn after the butter has been taken away. It has lost the greater part of its fatty matter by churning, and should therefore be more digestible, though not so nourishing. *Whey* contains a little sugar, cheese, and butter, but is apt to turn acid in the stomach.

Eggs.—These are more nourishing than milk, but not so digestible. The white of the egg is almost wholly albumen in a pure state; the yolk is oily matter with albumen. When heated, the white of the egg, or albumen, becomes cloudy or thick, and is then said to coagulate. It is more digestible when slightly boiled than when raw. The yolk, on account of its fatty matter, is not so digestible. One great advantage of the egg as an article of food is the large amount of nourishing matter contained in a small space. Fried eggs are not very digestible, for the albumen becomes hardened and the oily matter is altered by the heat, so as to be unfitted for digestion. All substances that contain a large amount of food in a small compass are digested by the stomach with difficulty.

Vegetable Food.—In some portions of the world vegetable food is almost the only diet, and there are many animals that live entirely on this kind of food. As already stated, animals contain much nitrogen; we may then ask, How does the flesh of such vegetable-eating animal get the nitrogen of which it is composed if there is none in its food? The air it breathes is largely made up of nitrogen, and this is doubtless the chief source of its supply, passing into the animal's lungs, and afterward into every portion of its body.

Bread is usually made from the flour of wheat. It contains a sugar or starchy matter and a thick gluey albuminous matter called gluten. When yeast or paste is added to it the bread is said to be *leavened.* The yeast or the paste acts as a *ferment,* as it is called; that is to say, just as soon as it is added it begins to affect the flour, until it changes the whole character of the mass into which it has been introduced. It is necessary that there should be ferments in the human body; we find them always present in the mouth, in the stomach, and in the upper part of the bowels; and wherever they are, we find that it is their duty to be getting the food into motion, stirring it up and changing its composition until it is fit to be taken into the blood for the nourishment of the body.

Sweet cakes and pies are not very digestible, for they are generally made up of sugar and eggs. They should be eaten sparingly for this reason.

Breads are made also of other flours, as bran, rye, barley, etc., but they are not so digestible or nourishing as that prepared from wheat, and are apt to turn acid in the stomach. Rice and corn flour are also eaten as bread, and are both digestible and nutritious.

Fruit.—By some persons fruits are considered as the most healthful articles that can be taken into the stomach; by others they are looked upon as a source of stomach trouble. As a rule to be generally observed, fruits should be eaten only when perfectly ripe, and the seeds and skins should not be swallowed, for they are thoroughly indigestible. Such fruits as the melon and canteloupe are the least digestible of all this class. Preserved fruits may disagree with the stomach, just as sugar does, although the mixture of fruit with sugar is not so likely to disorder the stomach as either sugar or fruit alone.

Cooking.—The value of food depends upon its being digestible and upon the amount of materials it contains with which to nourish the body; but the manner of preparing the food in cooking is also important. Few articles of food are ready at once to be taken into the stomach without being cooked. In this way the flavor of the meat is brought out or new flavor added, and the article itself made digestible by the softening and dividing of its particles, either before or during the cooking, by chopping or cutting or by the aid of heat or water or salt. By heat especially the most active parts are often entirely separated.

Drinks.—The drink of all drinks to be used by man should be water alone. It is needed by the body for various useful purposes, being especially required to keep the different tissues moist and soft. It will surprise many young readers to learn that water is found in some of the most solid parts of the body, as the teeth and the bones and in the muscles. About two-thirds of the weight of the body is water. When we say that a man weighs a hundred and fifty pounds, we know that one hundred pounds of this is water. Nearly a fourth part of his bones is water, and about three-fourths of his skin and of his brain and of his muscles. Milk and blood are very largely composed of water, and the tears have scarcely anything else in them.

A man can live for a longer time without solid food than he can without water, so necessary is it to his life and health. For drinking purposes, water should be perfectly pure, for if impure it may give rise to severe sickness, such as typhoid fever. The amount of drink necessary for an individual to take in the twenty-four hours depends on habit, for some persons can take a large quantity, while others, equally healthy, use but little. Whatever the system requires must be taken. If solid food is swallowed too rapidly, the fluids in the mouth cannot soften it, so that it will be necessary to swallow a considerable amount of water to produce that effect. The amount of water or other liquid swallowed at meals should not be very great, as the food becomes too much softened, and the fluids of the stomach are so much diluted that they will not act properly on the food. Acid and sweet drinks, or drinks of any kind, should be avoided immediately before meals, as they excite the stomach to action before the food is taken. Hot drinks stimulate the stomach to increased secretion, and at the same time increase the action of the muscles of that organ; but if we get into the habit of exciting the stomach in this way, we injure it, and finally weaken it.

For drinking purposes, rain-water and water from springs, rivers, wells, and lakes are used; but river-water, which is obtainable usually in larger quantities, is generally used. It sometimes contains impure matters that have been emptied in it from factories or dwellings, or decayed animal or vegetable matter carried into it from smaller streams. If water is not pure, it should be filtered or boiled. Boiling kills the germs of disease that may exist in the water. Filtering with charcoal takes away the solid impure matters and removes any bad odors from the water. Sometimes the impure matters may be driven off by distilling the water; that is, the water is heated until it passes off in the form of vapor or steam, and then as the vapor cools it will be collected again, drop by drop, as water in another vessel.

Alcoholic Drinks.—Cider, wine, beer, whisky, and brandy are forms of alcoholic drinks commonly used. Some of them, such as cider and beer, have only a small quantity of alcohol in them; while others, such as whisky, brandy, and rum, contain a very large quantity of alcohol. The power which they have of intoxicating is due to the alcohol. Although the amount in cider and beer is quite small, it is better to avoid their use entirely, because they may lead to the habit of taking alcoholic drinks. Beginning with cider or beer, the drinker will not be long in getting into the habit of taking stronger liquors, as brandy or whisky.

Alcohol is a clear, colorless liquid, lighter than water, and is formed as the result of a process called fermentation. The grape, the melon, and other fruits, and rice, have been used for this purpose. These articles contain sugar, and when fermentation takes place alcohol is formed as one of the results. The gas which bubbles up in it is called carbonic acid. Wine is usually made by the fermentation of grapes; cider, by the fermentation of apple-juice.

Alcohol is not a food, for it does not nourish the body or help to build it up when it is wearing out. It gives rise to thirst, which we shall soon learn is the desire for more drink. It takes water from the other parts, where the water is needed for better purposes. The alcohol passes into the blood, and is not changed as true food would be. It does not relieve hunger, which is a desire for solid food. It does not help other articles of food to be digested. It does not warm the body, as some persons might think. It may flush the face, but that is because the little nerves which control the small blood-vessels of the face are deadened, and the blood fills the vessels and keeps them full all the time, so that the face is reddened. Besides all this, poisons of various kinds are sometimes mixed with the whisky or rum sold in the saloons, and the alcoholic drink is made still more dangerous to take. Aloes, strychnine, jalap, copperas, and other injurious articles are used for this purpose.

Alcohol acts as a poison on the stomach and bowels. At first it causes sickness of the stomach, or the food taken into the stomach does not agree with the person taking such drinks; and after a while the lining of the stomach gets diseased and inflamed, and the person dies. The worst effect of these alcoholic drinks is upon the liver, for as soon as they are swallowed they pass into the stomach and go at once to that organ. Soon the liver becomes yellow and looks like a lot of hob-nails, and the drinker dies after much suffering and sickness.

Alcohol should be looked on as a medicine, and only to be taken as such, and not as either food or drink. It is really a poison, and the sooner we regard it as such the better it will be for the health and happiness of us all. As a drink it should be avoided as if it were an enemy to human life. It is the cause of hundreds and thousands of cases of sickness, and some of the nervous and other diseases which it produces may be inherited in some form or other by innocent children, who will be weak in mind and body from this cause. One of the leading physicians of England not long since stated as a fact that in the hospital which he attended seven out of every ten cases of sickness were caused by drinking alcohol.

Effect of Tobacco and Opium on Digestion.—Many persons indulge in the use of tobacco, either smoking cigars, and thus taking the poisonous weed into their lungs with every breath, or chewing it in solid pieces.

In both these ways, as well as in the old practice of snuffing it up the nose, it is positively injurious to the system. It disturbs the stomach and produces vomiting and giddiness, and also affects the brain and the heart. The Government found that the cadets at West Point and Annapolis, who were at school there studying to enter the army and navy, were so much injured by using tobacco that it passed a law that all those chewing or smoking it should be severely punished. After using tobacco there is less appetite for food, and sometimes disease of the mouth and throat.

Some persons use *opium* and other articles of the kind to give them rest or to make them sleep, or because they think that such substances afford them some sort of pleasurable feeling. All such articles should be strictly forbidden. Their use does not produce healthy sleep, and the stomach or heart or brain will be greatly disturbed in their action. After the opium habit, as it is called, is once formed, the person cannot do without it. Opium takes away the appetite and checks the muscular action of the stomach and bowels. It should never be taken without the order of a physician.

When we come to study the physiology of the heart and lungs and brain, we shall learn how injurious alcohol and tobacco and opium are in their effect on those important organs.

Tea and Coffee.—These articles are used as drink by the people of almost every nation. Tea was first used in England more than two hundred years ago. In moderation tea and coffee may assist the work of digestion and satisfy the stomach, and thus prevent the person from taking anything stronger, such as whisky or brandy or beer, into the stomach. When they injure the stomach or the nervous system, it is because the tea or coffee is made too strong or taken in too large a quantity, or because from some peculiarity of the person taking them these articles do not agree. A cup of tea or coffee should be made by placing a small quantity of either in boiling water for a few moments, but the mixture itself should not be boiled.

Tea has a good deal of tannic acid in it, and this has the effect of checking the action of the stomach and bowels. Taken in excess, tea may weaken the action of the heart. Coffee, taken very strong, may produce disagreeable feelings of fulness in the head, and indigestion. Milk is the best food for children; they will grow strong and healthy from its use, without using either tea or coffee.

Quantity of Food to be Taken.—It is hard to say exactly what is the proper quantity of food for any one to take at a meal or in the course of the day. Everything must depend upon the age and health of the person, and whether he is living in a warm or a cold climate. A strong man can take more food than a weak or old person or a young child. Eating too much is a common cause of sickness, especially with children. If the food should be swallowed too rapidly, the stomach will have too much work to do to get it ready for the good purposes it will serve afterward.

The usual quantity eaten every day by a grown person in full health is said to be half a pound to a pound of meat, about a pound of bread, about a quarter pound of fat, and between three and four pints of water, either taken as such or in the form of milk, tea, or other fluids. A larger amount is eaten in cold than warm climates, and in cold seasons of the year than in hot. The daily amount of food taken by an Esquimaux is said to be twelve to fifteen pounds of meat, besides a large mass of fat; but this is because the climate is so very cold that he has to eat plenty of meat and fat to keep himself warm. A Russian admiral who was in the Arctic regions says that he saw a man eat twenty-eight pounds of boiled rice and butter at a single meal. One of the Arctic explorers saw an Esquimaux who in twenty-four hours devoured thirty-five pounds of meat, in addition to a number of tallow candles.

Children need plenty of food, because they are always growing and taking exercise; and it is a well-known fact that those who take exercise need much more food than those who do not. Meals should be regular and far enough apart to allow of full digestion being completed. Some persons require much more time than others, but scarcely any more than four or five hours between meals. Children can eat more frequently than grown persons, but the quantity at each meal should be moderate, not excessive, so that the stomach will not have too much to do. Supper should be light, and, as a rule, without meats of any kind, especially in the case of children, as a full supper eaten before going to bed is apt to disturb the brain and cause dreams or restlessness.

Change in the kind of food is desirable. The strong require a different kind from the weak, and those who are engaged in heavy and fatiguing labor should eat more food and of a better kind than those who have to sit at their desks. Delicate persons and those with weak stomachs should eat only such articles as are easily digested, and in small quantities frequently repeated. Bread and milk, a small quantity of meat and of vegetable food with fruits, form a good diet for such persons. As will be hereafter stated, food should not be swallowed in a hurry, as the action of the teeth in dividing the food, and of the fluids of the mouth in softening it, will not then take place.

Hunger and Thirst.—After the stomach has been empty for a while—that is, after the person has not eaten for several hours—he begins to feel hungry. This is because the body needs food, and the feeling of hunger, as it is called, is the way in which our bodies tell us they need something to eat. If no food be taken, the different tissues will gradually break down, and the body will have to feed on itself. This condition could not last long, for, like the steam-engine, the body must have fuel or it will soon stop working. Even the vegetable seems to get hungry sometimes, for it sends out its little roots in all directions in search of food.

The feeling of hunger, or the desire for solid food, seems to come from the stomach, but when we get thirsty the feeling comes from the throat, and is an evidence that we want more water in our bodies. We have to drink a certain quantity of water every day in some form or other, either as pure water or as tea or coffee or milk. We can live longer on water alone than on any dry food without water.

Hints about Eating.—No more food should be eaten than is necessary to satisfy the appetite. It should not be eaten oftener than the wants of the body require, and this is usually shown by the feeling of hunger, or appetite. Three meals a day, five or six hours apart, are enough. The supper should be light; the dinner should be the most nourishing, as more work, and therefore more loss to the system, has occurred. The food should be eaten slowly and be well chewed before swallowing. It is better not to overload the stomach, as that organ will soon get tired of being overworked. Water should not be taken in large quantities at meals, as it dilutes the food too much and weakens the power of the stomach. Alcoholic liquors in any shape should not be taken at meals or at any other times; they do not add anything nourishing, nor do they help other things to be digested.

For children vegetable foods are better than animal, because they do not have the same stimulating or exciting effect. Veal, pork, ham, fried meats, and pastry should be avoided by children; they disagree with many grown persons. Hot biscuit, cakes, and pies should be avoided at night. Meals should be taken at regular hours, as the stomach needs regular work and regular rest. Exercise, work, or study should be avoided after a full meal; the needs of the stomach require at that time that the blood and the powers of the body shall not be called away to do other work. Running, leaping, and jumping rope should not be indulged in for at least two hours after a full meal. At meal-times the mind should be cheerful and free from care; children should not hurry to their meals when flushed and excited or heated by play, but wait until their nerves get quieted down.

The food should not be eaten too hot or too cold. Very hot drinks may injure the teeth or the stomach and delay digestion. Very cold food chills the stomach. Ice-cold water should not be taken into the stomach in any large quantity, especially when the body is heated. Such a freezing mixture as ice-cream, although very pleasant to the taste and cooling to the mouth and stomach, may injure the stomach from the sudden chilling received by that organ. It should therefore be eaten slowly. Spiced food, pepper, mustard, sauces, pickles, and horseradish may disagree with the stomach by exciting it so much that in time that organ gets tired of the constant stimulation, and may become much weakened in its action.

Organs of Digestion.—The simplest arrangement for digestion is that of the vegetable, which obtains its food from the earth. It has no other organs, such as a stomach, but the water or other matter from the earth passes directly into it. In some of the lowest and smallest forms of life the whole animal is a sort of sac, or bag, with only one opening, and looks like a delicate gum-bottle. The animal is all stomach, and like a thin rubber bottle can be turned inside out. In some fluids there are little living bodies which are so small that they can only be seen with a microscope, and yet in them there is a body having an opening for food, a part like a stomach, with an open tube or canal leading from it. The organs of digestion are most perfect in man and the higher classes of animals, and in them we find a cavity or a number of cavities in which the nutritious portion of the food is prepared, and the useless portions of food are expelled.

In man the arrangement for digestion consists of a long tube or canal, varying greatly at different parts in size and structure. It is usually divided into the following parts: mouth, pharynx, œsophagus or gullet, stomach, and bowels or intestines. The stomach and bowels occupy the greater portion of the abdo′men, as the cavity is called (Fig. 25), and are the chief organs of digestion.

The Mouth.—The mouth receives the food taken into it; the teeth cut and crush it; the tongue and cheeks move it around and around, while the mouth pours out a thin fluid which softens it.

The Teeth.—The teeth are made up of a very hard material called the *ivory* or *dent′ine*, and they are inserted deeply into the jaw by roots. The part of the tooth above the gum is called the *crown*, which is covered by a thin layer of material called *enam′el;* and this is the hardest substance in the body. Inside the tooth is a cavity containing nerves and blood-vessels.

When a child is born it seems to have no teeth, but many of them are already in the jaw, but have not risen to the surface of the gum. When a young child gets its first full set of small teeth it should have twenty altogether. These are called *temporary teeth* (Fig. 16), because they do not stay in the jaw all through life; and they are called *milk teeth*, because most of them come at a time of life when the child is living entirely upon milk. When the child gets to be about six or seven

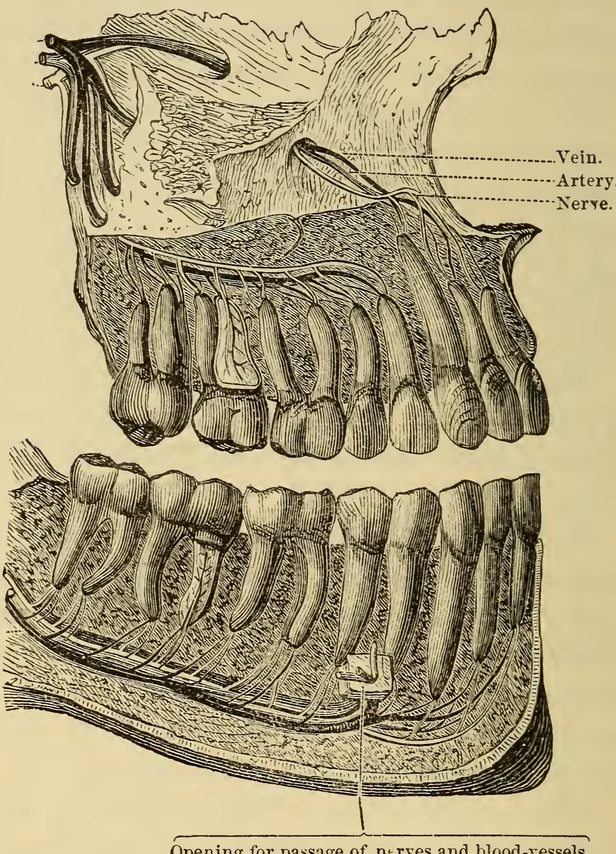

Fig. 15.—General View of the Teeth, the bone being divided to show this more clearly.

years old the roots of the milk teeth become absorbed, and the teeth are ready to fall out. Then the *permanent teeth* come and take their places, and these stay in the mouth during all the rest of life unless they become lost by disease or decay. There are thirty-two permanent teeth, sixteen in each jaw.

The smaller sharp teeth seen in Fig. 15 are intended for cutting and dividing the food, the large ones for grinding or mashing it. The permanent teeth are devel-

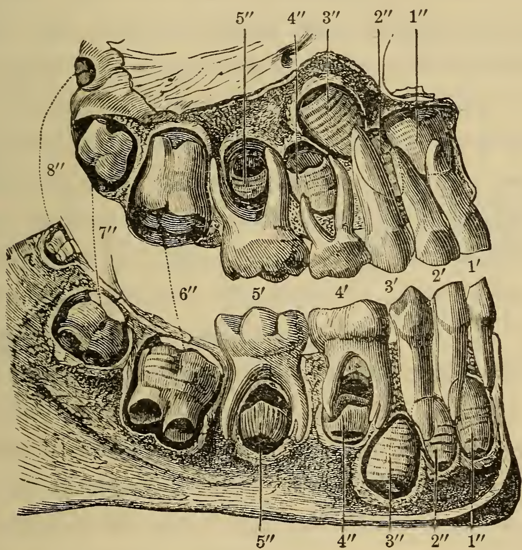

FIG. 16.—MILK TEETH AND PERMANENT TEETH AS FOUND IN THE JAW AT THE SAME TIME.

1′ to 5′ are milk teeth; 1″ to 8″ are permanent teeth.

oped in the jaw below the milk teeth, and both are found in the jaw at the same time, about the fifth year of age (Fig. 16). They gradually push out the milk teeth from that time of life until the twelfth or fourteenth year of age. The "wisdom tooth," so called on account of its not making its appearance until the twentieth or twenty-first year of life—when a young person is supposed to be wiser than during his younger years—is the third large tooth of each jaw.

The teeth are of such shape in various animals as to be adapted to the special food on which they live. The sharper teeth in front are called inci′sors from their cutting properties, and canine because they are like those of the dog. The largest teeth are called molars, from a Latin word meaning "a mill," because they grind the food as a mill would. The motions of the jaw also admit of a cutting or crushing action upon the food. In animals which live entirely on animal food the jaws are very strong, and move more readily up and down than from side to side. The muscles of the jaw are also very strong, and the cutting teeth are much more powerful than those for crushing, the latter being sharper than in other animals. By looking at a tooth we can usually know at once the kind of animal, and some learned men have been able to decide from a single tooth exactly what the rest of the animal must have looked like, although the kind of animal may have long since ceased to exist upon the earth in any part of it, for each animal is formed by Nature on a general plan or system.

Fig. 17.—Teeth of Insect-eating Animal.

Some animals feed entirely on flesh, some on insects, and some on grain, others on grass. Man has teeth and digestive organs adapted to all kinds of food, whether animal or vegetable. Animals which feed entirely on insects have conical or sharp-pointed teeth which fit closely into one another in the two jaws like the teeth of clock-work (Fig. 17). Those animals which live mainly on fruits have the teeth rounded rather than sharp (Fig. 18). Grain-eating animals, whose food requires crushing or bruising rather than cutting, have large flat teeth, which, like millstones, crush and break up the food into fine particles by the side-to-side movement of the jaws (Fig. 19). In the flesh-eating animal (Fig. 20) the large teeth or molars are sharper, and so placed as to meet like scissors-blades, while the front or canine teeth are very large. The sharp front incisor teeth in other animals become in the horse more like grinders or molars in structure and shape. A number of animals have grinding or molar teeth in some form or other. The teeth of the elephant are entirely of this kind. Some animals, as the whale, have not any teeth. Of the thirty-two teeth of man, twelve are like those of the flesh-eating animals, and twenty like those of grass-eating animals.

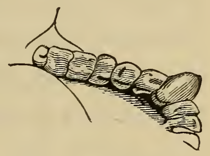

FIG. 18.—TEETH OF FRUIT-EATING ANIMAL.

FIG. 19.—TEETH OF GRAIN-EATING ANIMAL.

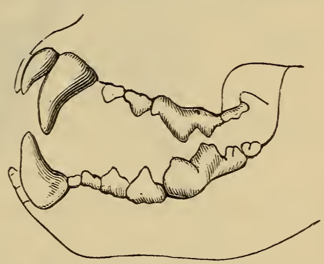

FIG. 20.—TEETH OF FLESH-EATING ANIMAL.

The movement of his jaws is upward and downward and sideways.

The Tongue.—The tongue moves the particles of food around in the mouth, to be acted upon by the various juices or fluids poured into it. Some of the lower animals seize their prey with the tongue. While man uses his hands to convey food to his mouth, the elephant has a long snout

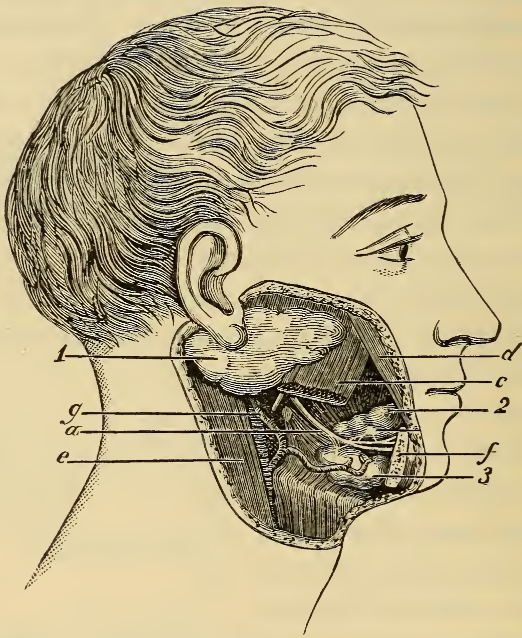

FIG. 21.—SALIVARY GLANDS.

1, parotid gland; 2, sublingual gland; 3, submaxillary gland; *a*, nerve; *c*, *d*, *e*, muscles of the face and neck; *f*, lower jaw; *g*, artery.

called the trunk, through which it can suck articles into its mouth. Insects have feelers around the mouth for similar purposes. In some animals the motion of the tongue in the mouth enables them to suck in liquid food.

The Sal′ivary Glands.—These glands (Fig. 21) are found on each side of the mouth in man, and are three in number. They pour out a thin and a thicker kind of fluid, which becomes mixed with that from the membrane lining the mouth. Although this fluid, called sali′va, is being constantly formed and swallowed, the presence of food in the mouth excites these glands, and an additional quantity of saliva flows into it. Even the mere sight of agreeable food has this effect, which is well known as "mouth-watering."

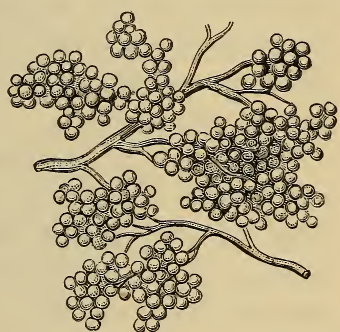

Fig. 22.—Structure of a Salivary Gland.

The amount of saliva poured out varies with the kind of food; if it is hard or dry a larger quantity is poured out. The saliva softens and moistens the food, and if the food has any starchy matter in it, it is changed by the saliva into a gummy substance called dex′trin, and afterward into grape-sugar. This, being soluble, is more easily absorbed. Perfect division of the food, and perfect mixture of saliva with it, are necessary to ensure perfect digestion in the stomach.

The salivary glands, when examined under the microscope, resemble a bunch of grapes (Fig. 22). The average amount of saliva poured into the mouth in the course of twenty-four hours has been estimated at from two to three pounds. The terms *parot′id*, *submax′illary*, and *subling′ual*, applied to the salivary glands, merely mean, from their Greek and Latin origin, that they are near the ear, under the jaw, or under the tongue, as will be seen in Fig. 21.

Swallowing the Food.—When the food has undergone these processes in the mouth it is swallowed. Swallowing, or *deglutit′′ion*, as it is technically called, includes the passage of the mass of food from the back part of the mouth into the stomach, and requires the action of the mouth, throat or phar′ynx, as it is called, and a tube called the œsoph′agus or gullet, which passes directly into the stomach.

The pharynx and œsophagus together form a muscular tube or canal extending from the mouth to the stomach (Figs. 23, 24). The cavities of the mouth, nose, and larynx, or upper part of the air-passages, open into the pharynx (Fig. 24). The œsophagus (Fig. 23) is about nine inches long, and, like the pharynx, is lined with a smooth membrane called a mucous membrane, which pours out a thin fluid called mucus to keep it moist. It also has a muscular coat which keeps the tube contracting, so that the food is moved onward toward the stomach.

The first part of the act of swallowing is under the control of the will, but the passage of the food from the throat to the stomach is entirely beyond our control. This is a wise provision, for otherwise the particles swallowed might pass into the upper opening of the air-passages, as they occasionally do when, in common language, they "go the wrong way." During the act of swallow-

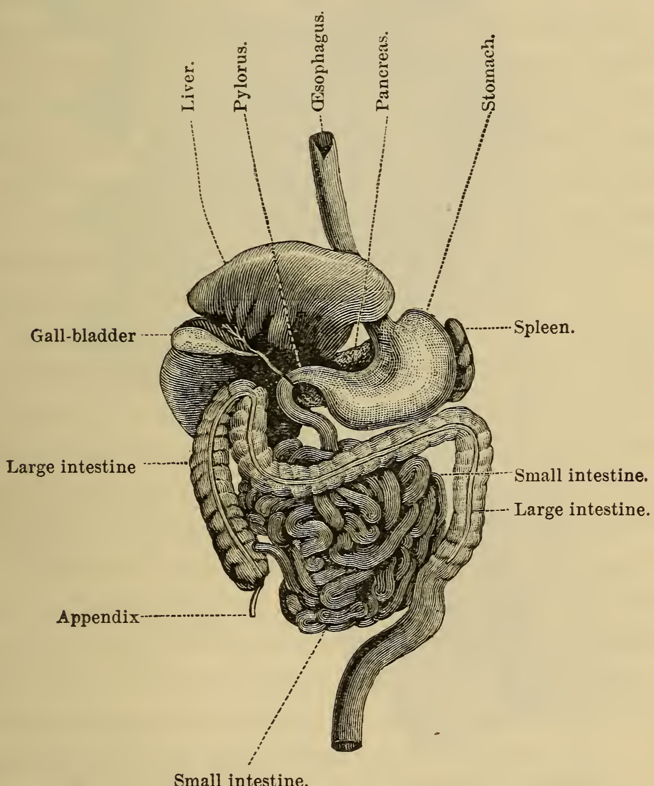

Fig. 23.—The Organs of Digestion.

ing the upper part of the air-passages is raised by the muscles connected with it out of the way of the mass of food. The passage from the back part of the throat into

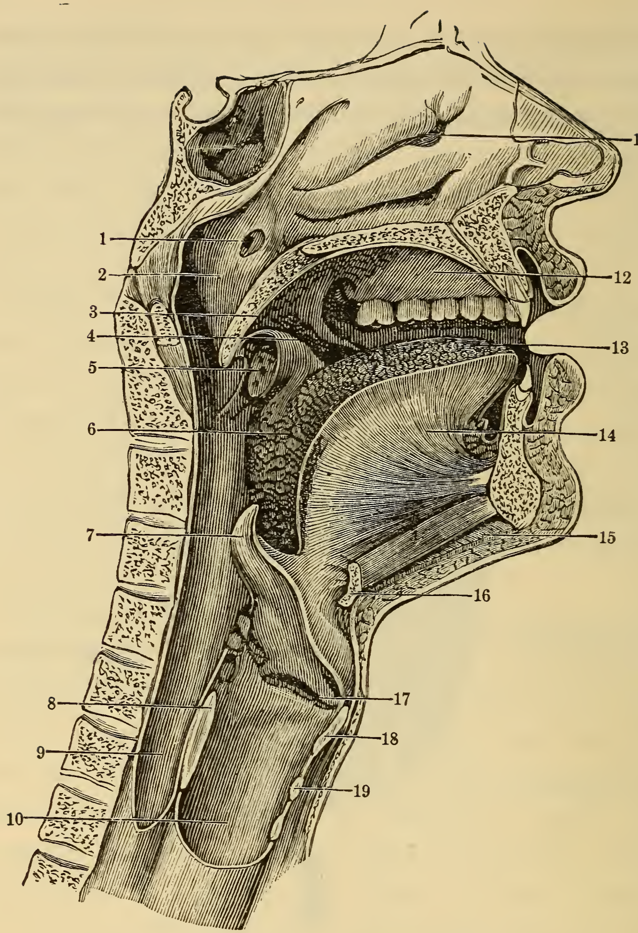

Fig. 24.—General View of the Mouth, Pharynx, etc.

1, canal from throat to middle ear; 2, back part of nose; 3, soft palate; 4, soft palate covering tonsil; 5, tonsil; 6, base of tongue; 7, epiglottis; 8, part of cartilage of larynx; 9, pharynx; 10, cavity of larynx; 11, nasal fossæ; 12, vault of the palate, or roof of mouth; 13, 14, tongue; 15, muscle beneath tongue; 16, hyoid bone; 17, interior of larynx; 18, 19, thyroid cartilage.

the nose is also closed, so that fluids cannot get into that cavity.

There is a cartilaginous body called the *epiglot'tis* (meaning "upon the glottis") which is placed behind the base of the tongue, and when the food is swallowed it covers the glottis, as the opening in the larnyx is called, and thus aids in preventing the mass from getting into the air-passages. When the muscles of the lower part of the œsophagus contract, they force the food into the stomach. The lower part of the œsophagus remains contracted for a while after the entrance of the food into the stomach, so as to prevent its return upward.

The Process of Digestion.—The first step of digestion is the taking of solid or liquid food into the mouth. Digestion in the mouth includes the action of the salivary glands, the teeth, etc., already described. Deglutition, or swallowing, is the next step, after which come, in immediate succession, digestion in the stomach and bowels.

When the food is hastily swallowed—and this is generally called "bolting the food"—the cutting and crushing action of the teeth does not take place, and the food passes into the stomach in a state unfitted for perfect digestion, so that dyspepsia or indigestion, as it is called, may result, especially if this neglect becomes a matter of habit. In the act of drinking, fluids are usually sucked into the mouth and swallowed without any action upon them in that cavity. They are acted upon in the stomach. When the lips are applied to a cup, the air is drawn inward by inspiring or breathing in, and the liquid flows into the mouth.

Digestion in the Stomach and Intestines.—When the food reaches the stomach it is subjected to entirely new action. Here it remains for a greater or less time according to its digestibility. The stomach and bowels of man are of such a length and arranged in such a way that all kinds of food taken into them can be digested. Flesh-eating animals do not require a long canal or a complicated stomach, as the food they eat is easily digested. Grass-eating animals require a long canal and plenty of room in the stomach for digestion, as the food is not easily digested. Some of these animals, therefore, have four stomachs.

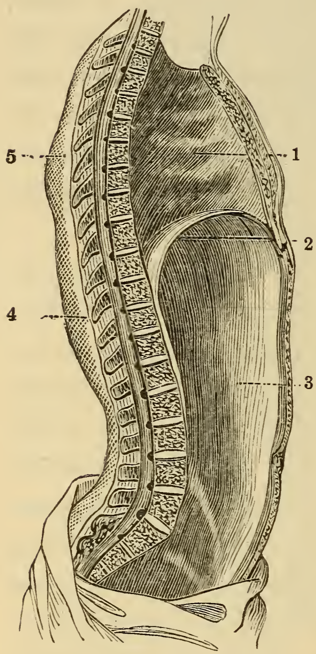

Fig. 25.—The Thorax and Abdomen.

1, thorax, or cavity for heart and lungs; 2, diaphragm; 3, abdomen; 4, spinal column; 5, spinal canal.

In man the stomach is the largest single part of the canal, and is in shape like the ordinary bagpipe. It lies across the upper part of the abdomen, and is separated from the chest, or thorax, in which the heart and lungs are placed, by a thick muscle, called the *di'aphragm* (meaning a partition) (Fig. 25), which covers the whole width of the floor of the chest.

The opening in the stomach at its left end (Fig. 26) is for the entrance of the œsophagus. It is opened and closed by muscles. The opening at the right side is the point at which the food passes into the intestine, or bowel, which here begins its course. The left end of the stomach is the *card′iac extremity* (meaning "near the heart"); the other, the *pylo′ric extremity* (from *pylorus*, "a jani-

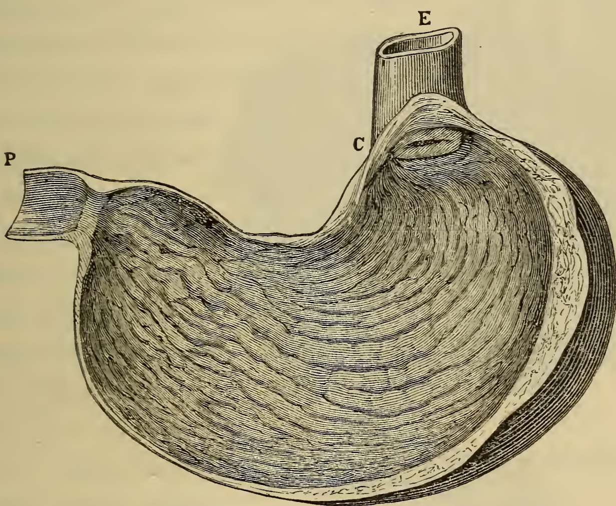

FIG. 26.—INTERIOR OF THE STOMACH.

P, pylorus, or right end of the stomach; E, œsophagus; C, cardiac orifice, at the left end of the stomach.

tor"), because a kind of valve is found here which, acting like a janitor or gatekeeper, will usually stop the food from passing into the intestine until it is properly prepared to do so. The stomach is lined by a membrane (Fig. 26) which pours out mucus, and is hence called a mucous membrane; and this is continuous from the inner edge of the lips through the whole tube or aliment′ary canal, as it is called. This mucus keeps the membrane always moist, and is the only fluid poured out when the stomach is empty.

When any article of food passes into the stomach a peculiar colorless fluid is poured into the interior of that organ, which is called the *gas'tric juice.* It is chiefly water, but contains an acid and a ferment to which the name *pep'sin* has been given. The internal surface of the stomach presents a network or honeycomb of very small ridges, in the spaces between which the mouths of little glands open. Very many blood-vessels enter these ridges and send numerous little branches or vessels around these glands. Many little glands are found in all parts of the stomach, but especially at the upper part. They pour out a thin fluid, and add to the moisture of the stomach. There is always fluid present, but the gastric juice, so called, is probably poured out in larger quantity in that part of the stomach lying next to the bowel, and only after food is taken. These glands (Fig. 28) are found more at the lower part of the organ.

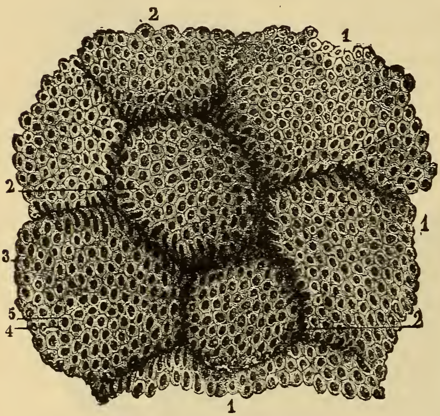

Fig. 27.

1, 2, 3, pits in mucous membrane of stomach; 4, 5, orifices of the glands.

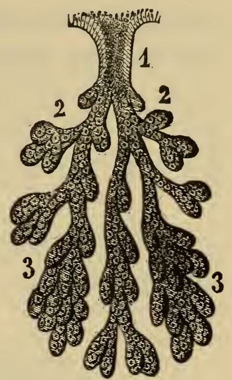

Fig. 28.—Gland from Pyloric Portion of Stomach (magnified).

1, duct or canal; 2, principal branches; 3, end portion.

The muscular coat of the stomach (Fig. 29) is outside the mucous one, but in contact with it. The contractions of the stomach, which produce the churning movement in digestion, are due to the presence of the muscular coat, which is made up of fibres running in different directions. Some of these fibres run the whole length of the stomach, some run around it, others cross it at an angle. The effect is to contract the stomach in every direction. Should all these fibres contract at the same time, the stomach would be emptied and the food expelled from it forcibly. One set of fibres, acting alone,

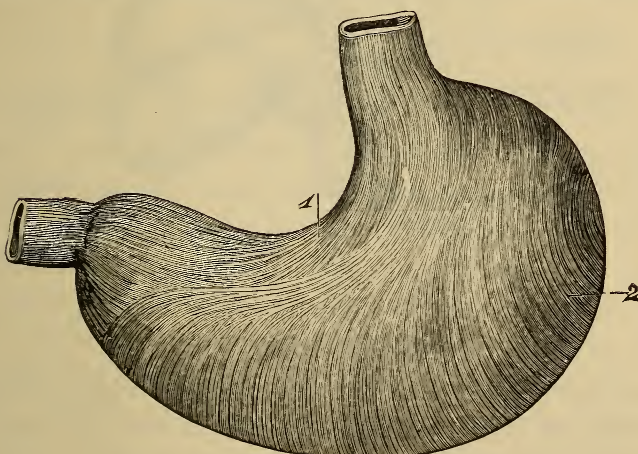

Fig. 29.—Muscular Fibres of the Stomach.

1, circular fibres; 2, oblique fibres.

contracts or shortens the stomach; another set presses on the contents of the stomach, and causes the food to pass from one end to the other. The oblique fibres when they contract change the shape of the stomach (Fig. 30), so that the organ is divided into two distinct portions.

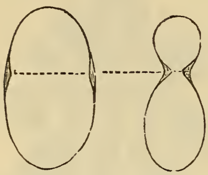

Fig. 30.—Showing Contraction of Muscles of the Stomach.

The outer coat of the stomach, the serous, is a delicate membrane, which is not concerned in digestion.

Stomachs of Other Animals.—In man the stomach is not as small as in the flesh-eating animal. In the herb-eating animal the stomach is very complicated. In the

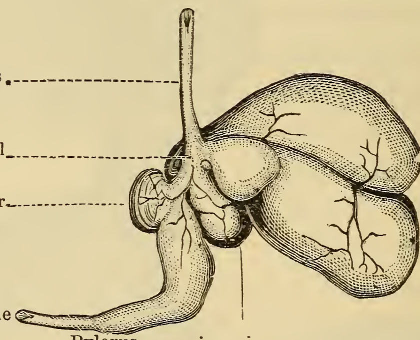

Fig. 31.—Stomachs of a Sheep (Outside View).

ox, for example, there are four distinct divisions, all of which are concerned in the process of digestion, but of which the fourth is the only one like the human stomach. Some of these animals have the power of returning the food from the second stomach to the mouth, to be *ru'minated*, as it is called, or chewed over again; and when it comes down again it passes directly into the third stomach without entering the first and second. The peculiar arrangement of a sheep's stomach is shown in Figs. 31, 32.

In *birds*, in which grain or seed is swallowed whole, a sac or bag called a crop (Fig. 33) exists, in which fluid is

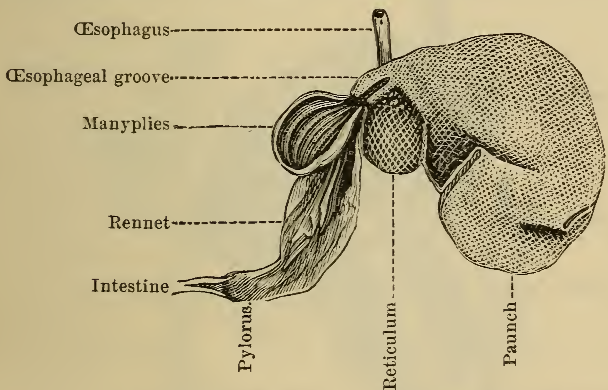

Fig. 32.—Stomachs of a Sheep (Inside View).

poured out to aid digestion. There is also another small cavity or second stomach, which leads into a third stomach or gizzard, a kind of paunch connected with the alimentary canal proper. This organ is made up of powerful muscles forming a thick sac with a small cavity, which may contain pebbles swallowed by the bird, that act like teeth and by their millstone action crush the food. In flesh-eating birds the gizzard is not so powerful, and the whole canal is much more simple, as the food does not require so much digestion. In some of them the stomach is merely a sac of muscles and membranes, and pours out a fluid which helps to digest the food.

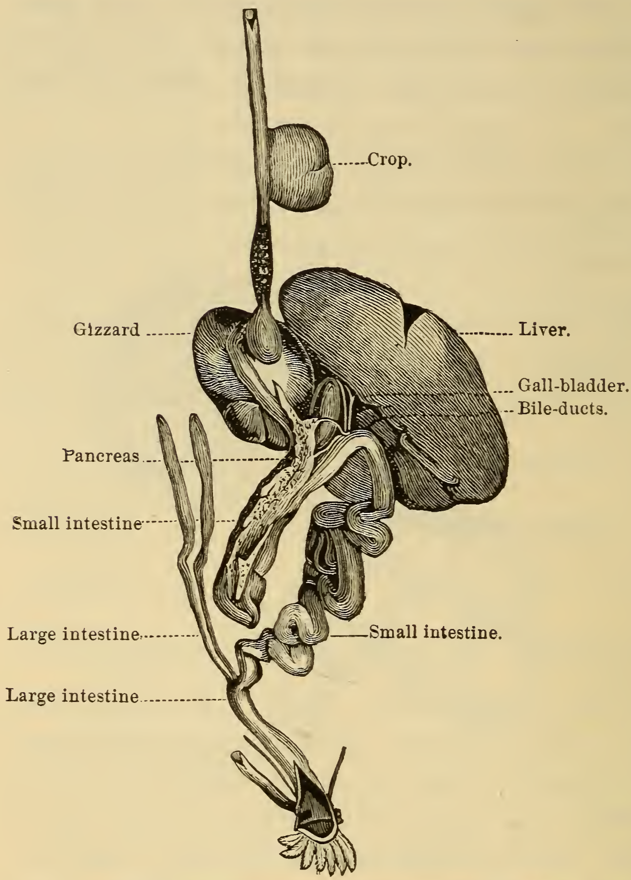

Fig. 33.—Digestive Organs of Domestic Fowl.

This is the more necessary as the animal does not possess any teeth for chewing, and the digestive organs are packed away in a small space so that its flight will not be interfered with.

In *reptiles*, a class of animals which is capable of abstaining from food for a long time, there is generally a large mouth, with teeth that form part of the jaw itself, or are inserted in sockets; or, like tortoises, their jaws are horny. The intestines are usually short.

Those *fishes* which feed on the blood and juices sucked from other animals have their mouth, teeth, and tongue arranged on the principle of the cupping apparatus of the

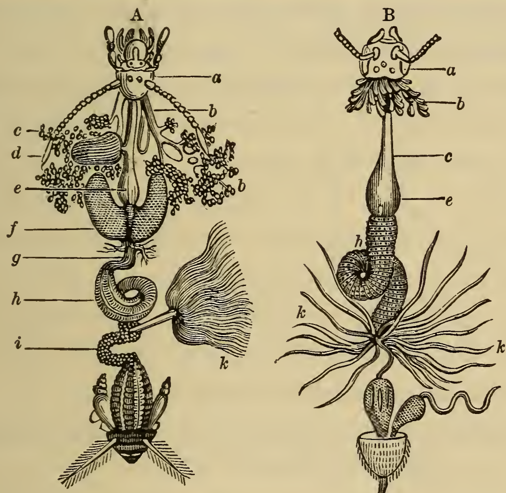

FIG. 34.—DIGESTIVE ORGANS OF INSECTS.

A, MOLE CRICKET: *a*, head and appendages; *b*, salivary glands; *c*, secreting granules of the same glands; *d*, feelers; *e*, cardiac part of stomach; *f*, accessory pouches of the stomach; *g*, middle part of stomach; *h*, pyloric part of stomach; *i*, intestines; *k*, canals representing liver.

B, BEE: *a*, head and mouth; *b*, salivary glands; *c*, œsophagus; *e*, crop; *h*, stomach; *k*, canals representing liver.

surgeon. In all the liver is large, and digestion is performed quite rapidly.

Some *insects* (Fig. 34) feed on the juices, others on the solid parts, of plants and animals. The grasshopper has a cutting arrangement to cut the food, in addition to feelers, a tongue, etc. In grass-eating insects the digestive organs are quite complicated. There are really three stomachs—a crop, gizzard, and stomach proper. The canal, including the intestines, is not straight, but generally winding, with enlargements and contractions at various points. In insects which live chiefly on animal food the canal is short, and in those which feed on vegetable substances the canal is longer. This we have already seen to be true of animals much higher in the

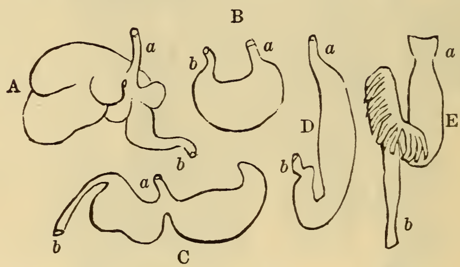

Fig. 35.—Stomachs of Various Animals.

A, sheep; B, hyæna; C, marmot; D, seal; E, salmon. *a*, cardiac opening of stomach; *b*, beginning of intestine.

scale. Such wonderful plans and systems are further indications of the wisdom and far-seeing knowledge of the Almighty.

The variety of forms of stomach peculiar to different types of animals is well shown in Fig. 35.

Action of the Stomach in Digestion.—When the food enters the stomach, that organ becomes gradually swollen, especially in its muscular coat, so as to occupy a much greater space in the abdomen, and rotates or turns partly upon itself. When too much food is taken into the stomach, it may press upward against the floor of the chest, so as to seem like a weight against it in breathing. The presence of food in the stomach causes the muscles of that organ to go on regularly contracting and relaxing, as muscles always will do when they are excited. The food thus gets thoroughly mixed with the fluids in the stomach by regular churning movements. When the diaphragm, the large muscle separating the chest from the abdomen (Figs. 25, 45), contracts, it also presses upon the food in the stomach.

Digestion in the stomach may therefore be said to include the churning motion of the organ and the mixing of the food with its fluids.

Changes in the Food in Digestion.—The soft, pulpy mass in the stomach is no longer the food proper, but food mixed with fluids from the salivary glands and the stomach. Saliva is probably poured into the stomach from the mouth during the whole time that the food is being digested in the stomach. If the food taken has been starchy, some of it has been changed into sugar in the mouth; but some of it that passed down into the stomach without being changed will be acted upon by the saliva in the stomach. Fatty matters are digested after they leave the stomach and pass into the intestine.

Albuminous, fibrinous, and other matters of the kind, such as those of which meat is composed, are digested in the stomach. All matters that are not digested, and are of no use to the body, pass down into the large intestine. Oily and fatty matters—and, as a rule, vegetable food—

are digested in the upper part of the bowel. Thick fluids, such as soups, may be acted upon in both the stomach and bowel.

Animal food is more digestible than vegetable. Bread, potatoes, and pastry are partly digested in the stomach and partly in the intestine. Thin liquids, such as water, alcoholic drinks, etc., as will be shown hereafter, are generally absorbed by the blood-vessels of the stomach at once, without being digested.

The *length of time* which food spends in the stomach in being digested is two to four hours, but longer than this in those who do not take the proper amount of exercise. Boiled rice only remains one hour; fried veal, about four hours and a half. While the food is in the stomach it is exposed to a temperature of at least 100° Fahr. The gastric juice, acids, heat, etc., all acting together, change the animal food into another form of albumen, called pep'tone or albu'minose, which is more easily absorbed than albumen. The active principle of the gastric juice, pepsin, is the ferment by means of which the changes in the food are effected.

Thin fluids, after being swallowed, enter the stomach without being changed in any way in the mouth, and are rapidly absorbed by the veins of the stomach without undergoing any other action, and by the veins of the small intestine. The veins into which they enter unite with other veins to go directly to the liver. After a short stay there this blood passes into the current of the blood to the heart, and so on all through the body. This is why the effect of alcohol is so soon felt when taken into the stomach, and why the liver becomes diseased in those who drink liquor to excess.

Digestibility of Food.—Substances are said to be easy of digestion if they are known to make but a short stay in the stomach; but some of these very articles may not be nourishing. It seems to be the rule that those articles of food which are most nourishing do not pass out of the stomach very rapidly. It seems as if that organ had the power or sense of choosing what is best for it. Milk probably disappears from the stomach very rapidly. It is said by one writer that an hour after it is swallowed there are scarcely any traces of it in the stomach; but milk is composed not only of sugar, water, and salts, all of which may be absorbed in that time, but it also has in it fatty matter, which is not so easily gotten rid of. Some writers say that five or six pounds of gastric juice are poured out into the stomach every day—ten or twelve pounds, according to others.

Over-exertion of any kind should be avoided soon after taking a full meal. It is well not to lie down soon after eating, or to take a long sleep at such a time, or to bend over a desk to study or write in such a way that the stomach will have its contents pressed upon too much. A short nap may be taken in a sitting position. The digestive powers of young persons are better than those of adults, considering the food which they are each capable of taking.

Some persons take little or no drink at meal-times. It is certainly wrong to wash down every portion of solid food with liquids, as is the habit of some. A small quantity of liquid may be taken, and after the gastric juice has ceased to act it may be excited to renewed action by a fresh supply of water. Some persons take a glass of pure water in the morning before breakfast. Exercise before breakfast disagrees with many weak stomachs.

Digestion in the Intestines.—The bowels or intestines are a continuous tube or canal leading directly from the

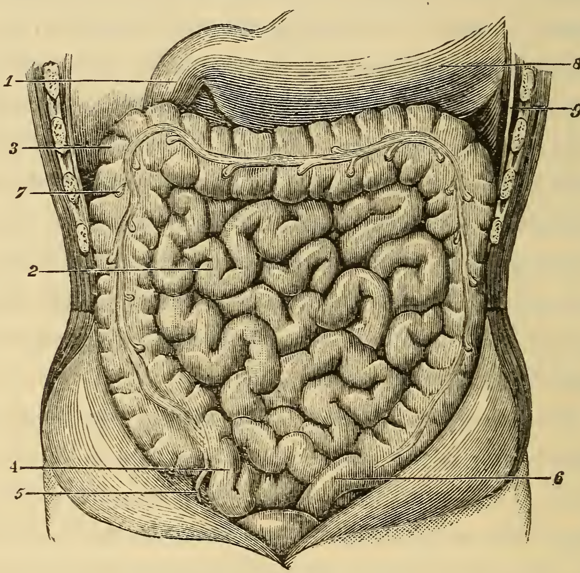

FIG. 36.—GENERAL VIEW OF THE INTESTINES.
1, 2, 4, small intestine; 3, 6, 7, large intestine; 5 appendix; 8, stomach; 9, diaphragm (cut).

stomach. They vary in length in different animals, and are usually divided into the small and large intestines. The small intestine (Fig. 36) is a narrow tube about twenty feet long, coiled upon itself. It is in this portion of the tube that intestinal digestion chiefly takes place.

The large intestine is intended rather as a receptacle for the useless and undigested portions of the food. The intestines have similar coats to the other parts of the

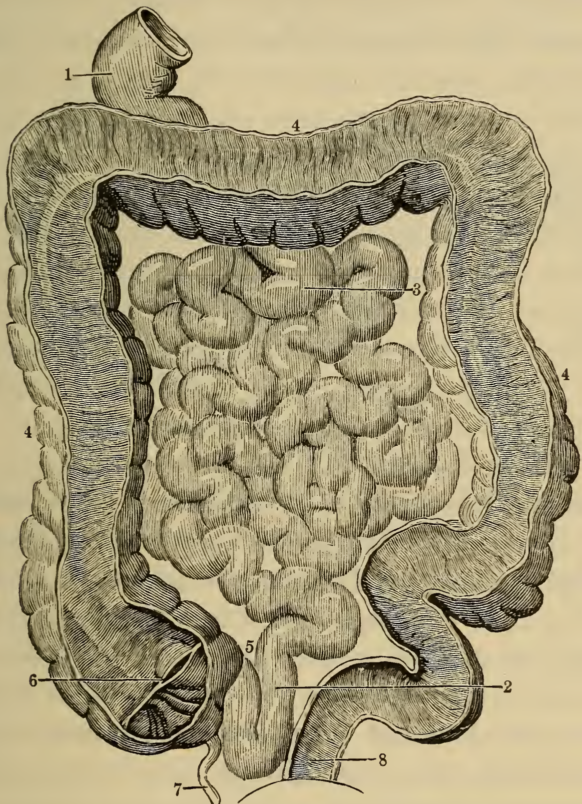

FIG. 37.—THE LARGE INTESTINE (OPENED).
1, 2, 3, small intestine, connecting with large intestine by a valve 6; 4, 5, 8, large intestine; 7, appendix.

canal, being lined with mucous membrane, which is covered by a muscular coat, and this again by a thin serous coat. The intestine has a worm-like movement of contraction and dilatation like that of the stomach, and this is excited by the presence of food.

Intestines of Other Animals.—The arrangement of the intestines in the lower animals differs from that of man. In the latter there is a small pouch connected with the intestine, called the *appen′dix,*(Fig. 23), of no known use whatever, but it seems to be left there to show that man is in some respects like the other animals in structure. In some animals it is so large as to be really a distinct intestine. In birds that eat grain or that feed on all kinds of food a portion of the intestine is double. In reptiles the intestines are short, and there is but little difference in size between the large and small intestines. In insects the intestinal canal is often more complicated than in some of the upper classes of animals.

Intes′tinal Juices.—In man the mucous membrane of the intestines is thrown into folds, and on this membrane is poured, from an immense number of little bodies or glands, a fluid called the *intes′tinal juice.* At a distance of four or five fingers' breadths from the pylorus, the opening which is at the right end of the stomach, two canals or tubes open into the intestine, which bring *bile* from the liver and gall-bladder, and a fluid called the *pancreat′ic juice* from an organ called the pan′creas, or abdominal sweetbread, as it is sometimes called, lying close to the stomach (Fig. 38). Both of these fluids aid in the digestion of the food in that portion of the intestine.

It has been estimated that at least twenty pounds of fluids useful in digestion are poured out in the twenty-four hours: Saliva, $3\frac{1}{2}$ pounds; bile, $3\frac{1}{2}$; gastric juice, 12; pancreatic juice, $\frac{1}{2}$ pound; and intestinal juice, $\frac{1}{2}$ pound.

When the valve between the stomach and intestine, which we have stated is called the *pylo'rus*, or gatekeeper, allows the food to pass, after digestion in the stomach has

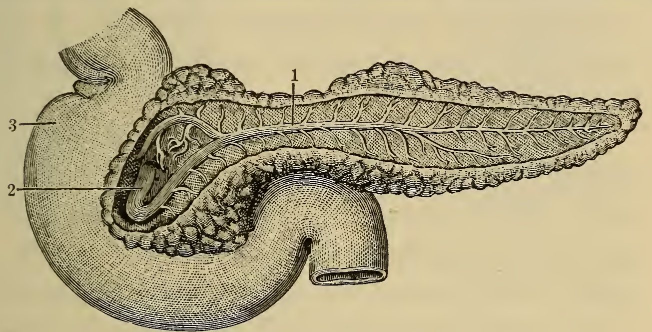

Fig. 38.—The Pancreas.
Divided, so as to show—1, pancreatic duct or canal; 2, canal emptying into the intestine 3.

taken place, the muscles of the stomach drive it out into the first part of the intestine. Here the food is mixed with the bile and pancreatic juice, and with the intestinal juice already referred to.

When the pancreatic fluid is mixed with the food the mixture looks like what the apothecary calls an emulsion, for an emulsion is nothing but an oily or fatty matter, with something else that keeps it well mixed, and it is more easily absorbed for useful purposes in the body. Besides this, the starchy parts of the food that were not changed into sugar in the mouth are here changed by the action of the pancreatic juice. This fluid also has some action on albuminous matters like that exerted by the gastric juice.

The *bile* is secreted by the liver, an organ lying under the diaphragm, above the stomach (Fig. 23); a very large organ, weighing three or four pounds and measuring ten or twelve inches in width. Only a small part of the bile formed by it and poured into the intestine is of use in digestion; the rest of it passes along with the refuse food. Bile is one of the chief agents in the digestion of fats.

There is a sac connected with the liver called the *gall-bladder* (Fig. 23), and this receives the bile from the liver. This is afterward poured both from the liver and gall-bladder into the intestine. While food is being digested in the stomach the bile from the gall-bladder, as if by a telegraphic signal from the stomach, begins to come down into the intestine, to be ready for its duty when the food arrives.

By the time the food has reached the large intestine all the matter that is likely to be of use to the body has been taken from it. Digestion proper may be said, therefore, to be almost ended with the small intestine. Nearly all the food taken into the mouth is digested in one form or another.

To sum up, we may briefly say that when *solid food* is taken it is disposed of as follows:

The starchy matters are converted in the mouth and stomach, by the action of the saliva, into sugar, and also by the pancreatic juice in the small intestine.

The fatty matters are chiefly digested in the small intestine by the pancreatic juice and bile together, being made into an emulsion for easy absorption.

Albuminous matters, such as meat, are acted upon by the fluids of the stomach.

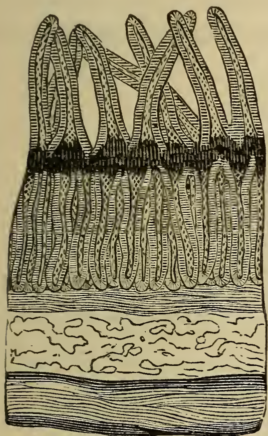

FIG. 39.—SECTION OF THE SMALL INTESTINE, AS SEEN UNDER THE MICROSCOPE, SHOWING THE VILLI.

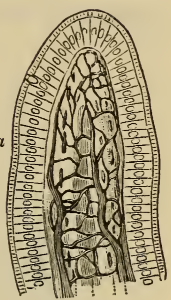

FIG. 40.—ONE OF THE VILLI OF THE INTESTINE, AS SEEN UNDER THE MICROSCOPE.

a, layer of cells; *b*, blood-vessels; *c*, commencement of vessel containing chyle.

How the Food is Absorbed.—The worm-like action of the intestines passes the food slowly onward from one portion to another. The mixture of intestinal fluids with food forms a milky fluid called *chyle* (pron. *kile,* from a Greek word meaning "juice"). In the folds of the mucous membrane of the intestine may be found a series of vessels which absorb this milky fluid and carry it to be emptied directly into the blood.

There are delicate elevations on the surface of the mucous membrane of the intestine which are called *villi,* so closely placed together as to give it the appearance of fine velvet. (Fig. 39 shows how these villi look when they are very largely magnified under the microscope.) In each villus is a network of small blood-vessels carrying the milky fluid just referred to, called chyle. When we examine one of these villi under the microscope, we find the appearance seen in Fig. 40. The cells on the outside

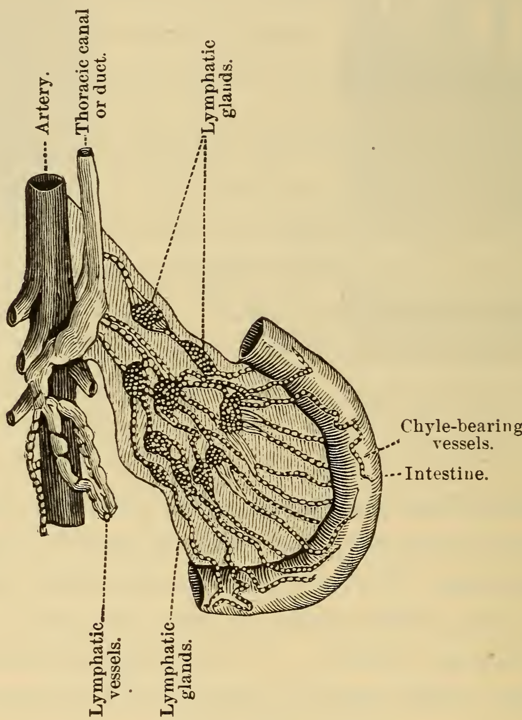

FIG. 41.—LACTEAL OR CHYLE-BEARING VESSELS OF THE INTESTINE.

of each villus come in contact with the food that has been already digested, and absorb it.

After entering the vessels which carry the chyle (sometimes also called the *lac'teals,* from a Latin word meaning "milk"), the chyle is emptied into a long canal which passes along the back part of the chest, in front of the spinal column, called the *thorac''ic canal* or *duct* (Figs. 41, 42). This carries the chyle up to the left side of the neck to empty it into one of the large

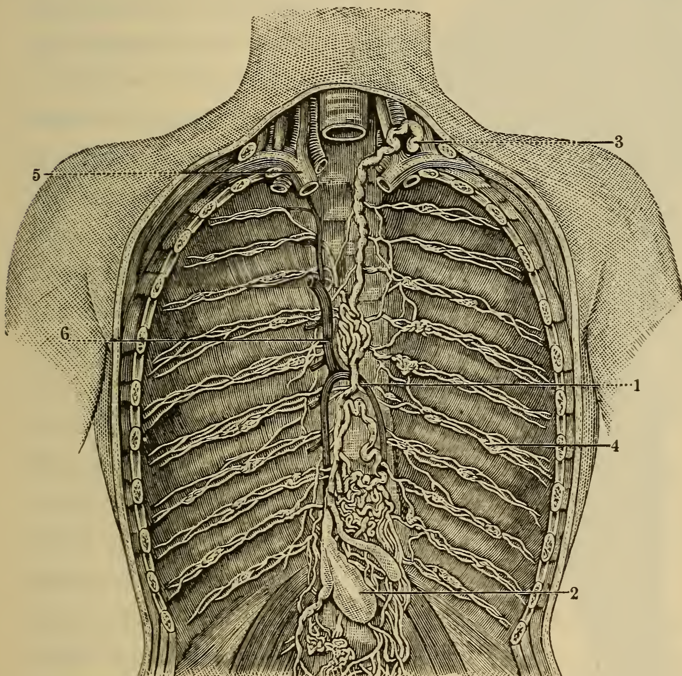

FIG. 42.—THORACIC DUCT AND CHYLE-BEARING VESSELS.

1, 2, thoracic duct; 3, termination in the vein; 4, lymphatic glands; 5, 6, veins of the right side.

blood-vessels in that region. On the way between the intestine and the thoracic canal (Fig. 41) it passes through a number of small bodies called *lymphat'ic glands* (Figs. 41, 42), which produce changes upon it to render it more like the blood with which it is to be mixed. When once mixed with the blood, it passes with that fluid to the heart.

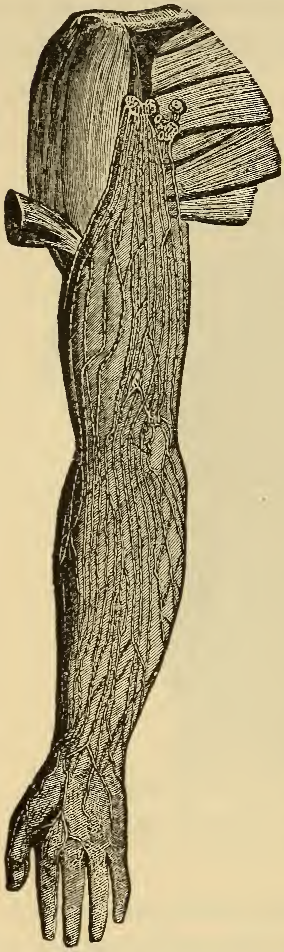

FIG. 43.—LYMPHATIC VESSELS ON THE SURFACE OF THE ARM.

To sum up, therefore, the action of absorption of *liquid food*, we may repeat that it is absorbed either, if very thin, through the blood-vessels of the stomach or intestine, passing directly to the liver, or by the lacteals and the thoracic duct to the veins of the neck. The chyle becomes more and more like the blood as it passes along with that fluid for the nourishment of the body. The chyle-bearing vessels absorb fatty matters which we have shown are made into an emulsion by the juices of the intestine, those albuminous matters which resulted from the action of the gastric juice on meats, and the portions of sugar which were changed from starchy matters.

Lymphat′ics.—There is another set of fine vessels in almost every part of the body which are busily engaged in absorbing the various materials collected from the wear and tear of the system. These vessels are called *lymphat'ics,* because they carry a very thin fluid, called *lymph,* which has no color and is carried by these vessels (Figs. 43, 44) to be emptied into the blood. These lymphatic vessels are very numerous, and run into one another like streams into a river, gradually forming vessels of considerable size, which finally unite and either empty into the thoracic duct, in front of and alongside the spinal column, or on the right side of the body into a large canal or tube called the right lymphatic trunk. Both of these empty the lymph into the current of blood. These vessels have projections called *valves,* which prevent the lymph from flowing backward.

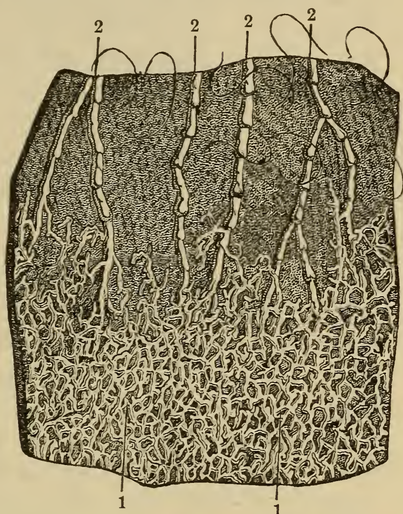

FIG. 44.—DEEP LYMPHATICS OF THE FINGER.

1, 1, deep network of lymphatic vessels of the skin; 2, 2, lymphatic trunks connected with these vessels.

This whole plan of vessels and glands is a system of drainage like that employed in some soils, in which the water drained from boggy lands forms channels, which unite to make larger streams, still increasing in size and occasionally expanding into pools, and at last pouring into a river or the ocean.

QUESTIONS.

Why does the body need food?

What is Digestion? Do vegetables have any digestion?

What kinds of articles are used as food?

Why is food of a simple kind, such as milk, the best?

What fluid in the body is the milk like?

Why are different salts, such as table-salt, etc., used as food?

Why is iron important as an article of diet?

In what form do we use starch for food? Sugar? Fats? Gums?

What is albumen? What are albuminoid matters?

Where do we find fibrin and casein?

What is the use of fat in the body?

Why do we mix the different articles for food?

What is nitrogen? What has it to do with the food?

Why is it important to eat a variety of articles of food?

What are some of the albuminous articles of food?

What portions of animals are used as food?

Why is very young meat not best for food?

What do we know about the meat of birds for food? Of fish?

What is milk composed of? What becomes of it when swallowed?

What is cream? Butter? Buttermilk? Cheese?

What do you know of eggs as articles of food?

What is bread? What effect has yeast upon it?

What are the different breads made from?

What are the effects of fruits? The best rule for eating them?

What is the effect of cooking upon the food?

What is the best fluid for drinking?

How much water is there in the body?

How much water should we drink in a day?

What kinds of water are used for drinking purposes?

What are the alcoholic drinks?

What is alcohol? Is it a food? Does it warm the body?

What organs are poisoned by alcohol?

What effect has tobacco? Opium? Coffee? Tea?

What do we know of the quantity of food to be taken?

How does very cold weather affect this?

What is said about the food of children? Of delicate persons? Of swallowing the food in a hurry?

What are hunger and thirst?

What are some of the principal rules to follow in eating?

What kind of digestion has the vegetable?

What kind have the lowest forms of animals?

What organs are contained in the mouth?

What are the temporary teeth? How many?

What are the permanent teeth? How many?

How are the teeth arranged in other animals for eating insects, fruit, grain, or flesh?

What are the salivary glands?

What effect has the saliva upon the food?

What is the arrangement of the pharynx and œsophagus?

What are the different steps in digestion?

What is the diaphragm? The gastric juice?

What are the ends of the stomach called?

What is the arrangement of muscles covering the stomach?

Describe the arrangement of the stomach in other animals, as the ox, the sheep, chickens, reptiles, fishes, and insects.

What takes place in the stomach when food is taken into it?

What kinds of food are digested in the stomach?

How long does food stay in the stomach to be digested?

What becomes of these fluids when swallowed?

How much gastric juice is poured out in the day?

Should liquids be taken at meal-times?

What are the two divisions of the intestines called?

How long is the small intestine?

What is the arrangement of the intestines in other animals?

What fluids are poured out into the intestine?

How many pounds of fluids are poured out for digestion every day?

What effect has the pancreatic juice on the food? The bile?

What becomes at last of all the food that has been digested?

What are the villi? The chyliferous vessels? The lacteals? The thoracic duct?

What are the lymphatics? What is their use?

RESPIRATION.

Why we Breathe.—It has now been shown in what way the fluids formed during digestion, and the lymph resulting from the wear and tear of the various parts of the body, pass into the blood; but these fluids and the blood with which they are mixed have to be made purer before they are fit to nourish the body. The blood, to be purified, must be brought near the air which we breathe into our lungs. The effect of air upon the blood as it passes through the lungs is to change it from dark red to a light red or vermilion color.

The oxygen of the air is added to the blood, and a gas called carbonic acid is driven off in the act of breathing. To show clearly to the eye that carbonic acid is given off from the lungs, fill a wineglass with lime-water, and breathe into it through a glass tube, when the carbonic acid of the breath will soon change the lime into chalk or carbonate of lime. If we then add a little vinegar to it, the carbonic acid will be set free, and be seen bubbling up.

There is also a certain amount of watery vapor discharged from the breath; for if we breathe upon a window-pane on a cold day it will become damp, and in the open air the breath will be seen as it comes from the mouth and nose in frosty weather.

During respiration oxygen and carbonic acid pass through the delicate membrane of the blood-vessels of the lungs. Before the blood reaches the lungs it is called *ve'nous blood*, because it flows through the veins and is of a dark bluish-red color. After it has received oxygen in the lungs the color is changed to a bright red or vermilion, and the blood is then called *arte'rial blood*, because it is carried in the arteries.

Venous blood must be changed, because it is an impure fluid containing matters that have already served for the support of life in various parts of the body. Breathing cannot be wholly stopped for more than a few moments without causing death.

Respiration includes only what takes place during the passing of the blood through the lungs, for when the purer blood leaves the lungs it is studied under the head of the Circulation (p. 117).

The Chest and its Contents.—The chest is a conical bony cage (Fig. 2), covered on the outside and lined on the inside with muscles, and separated from the abdo'men by a large muscle called the *di'aphragm* (Fig. 45), which forms the floor of the chest and separates it from the abdomen.

The chest is made up of a portion of the spinal column at the back part and ribs on each side. Two large marble-blue organs, called the *lungs*, with the heart, fill the whole cavity of the chest (Fig. 45, C, D, E, F). When once filled with air the lungs will always float in water, as may be shown with a calf's lung removed from the animal after death.

The ribs are made very movable, so that they can rise and fall, and in this way raise and lower the chest during the act of breathing. Muscles pass between the ribs, and by their action upon them assist in respiration. The most important muscle is the diaphragm (Fig. 45. G), which is at the bottom of the chest, and moves whenever we breathe. All the muscles of the chest and abdomen take part in the act of breathing.

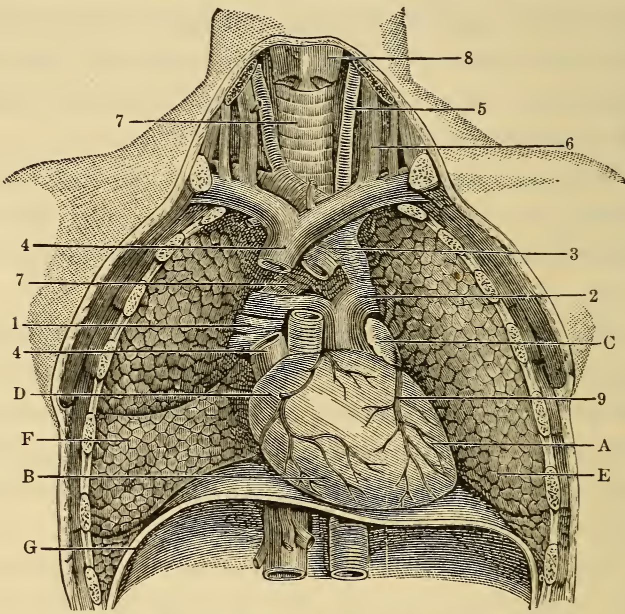

FIG. 45.—LUNGS, HEART, AND DIAPHRAGM IN POSITION.

1, pulmonary vein; 2, pulmonary artery; 3, main artery from heart; 4, vein; 5, carotid artery; 6, jugular vein; 7, windpipe; 8, larynx; 9, coronary artery; A, B, C, D, heart; E, F, lungs; G, diaphragm.

The Lungs.—In the lungs there are thousands of very small blood-vessels, and these are so arranged that each of them is completely surrounded by air. A very thin membrane, called the *pleu'ra,* lines the interior of the chest, and then covers the lungs and heart. It pours out a fluid which keeps it always moist. In very little children the lungs are pale red, but they get darker by age, and in old persons are a livid blue. When we breathe the air into our lungs we bring it near the warm blood

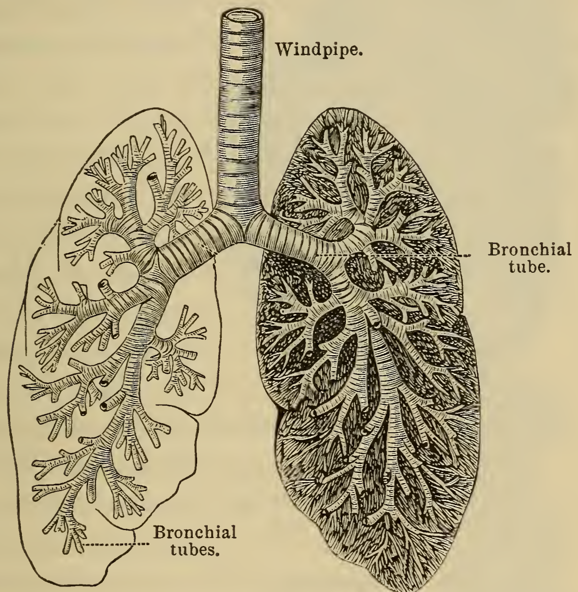

Fig. 46.—The Lungs and Bronchial Tubes (the lung-structure on one side being supposed to be removed).

that is passing through the blood-vessels in those organs, so that it does not chill their delicate structure.

The air after it enters the mouth passes along the throat into the *lar'ynx* (Fig. 45), which will hereafter be described as the true organ of voice; thence into the windpipe or *trache'a* (Figs. 45, 46), which divides into two large tubes or canals called the *bronch'ial tubes* (Fig. 46)

One of these tubes enters each lung, and divides and subdivides into a large number of very small tubes, which go to every part of the lung (Fig. 46), and end at last in little closed cavities called *air-cells* (Fig. 47). Around these cells are many very small blood-vessels.

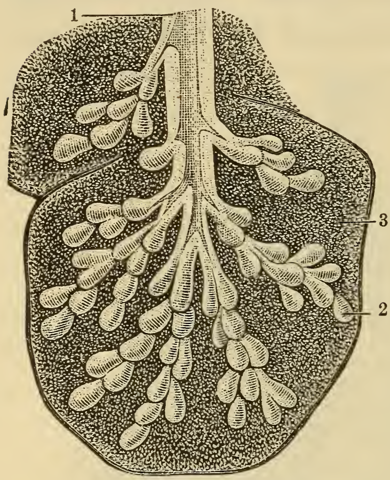

FIG. 47.—A SMALL PORTION OF THE LUNG (greatly magnified).

1, small bronchial tube; 2, termination in air-cell; 3, tissue of the lung.

The air we breathe does not get beyond the air-cells (Fig. 47) into the lung itself. These air-cells swell up after we take a full breath, and as long as we live they never get emptied of the air. The air-passages are lined by a mucous membrane, and a fluid called mucus is poured out to keep the air-tubes moist.

The Act of Breathing.—The terms *in'spiration* (or "breathing in") and *ex'piration* (or "breathing out") are applied to the filling and emptying of the lungs in the act of breathing. These acts are caused by the raising and lowering of the chest by muscles, especially those moving the ribs. When the chest contracts expiration occurs, and the air is driven out of the lungs through the mouth and nose. When we enlarge the chest by inspiration, or breathing in, we take in a large quantity of air to fill the lungs. The process of respiration is not under the control of the will; it goes on as long as life lasts. After breathing out, no matter what we are doing, whether talking, eating, sleeping, or reading, we have to breathe in, and then breathe out, and so on.

If we take a pair of bellows, we can imagine the nozzle to be the windpipe, the flexible leather uniting the boards the diaphragm, the boards themselves the ribs, and the hinges the place at which the ribs are fastened to the spinal column. When we separate the boards of the bellows, it is just as if we were enlarging the chest and raising the ribs to fill that cavity. The air rushes into the nozzle as it would into the windpipe, and the bellows is emptied as we empty the lungs in breathing out. In expiration, or breathing out, the lungs empty themselves gradually by their own elasticity.

Fig. 48. — Gentle and Forced Respiration (the latter shown in the dotted line).

We go on breathing without thinking or knowing that we are doing it; and this is because the diaphragm is being raised and lowered all the time without calling other muscles into active play. When the diaphragm is lowered in the act of drawing in the breath, the stomach and intestines are pressed on; in breathing out the diaphragm is raised, and the stomach and intestines return to their natural position. This explains why the abdomen seems to rise and fall during respiration. This is the easiest form of breathing; that is, by the diaphragm and muscles of the abdomen. Such easy respiration is seen in those who are sleeping. In the deeper and more active forms of breathing, such as that occurring under excitement, a large number of other muscles are called into exercise, such as those of the chest. (In Fig. 48 we can notice the difference between the easy and the forced forms of respiration.)

Number of Respirations.—As a general rule, the number of respirations is eighteen in a minute; that is to say, in each respiration the person breathes in and breathes out, and then a very small period of rest follows. Of course during exercise and motion the number of respirations is increased. In very young children the number is much greater than in the adult. A young baby will breathe at least forty times a minute; a child of five years of age, about twenty-five; a grown person, about eighteen per minute.

When we breathe rapidly or forcibly we call into use the muscles of the chest, and even those which are attached to the neck or the arm, so as to enlarge the cavity of the chest. Woman breathes more with the chest, even in gentle, easy respiration, than man. Her mode of dress should not be such as to press upon the walls of the chest or to interfere with the free motion of the ribs.

Sounds of the Chest.—In placing the ear over the chest a gentle sound is heard, caused by the air passing into the air-cells. This sound, as well as the louder and rougher sound caused by the passage of air along the tubes, is altered by disease of those parts; and this is why the physician applies his ear over the chest when a person has heart or lung trouble. He strikes over the chest with his finger, and if the sound is clear he knows that he is striking over a cavity filled with air; but if the cells do not contain air, and have become obstructed from any cause, the sound will be dull and obscure.

Capacity of the Lungs.—When air enters the air-cells it is not wholly driven out in breathing; a certain quantity always remains behind. It is hardly correct, therefore, to say that we empty the lungs in the act of breathing. The entire air in the lungs is thoroughly renewed about once in a minute. In easy respiration the whole amount of the breathing capacity of the lungs is not called into play. The quantity of air breathed every minute is about ten pints. This gives an idea of the immense quantity breathed in the course of twenty-four hours.

The Air-Cells.—The smallest bronchial tubes—cap′il-lary tubes they are called, because they are almost like hairs in size—are so small that from thirty to fifty of them measure only an inch, and it takes from seventy to two hundred air-cells to make an inch. An immense number of small, delicate blood-vessels covers the walls of the air-cells and the spaces between the air-cells; and here the change from venous blood to arterial blood takes place.

The Air we Breathe.—Pure atmospheric air is composed of two gaseous substances called nitrogen and oxygen. There is, in round terms, one part of oxygen to four of nitrogen. Besides the gases the air always has in it a little watery vapor and a very small quantity of carbonic acid. Oxygen alone would be too stimulating, and respiration would be at such high pressure that death would soon occur. When the air is examined after it has been breathed out of the lungs, it is found to contain a much smaller amount of oxygen than when it was inhaled, and a much larger quantity of carbonic acid. This shows that oxygen has been absorbed into the lungs and carbonic acid given off from them.

It will be seen hereafter that the blood contains numerous little structures called *corp'uscles* (signifying "little bodies," from a Latin word meaning "a body"), and these can only be seen with a microscope. These are the parts of the blood that are acted upon by the oxygen that is taken into the lungs every time we breathe.

Some Ordinary Breathing Acts.—Many things we do in every-day life are part of the act of respiration or breathing. When we speak or sing or cough or sneeze or laugh or smell or sob or spit or yawn or snore, we are using our breathing organs in some way or other.

When we sigh, it is often because the blood is not receiving enough pure air into the lungs, and the poor venous blood does not become properly changed into the richer arterial blood. A long sigh or series of sighs will supply the amount of air necessary to give to the blood the oxygen it needs.

When we cough, we use the muscles violently that assist in breathing out, and at the same time we contract the muscles of the bronchial tubes, so as to drive out anything, such as mucus, that is there. When we laugh, we make the muscles used in breathing act rapidly, and at the same time we use the voice and the muscles of expression of the face. Panting is a series of short, quick inspirations and expirations, and has for its object the rapid renewal of air in the lungs in cases in which the circulation of the blood is too rapid or where an extra supply of fresh air is required. Smelling is a series of short inspirations while the mouth is shut, so that the whole effect of the odor may be made upon the inside of the nose alone.

How Breathing is sometimes Interfered with.—We have already said that the danger to life is great and immediate if the breathing be checked for a few moments. This may occur from drowning, from hanging, from anything pressing on the chest too heavily, etc.; but, whatever the cause may be, the effect is always the same: the venous blood is not changed into arterial blood, the proper amount of oxygen not being breathed in. If any one is placed where there is no pure air or not enough of it, or where there is some other kind of matter in the air, such as burning gas, which the lungs cannot breathe, then the venous blood cannot be made purer and the person will die. Air that has once been breathed is not fit to be breathed again, for it is no longer pure.

If too many persons are crowded together in a room, there will be so much carbonic acid breathed out from all their lungs and impure matter given off from their bodies that the room will soon be unfit to stay in, for we cannot breathe carbonic acid gas. They will soon begin to be restless and yawny, with perhaps headache, all due to the bad air they are breathing.

In a war between the English and the people of a portion of India in the eighteenth century, one hundred and forty-six Englishmen were taken prisoners and shut up in a room only twenty feet square, to which but little light and air were admitted, and the heat was intense. The next morning, after only eight hours, one hundred and twenty-three were found dead.

Hygiene of the Respiration.—We have seen how necessary it is that the air of rooms occupied at the same time by a number of persons should be properly changed and kept pure. Schools, concert-rooms, churches, hospitals, etc. should have their doors and windows and chimneys arranged with this view. The first and most important object is to give an outlet to the impure air, which, as it becomes warmer, will rise, and an inlet to the pure air from outside. Cold air is not any purer than warm. It is not necessary to create a strong draught of air: a gentle current is all that is required. One of the best modes of ventilating a room is the open fireplace, which makes a draught up the chimney, and thus carries off impure matters that are in the air of the room.

Where many persons are together in a room, and no proper outlet is offered through windows or doors for the escape of impure matters from it, the place is said to be badly *ventilated*. If a long stay in an atmosphere breathed by healthy persons has such bad effects, how much more serious it becomes if we have to breathe air that is full of impurities from the lungs or bodies of those affected with disease! Such impurities are not only unfit to be rebreathed, but they may give rise to serious diseases.

The rooms occupied by both sick and well should be properly ventilated by windows that will admit light and air during the day and keep the air pure at night. If fires be employed in sleeping-rooms, there must be sufficient outlets for the escape of the overheated air. Openings at the top will allow hurtful gases to escape, and fresh air should be admitted from without. The impure air at the bottom of the room should be carried off, by shafts into the flues or chimneys, into the current passing upward and outward to the external air.

The practice of tight-lacing interferes greatly with natural breathing. It presses upon the ribs so as to change the whole shape of the chest, and does not allow the ribs to rise and fall as they should do in the act of breathing. It does not allow the lungs to move freely in the chest. It presses upon the stomach and liver, so that they cannot properly attend to their duties. The healthy lungs cannot be thus checked in their movements, nor can the air be prevented from entering them in proper quantity, without serious consequences. The lower portion of the chest is naturally the largest (as seen in Figs. 2 and 45), and well adapted for the capacity of the lungs in breathing, but tight-lacing makes this the narrowest part of the chest.

In breathing, the air should pass in and out through the nose, not through the mouth, and at night the mouth should be kept closed. Children and grown persons should stand or sit in such a way that the chest is not cramped, so that the lungs will act to their full capacity and respiration go on perfectly.

The breathing air is sometimes poisoned by the bad air or gases from sewers and drains, and from some factories, and disease, such as typhoid fever or diphtheria, arises from such causes. Many persons work for a living in the kind of occupation that may some time or other injure their lungs. Those who work on steel or emery may breathe the very fine particles into their lungs. Miners may breathe a very fine dust from the mines; those working in paper-manufactories may inhale the arsenic used in making it; or workers in white-lead works may breathe the fumes of the white-lead.

Action of Alcohol upon the Respiration.—This poison has the effect of interfering with the change of venous into arterial blood. As alcohol has been shown to irritate and excite the part into which it is introduced, its passage through the thin walls of the air-cells injures such delicate structures, producing inflammation of the lungs and a tendency to severe cold, pleurisy, etc. Alcohol changes the shape of the red corpuscles of the blood, causing them to shrink up and to be wrinkled and irregular, with notching of their edges. Habitual drinking of weak alcoholic liquors thins the blood, so that it escapes too easily from the vessels and appears near the surface of the body, giving the skin a swollen or bluish hue; or if strong drink be habitually indulged in, the blood may clot and clog up the smaller vessels or the heart itself, and cause instant death.

The effect of alcohol on the lungs themselves is soon visible. The blood-vessels are often paralyzed by this poison, and death results from such a condition. Even persons who seem capable for a while of taking alcoholic liquors in moderation without apparent danger may suddenly be seized with disease of the lungs attended with cough and pain, and rapid consumption may follow.

Action of Tobacco on the Respiration.—Smoking of pipes or cigars passes the poisonous vapor directly into the lungs, and thence to all parts of the body. Not only is the nicotine of the tobacco taken in this way, but another active poison is developed in it by smoking; and this is called carbonic oxide, and is much more poisonous than carbonic acid, producing headache, sleepiness, sick stomach, and irregular beating of the heart. Tobacco-smoking also injures the red corpuscles of the blood.

Summary.—We may briefly sum up what we know of the respiration in man: The air around us loses some of its oxygen, but gains carbonic acid from our lungs. The blood changes its color from its contact with oxygen. The blood in the lungs loses some of its carbonic acid. The oxygen of the inspired air passes directly through the coats of the vessels of the lungs. Watery vapor is also discharged from the lungs.

Respiration in Other Animals.—Respiration in other animals is like that of man, so far as the passage of gases to and from the lungs is concerned, oxygen being taken in and carbonic acid given off. In the lowest forms of animal life, however, there are no lungs, the whole outside of the body being so thin as to allow the air to enter it, and thus to act upon the fluids contained within.

In birds the lungs are quite small and attached to the chest. A large part of the chest and also of the abdomen is occupied by air-cells, with large openings communicating with the lungs (Fig. 49). In some birds there are cells or spaces in the bones for the air, the object being to make the body so light that the bird will fly more easily; and it can fly and sing without having to take its breath all the time. Birds which fly most rapidly and rise to the greatest heights—the eagle, for example—have a very large number of these bony cells.

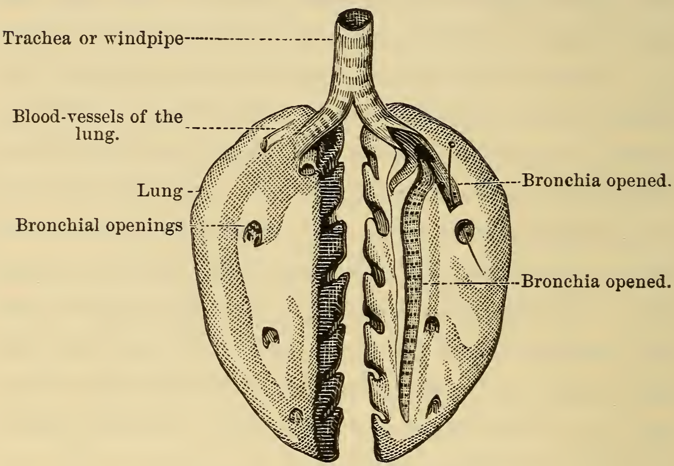

Fig. 49.—Lungs of a Bird.

Respiration in fishes is performed by what are called gills, which are membranes largely supplied with blood, placed behind the head on each side, with movable gill-cover. Generally there are four gills on each side. The fish breathes the air that is in the water in which it swims. The water passes into the throat, and then through the openings of the gills. There is more oxygen in water than in the air. Some fish, however, do not get enough oxygen from the water, and this is why we sometimes see fish rising to the surface of the water so as to get a larger supply.

Reptiles do not have strong breathing powers; some have lungs; some early in life have gills; others have both lungs and gills, so that they can live both on land and in water. Some of them have the whole surface of the body arranged for the passing in and out of gases through the skin. The lungs of reptiles receive air that is swallowed rather than breathed.

In insects, respiration is usually effected through the

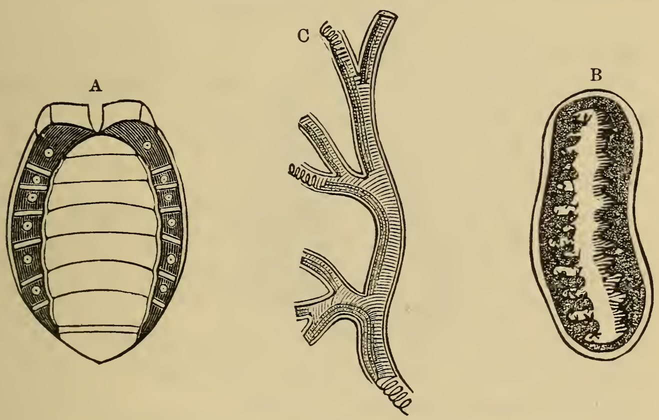

Fig. 50.—Respiration in Insects illustrated.

A, breathing orifices of water-beetle; B, a single opening, greatly enlarged C, air-tube.

exterior of the body. The air enters through openings (Fig. 50) which are the ends of air-tubes and convey the air to all parts of the system. In all cases, however, there is the same kind of changing of gases in animals generally that has been described in the respiration of man.

Respiration in the Vegetable.—Vegetables under the influence of light absorb carbonic acid and give off oxygen, the carbon becoming a part of the plant itself. At night oxygen is absorbed and carbonic acid gotten rid of by them, so that plants are not safe companions in a sleeping-room. Portions of the plant which are not green, the flowers especially, absorb oxygen and give off carbonic acid in the light of the sun or in the shade.

QUESTIONS.

What is the object of breathing?

What gas is given to the blood in the lungs? What gas is given off? How is the blood changed in the lungs?

What organs are contained in the chest?

Describe the diaphragm. The lungs.

What does the air pass through on its way to the lungs?

What are the air-cells and their uses?

What do you mean by inspiration or expiration?

What is the easiest form of respiration?

How many acts of respiration are there in a minute?

What sounds do we hear in listening to the chest?

How much air is breathed in a minute?

How large are the smallest air-tubes and air-cells?

What is the air we breathe made up of?

What are the acts of coughing, laughing, and smelling?

What is the effect of crowding or of breathing impure air?

What are the best rules for ventilating rooms?

What is the effect of tight-lacing?

What effects have occupations on the lungs?

What effect has alcohol on the respiration?

What effect has tobacco on the organs of respiration?

Sum up what we know about the process of respiration.

How do birds breathe? Fishes? Reptiles? Insects? Vegetables?

CIRCULATION OF THE BLOOD.

The Circulation Defined.—We must now study the manner in which the blood is sent to the various organs. The purified blood, after leaving the lungs, passes di-

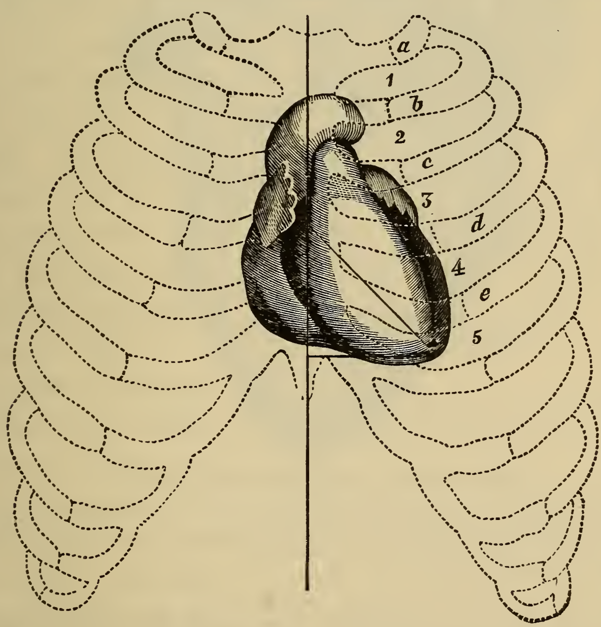

FIG. 51.—THE HEART IN ITS NATURAL POSITION IN THE CHEST.

a, *b*, *c*, *d*, *e*, ribs; 1, 2, 3, 4, 5, spaces between the ribs covered with muscles. (The vertical line represents the middle line of the body.)

rectly to the left side of the heart. The heart sends the blood out upon its travels, to receive it once more after it has gone its rounds and performed its duty. The process is called the Circulation, because the passage of blood all through the body and back to the heart through the blood-vessels is like a movement in a circle. The

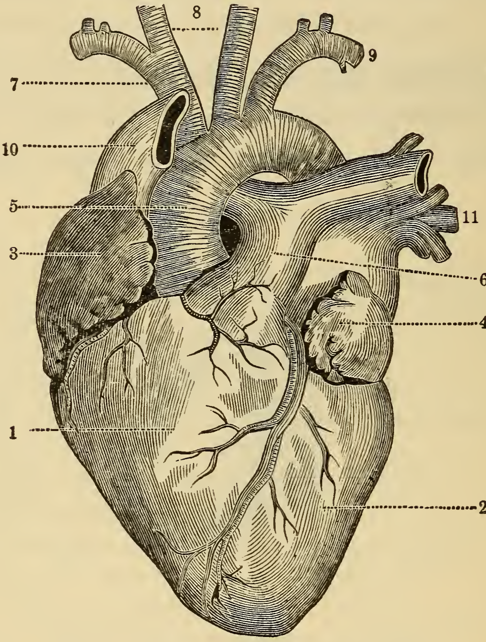

Fig. 52.—The Heart, Exterior View.

1, right ventricle; 2, left ventricle; 3, right auricle; 4, left auricle; 5, aorta; 6, pulmonary artery; 7, 8, 9, large arteries branching off from aorta; 10, vena cava; 11, pulmonary veins.

discovery of the circulation was made by a physician named William Harvey, of London, England, early in the seventeenth century.

The Heart.—The heart (Fig. 52) is a muscular organ, in shape somewhat like a cone, and lies in the middle and front part of the chest, a little to the left (Fig. 51), between the lungs (Fig. 45). It weighs usually about ten or twelve ounces, being, it is said, about the size of the fist, although this is an uncertain measurement. It is five inches long, three and a half wide, and two and a half thick. It is lined by a thin membrane like the pleura, which covers the lungs, and is covered by another of the same kind.

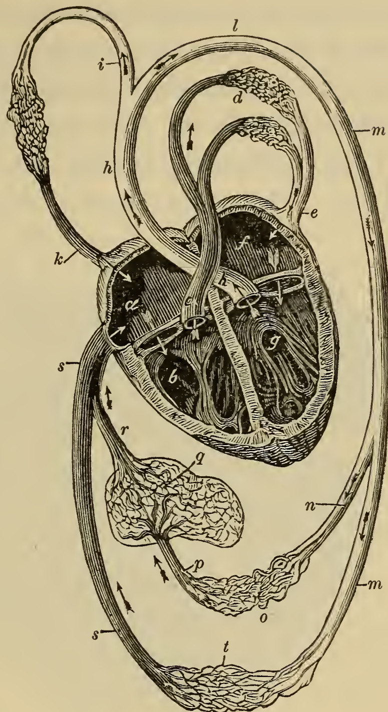

Fig. 53.—The Heart and its Cavities. (Showing lesser and greater circulations.)

a, right auricle; *b*, right ventricle, communicating through opening; *c*, pulmonary artery with branches to lungs; *d*, capillaries of lesser circulation; *e*, pulmonary veins; *f*, left auricle; *g*, left ventricle, communicating through opening; *h*, aorta; *i*, arteries; *k*, vena cava, bringing blood from upper portions of body to right auricle; *l*, *m*, aorta; *n*, *o*, blood-vessels of stomach and intestines; *p*, portal system; *q*, portal system in liver; *r*, veins of liver; *s*, vena cava, bringing blood to right auricle from abdomen and lower portions of body; *t*, capillaries of greater circulation.

Cavities of the Heart.—The heart consists of four cavities, two of which receive the blood and two push it forward. The right side—or right heart, as it might be called—receives the dark venous blood from the body, and sends it to the lungs to be changed into red arterial blood. The left side, or left heart, receives the blood from the lungs, and sends it out everywhere through the body.

Each side has two cavities, called an *aur'icle* (meaning "a small ear") and a *ven'tricle* ("a little stomach") (Figs. 52–55). The blood cannot go from the right side of the heart to the left without going through the lungs. The right auricle receives the blood, and sends it into the right ventricle, which forwards it to the lungs (Fig. 53). The left auricle receives the blood from the lungs, and the left ventricle pushes it forward into large vessels called *art'eries*, which send it all through the body.

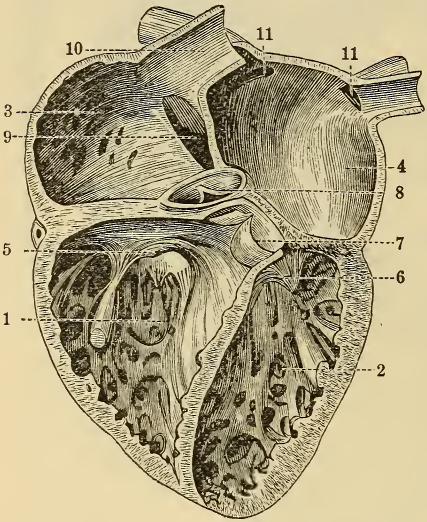

FIG. 54.—INTERIOR OF THE HEART.

1, right ventricle; 2, left ventricle; 3, right auricle; 4, left auricle; 5, opening between right auricle and ventricle—tricuspid valve; 6, opening between left auricle and ventricle; 7, pulmonary artery and semilunar valves; 8, origin of the aorta with its valves; 9, 10, opening of venæ cavæ into the heart; 11, openings of pulmonary veins.

The left side of the heart, having more work to do in sending the blood through the whole body, has much thicker muscular walls than the right side. The walls of the ventricles on both sides are thicker than those of the auricles for the same reason.

The Greater and Lesser Circulations.—There are two kinds of circulation—one from the right side of the heart, through the lungs to the left side, the *lesser or pulmon'ic circulation,* because it goes through the lungs (from the Latin word *pulmo,* meaning a "lung"). The other circulation is that formed by the blood passing all through the

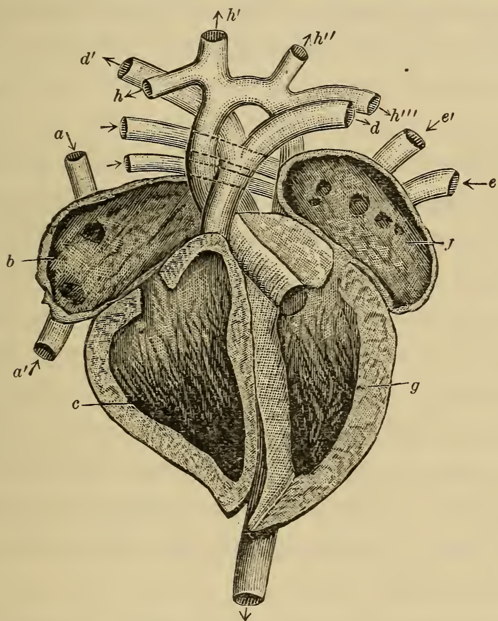

FIG. 55.—GENERAL VIEW OF THE HEART AND GREAT VESSELS PROCEEDING FROM IT.

a, a', venæ cavæ; *b*, right auricle; *c*, right ventricle; *d, d'*, pulmonary arteries; *e, e'*, pulmonary veins; *f*, left auricle; *g*, left ventricle; *h, h', h'', h'''*, main arteries branching off from the aorta.

body from the left side of the heart, through the arteries and back by the veins, to the right side of the heart, and is called the *greater* or *system'ic circulation,* because it goes all through the system (Fig. 53).

Valves of the Heart (Fig. 54).—The opening between the right auricle and right ventricle is guarded by a valve called, from its shape, the *tricusp'id valve* (because it has three cusps or points). That between the left auricle and left ventricle is the *mi'tral valve,* because it is thought to look like a bishop's mitre. When these valves are closed they prevent the blood from flowing backward. There are valves shaped like a half moon, called *semilu'nar,* at the mouth of the pulmonary artery (Figs. 54, 55)—a vessel which carries the blood from the right ventricle to the lungs—and at the origin of the aor'ta (Figs. 52, 54), the main artery of the body, from the left ventricle.

Movements of the Heart.—The movements of the heart occur in regular succession. The two auricles contract and dilate at the same time, and so do the two ventricles soon afterward. After these movements the heart takes a short rest. The beat of the heart may be felt by placing a finger between the fifth and sixth ribs, near the breast-bone. When the heart contracts it alters its shape, and has a motion against the walls of the chest called its *impulse.*

Movements of the heart are not under the control of the will. We cannot stop the heart from beating. When the heart contracts it sends out all the blood it contains, and when it dilates it fills again with that fluid.

The beating of the heart goes on through a long series of years without interruption. In some animals, as the turtle, some serpents, and the alligator, the heart will continue to beat for many hours, or even days, after its removal from the body.

Sounds of the Heart.—When the ear is applied over the heart, two sounds are heard—one, louder than the other, over the lower part of the heart; the other over the upper part. The words *lupp, dupp,* express the sounds heard. These sounds are connected with the closing of the valves, or the movement of the blood through the heart, or the contraction of the muscles of the walls.

Course of the Circulation.—In passing through the heart the blood takes the following course:* The venous blood, when it comes back by the veins to the right side of the heart, enters the right auricle, which dilates and fills; the auricle then contracts and fills the right ventricle. This in turn contracts and sends the blood with some force into the pulmonary artery, which carries it to the lungs to be purified. After being purified by the air in the lungs the arterial blood returns to the left side of the heart, entering the left auricle. This cavity contracts and sends the blood into the left ventricle, which by its contraction forces the blood into the arteries to be sent all through the body, and back by the veins to the right auricle, as before. The valves open freely, so as to allow the blood to enter, but at once close to prevent a reflow.

The Pulse.—The series of contractions and dilatations is called the *beat* of the heart. When felt at the wrist or at any other part of the body where the artery is near the skin, as at the temple, it is called the *pulse.* These beats in a grown person average about seventy-two to the minute. The pulse is increased by food, exercise, or heat.

* This should be studied in connection with Figs. 53, 54, 55.

Standing increases the number of beats, while lying down diminishes it. Fasting diminishes it. The greater the quantity of blood in the body, the greater will be the number of beats of the heart. When we become excited the pulse will beat violently, giving rise to palpitation of the heart. When the person is affected with grief or fear, the action of the heart may be so checked as to cause fainting, or even death. The healthy pulse may be much slower or faster than the seventy-two beats mentioned as the average. Cases have been known in which through a lifetime the pulse has been as low as sixty, or even less, to the minute.

The pulse of a young baby is about one hundred and forty beats a minute, and during early childhood it is much more rapid than in grown persons. The pulse of a girl or woman is somewhat more rapid than that of a boy or man—about ten beats faster—although the heart is in size slightly smaller.

The Heart's Work.—The heart does an immense amount of work during a lifetime. If we take the number of beats as 72 to the minute, we find that the heart beats more that 4000 times an hour, or more than 100,000 times a day. A little baby's heart, beating 140 times in a minute, will beat in the first year of its life more than 70,000,000 times. The only rest the heart gets is the momentary repose which takes place after the second sound of the heart. This seems to be but slight, and yet we find that by the end of the day the heart has had many hours of rest from labor. Some writers say that during twenty-four hours the ventricles work twelve hours and rest twelve, and the auricles work six hours and rest eighteen.

The Quantity of Blood.—The ventricles send out at each beat or pulsation four and a half ounces of blood; so that if the heart beats 72 times in a minute, there would be sent out in that time 324 ounces, or about 20 pounds. This would be about 1200 pounds every hour, or nearly 13 tons a day, sent out by the ventricles.

The whole quantity of blood in the body has been estimated as being in man $\frac{1}{14}$ of the weight of the body; in the dog, $\frac{1}{13}$; in the cat, $\frac{1}{15}$; in birds, $\frac{1}{12}$; in fishes, $\frac{1}{60}$.

It has been found by experiments that in most animals the blood passes all through the body in the time that the heart spends in making 27 beats or pulsations. As the heart of man beats 72 per minute, the blood would take only $\frac{27}{72}$ of a minute in passing through the heart, the lungs, the arteries, the capillary vessels, and the veins, and returning to the heart. This would be only twenty-two and a half seconds—surprisingly rapid, considering the delicate structures that the blood must pass through and the amount of change that takes place in it in its course.

The Arteries.—The blood passes from the left ventricle into the aor'ta—the largest artery in the body—through the half-moon shaped valves called the *semilu'nar*. This is the beginning of the system of vessels called the *arteries* which carry the blood which has been purified in the lungs everywhere throughout the body to nourish it. We might compare this arrangement to the way in which the pipes that convey water through a city start from a large reservoir, and connect with smaller and smaller pipes to go into every street, every house, and possibly every room.

The arteries (Fig. 56) are solid elastic tubes composed of three coats, the middle one of which is muscular and elastic in the larger vessels, and very muscular in the smaller arteries. In old times it was supposed that they contained air; hence their name (from two Greek words meaning "to contain air"). The arteries are tough, to bear the heavy pressure of the blood sent into them by the force of the heart, and are lined by a very smooth membrane which allows the blood to pass along without anything to check it.

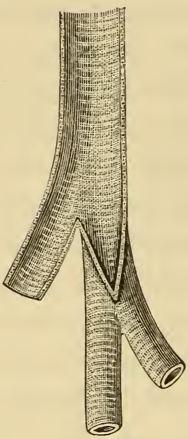
Fig. 56.—An Artery.

The arteries divide until they get to be so small that they can only be seen with a microscope. Every part of the body is thoroughly supplied with them. The pulse or beat of the heart is felt at the wrist only because the artery is there near the surface. Almost all the other large arteries are more deeply seated, being placed beyond the risk of injury, protected by muscles, bones, etc. The pulse is felt by the physician, so that he may learn how strong or how regular the action of the heart is, and whether it is beating too often.

Pulse-Writing.—Some one, a number of years ago, invented an instrument called a "pulse-writer," which traces on paper the course of the pulse. It has a lever upon it, carried along by clockwork over a blackened surface, and this gives the tracing (Fig. 57). In disease

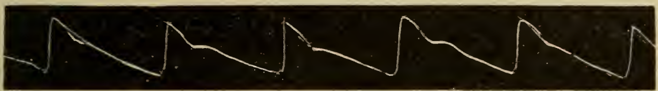

FIG. 57.—TRACING OF THE PULSE AT THE WRIST IN HEALTH.

this line would not be so regular. The effect of disease on the pulse is shown in Fig. 58, in which the tracing

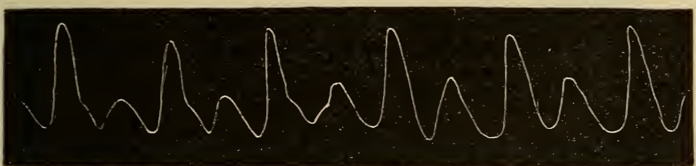

FIG. 58.—TRACING OF THE PULSE AT THE WRIST IN DISEASE, SHOWING A DOUBLE BEAT.

exhibits a double beat, which the physician knows is a sign of serious disease.

The Veins.—After the blood has gone its rounds in the arteries it comes back to the heart by the veins. These are thinner vessels and not so elastic as the arteries, and they have no beat or pulsation. When an artery is cut the blood flows from it in jets or spurts, on account of the great contractility of its coats; but if a vein is cut, the blood "wells out" in a stream.

The veins are very small at their origin in the different organs of the body, and gradually unite to form larger vessels, which at last empty into the right auricle by two large veins, the *ve′nœ cav′œ*, or hollow veins—one into the upper part of the auricle, the other into the lower (Figs. 53, *k*, *s*, and 54, 9, 10). This is like the plan in large cities of carrying off the waste water in pipes, which gradually get larger and larger, and at last empty the water into sewers or the river.

Valves of the Veins.—The veins differ from the arteries in having *valves* (Fig. 59), which are folds that open to receive blood flowing in the direction of the heart, and close so that the blood cannot return in the opposite direction. There are no valves, however, in the veins of the brain and the lungs. The veins are generally nearer the surface of the body than the arteries.

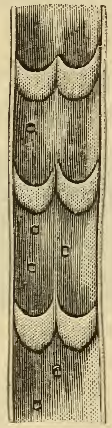

FIG. 59.—VALVES OF A VEIN.

The Cap′illaries (from *capil′lus*, a hair, "hair-like") are very small vessels which are placed between the arteries and the veins. Through the circulation in these vessels the nourishment of the various organs takes place. They may be seen under the microscope in transparent membranes, as the web of a frog's foot, the wing of a bat, etc., in which we can trace them coming off from the arteries and finally merging in the veins. The more active or important an organ is, the more capillaries it has.

So completely is the body supplied with these vessels that the slightest scratch or cut may produce bleeding. A grain of sand striking the eye will produce what is called a bloodshot eye, because there are so many of these little vessels in the eye. Blushing is caused by these vessels in the cheek filling with blood.

Circulation in Other Animals.—The circulation in the higher classes of animals is like that of man. The heart is composed of two auricles and two ventricles, with a double circulation, the greater and lesser. Animals that live partly under water have some of the vessels large and winding, so as to hold more blood while their breathing is suspended during their stay under water.

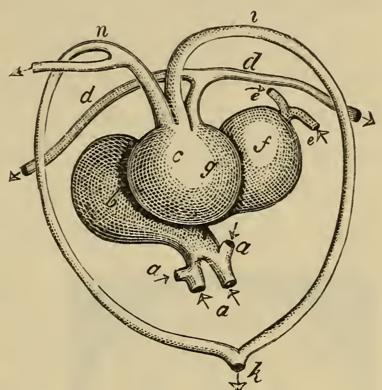

FIG. 60.—CIRCULATION OF THE TORTOISE.

a, *a*, venæ cavæ; *b*, right auricle; *c*, *g*, right and left ventricles united in one; *d*, *d*, pulmonary arteries; *e*, *e*, pulmonary veins; *f*, left auricle; *n*, aorta; *i*, large artery uniting at *k* with the aorta.

In *birds* the circulation is very much the same as in man. In the right ventricle, however, instead of a valve there is sometimes a strong muscle, which helps to force the blood to the lungs.

In *reptiles*—as the tortoise (Fig. 60)—there is but one ventricle, and there is direct communication between the arterial and venous blood. The blood is of course only partly purified.

In *fishes* the heart has only one auricle and one ventricle. The blood passes from the ventricle to the gills, where it is changed into arterial blood, and then goes by a large artery like the aorta into the general circulation and back to the auricle.

Insects, as a rule, have neither arteries nor veins. The fluid which nourishes them diffuses itself through their tissues. There is no heart, but a tube along the back, which moves like a heart. The blood is watery and without color.

In some spiders the blood is white, but some of them have a kind of heart at the back, which sends out blood and receives it again through the lungs. In the lobster and other shellfish there is a heart with one ventricle—but no auricle—and blood-vessels, and also something like lungs. In the very lowest forms of animal life the blood or fluid which nourishes it is diffused through the wall of the digestive tube, there being no heart or vessels.

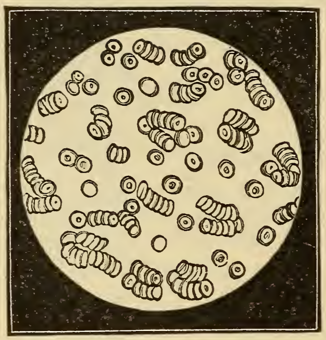

Fig. 61.—Human Blood-corpuscles (magnified).

The Blood itself.—The entire amount of blood contained in the body of a grown person is estimated at about one-fourteenth of his whole weight. A child weighing thirty pounds would therefore have rather more than two pounds of blood in it. A man weighing one hundred and fifty pounds would have about eleven pounds of blood. The blood is dark red as it flows from the veins, and a bright red or scarlet in the arteries. It is about 100° in temperature in man, but in some other animals it is much higher, as in the sheep, in which the temperature is 107°.

The Blood-Globules.—With a microscope we find the blood to consist of a large number of very small red particles, called *blood-corp'uscles, blood-glob'ules,* or discs, floating in a thin fluid called the *serum.* The smallest drop of blood on the point of a needle contains myriads of them. They are of a regular and certain shape in the same animal, but are of different shapes in different animals. In the highest classes of animals, the blood-corpuscles are circular, while in birds and some other animals they are elliptical; that is, longer in one direction than the other. The human blood-corpuscles are flat discs, somewhat concave or slightly hollowed in the middle, with rounded edges (Fig. 61).

To give some idea of their very small size, we may state that if 3200 of these red corpuscles were laid alongside of one another in a straight line, they would only occupy the space of one inch. If 12,000 of them were laid one on top of another, they would only occupy one inch in height. The serum in which they float is transparent and colorless, the redness being entirely due to the red corpuscles. Sometimes the corpuscles arrange themselves in rolls, like coin piled up together, and then they seem of a redder color to the eye. The size of the corpuscles varies in different animals, being, in man, $\frac{1}{3200}$ of an inch in diameter; in the elephant, $\frac{1}{2745}$.

White Corpuscles.—Round white corpuscles are also found in the blood—not so well defined as the red, although somewhat larger. They are much fewer in number than the red, and do not move along as actively in the vessels. In healthy blood there is about one white corpuscle to every four hundred or five hundred red corpuscles. The globules absorbed into the blood from the lymphatics and the chyle are developed afterward into red corpuscles.

Number and Uses of the Red Corpuscles.—The number varies greatly in different animals, but in all of them they are to be counted by millions. It is said that five millions of them are contained in the space occupied by a very small drop of blood. One writer states that if the red corpuscles of the adult man were placed side by side on a flat surface they would cover a space of about 3000 square yards.

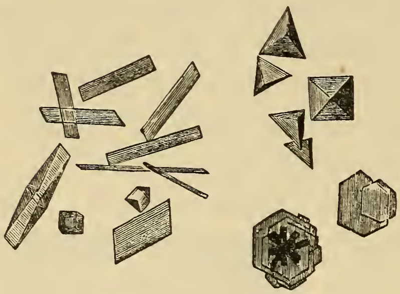

Fig. 62—Blood-crystals.

By chemical action beautiful crystals can be obtained from the coloring-matter of the blood, which under the microscope have the appearance presented in Fig. 62.

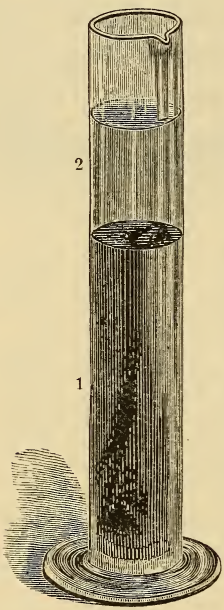

Fig. 63.—Coagulation of the Blood. 1, clot; 2, serum.

The blood-globules are really carriers of oxygen, which they obtain in the lungs during respiration, as has been already shown, and they carry this with them to the different tissues. Parts which are in active exercise, such as the muscles and nerves, need this fresh supply of oxygen, and in the course of the wear and tear of the body give to the blood, by absorption through the lymphatic vessels, a certain amount of carbonic acid, which passes along with the blood, to be gotten rid of in the lungs by expiration. Life can go on in full health only as long as the blood-corpuscles are well organized and contain the proper amount of oxygen.

Coagulation (or Clotting) of the Blood.—Blood that is circulating in the body consists of two portions—the red corpuscles and a watery portion called the liquor sanguinis (water or solution of the blood). When blood is drawn from the body a rapid change takes place in it. It becomes separated in a short time into two distinct parts—a reddish jelly-like, trembling mass, to which the name *clot* is applied, and a yellowish liquid called the *serum*. The cause of this change is due to the separation from the blood of an element in it called fi′brin, which is soluble in living blood and insoluble in dead blood, if we may so call it, or that which has been drawn from the blood-vessel. The fibrin leaves the liquor sanguinis, of which it formed a part, and draws the red corpuscles down with it to the bottom of the cup. The clot is therefore the union of the red globules and the fibrin of the blood; the serum is the thin liquid portion left behind, in which the other parts of the blood are dissolved (Fig. 63).

Circulating Blood.		Coagulated Blood.
Liquor sanguinis	{ Serum.	Serum.
	{ Fibrin. ········	
Corpuscles ················		Clot.

(The dotted lines show the union of the fibrin with the corpuscles to form the clot, while the serum is left alone.)

When a blood-vessel is accidentally cut, the clots formed stop up the mouth of the vessel. In some animals, as birds, the formation of a clot takes place instantaneously. Thus Nature seems constantly to guard the lives of some of the most helpless of her creatures. During life, while the blood is in constant circulation, clots rarely form, but when they do they block up the smaller vessels, and possibly a cavity of the heart, and may destroy life.

Hygiene of the Circulation.—The healthy circulation of the blood is greatly assisted by exercise, by attention to the general health, and by other causes. Rapid exercise, moderately employed, contracts the muscles, increases the flow of blood in the vessels, and quickens the action of the heart and of the circulation generally, while it sharpens the appetite and assists digestion. Any articles of clothing that press too tightly on the blood-vessels on the surface of the body impede or arrest the circulation. Changes of temperature (as elsewhere shown), wet feet, and exposure affect the local circulation on the outside of the body, and the general circulation in such organs as the lungs or throat.

In all the duties of life, in our meals, in our exercises, in our amusements, and in our work, we should never forget that the heart and blood-vessels have, under the best of circumstances, much hard work to do to sustain life and health. Let us do as little as we can ourselves to add to this labor by knowingly breaking any of the laws of health.

Action of Alcohol on the Heart and the Circulation.—Upon the heart alcohol at first acts as a stimulant, producing an increase in the number and force of its beats, so that the period of rest is diminished, and a greater amount of strain and labor thus placed upon it. If the number of beats be increased only five every minute, and this continued stimulation should become a habit, the heart would beat over seven thousand times a day more than its accustomed number.

Although the action of the heart is thus quickened, it soon becomes much weakened, and requires additional quantities of the same stimulant to revive it. The circulation becomes irregular, being sometimes excited and at other times fatigued. The heart may soon beat irregularly, or it may become dilated from over-action and the valves lose their power, or the membranes lining the cavities of the heart may become thickened and the blood-vessels connected with the heart diseased. The heart may suddenly fail to do its work or the vessels become ruptured, and the blood flowing continuously through the heart will be thrown back upon other organs, as the brain or lungs, and produce violent death at any moment.

Alcohol, as we have already seen, passes at once into the blood-vessels of the stomach and goes directly to the liver. Some of it may get into the bowel and be absorbed into the lacteal vessels, and pass into the blood in that way. Whatever route it takes, it gets rapidly to the heart; but when it goes to the liver directly it soon gets into the main stream of blood. This is why a drink of brandy or gin soon goes to the head, as it is called, and acts upon the brain. Every part of the body feels the effect of the poison. The brain, the liver, the lungs, and the heart, all receive it as it reaches them mixed with the blood as it goes to and through every organ.

The flow of blood through the vessels is regulated by a central system of nerves not under the control of the will. The use of alcohol as a drink paralyzes these nerve-centres, and also the little nerves which control the action of the small vessels, so that the man who drinks alcohol as a habit soon gets redness of the face and of the nose, because the little vessels in these parts of the body get too full of blood and remain so. The eye itself and the lids become inflamed and red, and continue so. The blood-vessels in other parts become diseased and lose their elasticity, and of course this gives the heart much more to do.

The nerve-centres that regulate the motions of the heart also become paralyzed, and the blood is not driven from its cavities regularly and quietly, as in health, and the drinker dies from a heart overworked by alcohol.

Action of Tobacco on the Circulation.—Tobacco makes the blood too fluid and causes palpitation of the heart. Its continued use injures the red corpuscles of the blood, and greatly disturbs the action of the heart and blood-vessels. It has been shown recently that while the pulse is 72.9 among non-smokers, the average pulse of those addicted to the use of tobacco is 89.9—an increase of about seventeen pulsations of the heart every minute. This is to say, that to every thousand pulsations in one who does not smoke there would be one thousand two hundred and thirty-three pulsations in him who does smoke. The effect of such increased action of the heart must be very injurious, giving it increased labor, and increasing the number of beats of the heart about twenty-four thousand every day.

The Effect of Narcotics.—Opium, Indian hemp, chloral, and other articles that are resorted to so blindly by many persons under the mistaken idea that they derive pleasure from their use, all affect the heart or the circulation through their influence on the nervous system. They should be avoided as poisons, which should not be used except under the advice of a physician, who will prescribe them for their qualities as medicines. Their effects will be studied more fully when we come to consider the Physiology of the Nervous System.

Mortality from Alcohol.—A recent writer states that no less than twenty diseases are acquired by the use of alcoholic liquors. Premature decay and old age might be added to the list. The deaths from alcohol are very many, as the diseases caused by its use attack those whose constitutions are already weakened by drink and are often beyond the reach of medical aid. Another writer states that in Great Britain and Ireland at least a hundred deaths occur every week from alcoholic excitement, and a thousand deaths every week from the diseases which follow from the use of alcohol.

Materials Separated from the Blood.—While the blood is going the round of the circulation there are little bodies called *cells* which are busy taking from the blood such materials as are of no further use in the body. This is the way that the tears and the perspiration are formed, and through them we get rid of some matters that are not nourishing.

The pancreatic juice and the bile and the saliva are all specimens of *secre'tions*, so called; that is, of fluids separated from the blood by the action of cells, for secretion means nothing more than separation. The bile, for instance, is secreted by the liver.

Secreting Structures.—The simplest arrangement for secretion is like filtering from a very small blood-vessel

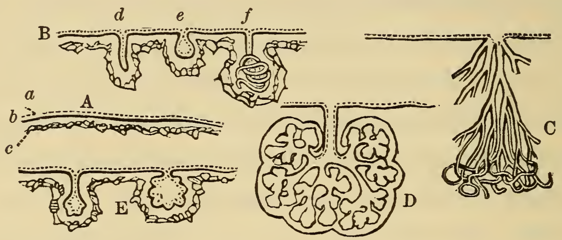

FIG. 64.—ARRANGEMENT OF SECRETING STRUCTURES.

A, *a*, cells; *b*, membrane; *c* capillary blood-vessels; B, simple glands, showing their different kinds of secreting apparatus; *d*, straight tube; *e*, sac; *f*, coil of tubes; C, compound tubular gland; D, gland arranged like bunch of grapes; E, other shapes of glands. The dotted lines represent the layer of cells through which secretion is effected.

through a membrane (Fig. 64, *b*, *c*). In more complicated organs, like the liver, the action of cells is also required, so that they can choose the proper materials to make the bile (Fig. 64, *a*). To get plenty of surface for secretion, the membrane is turned in as shown in Fig. 64. A single inch of skin in this way becomes lengthened into many yards. Some of the glands are made up of tubes (Fig. 64), some are in shape like a bunch of grapes (Fig. 22), while others are mere sacs.

Glands.—The organ or body whose duty it is to separate materials from the blood is called a *gland*. We have glands in the skin (Fig. 80), and the liver and pancreas are also glands. They have a canal leading from them to carry off the fluid which they have been forming. The bile is poured out by a canal into the intestine; the perspiration is poured over the surface of the skin through thousands of little tubes leading from the sweat-glands.

In the lower back part of the abdomen are two of the most important glands of the body—the kidneys—one on each side of the spinal column. A large amount of blood is sent to them, and from this blood useless solid and liquid materials are separated, to form a fluid which afterward passes, drop by drop, into a sac called the bladder.

QUESTIONS.

What do we mean by the Circulation?

State size, position, etc. of heart. What are its cavities?

What are the two circulations? The valves and their uses?

What are the movements of the heart? The sounds of the heart?

What is the course of the blood after leaving the heart?

What is the pulse? In childhood? In grown persons?

How much blood is there in the body?

What are arteries? Veins? Capillaries? What is pulse-writing?

What is there in the veins to prevent the blood from flowing back?

How do exercise, etc. promote the circulation?

What is the action of alcohol on the heart? On circulation?

What effect have tobacco and narcotics?

How is the circulation carried on in other animals?

Of what parts is blood composed?

What do we know of the blood-corpuscles? Their uses? The white?

What is coagulation due to?

What materials are secreted from the blood? By what agency?

What is meant by a secretion? Give examples. How effected?

What is a gland? How is the fluid from glands carried off?

What is the simplest arrangement for secretion?

ANIMAL HEAT.

Temperature of Animals.—The temperature of the body of man and other animals is known as animal heat. Each animal has a temperature which does not usually vary. Such animals are known as *warm-blooded.* Those animals whose temperature is not constant, and not much above that of the air or the water in which they live, are called *cold-blooded.* Reptiles and fishes are cold-blooded.

A great deal of oxygen is taken into the lungs in breathing, and a part of it unites, all through the body, with some of the chemical parts of the food, such as carbon and hydrogen. This union gives rise to heat. Every chemical change which occurs in the body results in the production of heat. The more active the respiration and the more nourishing the food, the greater the amount of heat.

Where the respiration is slow and inactive, as in reptiles, the animal heat is not high. Increased exercise raises the temperature. In the Arctic regions more food, especially of an oily and fatty kind, is taken than by those living in milder climates. The animal heat is reduced during starvation, and in such a condition freezing to death takes place rapidly.

Temperature of Different Organs.—When a thermometer is placed in the armpit or beneath the tongue, it registers in health from 98° to 99° (Fahrenheit), and the temperature of the body generally is stated to be 98½°. It usually varies but a degree or two in health. In young children the temperature is about two degrees higher than in grown persons. In some diseases, such as typhoid fever, there is an increase of the heat of the body, while in cholera it may fall many degrees.

The temperature of some of the organs, as the lungs and the muscles, is rather higher than that of the surface of the body. The blood is hotter on the right side of the heart than on the left, and cooler when it leaves the heart after passing through the lungs. It is cooler in the veins near the surface of the body than in the arteries, but in interior organs the blood coming from them by the veins is warmer than that going to them by the arteries.

Friction, muscular movement, etc. give rise to additional heat. The greatest amount of heat is produced in the liver and by the muscles, and it is found that the blood is warmer after coming from a muscle than it was in going to it, thus showing the effect of motion in producing heat.

Hygiene of Animal Heat.—Man, having an even temperature in health, and being able to regulate his food and exercise, as well as to protect himself against intense heat or cold by proper clothing, can bear great heat or cold better than any other animal. No matter what the climate or season, the heat of the human body remains very nearly the same.

The heat of the body is not much affected, even in those who have to work in very high temperatures, such as those of iron-works, furnaces, etc. The effect is warded off by the increased amount of perspiration produced by such exposure. During such evaporation heat is abstracted, and the part becomes really cooler; the more rapid the evaporation the more decided the sensation of cold.

In warming the rooms we occupy in winter we endeavor to prevent the heat of the body from being too rapidly lowered. The heat of the body is always higher than that of any artificial heat we obtain or could bear in our residences. In cold seasons there is but a small amount of perspiration poured out, so that evaporation can produce but little coldness of the surface, and there will be only a slight reduction of the heat of the body.

The chemical changes causing animal heat take place through the agency of the capillary blood-vessels which are found everywhere through the body.

Clothing is necessary to prevent too rapid loss of heat, either from contact of the surface with cold air or from the evaporation of the perspiration; the material used for the purpose depends on the fact of its being a non-conductor of heat. Porous materials are usually employed for this purpose, as the pores or openings are filled with air and their conducting power for heat is low. Wool, silk, cotton, and linen are the articles generally used.

The material of which the clothing is made is important for the health. Woollen clothing is employed because, being a poor conductor of heat, it does not allow the natural warmth of the body to escape through it, and it absorbs the perspiration without becoming moistened by it. For these reasons flannel is worn, or should be worn, next to the skin at all periods of the year; even, to a slight degree, during the summer season. In milder climates cotton may be worn; it readily absorbs moisture. Linen is a cool material for wear in summer, as it is a good conductor of heat and rapidly carries off the warmth of the surface. Silk is a good non-conductor of heat.

When the skin is rapidly chilled by exposure of any kind, what is popularly known as "taking cold" results —the blood at the surface temporarily receiving a shock by which the blood is sent in unusual quantity to the interior of the body, some part of which may become congested and inflamed, producing sore throat or inflammation of the lungs. Warm applications and the use of such internal medicines, under proper advice, as will stimulate the secretion of the skin and the blood to more active circulation toward the surface of the body, will frequently relieve the "cold."

Action of Alcohol on the Temperature.—If a delicate thermometer be placed under the tongue of a person who has taken a quantity of alcoholic drink, it will be found that, though there may at first be a slight increase in the temperature, there will soon be a reduction in the natural heat of two or three degrees, lasting for several hours. At first, after taking alcohol, there is a slight feeling of warmth, but there is no real increase of heat. If the skin is warmer, it is because the natural heat has been taken from organs inside the body. This heat of the skin is soon lost, and the general heat of the body is lowered, because so much blood is carried to the surface. Alcohol lessens the power to bear extreme heat or cold; those who live in the coldest regions do not use it.

Effect of Tobacco on the Temperature.—In some observations recently made in France it was found that the mean temperature of the body for the twenty-four hours in non-smokers of average constitutions was about 98° Fahr., while in those addicted to the use of tobacco the mean temperature was 98.6° Fahr. In those of weak constitutions the temperature rose to a much higher degree. Tobacco, therefore, may be said to raise the temperature of the body nearly one degree.

QUESTIONS.

What is meant by animal heat?

What are warm-blooded and cold-blooded animals?

What effect has oxygen in producing animal heat?

By what kind of action is the heat of the body produced?

What effect have food, respiration, and exercise in producing heat?

What is the temperature of the body? Of young children?

Is the external or internal temperature the highest?

On what side of the heart is the blood the hotter?

In what organs is the greatest amount of heat produced?

Why is man able to tolerate excessive heat or cold?

What effect has evaporation on the heat of the body? Clothing?

What blood-vessels are concerned with animal heat?

What is "taking cold"?

What effect has alcohol on the animal heat? Tobacco?

THE NERVOUS SYSTEM.

Peculiar to Animals Alone.—The vegetable has not any nervous system. By it man feels and thinks and moves at will. By it he lives, although he may be asleep, and the nutrition of his body goes on whether waking or sleeping.

Divisions of the Nervous System.—One of the great divisions of the nervous system consists of the brain and spinal cord as centres, and is therefore called the *cere′bro-spi′nal system* (from cere′brum, "brain"), (Figs. 67, 68). Slender white cords, called *nerves,* pass from them, which divide and subdivide until they get to be very small indeed, and every part of the body is supplied with them. There is not a point of the skin which does not, when cut or pricked with a pin, show by the pain that it is fully supplied with these little nerves.

Another part of the nervous system is called the *sympathet′ic system,* because it brings all parts of the body into direct sympathy with one another (Fig. 74). Its nerves communicate with the nerves of the other system to make the chain of sympathy complete. If it were not for such a nervous system, each organ would be acting by itself, and perfect health would be impossible.

Nervous Matter.—This is a soft substance, almost fluid at birth. Under a microscope it is seen to be made up of a white and a gray matter. The white substance is made

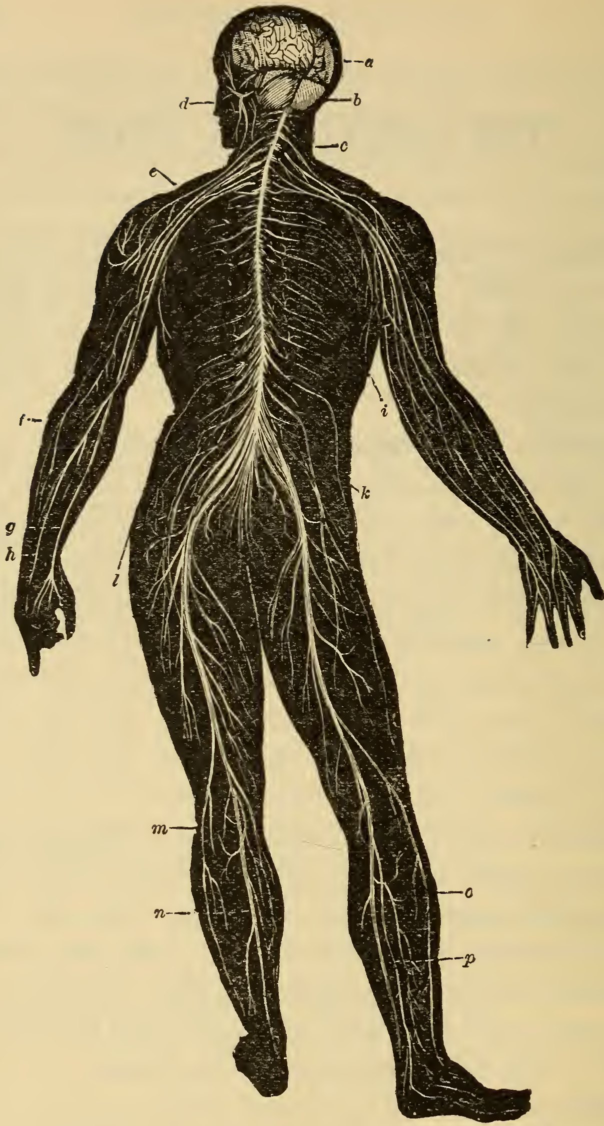

FIG. 65.—GENERAL VIEW OF THE NERVOUS SYSTEM.

a, cerebrum, or brain proper; *b*, cerebellum, or little brain; *c*, spinal cord; *d*, nerve of face; *e*, *f*, *g*, *h*, nerves of arm; *i*, nerves between ribs; *k*, nerves of lower part of back; *l*, nerves in region of hip; *m*, *n*, *o*, *p*, nerves of the leg.

up of delicate nerve-fibres about the $\frac{1}{6000}$ of an inch in diameter. The gray or ash-colored matter is made up of nerve-cells of various sizes, rounded, with a central spot on each (Fig. 66). White fibres are largely found in the long cords, called nerves, which pass to and from the various parts of the body. The outside of the brain is made up of gray matter; the inside, of white matter. The gray matter gives origin to nervous power; the white carries it.

FIG. 66.—VARIOUS FORMS OF NERVE-CELLS.

The Cerebro-Spinal System.—The central parts of the cerebro-spinal system (Figs. 67) are the brain and the spinal cord, both of which are soft masses of white and gray matter. The part contained in the skull is the *brain;* that in the spine is the *spinal cord* or *spinal marrow.*

All these parts (Fig. 67) are protected from injury by bones and by membranes covering them. For this reason a blow or a fall on the head does not injure the brain as much as it would if the brain had been nearer the surface. The brain and spinal cord are both covered with

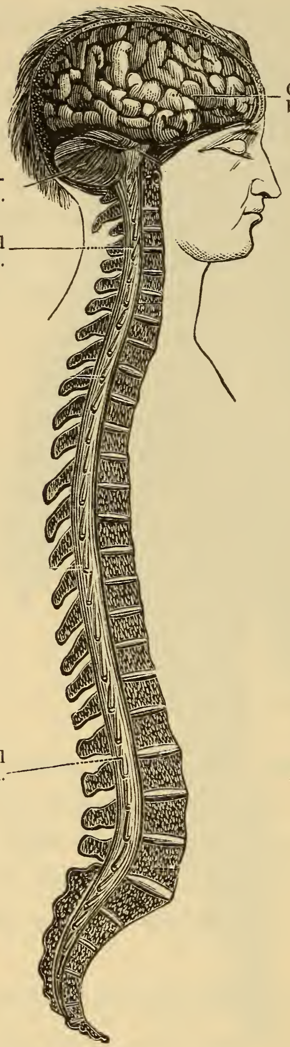

Fig. 67.—The Brain and Spinal Cord.

three coats, one within the other, the outer coat being thick and strong, and dipping down between folds of the brain to protect it from being pressed upon. One of these coats is as thin as a spider's web.

The Brain (Figs. 67, 68, 69).—This organ, placed in the skull, is divided into three parts—the brain proper, or *cere'brum*, the large round mass which fills the greater part of the skull; the little brain, or *cerebel'lum*, a smaller portion at the lower and back part of the skull; and a still smaller part, the *medul'la oblonga'ta*, which, translated into English, means the spinal cord prolonged (into the skull). There is a large opening in the under and back part of the skull for the very purpose of allowing it to pass through.

Seven-eighths of the space in the skull occupied by the whole brain belongs to the cerebrum, or brain proper. This part of the brain is the seat of the mind or intelligence of the animal.

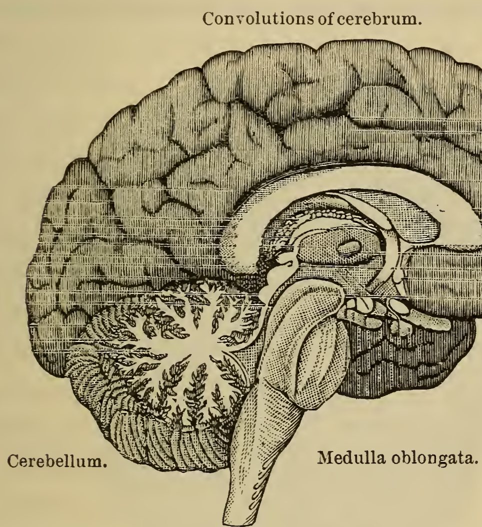

FIG. 68.—INTERIOR OF THE BRAIN (showing, by section through it, its various parts).

Weight and Size of the Brain.—The average weight of the brain of man is a little over three pounds. The brain of woman is generally from four to six ounces lighter. The brain of an idiot seldom weighs more than 23 ounces. Some human brains have been found after death to weigh between 60 and 70 ounces.

The brain proper of man is greater in proportion to the weight of the body than that of any other animal. The brain of the elephant weighs only 120 to 150 or 160 ounces, and of the whale about 80 ounces. This is a much smaller amount of brain, in comparison with the size of the animal, than that of man. The brain of the elephant is only the $\frac{1}{500}$th part of the weight of his whole body, while in man it is about the $\frac{1}{50}$th.

The Caucasian race, including the European and Ameri-

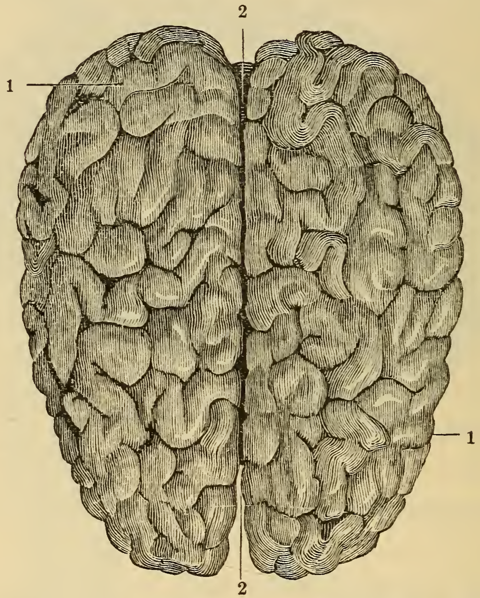

Fig. 69.—Exterior View of the Brain.

1, 1, right and left hemispheres of brain; 2, 2, crack or fissure dividing the brain.

can, has the brain more fully developed than any other. As the front part of the brain is the seat of intellect, the prominence of the forehead has been considered a sign of intelligence.

The Brain Proper.—The cerebrum, or brain proper (Fig. 68), is made up of thick, worm-like folds called *convolu'tions*, having deep cracks between them (Fig. 69, 2, 2). The brain is made up chiefly of fat and phosphorus. The principal crack or fissure of the brain divides it into two parts, called *hem'ispheres* (Fig. 69, 1, 1).

The outer part of each hemisphere is made up of gray or ash-colored matter, but the interior is almost entirely white matter. At the base of the brain are bodies, called *gang'lia*, made up of gray matter, through which the fibres pass from below upward to the brain.

In the brain is quite a variety of cavities or spaces, with arches and delicate veils and odd-looking halls and passage-ways, of whose uses we know little or nothing.

Cerebellum.—The little brain, or cerebellum (Figs. 67, 68), is not in convolutions, but in layers like the leaves of a book. When cut into, it has the appearance of a tree, and is therefore called *ar'bor vi'tæ*, or "tree of life."

Spinal Cord (Fig. 67).—The cord, or spinal marrow, is a combination of cords of nervous matter, separated by fissures running their whole length, and covered by a membrane common to all. Before passing into the skull the fibres from the right and left sides of the cord pass across and into one another, and then go up into the cerebrum or brain proper, in which they spread out in all directions.

The Nerves (Fig. 70).—These are continuous threads of nervous tissue which are sent to all parts of the body. They are made up of collections of little nervous threads or filaments bundled together. Each filament is composed of a fine gray thread, surrounded by a soft white substance, enclosed in a thin covering. They are very numerous on the skin. They convey impressions backward and forward, to and from the surface of the body or from organ to organ within the body. They are the telegraphic wires through which the will and the mind, and even life itself, make themselves known.

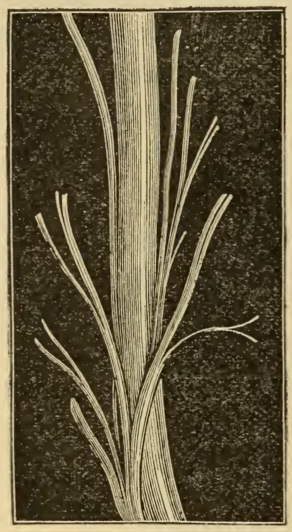

Fig. 70.—A Nerve and its Divisions.

After a nerve nears the surface, where, by motion of the limbs or by pressure, it might suffer, it becomes covered with a strong white covering, called the *nerve-sheath*, which binds together the different filaments. In the course of some nerves, as the great sympathetic nerve, there are enlargements or knots called *ganglions*.

The nerves do not communicate with one another, as the arteries and veins do, by open vessels. In Fig. 71 is shown a representation of tubular nerve-fibres from different parts. They are very distinct from the nerve-cells already alluded to, and assist in carrying nervous influence.

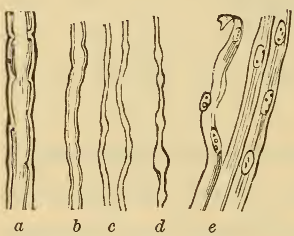

Fig. 71.—Nerve-fibres.

a, b, c, d, nerve-tubes of different sizes; *e*, nerve-tube from sympathetic.

The Nerves in Pairs.—The nerves come off from the brain and spinal cord in pairs—that is, one from each side of the axis right and left. Those which come directly from the brain and spinal cord number altogether forty-three pairs. There are twelve pairs of cranial nerves and thirty-one pairs of spinal

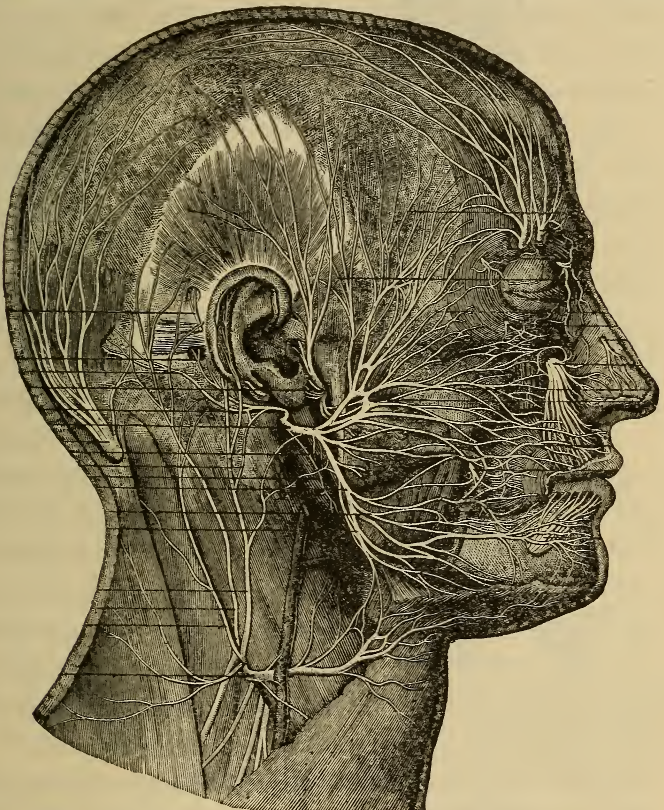

FIG. 72.—NERVES ON THE SURFACE OF THE FACE AND NECK.
(The guiding lines indicate the most important nerves and their branches.)

nerves. Those coming from the brain pass out to various organs through openings in the skull; the spinal nerves through openings in the spinal column.

Cranial Nerves.—The cranial nerves supply the organs of sight and smell and hearing, the face (Fig. 72), the mouth, and the tongue and throat; and some of them go to the heart and lungs and stomach. The *fifth pair of nerves* is sent to the face, the eye, the nose, the mouth, etc., and gives feeling to those parts (Fig. 72). Some persons when puzzled scratch their heads or rub their foreheads, and in doing these acts they stimulate branches of the fifth pair; as other persons do who, when thinking, strike their fingers against their noses. Others do the same by taking snuff. Some of the cranial nerves are connected with the motions of the face; some are merely nerves of special senses, like hearing and sight, and would cause no feeling of pain if cut or injured.

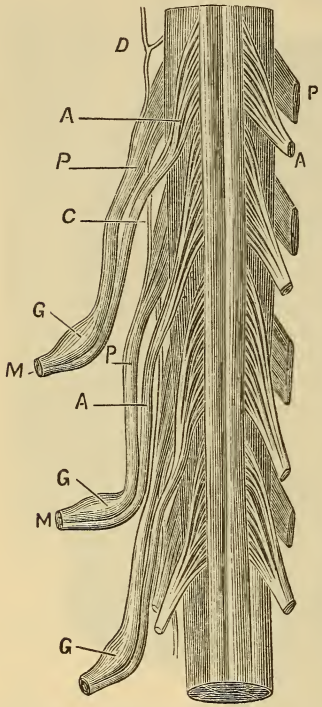

Fig. 73.—Origins of the Spinal Nerves from the Spinal Cord.

A, A, A, anterior roots which unite afterward to form the fibres of the root; P, P, P, posterior roots; C, D, filaments passing between the posterior roots; G, G, G, ganglions of posterior roots; M, M, nerves formed by union of two roots. (The size of the roots is larger than natural.)

Spinal Nerves.—These, as they issue from each side of the spinal cord, have two roots, which join to form the nerve before it passes through the spinal column. The substance of the spinal cord consists of gray and white matter, but differently arranged from that in the brain, the white substance being on the outside, the gray on the inside. Three coats cover the cord, similar to those of the brain. The fibres which make up the larger root of each spinal nerve are nerves of sensation, while those which form the anterior or lesser root are nerves of motion. On the posterior root is a small ganglion (Fig. 73).

The nerves which are sent out from the spinal marrow convey feeling and motion to the most distant points.

The Great Sympathetic Nerve (Fig. 74).—This nerve consists of a series of small nervous bodies or ganglia connected by nervous cords and threads, and communicating with the other great nervous systems. It spreads itself through the most important parts of the body, especially the chest and abdomen, and on each side of the middle line in front of the spinal column. It has a place also in the brain, from which muscles of the eye and ear and other organs are supplied. It has much to do with several of the processes that maintain life, as digestion, respiration, circulation, etc., but has nothing to do with the great acts of the mind or with the motion of the person at will. These are controlled by the cerebro-spinal system.

The small bodies, or ganglia, of the sympathetic nerves (Fig. 74) start out nerve-power and send it along the nervous wires to the various organs. Branches are supplied to the muscular coats of the blood-vessels, which regulate the quantity of blood they may contain. Blushing and paleness of the face are examples of this influence.

Functions of Nervous System.—When an impression is made on any part—as by a blow or by excessive

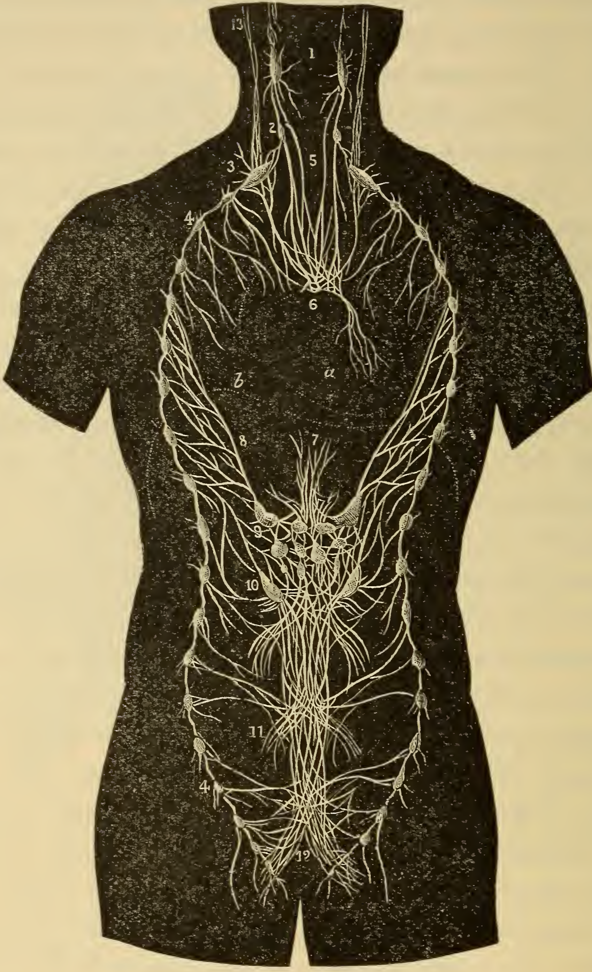

Fig. 74.—The Great Sympathetic Nerve.

1, 2, 3, ganglia in the neck; 4, spinal ganglia; 5, 6, branches going to heart; 7 nerves about diaphragm; 8, nerve to digestive organs; 9, semilunar ganglion; 10, 11, 12, nerves to abdomen; 13, small nerves going with arteries to brain. Dotted lines show position of *a*, heart, and *b*, diaphragm.

heat or cold—the very small nerves of the skin carry it inward along other nerves to the brain. These impressions are the *sensations* with which we are so familiar. The brain is the seat of the will; and the nerves going back to the skin receive another impression from the brain, and send or carry it to a particular muscle or organ, which they thus call into motion or action.

We thus learn that there are two sets of nerves—one set called *sens'ory nerves*, or nerves of sensation; the other set *mo'tor nerves*, or nerves of motion.

If the hand be accidentally brought into contact with a hot substance, a sensation of pain is sent to the brain by the nerves of sensation, and the hand is at once removed, by what seems a message sent through the nerves of motion to the proper muscles.

When we are asleep the gray part of the spinal cord takes notice of impressions from without. The rest of the spinal cord and the brain are connected with this gray matter of the cord. The impression is made on the skin first, and carried thence to the spinal cord, which calls the proper muscles at once into action. This is called *reflex action* (Fig. 75).

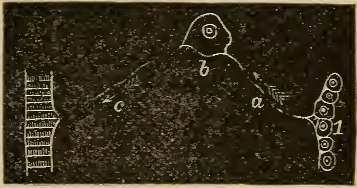

FIG. 75.—SIMPLE REFLEX ACTION.
1, the skin; *a*, nerve to spinal cord; *b*, spinal cord; *c*, nerve to muscles. (The nervous influence travels in the direction indicated by the arrows.)

When we throw up the arm as a shield from a blow, we do it by this reflex action. If we lay hold of a substance that is too hot to hold, we drop it through this reflex action. During sleep the mouth will receive and the throat swallow water when placed to the lips; the body will turn in bed during sleep by the same kind of reflex action.

Functions of the Medulla Oblongata.—This is the link between the brain and the spinal cord. It chiefly takes charge of the breathing or respiration and swallowing or deglutition. Of course all impressions going to or from the brain, from or to the spinal cord, pass along it (Fig. 68).

Functions of the Cerebellum.—This part of the brain (Fig. 68) regulates and keeps in order the motions of man and animals. In experiments on animals, when this part was cut, the animal could not move, fly, walk, or even stand.

In some experiments on pigeons—which seemed important at first to establish the fact, but which can hardly be considered necessary now merely to gratify idle curiosity—it was found that if the cerebrum, or brain proper, was taken away the animal would remain firm on its feet, while a pigeon from which the cerebellum was only partially removed was as unsteady as if it was drunk. The cerebellum does not originate movements, but it regulates and gives precision to them.

Functions of the Cerebrum, or Brain Proper.—The cerebrum, or brain proper, is the great organ of thought, sensation, and the mind, and of voluntary motion. The brain of man is in size and development far superior to that of all other animals. It has been thought that the two hemispheres of the brain may act—that is, think—

separately as well as together. Our minds certainly wander off to a hundred other fancies while we seem to be interested in only one subject.

Sleep.—The active exercise of the brain is of course checked during sleep; respiration, digestion, and circulation go on, but not so actively as when we are awake. The amount of necessary sleep depends on the age and habits. The very young require a great deal of sleep, because all their organs are so active that they must have rest; old people, because they are feeble. There seems to be less blood in the vessels of the brain during sleep. Eight hours are usually required by grown persons, and more than this by children.

When the brain becomes active during sleep *dreaming* results, but this may be due to disturbance of the digestive organs, as after a full meal.

The Nervous System of Animals.—Animals next to man in the scale have the same organs for a nervous system that he possesses. Those lower in the scale have the hemispheres of the brain less and less developed. Other portions of the brain are less perfect, and some parts entirely absent. In the lowest forms of animal life the nervous system seems to be absent.

In insects nerves are found in the organs of digestion and circulation like the sympathetic system in man. In some of them ganglions are arranged like a chain, from which nerves are given off (Fig. 76).

In animals which have a spinal column the nervous system is along the back part of the body. They have a brain and spinal cord. As we ascend in the scale the hemispheres become larger and the convolutions deeper and more developed.

Hygiene of the Nervous System.—The nervous system must be cared for in every possible way, as by healthful exercise, by rest, and by sleep. Sound and regular sleep, especially at night and after fatigue, will do much to revive it. If we will take care of the health of all the other organs, we will have the nervous system healthy also. The brain and nervous system should not be overworked. Steady mental work does the brain good if a person does not neglect the other organs of the body. Mental worry and anxiety in study or in the affairs of the world break down the nervous system and the general health. Regular study at school or at home, regular habits and regular meals, regular exercise and regular sleep, will keep the brain and nervous system in good health.

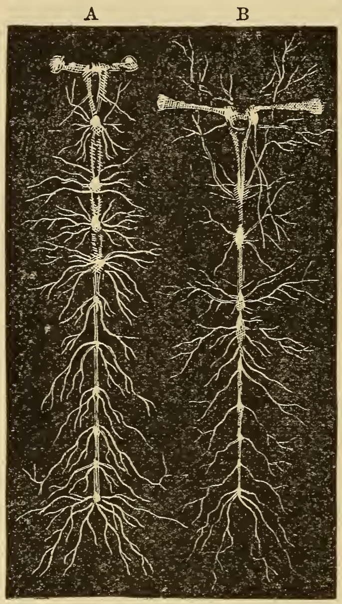

FIG. 76.—NERVOUS SYSTEM OF INSECTS.

A, grasshopper; B, stag-beetle.

Action of Alcohol upon the Nervous System.—The effect upon the brain of small quantities of alcohol taken occasionally is to increase the amount of blood going to that organ. This is still more marked if the quantity be increased, and alcohol be taken as a habit. The condition resulting from abuse of intoxicating liquors is called *al'coholism.* The coats of the blood-vessels become weak in such persons, and they give way and produce apoplexy; that is to say, the blood passes from the blood-vessels into or upon the brain-substance. Besides this, the brain-substance is hardened and wasted away, and water is found in the cavities of the brain.

The person so affected by alcoholic drinks soon gets his mind clouded and confused with delusions of various kinds; it does not have rest; there is loss of sleep; he cannot think or reason properly; his muscles are not steady; and he has intense desire for drink.

Under such a condition of his mind the moral powers become affected, and crime and poverty soon follow. When once formed, the habit of drinking controls him; he becomes in every sense a moral, mental, and physical wreck, from which death is often a relief to himself and his friends.

It is fully proven that crime keeps pace with drunkenness, and wicked deeds of every description occur much more frequently in those places in which alcoholic liquors are indulged in to excess. Drink is the exciting cause of crime in a vast number of cases.

In its effects upon the brain and nervous system generally alcohol belongs to the class of *narcot'ics* (from a Greek word meaning "stupor"). Its first effects are stimulant, and seem to increase the activity of the muscles and to excite increased warmth and activity of the mind; but these effects are transient and deceptive. If the habit be continued, self-control is lost and the man becomes thoroughly poisoned. Sounds are heard that have no reality, objects are seen which have no existence, and a condition known as *delirium tre′mens* or *ma′nia-a-po′tu* ("mania from drink") results. Sometimes paralysis or loss of power of both mind and body occurs, from the action of the poison upon the nervous matter and upon the membranes covering the brain and spinal cord; and death soon follows.

The children of parents who have been alcohol-drinkers are more likely to get nervous diseases than other children. The sins of the fathers are thus often visited upon the children.

Action of Opium upon the Nervous System.—Opium is a poison of the narcotic class, which, when properly given, under medical advice, is capable of acting as a valuable remedy in relieving pain, producing sleep, etc.; but when it is used for self-indulgence the habit will sooner or later wreck the unhappy individual who indulges in it. Opium is the thickened juice of the poppy. Morphia is its active principle, and laudanum, paregoric, and Dover's powder, and similar preparations owe their virtue for relieving pain and causing sleep to the opium which is in each. Opium is sometimes given to very young children to produce sleep, but it is a dangerous poison, and death will occur sometimes from the giving of even the smallest doses—a drop of laudanum, for instance. "Drops," "soothing syrups," etc., given in this way, may kill the child.

The "opium-habit," "morphia-habit," etc., as it is called, shows its effect on the nervous system by the dulling and weakening of the powers of the intellect. After taking opium or other narcotics to produce sleep, the individual awakens to a disturbed and unsettled feeling of unrest of a most distressing kind. The same results follow the use of opium, whether it be smoked or eaten, except that a larger quantity will be taken in the latter way. Paralysis frequently occurs as a result of its use.

Action of Chloral and Other Narcotics.—Chloral is made from alcohol by a peculiar chemical action. Like opium, it may be abused by self-indulgence until the chloral-habit becomes as firmly settled as the opium-habit. It soon impairs the digestion and circulation, disturbs the action of the heart and nervous system, and before long sleep cannot be procured without it.

Indian hemp is sometimes taken to intoxicate, on account of the drowsiness and dreaminess produced by it; but the effect of all such articles, taken as a habit, is to excite and cloud the intellect, and their employment often leads to insanity.

Action of Tobacco.—When tobacco is indulged in to any great extent it produces confusion of sounds in the head, with ringing in the ear, and imperfect vision, sometimes amounting to total blindness. If it does not have such a powerful effect, it leaves the person nervous and irritable, and unfitted for manly work or mental labor or usefulness. Tobacco is such a deadly poison that physicians scarcely ever prescribe it as a medicine.

Cigarettes should not be smoked by young persons, as they are nothing but tobacco in packages of smaller size, and are often mixed with other articles, as opium or refuse matters, which are very injurious to the health.

QUESTIONS.

What is the cerebro-spinal system? What are the nerves?

How many coats has the brain? The spinal cord?

What is the sympathetic system? What are its uses?

What two kinds of nervous matter are there? Their uses?

What three parts has the brain? How much is the brain proper?

What is the average weight of the brain in man and woman? Compared with the weight of the body?

What races have brain most developed?

What are the hemispheres of the brain? What is the cerebellum?

What is the arrangement of the spinal cord?

What are the nerves? Of what formed? Their uses?

What is the sympathetic system?

How many spinal nerves are there? How many cranial nerves?

What organs are supplied by cranial nerves? The fifth pair?

What are the roots of spinal nerves? Their action?

How are impressions conveyed to and from the brain?

What is the great central organ of sensation? Of the will?

What are the duties of the two kinds of nerves?

What is reflex action of the spinal cord?

What are the duties of the medulla oblongata? Of the cerebellum? Of the cerebrum?

What occurs during sleep? How much is necessary?

What peculiarities are there in the nervous system of other animals?

What is the best way to keep brain and nervous system healthy?

What is the effect of alcohol upon the brain? On the nervous system? Alcoholism?

What are narcotics? What is opium? What are its effects?

What effect have chloral, tobacco, etc. upon the nervous system?

THE SENSES.

THE Senses, as they are called, are touch, taste, vision, hearing, and smelling. These all require special organs. The object of the senses is to make us acquainted with the world around us; without them we would have no ideas of taste, odor, or sound, or the properties of bodies, such as we acquire through the tongue, the nose, the ear, the eye, and the skin.

TASTE.

The Organ of Taste.—The surface of the tongue and the mucous membrane of the mouth form together the organ of taste. If the lining of the mouth be injured in any way pain will take the place of taste. By the action of the teeth and salivary glands the food is brought in contact with the nerves of taste in all parts of the mouth. The impression is made on the nerves of taste, and thence carried to the brain, which appreciates it.

The tongue has several important nerves and also muscles, which move it in various directions, as in chewing or in swallowing.

The tongue is covered with points, called *papil'lœ,* in which are the delicate threads of the nerve of taste (Fig. 77). Some of these papillæ are concerned with the sense of touch, others with the sense of taste. The tongue is also supplied with little glands, which pour out a thin fluid to moisten the interior of the mouth.

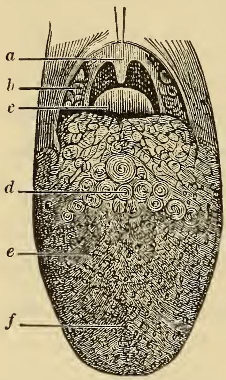

Fig. 77.—The Human Tongue. (Showing also the back part of the mouth.)

a, the palate; *b*, tonsil; *c*, epiglottis; *d*, *e*, *f*, papillæ.

The tongue must be moist and the article soluble before there can be perfect taste.

Conditions of Taste.—Solution of an article in water separates the particles so that they come directly in contact with the tongue; but some articles, as metals, held in the mouth, have a peculiar taste without being dissolved.

Articles of food are spoken of as sweet, sour, bitter, etc., agreeable or disagreeable. Substances of agreeable taste are generally useful; those of disagreeable taste, either injurious or without any advantage as food. The quantity of food necessary to give rise to a taste is sometimes so small that it can scarcely be weighed on the lightest balance. A drop of a bitter article will sometimes give a bitter taste to a quart of water, but it requires a great deal of sugar to give a sweet taste to the same quantity of water.

The sense of taste is under the control of the will. It may be injured by indulgence or excess in drinking. Taste is not perfect unless the power of smell is also perfect. If we close the nose tightly, taste is blunted or destroyed. As a rule, articles of food pleasant both to taste and smell are generally likely to agree with the stomach; those which are not pleasant both to taste and smell are likely to disagree.

Many articles taken as food in one part of the world are not liked in other parts. Many years ago horse-flesh was not eaten as food, while now there are several hundred establishments in France devoted to the preparation of it for food.

Nerves to the Tongue.—Three nerves are distributed to the tongue: the fifth pair, from the brain, which gives it sensation or feeling; the eighth pair, which with the fifth seems to make the taste perfect; the ninth pair, which moves the tongue, as in swallowing, speaking, etc.

Organ of Taste in Other Animals.—In the higher classes of animals the organ of taste is very much the same as in man. The sense is not strongly developed in birds. The tongue of the woodpecker is not an organ of taste, but it is sharp and like a fork, with which it pierces insects. The parrot uses his tongue to hold the article he may be eating. In some reptiles the tongue is large and muscular. In serpents it is sharp and forked and moves very quickly. In the bee the tongue is like a little tube, through which it sucks juices from flowers. The tongue in some fishes does not move in the throat.

QUESTIONS.

What are the five senses and their objects?

What is the organ of taste? What are the papillæ?

What nerves are distributed to the tongue?

What effect has the sense of smell on taste?

What is the arrangement of the tongue or organ of taste in other animals?

SMELL.

The Organ of Smell.—The organ of smell is the mucous membrane lining the nose, particularly its back part. The odorous properties of bodies pass into the interior of the nose in very fine particles. The surface is full of nervous papillæ or projections. The membrane is continued up into the bony cavities back of the nose, which open behind into the throat, so that the air can pass freely through.

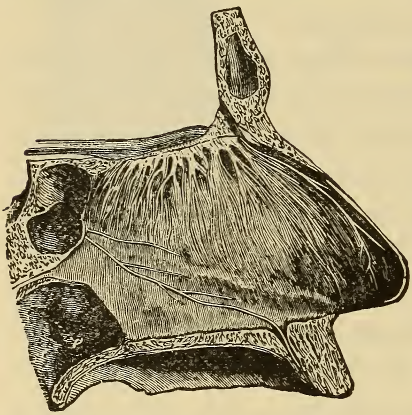

Fig. 78.—Nerves supplied to the Cavities of the Nose.

Each nostril is divided at its back part into three passages. Two of these communicate with cavities in the bones, thus forming large spaces for smell. The mucous membrane is smooth and velvety, lines all the cavities, and pours out mucus to keep the parts moist.

The Nerve of Smell.—This is the first pair of cranial nerves, which divides into small branches, and passes through openings in the skull, and when it reaches the upper and back part of the nose it is scattered to be sent like a shower in fine branches over the upper and middle parts of the mucous membrane (Fig. 78). The fifth pair sends branches to the nose, and gives general sensibility to it, and perfects the sense of smell.

The shape of the nose supplies a funnel in which to collect odorous particles.

Odors.—Odors are separated from bodies by rubbing, heat, light, chemical action, moisture, etc. The effect of moisture is shown in the smell to be noticed after a shower in a garden of flowering plants. For perfect smell, the nose must be thoroughly open, the membrane healthy and moist, the nerve and brain perfect.

The particles that give odor need not be placed close to the nose. The smell of cinnamon has been noticed two hundred miles from land.

How Smell is Effected.—The air containing the odor is drawn into the nose, so as to carry it as far as possible up that organ to reach the nerve of smell. The mucus on the lining membrane stops the progress of the particles, so that they can affect that nerve.

Through the nose and its cavities, in respiration, the air passes to the lungs, and if there be anything offensive in the air we breathe, the nose warns us in regard to it.

Sense of Smell in Animals.—Animals which have the greatest development of the nerves of smell have the strongest instincts of scent, as it is called. Birds searching for food generally use their sight more than their smell.

The scent of animals, as of the pointer and bloodhound, depends on their power to detect by the nose the odorous particles given off by other animals. These, being heavy, are generally noticed near the ground, and this is why scenting dogs apply the nose as low as possible.

QUESTIONS.

What is the organ of smell? The object of the sense of smell?
What membrane lines the cavities of the nose?
What is the nerve of smell?
What other nerves go to the nose?
For perfect smell what organs must be perfect?
How is smell effected?
What is the condition of this sense in other animals?
What does the scent of animals depend upon?

TOUCH.

The Organ of Touch.—In the skin are myriads of nervous points called *papil'læ*—in greater numbers wherever touch is most acute, as in the fingers. Here are also small firm bodies, closely connected with the nerve,

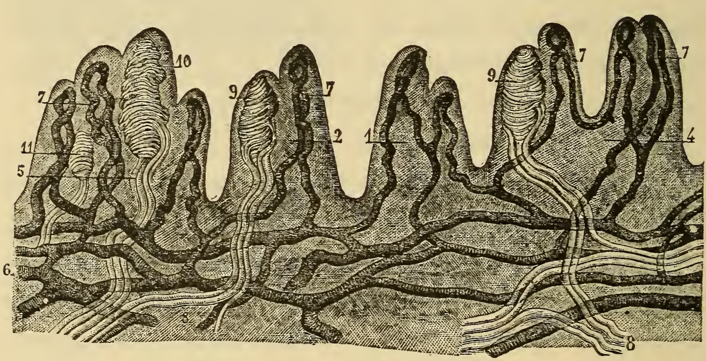

Fig. 79.—Papillæ of the Skin of the Hand (greatly magnified).

1, papillæ with blood-vessels; 2, papillæ with touch-body; 4, 5, large papillæ; 6, 7, vessels beneath or in papillæ; 8, nerves beneath papillæ; 9, 10, 11, touch-bodies.

called *touch-bodies,* which render touch still more acute (Fig. 79). The sense of touch is most perfect in the hands. Here there are 20,000 papillæ to the square inch. Beneath the skin is a layer of fat, which gives the figure its round appearance.

The papillæ vary in size, being usually about $\frac{1}{100}$th of an inch long and $\frac{1}{250}$th of an inch broad, well supplied with capillary blood-vessels, as in the fingers (Fig. 79).

The Skin.—The skin protects the parts beneath, and also gets rid of some watery and fatty matters. The outer layer, the *epider'mis* (from Greek words meaning "upon the skin"), is thick where it is pressed upon, as in the fingers or heels, and thin over the lips. It has no nerves or blood-vessels, and therefore any pain in the skin, or any bleeding from it, must come from the layer of the skin beneath it, the *cu'tis* (Latin for "skin"), *der'ma*, or *true skin*, which has in it a great many vessels and nerves.

Sweat-Glands (Fig. 81).—The sweat or perspiration is obtained from the blood by glands in the skin. Each gland is a tube turned upon itself, and empties on the skin.

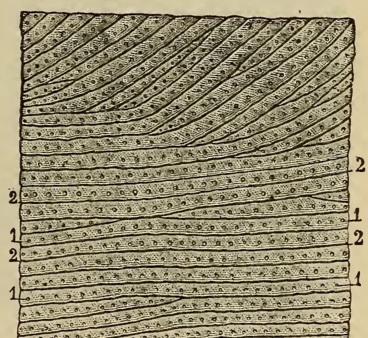

Fig. 80.—Surface of the Palm of the Hand (slightly magnified).

1, 1, 1, opening of ducts of sweat-glands; 2, 2, 2, grooves between the papillæ of the skin.

The sweat-glands number nearly 3000 in each square inch of skin on the palm of the hand or the sole of the foot, and in the whole body they number about 7,000,000. If all the sweat-glands were placed end to end they would extend more than three miles. The sweat from these glands is not generally seen; it is carried off as a vapor. It is noticeable after exercise or in hot, moist weather. The amount poured out in twenty-four hours is about two or three pounds.

Sebaceous or Fat-Glands.—The skin is kept soft by fatty matter poured out on its surface by *seba'ceous glands* (from a Latin word meaning "suet"). There are a great many of them on the face and the top of the head, where they moisten the hair.

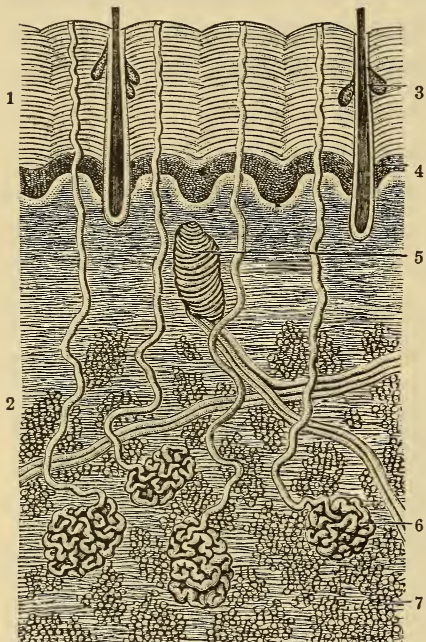

FIG. 81.—SECTION OF SKIN (magnified).

1, epidermis; 2, dermis; 3, hair-follicles; 4, coloring matter; 5, touch-bodies; 6, sweat-glands; 7, fat-cells.

Hair (Fig. 81).—A hair is not so simple as it looks; it has a shaft above the skin and a root within it. When a hair grows to excessive length it may split into fibres like a painter's brush, which will become brittle and break off. This is not likely to happen if there is enough fatty matter to keep the hair from becoming dry.

The hair partially protects the head from injury or from excessive heat or cold. The eyebrows and eyelashes protect the eyes from dust or other matter that might injure them. The color of the hair depends on the presence of coloring-matter in the cells at the roots of the hairs. A hair becomes gray or white because there is not enough coloring-matter secreted.

The *nails* aid in touch, and give a support for the ends of the fingers. Horns, feathers, hoofs, scales, bristles, etc. have similar uses.

Color of the Skin.—This depends on the deposit of coloring-matter in the deeper layer of the skin. Black coloring-matter is found in the negro, red in the Indian.

The Hand.—This is in man the principal organ of touch. By it he learns shape, weight, hardness, etc. Its joints and tendons (Fig. 82) admit of great variety of motion. The thumb is especially characteristic of man.

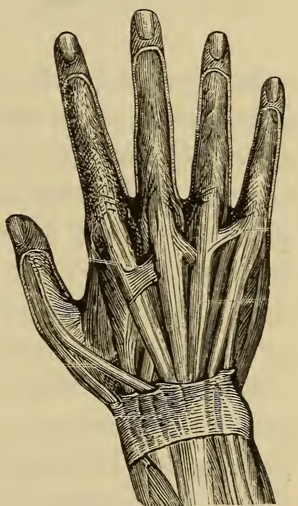

Fig. 82.—Tendons of Hand.

The Sensation of Touch.—The sensation differs with the nature of the body touched, the temperature, etc. It sometimes deceives us. If, for instance, we place a marble between the fingers, as in Fig. 83, we feel only one marble; but if we afterward cross the two fingers we think we feel two marbles. A separate impression is made on each finger in spite of our knowledge that only one marble is there.

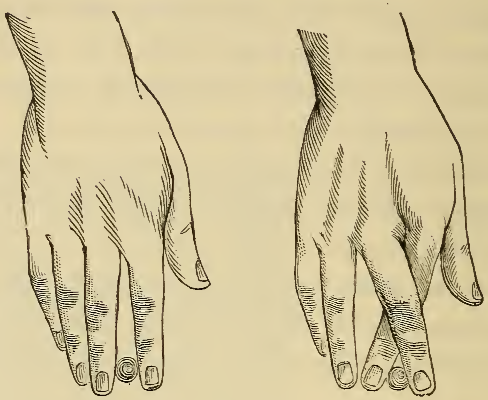

FIG. 83.—AN ILLUSION OF TOUCH.

Sense of Touch in Other Animals.—In most of the higher classes of animals the tongue, lips, and snout are the chief organs of touch. In many insects the outer covering of the body is thick and shell-like, and some of them have near the mouth movable feelers, which can be directed toward any object. The scales of fishes interfere with their sense of touch. The whiskers of the cat and of other animals assist them in their touch.

Hygiene of the Skin.—The health of the body is improved by attention to two very important matters—clothing and bathing.

The *clothing* must be clean, and not worn so long as to be soiled with waste matter from the skin, which will otherwise remain in the system to exert an injurious and perhaps poisonous effect. Clean and frequently-changed underclothing, as it comes directly in contact with the skin, is especially desirable, as it readily absorbs moisture from the skin. Clothes worn during the day and bed-clothes used at night should be well aired, and thus purified.

Bathing.—Bathing the surface of the body, with friction from the towel, removes dirt or dust from the skin, and clears it of any matter left as a deposit after evaporation of the watery particles from the sweat-glands and the fatty matter from the sebaceous glands. A cold bath taken daily will, as a rule, agree with those of strong constitutions, but it should be immediately followed with active friction with a coarse towel until a glow is produced, and a certain amount of after-exercise must be practised.

A chill after a cold bath shows that it does not agree with the bather. Those who are feeble should use moderately warm water, say once or twice a week, and for a short time only; but the skin should be thoroughly dried and rubbed until it becomes warm. Sea-bathing has a still more stimulating effect.

Perfumery is sometimes used to conceal the odor from an unclean body, and cosmetics to give artificial color to the face; but many of these articles are made up of poisonous matters, such as lead, and few are perfectly harmless. Soap is decidedly better for the removal of dirt from the skin, and perfumes, if employed at all, should follow its use.

A bath should not be taken after a full meal, about three hours being allowed to elapse. Early morning is the best time for a cold bath, but any one not accustomed to it should begin at a higher temperature—say 65° or 70°—and gradually reduce it. A stay in the bath of ten to twenty minutes is sufficient, and even at the seashore it should not be protracted to a much longer period. The body should not be chilly when entering the water.

QUESTIONS.

What is the organ of touch? What are the papillæ? Touch-bodies?
What is the use of the skin? What fluids pass through it?
What are the layers of the skin called?
What is the size of the papillæ?
From what is sweat derived? How many sweat-glands in the body?
How much sweat is secreted in twenty-four hours?
What are the sebaceous glands? What do they pour out?
Into what parts is a hair divided?
What does the color of the hair depend on?
What does the color of the skin depend upon?
What are the chief organs of touch in other animals?
What is said of clothing? Of bathing?
What rules are best as to taking baths?

VISION.

The Organ of Vision.—By vision we judge of light and color, and of the shape, size, distance, and properties of objects around us. Sight or vision depends on the optic nerve—the second pair of nerves—and an organ, the eye, conveying light to it.

The parts necessary for sight are contained in the *globe* or *ball* of the eye. These parts, as well as the nerve of vision and the brain itself, must be perfect. The optic nerves as they pass from each side to the eyes cross like the lines in the letter X.

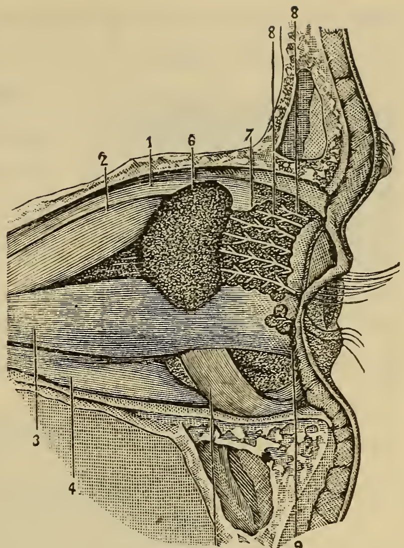

Fig. 84.—Section of the Eye.

1, 2, 3, 4, 5, muscles of the eyeball; 6, lachrymal gland, with its ducts, 7, 8, 9.

Protection of the Eye.—The eyelids, eyelashes, and eyebrows shield the eye from excessive light and prevent dust from irritating it, while the tears poured over the eye and the sebaceous matter keep it moist.

The Tears.—The tears are poured out by the *lach'rymal gland* (from a Latin word meaning "a tear"), one on each side, above the outer part of each eyebrow (Figs. 84, 85). The tears are being poured out at every moment of our lives.

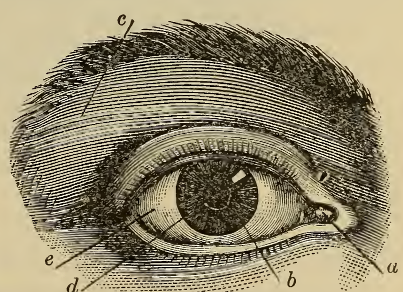

Fig. 85.—The Eye.

a, canal for passage of tears into the nose; *b*, iris; *c*, position of lachrymal gland; *d*, pupil; *e*, mucous membrane.

They keep the surface clear and transparent, and give lustre to the eyes. The tears then pass into the inner corner of the eye, and thence by a little canal into the nose.

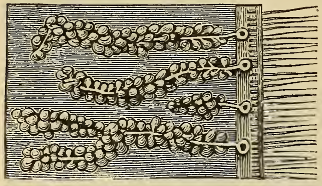

Fig. 86.—Sebaceous Glands of the Eyelashes (slightly magnified).

The Orbits.—The eyeball is placed in a deep bony space or cavity—the *socket* or *orbit.* Some fat in this cavity furnishes a cushion for the eyeball.

The Eyelids.—The eyelids act like a curtain to the eye; they are covered on the

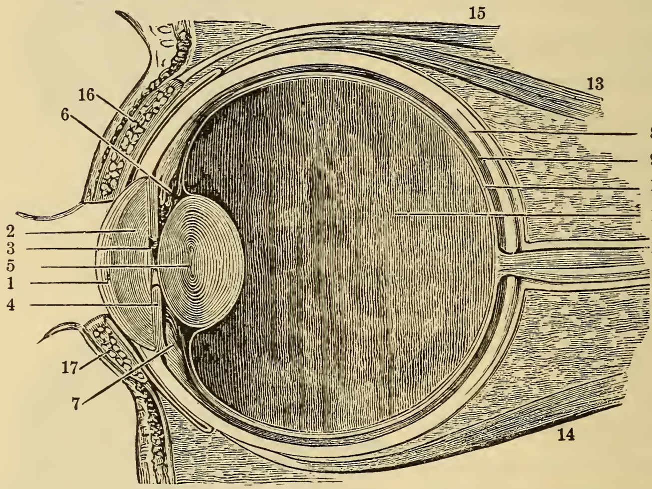

Fig. 87.—The Eye. (A vertical section through the middle of the eyeball.)

1, cornea; 2, aqueous humor; 3, pupil; 4, iris; 5, lens; 6, ciliary processes; 7, canal around the lens; 8, sclerotic coat; 9, choroid; 10, retina; 11, vitreous humor; 12, optic nerve; 13, 14, 15, muscles of the eyeball and of the eyelid; 16, 17, eyelids.

outside by skin, on their inside by delicate mucous membrane, which is reflected over the front of the ball.

The Eyelashes.—The eyelashes and lids regulate the amount of light to the eye. Little sebaceous or fatty glands (Fig. 86) pour out an oily fluid on the lids, so that they do not stick to one another, and also prevent the tears from overflowing the cheek.

Transparent Parts of the Eye (Fig. 87).—The front part of the eye, shaped like a watch-crystal, acts like a window, and is called the *cor'nea,* from its looking like a horn (*cornu,* "horn") (Fig. 87, 1). Behind this is the *anterior chamber* (front apartment), containing a watery fluid called the *aq'ueous* or *watery hu'mor* (Fig. 87, 2). Behind this is the only solid part of the eye, the *crys'talline lens* (Fig. 87, 5), convex on its front and back surfaces. It is about a quarter of an inch thick, and is perfectly transparent.

Farther back is a transparent, jelly-like material, the *vit'reous* or *glassy humor,* resembling melted glass, placed in the *posterior chamber* (back apartment), and occupying about two-thirds of the eyeball.

Coverings of the Eye.—The eye has three coverings or coats. The outer one, giving shape to it, is the *sclerot'ic* (Fig. 87, 8) (from a Greek word, meaning "hard"). The muscles moving the eyeball are fastened to it. It is the "white of the eye." The next coat is the *cho'roid* (Fig. 87, 9), a black, opaque membrane, with numerous vessels passing into it, and this coat absorbs unnecessary rays of light, and thus prevents confusion of sight.

The third and last membrane, the *ret'ina* (Fig. 87, 10), lines the back part of the eyeball. It is a spreading out of the optic nerve, and is therefore sensitive to light.

In the front part of the choroid is a movable curtain, the *i'ris* (Figs. 85, *b ;* 87, 4), with muscular fibres, which dilate and contract the *pupil*—the opening in the centre of the iris (Figs. 85, *d;* 87, 3). The dark coat of the choroid acts like the black coating we see in telescopes: it shuts out unnecessary rays of light, and thus prevents confusion. The color of the choroid as seen through the iris gives color to the eye—as blue, hazel, gray. Dark eyes, for instance, depend on the deep color of the choroid; light eyes, on a pale and colorless choroid. The amount of light passing through the pupil may be made smaller by contracting the iris. When the light is not sufficiently bright the pupil will enlarge itself. The size of the pupil has much to do with the brilliancy of the eye.

There are six muscles which move the eyeball, and they act independent of the will, although we have the power also of moving the eye in different directions.

Light.—The cause of vision is the action of light on the retina. We suppose that an elastic medium occupies all space, which is excited into rapid waves by the sun or any other luminous body. These waves travel nearly 190,000 miles a second; the light of the sun—which celestial body is said to be 95,000,000 miles away from us—takes over eight minutes to reach us.

The Course taken by the Rays of Light.—Light (Fig. 88, *c d*) passing through a transparent uniform medium, *a b*, like air, proceeds in a straight line. If it comes in contact with any other transparent body that is denser and heavier, such as water, it is either *reflected, e h*—that is, turned back in its course—or it is broken or *refracted, e g.*

Rays of light striking upon the eye pass first through the cornea, which is convex, and therefore refracts them; then through the aqueous humor, which does not cause much change; they next strike upon the iris, which reflects those falling on its surface, and only such rays as pass through the pupil reach the retina.

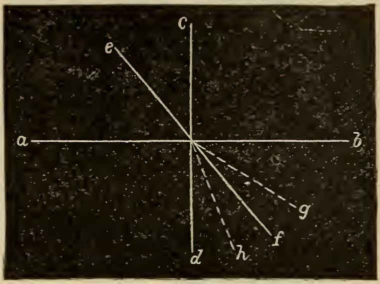

FIG. 88.—REFRACTION OF LIGHT.

They next come in contact with the crystalline lens (Fig. 87, 5), which refracts them; and then through the vitreous humor, falling at last on the retina, producing upon it an image of the object.

The Image on the Retina.—This image (DE, for instance, Fig. 89) is reversed; that is, upside down: and

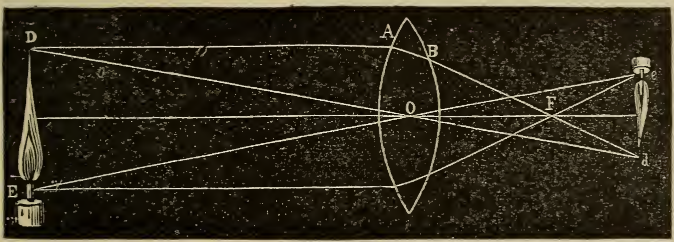

FIG. 89.—FORMATION OF AN IMAGE ON THE RETINA.

yet the brain sees the object in its natural position. Each retina receives an image, but the brain sees only one.

Far Sight and Short Sight.—In the healthy eye parallel rays (Fig. 91, A) from a distance must come to a focus, or central point (x), on the retina, or the image will be indistinct. In *short-sighted* persons (Fig. 91, B) they

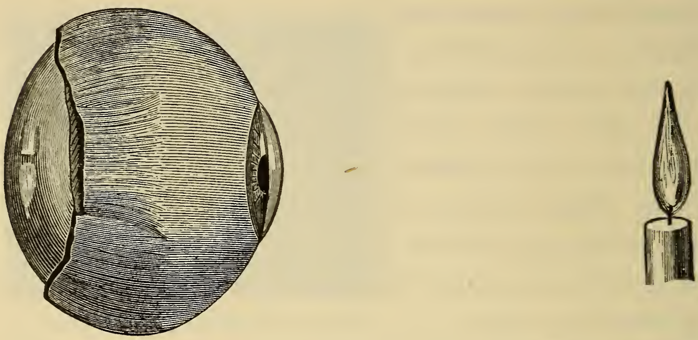

Fig. 90.—Inverted Image on the Retina shown in the Bullock's Eye.

come to a focus (x) *in front* of the retina. In the *far-sighted* (Fig. 91, C), they come to a focus (x) *behind* the retina. Short-sighted persons must use concave glasses, to remove the focus farther back to the retina. Far-sighted persons must use convex glasses, to bring the focus farther forward.

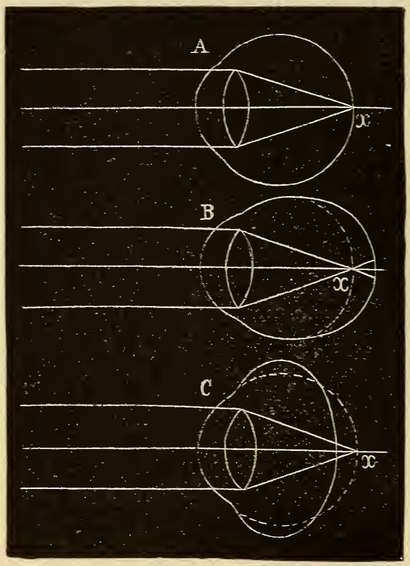

Fig. 91.

A, natural sight; B, short sight; C, far sight.

Impression on the Retina.—An impression on the retina generally lasts from $\frac{1}{50}$th to $\frac{1}{30}$th of a second. Take a round piece of card having one side black and the other white, and turn it rapidly, when only continuous dark bands will be seen. If a red spot be painted on the face of the card, it will appear like a red band when it is turned rapidly, showing that the impression is continuous. Each impression is confounded with those which follow it.

There is a spot on the retina, the *blind spot*, at the entrance of the optic nerve, at which light and color are not appreciated. To prove this, shut the left eye; with the right eye look steadily at the cross on this page (Fig. 92), and then move the book toward the eye and away from it. The round spot will disappear, just as soon as the image from it falls directly on the blind spot, which although small, is large enough to cause a figure of a man to disappear at a distance of about six and a half feet.

FIG. 92.—EXPERIMENT IN REGARD TO THE "BLIND SPOT."

In the centre of the retina is a *yellow spot* very sensitive to light. When we read a book we bring each word in the text opposite the yellow spot, the centre of vision.

Perception of Colors.—The eye also perceives colors, of which there are seven elementary ones—violet, indigo, blue, green, yellow, orange, and red (remembered by the word "*vibgyor*," which contains the first letter of each color). Some persons cannot tell one color from another, and are therefore said to be *color-blind*. Red and green are the most confusing colors. In all parts of the world they now regularly examine the eyes of locomotive engineers and signal-men, as, if color-blind, they might mistake the color of the signals and thus cause terrible accidents.

Vision in Other Animals.—In some low forms of animals the eyes are merely dots to distinguish light from darkness. In some fishes, and in some other animals that live both on land and in water, the eyes are covered with a skin. In some animals, as the tortoise, there is a movable membrane. In many birds it can be drawn over the surface of the eye to protect it from light or foreign bodies.

In some animals the choroid is absent and the eye looks white or metallic. In the cat and the lion a portion of the choroid is covered with a bluish layer shining like metal, so that the light is strongly reflected and the eyes seem like balls of fire. In cats and crocodiles the pupil is longer up and down than it is from side to side. In animals which seek their prey by night the eyes are usually large; in the daytime the pupil appears almost like a buttonhole, while at night it is round, as in man.

Insects and such animals as crabs and lobsters have *compound eyes*, made up of tubes, which go off from a centre like spokes of a wheel placed closely together. There are sometimes 10,000 to 20,000 of these tubes in a single eye, each one an eye itself, and all packed in a space of a small fraction of an inch. The ant has 50 of these eyes, the fly 4000, the butterfly more than 17,000. They seem to have eyes for every direction.

Eyes are not always placed alike, on opposite sides. Insects living entirely in dark caverns or deep wells are devoid of organs of sight. Birds are far-sighted; fishes are near-sighted.

Hygiene of the Eyes.—Every care should be taken to preserve the sight in as perfect condition as possible. It may be well, therefore, to give rules for the avoidance of the usual causes of injury to vision in every-day life.

Never look or gaze at objects that are intensely bright, as a full gas-jet or electric light; especially at the sun itself, even when it may be partly or wholly eclipsed. Never strain the eyes to read or sew when the light is feeble or flickering. Do not use a lamp with a shade or globe upon it which renders the light intensely white to the eye; the light from it should be modulated with a colored paper or silk shade. When the day is dying out do not attempt to read or sew up to the very last moment of visible light, when the eye can scarcely see the objects before it. Do not attempt to read printed matter, especially fine print, while riding in a carriage, street-car, or train; the effort of the eye to accommodate itself to a changing focus will fatigue and injure the delicate nervous coat of the eye, and probably lead to defective power of that organ.

Never read a paper or letter with the light shining directly upon it; it is better that the light should come from the side or back of the person, and not from the front. The eyes should not be used to the point of extreme fatigue; they need rest after work, as does every other organ of the body. If the eyes are used continuously and intently on one kind of work, such as sewing, they may sometimes be rested by changing their occupation for a while, as by reading. Never allow them to be strained over very fine type; it is better to lay aside a book entirely than to force the eyes to labor over its text with such effort as the reading of small type will call for.

Do not continue to use an eye that is inflamed, defective, or feeble without seeking good medical advice, as its continued employment will only increase the mischief already existing, and may at last produce blindness or impaired vision. Do not rub the eye to remove dust or other particles from it; these can generally be seen and taken away by carefully applying the corner of a soft handkerchief folded. Do not pull the eyelids in hopes of bringing to the eye enough tears to wash out the offending substance.

Wash the eyes always with cool water; avoid using water for this purpose that is very hot or very cold. Do not read while lying in bed or on a sofa, as some of the muscles of the eyeball are overstrained by such an act.

Effect of Alcohol and Tobacco on Vision.—When alcohol is used as a drink it is apt to cause inflammation or congestion of the eyeball and of the lining membrane of the eyelids. Weakness of vision is quite well known as a disease of drinkers, and this is apt to last as long as the cause—alcoholic drinking—is indulged in, and at last the whole structure of the eye becomes changed and the nerve of sight wastes away, and perhaps blindness may result.

Tobacco produces confusion of sight, with specks before the eyes, and deeply-seated pain. The nervous coat becomes so seriously affected that the object that impressed it is seen long after the eye has ceased to look at it.

QUESTIONS.

What is the nerve of vision? What parts protect the eye?

What effect have the tears and sebaceous matter?

What gland secretes the tears? When does this take place?

What is the socket or orbit of the eye? What are the eyelids?

Of what use are eyelashes? How are their edges greased?

What is the cornea? The anterior chamber of the eye? The crystalline lens?

What are the other transparent parts of the eye?

What are the three coverings of the eye? What is the nervous coat?

Through what transparent parts must light pass to reach the retina?

What is the iris? The opening in its centre? Its uses?

What muscles are attached to the sclerotic coat?

What kind of a membrane is the choroid? Its uses?

What part of the eye gives color to the eyes?

What kind of a membrane is the retina? Its uses?

How is the eyeball moved?

What is the cause of vision? The theory of light?

How fast does light travel?

What is reflection of light? Refraction?

What effect has the cornea upon light? The iris? The lens? The pupil? What is the position of the image on the retina?

What becomes of the parallel rays of light in the healthy eye? In the near-sighted eye? In the far-sighted eye?

How can short sight be corrected? Far sight?

How long does an impression on the retina last?

What is the blind spot of the retina? What effect on vision? What is the yellow spot? What effect on vision?

What are the seven elementary colors?

What is color-blindness? What colors are generally confounded?

What peculiarities of vision are noticed in the lower animals?

Is the pupil always round, as in man?

What are the compound eyes of flies, butterflies, etc.?

What are some of the rules for taking care of the sight?

What effect have alcohol and tobacco on vision?

HEARING.

The Organ of Hearing.—The organ of hearing is the ear. It consists of three parts—an outer ear, the middle ear, and an inner ear, in which is the nerve of hearing.

The *Outer Ear* (Fig. 93) consists of the projecting part

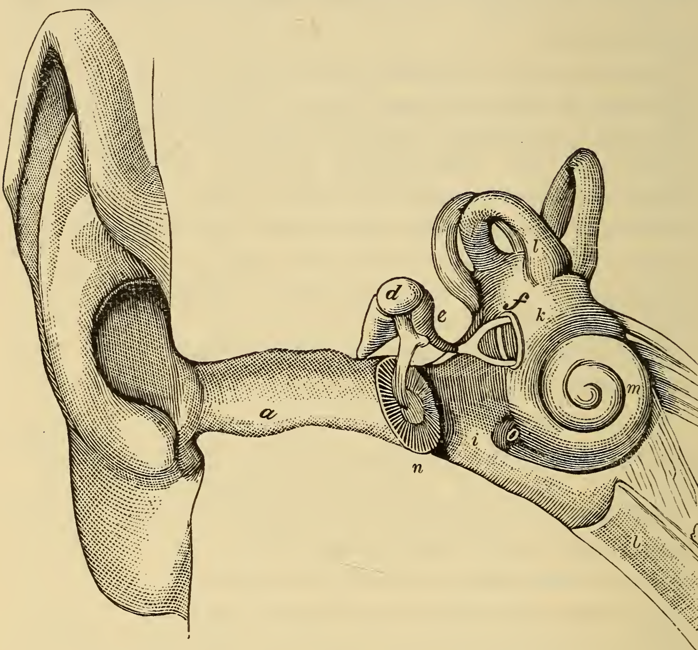

FIG. 93.—THE EAR.

a, external auditory canal or tube; *b*, Eustachian tube; *f*, oval window in the vestibule; *o*, round window; *d*, *e*, *f*, little bones of the ear; *i*, middle ear; *k*, vestibule; *l*, semicircular canals; *m*, cochlea; *n*, membrane of the drum. (All the inner parts are here larger than natural.)

on the side of the head and a canal or tube (Fig. 93, *a*) leading inward, the *aud'itory canal* or *tube*, closed at its inner end by the *membrane of the drum* of the ear (Fig. 93, *n*).

The *Middle Ear*, or drum, is filled with air, and communicates with the throat by the *Eustach'ian tube* (pron. Use*take*ian), named after the anatomist Eustachius, who first described it.

The *Inner Ear* is called the *lab'yrinth*, because it is so intricate. In the inner ear is the nerve of hearing.

The bony labyrinth is made up of apartments and canals hollowed out in the bone (Fig. 93). In it is a small quantity of fluid. In this labyrinth, and surrounded by this fluid, is the *mem'branous labyrinth*, in which is the nerve of hearing, bathed in another fluid. In the membranous labyrinth are parts called the *vestibule*, with the *semicircular canals* (Fig. 93, *k*, *l*). In each canal are fine long threads like hairs, which are part of the nerve of hearing. There is also a part called the *coch'lea* ("a snail-shell"), Figs. 93, *m*; 95, A, D), a portion of which is winding like a staircase (Fig. 94).

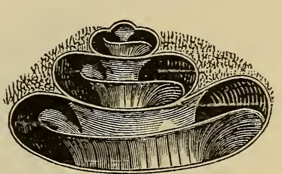

Fig. 94.—The Cochlea (representing its spiral structure).

How Sound is Heard.—The outer ear collects the waves of sound and forwards them to the membrane of the drum. The familiar habit of applying the hand behind the ear when we desire to increase our capacity for hearing is practised with a view of collecting the vibrations or waves of sound, so that they will pass in greater quantity and force into the outer ear. The external auditory canal (Fig. 93) is protected from injury from insects and foreign bodies by a form of secretion called ear-wax, poured out by certain glands called *ceru'minous glands* (from *ceru'men,* "wax") on its surface, and by the hairs that grow along the canal. The middle ear, or drum, has several small bones connected with it, moved by very small muscles, which vibrate and render the membrane of the drum tight or loose according to the intensity of the sound.

The vibrations of sound are forwarded to the inner ear, partly through the air in the middle ear and partly

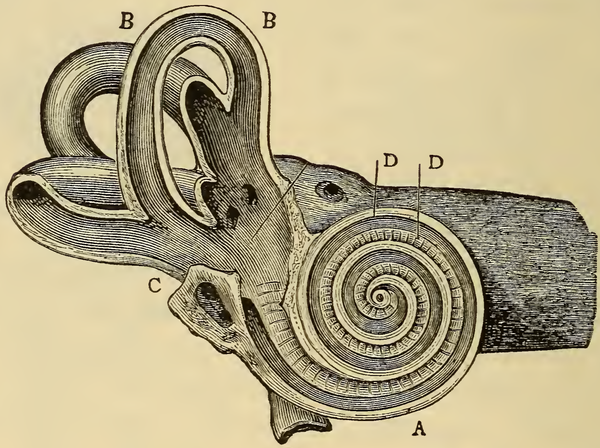

Fig. 95.—Interior of the Inner Ear.

A, D, cochlea; B, B, semicircular canals; C, vestibule.

along the chain of little bones, which are called, from their shape, the hammer, the anvil, and the stirrup (Fig. 93, *d, e, f*). The vibration of the little bones is communicated to the fluid in the labyrinth, and thence to the hair-like ends of the nerve of hearing, through which the impression is carried to the brain. For perfect hearing both the brain and the nerve of hearing must be in a healthy condition.

Sound.—The lowest sound that can be heard is said to be that made by a pith-ball, about $\frac{1}{65}$ of a grain in weight, falling upon a smooth piece of glass from a height of $\frac{1}{20}$ of an inch at a distance of $3\frac{1}{2}$ inches from the ear. A certain number of vibrations is necessary to produce a tone, otherwise sound will not be heard. The lowest limit is said to be 30 vibrations a second, the highest between 30,000 and 35,000.

The two ears hear a single sound, and the brain appreciates but one sound. Sound is transmitted, as light is, by waves.

The Sense of Hearing in Other Animals.—All the higher animals have outer ears, which in some of them can be turned in a direction to catch the sound. Birds do not have any outer ear, but in some of them the drum communicates with cavities in the bones of the skull, which act like a sound-board of a piano. The little ear-stones in the inner ear are noticeable in fishes, some of which have them as the whole organ of hearing, in addition to a nerve.

Hygiene of the Hearing.—Avoid draughts of cool or damp air, which can affect the ear either by the Eustachian tube from the throat or directly through the outer ear. Do not strike any one on the ear or on the side of the face, as the drum of the ear may suffer, perhaps be ruptured, or the little bones of the middle ear may be injured, and deafness result. Be careful in picking out wax from the ear; it not only protects it from insects or foreign bodies, but in the effort to dislodge it the person may injure the membrane of the drum of the ear.

Loud sounds, such as the firing of cannon, explosions, etc., have been known to affect the hearing by bursting the membrane of the drum. As it is better to open a window before an expected explosion or cannonade, so as to break the effect of the vibration, so is it well to open the mouth in order that the Eustachian tube from the throat may also be open, and the whole force will not then be spent upon the membrane of the drum.

Deaf persons, of course, fail to hear the voices of friends, the sounds of music, etc., and as these are great sources of pleasure, we should avoid, as much as possible, all influences that are apt to lead to deafness. The outer canal of the ear should never be violently washed out with a syringe or rudely wiped out with a wash-rag; force is never necessary. Never pick or dig into the ear with hair-pins, toothpicks, pins, or any other articles, as the membrane of the ear may be pierced by them.

Oily and greasy matters dropped into a healthy ear often irritate it, and should not be recklessly used when the ear is inflamed. Diving into the water or dropping into it from a height will often injure the ears or affect the hearing. Do not throw very cold or very hot water into the ears.

Alcohol and *tobacco* injure the sense of hearing. Alcohol may produce an inflamed condition of the throat, and the inflammation may travel up the Eustachian tube into the middle ear, and produce deafness. Tobacco may produce catarrh of the throat and nose, and disease of the ear may follow. It frequently leads to confusion of sounds in the ear, and the extremes of sound—such as loudness and softness—which are the test of delicacy of hearing in the healthy ear, are not properly appreciated by the organ of hearing. Some of this effect may be due to the fact that the brain itself is confused by the tobacco or the alcohol, and rendered unfit for the appreciation of sounds.

QUESTIONS.

Of what three parts does the organ of hearing consist?

What parts compose the external ear? The middle ear?

What is the labyrinth? Of what parts is it composed?

What are the little bones of the ear called? Their uses?

What is the cochlea?

How does sound reach the inner ear? The brain?

What parts must be perfect to ensure perfect hearing?

What is the lowest sound that can be heard? The lowest and highest number of vibrations of sound that can be heard by the ear?

What peculiarities of the ear in other animals?

What are some of the rules for taking care of the hearing?

What effect have alcohol and tobacco on the hearing?

VOICE.

The Organ of Voice.—Voice is produced by vibration of the vocal cords in the larynx while the air is passing through it. The parts concerned in its production are the larynx, windpipe, lungs, mouth and nose, and muscles of breathing.

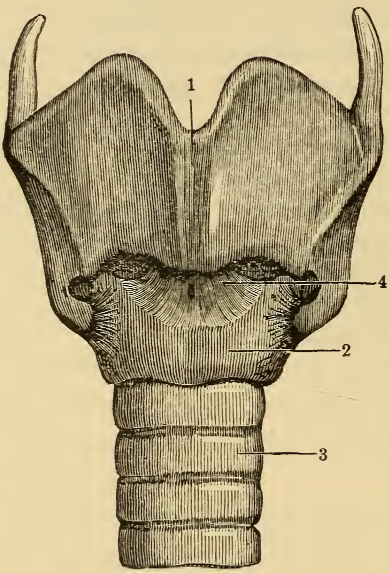

Fig. 96.—The Larynx (front view).
1, 2, cartilage; 3, windpipe; 4, ligament.

The Larynx.—The larynx (Fig. 96) is situated in the front of the neck; it is more prominent in the male, in whom it is commonly called the "Adam's apple," as if the apple which Adam ate had stuck in his throat. The mucous membrane of the mouth and throat passes down into the larynx and windpipe. The larynx is made up of four cartilages, movable upon one another, united by ligaments, and having muscles attached.

The Vocal Cords.—Inside the larynx are two triangular spaces (Fig. 97). The upper space has at the side two folds of mucous membrane, the *upper*, or *false vocal cords;* the lower one has at the side two folds, the *lower*, or *true vocal cords.* The vocal cords are perfectly free to move, and are only separated from one another about a third of an inch.

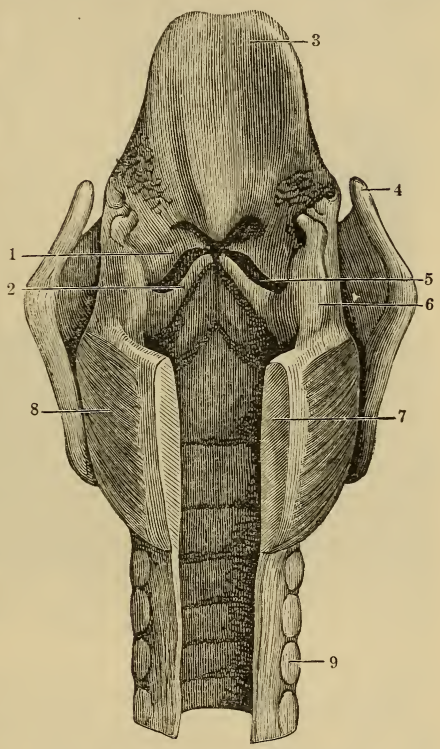

FIG. 97.—INTERIOR OF THE LARYNX.

1, upper or false vocal cords; 2, lower or true vocal cords; 3, epiglottis; 4, thyroid cartilage; 5, vertical section of glottis; 6, 7, cartilages; 8, muscle between cartilages; 9, windpipe.

Muscles of the Larynx.—The muscles concerned in the production of voice either tighten the vocal cords or separate the cartilages from one another, so as to open the *glot'tis* (Fig. 97, 5), as the space between the lower vocal cords is called, or bring them together to close the glottis.

How Voice is Produced.—To produce voice, air must pass from the lungs through the windpipe into the larynx, cause a vibration of the vocal cords, and pass out through the mouth and cavities of the nose (Fig. 23). This is under the influence of the will; otherwise voice would be produced every time we breathe. The lower vocal cords (Fig. 97, 2) are the parts directly concerned in voice.

To illustrate the passage of air through the glottis: Take two pieces of bladder or India-rubber and stretch them over the end of a tube (Fig. 98), so that each shall cover rather less than the opening, a space being left between them. If air be forced upward through such a tube by bellows a sound will result if the opening be not too wide. If the membranes be tighter or looser, the sound will vary in character.

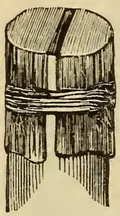

Fig. 98.—Plan of the Glottis.

Some writers describe the larynx as being like a flute, the vibrations being caused by air passing through; others speak of it as a stringed instrument, on account of the vocal cords. Most writers think it is more like a reed instrument, such as a clarionet. The larynx is more developed in the male than in the female, and hence his voice is stronger.

Quality of Voice.—Every person has his own quality of voice, which distinguishes him from every one else. In the female the larynx is more cartilaginous than in the male. The change of voice in boys twelve to fourteen years old is due to the fact that the ligaments and the opening of the larynx then become enlarged.

Whispering is the giving of slight voice to the air breathed out; whistling is caused by dividing the air as it passes through the lips.

The Singing and the Speaking Voice.—The voice in singing differs from the ordinary voice in speaking by being made up of distinct musical tones, following in regular order. Fig. 99 shows the ordinary average of the singing voice. The deepest male voice is the bass, the highest the tenor; the baritone occupies a place between these two. The lowest female voice is the contralto or alto, the highest the soprano, and the mezzo-soprano occupies a place between them.

The singing voice is generally from the larynx—chest-voice it is then called—but sometimes also from

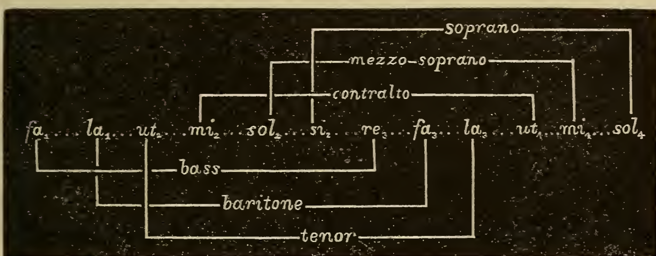

FIG. 99.—RANGE OF THE SINGING VOICE. (The figures denote the different octaves.)

the throat. The larynge′al voice is usually an octave higher in woman than in man. The range of the human voice is generally considered to be three octaves, say from low fa or fa_1 (generally known as F_1 on the scale of the piano), representing 174 vibrations a second, to high sol or sol_4, representing 1566 vibrations.

The true vocal cords in men are longer than those of women in the ratio of 3 to 2, so that the male voice is stronger and lower in pitch.

Sounds are sometimes produced that seem to come from parts deep down in the chest, by *ventril'oquism,* as it is called, which really means "speaking from the stomach." The man thus manages his natural voice so as to mislead his hearers.

The muscles regulating the vocal cords are only about three-quarters of an inch long, and all the different musical notes are produced by their action. They can be varied to a movement of 1-1200th to the 1-12000th of an inch.

The Formation of Language.—Speech is a series of sounds to convey ideas, and is under the control of the will. A parrot may speak distinctly, but its brain does not appreciate the meaning of what it says. Before language was formed, words were derived from familiar sounds, such as cries of wild beasts, notes of birds, etc. The names given to some sounds, as hissing, humming, snoring, grunting, whistling, wind, etc., convey as nearly as possible a notion of the sound itself. The word "cuckoo," which is the cry of the bird, is very much the same word in Greek, Latin, German, Dutch, French, and other languages.

The Voice and the Hearing.—The vocal organs of a child may be perfect, but if he has been born deaf he cannot use words to express his ideas. He cannot repeat sounds that he has never heard, and is therefore dumb as well as deaf.

Hygiene of the Voice.—The proper exercise of the voice is dependent upon a healthy condition of the throat and nose, as well as of the larynx itself. Changes of temperature, especially from hot to cold, exposure to wet or to sudden draughts of air, changes of clothing, and many other causes, produce sore-throat, cold in the head, pain in the chest, or lung trouble. Whatever interferes with the action of the lungs must affect the voice in its fulness or quality. It is our duty to shun all such influences as we know will generally produce these effects.

We must avoid exposure to cold or to draughts when the body is overheated. If subject to sore-throat, we must wear such articles of underclothing—woollen or silken goods, for example—as the season or temperature require, and not change them by the almanac only. In going from a warm, crowded room into the open, cold air we must guard the mouth against the change for a few moments, so as to avoid the shock to the throat, by which hoarseness or loss of voice may be produced. Do not muffle the throat with wraps or scarfs; they make one more liable to catch cold, especially if accidentally left off.

As respiration through the nose is the natural, easy way of breathing, it is our duty to inquire, when children breathe through the mouth almost entirely—and especially when the voice is distinctly changed by such an act—whether there does not exist some obstruction, such as enlarged tonsils or a swollen condition of the nose itself. Breathing through the mouth produces dryness of the throat, perhaps inflammation, and the air is not warmed for healthy purposes, as it is when it passes through the moist nasal passages. Particles of dust can also be breathed much more readily through the mouth than the nose, and these may become attached to the delicate cords of the larynx, and thus produce thickening and huskiness of the voice.

In singing, the voice should not be forced beyond its limit or strained to produce certain effects, as high or low notes, which require too much effort to reach. Any one teaching singing should understand fully the physiology of the organ of voice, and then he would appreciate its delicacy, and not allow screaming or use of the voice when fatigued or hoarse. Indeed, screaming or shouting at any time is injurious to the voice, as the vocal cords cannot be strained or stretched without risk of injury. Loud talking or loud reading should also be avoided, as leading to the same effects.

The use of *tobacco* or *alcohol* is certain to injure the throat or larynx. Breathing air loaded with tobacco smoke will affect not only the lungs, but the larynx or organ of voice, and may produce serious disease of those parts. Alcohol will produce huskiness of the voice from congestion and inflammation of the larynx and throat, and thickening of the vocal cords, which may not be curable.

Proper exercise of the voice will strengthen it, and any one by care can increase its clearness and purity of tone. Singing, reading, and speaking, if effected with care and without straining, will give power to the voice and also strengthen the lungs.

The Voices of Animals.—Birds have very active organs for breathing, and it is easy, therefore, for them to sing continuously. Some insects produce noises by the rapid motion of their wings—the mosquito, for instance. The friction against one another of different parts of the cricket produces its peculiar shrill noise. The grasshopper's shriek is produced by its rubbing its legs against its wings. In South America a locust exists with a kind of drum under its wings, the sound of which can be heard a mile or more: if a man had a voice in proportion it would be heard from one end of the world to the other. Insects which fly most rapidly are the noisiest.

QUESTIONS.

How is the voice produced? What are the organs concerned?
What is the larynx? The glottis? What are the vocal cords?
What effect have the muscles on the cords?
What parts are absolutely essential to produce voice?
What kind of a musical instrument is the larynx?
What is the difference in voice of the sexes?
What is whispering? What is whistling?
What three kinds of male voice are there? Of the female voice?
What is the range of the singing voice?
What is ventriloquism? Speech? How was language first formed?
On what principle are words like "hissing," "cuckoo," etc. derived?
Why is a person born deaf usually dumb also?
What are some of the rules for taking care of the voice?
What effect have alcohol and tobacco on the voice?
What peculiarities are there in the noises of animals?

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THE END.