SCIENCE TEXT BOOKS

PHYSIOLOGY
BRIEFER COURSE

COLTON

D. C. HEATH & CO.

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BRIEFER COURSE

PHYSIOLOGY

ILLUSTRATED BY EXPERIMENT

BY

BUEL P. COLTON, A.M.

AUTHOR OF "PHYSIOLOGY, EXPERIMENTAL AND DESCRIPTIVE
"PRACTICAL ZOÖLOGY"; AND PROFESSOR OF NATURAL
SCIENCE IN THE ILLINOIS STATE NORMAL
UNIVERSITY

BOSTON, U.S.A.
D. C. HEATH & CO., PUBLISHERS
1904

TYPOGRAPHY BY J. S. CUSHING & CO., NORWOOD, MASS.

PREFACE.

THE author's "Experimental and Descriptive Physiology" has been adopted by a large number of schools and colleges. But there are many schools in which, owing to the youth of the pupils, the shortness of the time allotted to the subject, or the meagerness of laboratory facilities, such a rigorous course cannot be taken. For such schools this simpler book is written. While it contains considerably less experiment and dissection than the larger book, it is still based upon experimental work. No teaching of physiology is worthy of the name unless it rests upon experiment, observation, and dissection. The ridiculous answers of the pupil who has learned mere "book physiology" furnish the standard jest of the educational journal. Trying to teach physiology without experiment is not only in opposition to modern views of pedagogy and psychology, but it is equally at variance with the common sense of the business man's view. Such teaching is a mere mummery of words—it teaches neither how to *know* nor to *do*.

In fitting this work for the less mature mind, special attention has been paid to conciseness and brevity of statement and to clearness of exposition. Sentences and parapliance with the law. Copious quotations have been taken from the best authorities on this subject. The same high-grade illustrations have been used that brought such favorable comment on the earlier work.

This briefer edition has, too, the full benefit of the criticism of the eminent authorities whose names are listed in the larger work.

TO THE TEACHER.

For any practical work in physiology it is very desirable to have a room furnished with tables and supplied with water.

Each pupil should make full notes and drawings of the work done and the organs studied and dissected. Only by so doing will he firmly fix and retain what he gathers from day to day.

In the larger work by the author are many experiments and dissections given in full which are here omitted in order to present a briefer course. In the larger work there is also given a list of books which are most helpful in teaching physiology.

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PHYSIOLOGY.

CHAPTER I.

INTRODUCTION.

Health. — Is it not a splendid thing to be well and strong? To be full of bounding health? To "feel one's life in every limb"?

Who does not desire to prolong, so far as possible, this condition characteristic of youth?

Natural and Artificial Modes of Life. — An animal living in a state of nature may keep well and live its natural period of life without knowing anything about the laws of health. But as students or indoor workers, many of us lead a sedentary life; we are not natural, but often highly artificial, in our mode of living. We move about but little, whereas the animal abounds in motion. We concentrate energy upon mental effort, thus diverting a large share of our sum total of energy away from the process of nutrition. We often shut ourselves in rooms nearly air-tight. We eat poorly chosen and ill-prepared food. We devour it hastily, often when we are not in fit condition to take food. In short, we frequently disobey the laws of Nature. Now, Nature punishes every violation of her laws. She never forgives, never forgets.

Value of Knowledge. — The out-of-door worker may not suffer so much from ignorance in these matters. From the character of his occupation, he is, to a certain extent, obliged to obey Nature. He gets enough fresh air. His bodily exertion generally brings a hearty appetite, vigorous digestion, active circulation of the blood. Still, he would greatly profit by knowing something of the nature of his food, its wholesomeness or unwholesomeness. The fact that he has fair health is no proof that he always does the best thing. His natural mode of life may keep him in tolerably good condition in spite of his violation of certain laws; but he could undoubtedly learn how to economize in the purchase, preparation, and proper combination of foods.

Importance of the Care of the Body. — Any machine of man's invention must be kept in good running order if we would have it do good work, or last long. We must keep a machine clean, well oiled, and not overtax it. Are not our bodies worth equal care? If some part of a machine is broken, we may replace it at moderate expense; but none of the vital organs can be replaced. We may get a new mainspring for a watch, but we cannot obtain a new stomach or lungs.

Its Admirable Mechanism. — Aside from the above considerations the human body is worthy of study for its own sake. Viewed simply as a mechanism, it is wonderful. Each organ is so well adapted to its work, and all the organs work so harmoniously through their connection and control by the nervous system, that we never cease to admire it. We admire a doll, or other toy, so ingeniously constructed that it can move its eyes or walk a short time after being wound up. But this live mechanism, which is self-winding, self-regulating, self-repairing, self-directing, amazes us.

Hygiene. — We take up the study of the human body mainly that we may learn how to preserve health; the science of health is hygiene.

Physiology. — In order to keep the various organs in good order we must know what their natural work is, and how they do it; the science of the action of the body and its parts is physiology.

Organ. — Any part, or member, of the body, which has a special work to do, is called an organ, as the hand, the eye, or the stomach.

Function. — The work, or action, of each organ is its function.

Anatomy. — In order to understand the working of each organ it is usually necessary to know something of its construction; the science of structure is anatomy. We do not need to go far into anatomy to obtain a fair knowledge of the manner in which our organs do their work. The surgeon, of course, must be able to locate accurately the various blood tubes, nerves, muscles, etc. We need to know only the general structure of the body and, more in detail, some of the more important organs, such as the heart, the lungs, the larynx, the eye, etc. It is fortunate for us that these organs in the sheep, pig, and cow are so nearly like our own that they serve admirably to enable us to understand ourselves.

Tissues. — Every organ is composed of several different kinds of material. For instance, in a slice across a ham we see the skin on the outside, then fat, lean, and bone.

These "primary building materials" of the body we call tissues. A tissue may be defined as an aggregation of similar cells devoted to a common work.

Cells. — The whole body is made up of small parts called cells, comparable to the bricks in a house. These cells are of various shapes in the different tissues.

In the more active tissues the cells are alive, and each cell may be compared to the ameba, a little mass of living jelly-like substance called protoplasm. The ameba is a protozoan often found in the slime at bottom of stagnant water. Within this is a small, rounded part called the nucleus. Most of the cells of the body differ from the ameba in having a distinct outer covering or cell wall. A grape serves very well to show what a cell is like. The whole body is built up of cells, few of them large enough to be seen by the naked eye. Although the cells are closely packed together, each cell leads, in one sense, an independent life. But all work together to maintain the life of the body. The cell is like the individual in a community. Each lives primarily for itself, yet all work together for the good of the whole.

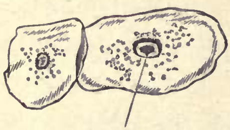


Fig. 1. Epithelial Cells from the Inside of the Cheek.

Epithelial Cells from the Inside of the Cheek. — With the blade of a very dull knife, or the handle of a scalpel, gently scrape the inside of the cheek. Place a little of the white scraping on a slide in a drop of water, cover with a cover slip, and examine under a quarter-inch objective. Many cells will be seen, some of them showing nuclei. Compare these cells with the accompanying figure.

The Physiological Division of Labor. — We are aware of the advantages of division of labor in a community. If each person learns to do one thing well, all together work economically for the common good, time is saved, and better goods are produced. In the body there is a division of labor similar to that of a community. Each organ has its own work to do, and all work together for the common welfare. The cells of each tissue have certain properties and peculiarities of form differing from the form and properties of the cells of any other tissue. While the general structure of all cells is essentially the same, and while they all have certain properties in common, each has some one kind of work that it can do well, and to which work it devotes itself. The nerve cells receive impressions from the outer world, carry nervous impulses, and control the various activities of the body. The muscle cells have as their work the production of motion. All the cells must take food for themselves and grow. Each has a birth, life, and death, as each individual in a community of men; and as the community endures, while the individual members are continually changing, so, in the body, while the form remains about the same from year to year, the cells are continually changing, some dying, and others taking their places.

In an animal of a single cell, like the ameba, the one cell must do everything for itself. The higher animals all begin their individual life as an egg, which is, in fact, a single minute cell. This grows and divides, forming two cells. By repeated division there accumulates a mass of cells. These take on the arrangement peculiar to the kind of animal from which the egg came. But as the cells increase in number one group of cells takes up one part of the work of the body, other cells another part of the work, and so on.

In studying history (sociology) we have to deal with the individual, the community, the state, and the nation. The cell is an individual, the community is a tissue, the state is an organ, and the nation is one body.

Let us proceed to study the nature of the individual cell, and the combined actions of these individuals in that community called the human body.

Summary. — 1. Health is essential to comfort and efficiency in work.

2. Our artificial mode of life is at variance with nature's laws.

3. Only by obeying the laws of nature can we preserve health.

4. We should learn these laws of nature from the advice and experience of others, and not by the expensive process of suffering from disobedience.

5. Anatomy is the science of structure. Human anatomy is the science of the structure of the human body.

6. Physiology is the science of function.

7. Hygiene is the art of preserving health.

8. Cells are the units of structure in the body.

9. A tissue is a group of similar cells having a single function.

10. An organ is a part having a special work or function. The organs work together for the common good of the whole organism. This working together results in —

11. The physiological division of labor, in which each organ works for all the others, and is dependent on all the other organs.

Questions. — 1. What are some of the ways in which we most frequently violate the laws of health?

2. Name the more important organs of the body and their functions.

3. Name the different tissues of one of these organs.

CHAPTER II.

MOTION.

Motion and Life.—Motion is the most manifest sign of life. While we are sitting still, as we say, there are frequent slight motions of the head, body, and limbs. Even during sleep the movements of breathing may be seen; the hand laid upon the chest may feel the beating of the heart, and the finger detect the pulse in a number of places.

We must move to get our food, or at least to eat and digest it. Motion is necessary for breathing, for circulating the blood, for getting rid of wastes. We often move to avoid injury.

Motion is necessary for seeing: we must turn the face toward the object; we move the eyeballs; within the eye are motions to regulate the amount of light admitted, and to adapt the eye for seeing at different distances.

In feeling, we put forth the hand to touch the object. In tasting, we touch the tongue to the object. In smelling, we sniff; and sniffing is a respiratory motion. In hearing and in speech there is also motion.

How are all these motions produced?

Experiments with the Muscles in our own Bodies.—1. Clasp the front of the right upper arm; draw up the forearm strongly and as far as possible. Note what changes are felt in the biceps muscle.

2. Repeat the experiment, and with the thumb and finger feel the cord, or tendon, at the lower end of the muscle, just within the angle of the elbow.

3. Place a weight in the hand, and repeat the act, noting the condition of the muscle during the experiment; also note the condition of the tendon.

4. Span the muscle, placing the tips of the fingers in the angle of the elbow, and the tip of the thumb as far as you can up the arm; again bend the arm. What change in the muscle does this show? Any muscle that bends a limb, as does the biceps, is called a flexor muscle.

5. Clasp the back of the right upper arm; forcibly straighten the arm. The muscle lying along the back of the arm is the triceps muscle. It is called an extensor muscle because it extends, or straightens, the arm.

6. Clasp the upper side of the right forearm near the elbow; clench the right hand quickly and forcibly; repeat rapidly.

7. Notice the thick mass of muscle at the base of the thumb; pinch the forefinger and thumb strongly together. What changes can be seen and felt?

8. Place the hand on the outside of the shoulder; raise the arm to a horizontal position; repeat with a weight in the hand.

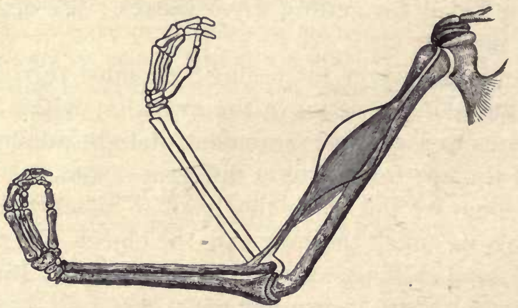


Fig. 2. The Shortening and Thickening of the Biceps Muscle in raising the Forearm.

9. Stand erect with the heels close to each other, but not quite touching; let the arms hang freely by the sides; rise on tiptoes, without moving otherwise; repeat ten times.

10. Place the tips of the fingers on the angles of the lower jaw; shut the teeth firmly on a piece of rubber, and note the bulging of the masseter muscles.

11. Press the fingers on the temples; again shut the jaw firmly, and feel the action of the temporal muscles.

12. Make a narrow band of paper that will snugly fit the forearm when the hand is open; now clench the fist strongly.

13. With a tape measure take the circumference of the upper arm when the arm hangs free; again when the forearm is strongly flexed.

14. In the same way measure the forearm when the hand is open, and when the hand is clenched.

By these experiments we learn that when a muscle works it becomes shorter, thicker, and harder.

Nerves and Muscles of a Rabbit's Leg. — In the hind leg of a rabbit the sciatic nerve may be found by separating two large muscles on the sides of the thigh, beginning behind the knee joint. The shape and connections of the muscles may be learned, and also the distribution of the nerve.

The Action of Muscle. — The action of muscle is always a "pull." The muscle shortens, at the same time thickening and hardening. These changes in muscle are roughly shown in the preceding experiments of feeling the arm during its action. But the isolated calf muscle of the frog may be made to prove the characteristic changes with great clearness.

Action of Frog's Muscle. — A frog may be killed painlessly by putting a teaspoonful of ether into a fruit jar of water, immersing the frog and capping the jar. When the frog becomes motionless, its head should be cut off and a wire run down the spinal column to destroy the spinal cord. After cutting the skin around the base of one thigh the skin may easily be stripped from the whole hind limb. If the muscles on the back of the thigh be gently separated there will be found a white thread running lengthwise, the sciatic nerve. It should be severed near the hip and carefully turned down upon the calf muscle. It should not be pinched or dragged. The muscles of the thigh should now all be cut away, being careful not to sever the nerve near the knee. The hip joint should be unjointed. With the handle of the scalpel the calf muscle should be separated from the shin bone, and just below the knee the shin bone and all the muscles except the calf muscle severed.

If now the heel cord be cut off below the heel there will remain such a preparation as is represented in the accompanying figure, consisting of the thigh bone with the calf muscle hanging from it, and the sciatic

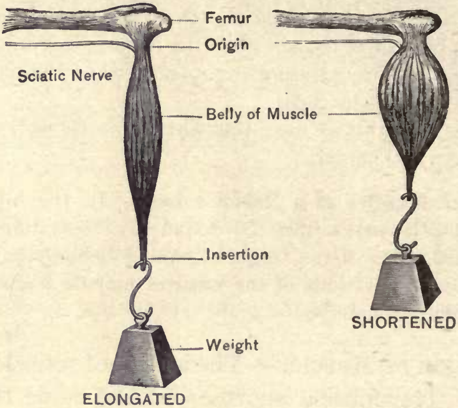


Fig. 3. Action of the Calf Muscle of the Frog, showing the Relations of the Sciatic Nerve.

nerve still connected with the calf muscle. This may be supported by holding the end of the thigh bone in a clamp on a retort stand. A light weight should be attached to the heel cord. The muscle and nerve should be moistened with water containing a little salt. On pinching the free end of the nerve, or cutting off the least bit with scissors, the muscle will be made to act. The shortening and thickening will be plainly seen, and by taking it between the thumb and finger the hardening may be felt.

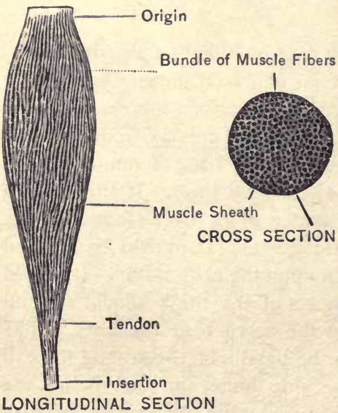


Fig. 4. The Structure of Muscle.

Structure of Muscle.—Chipped beef shows well the structure of muscle. The white network is the connective tissue. In the meshes is the red muscular tissue. The partitions which run all through the muscle are continuous with the muscle sheath, and both are continuous with the tendons at the ends of the muscle. In fresh muscle the sheath and the partitions are nearly transparent, and are not easily seen. When the meat is cooked or salted the connective tissue becomes white and opaque.

Microscopic Structure of Muscle. — In frog's or rabbit's muscle observe the thin, transparent membrane covering the muscle, the muscle sheath. With forceps tear away part of the muscle sheath. Tear the muscle to pieces, and note its fibrous structure. A shred of muscle may be mounted in a drop of normal saline solution on a slide, and examined with low power of the microscope. If examined with a higher power the cross-markings, or striations, will be seen. Such muscle is called striated or striped muscle. All of the muscles used in ordinary motions are of this kind.

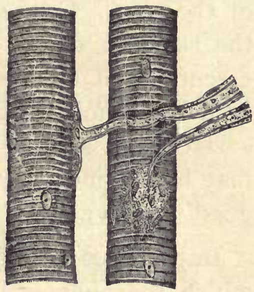


Fig. 5. Two Muscular Fibers showing the Terminations of the Nerves.

Effects of Cooking Muscle. — In well-cooked corned beef the connective tissue is thoroughly softened, and the muscle fibers are easily separated. Thorough cooking, especially slow boiling, will soften the connective tissue, and may render palatable meat that, cooked otherwise, would be exceedingly tough on account of the large amount of connective tissue.

Imitation of Structure of Muscle. — A good way to represent the structure of muscle is to take a number of pieces of red cord to represent the muscle fibers. Wrap each in white tissue paper; this represents the individual fiber sheath. Lay a number of these side by side; wrap all in a common sheath; let the tissue paper project beyond the threads, and here compress it into a compact cylinder; this last corresponds to the tendon.

Connective Tissue the Skeleton of Muscle. — If all the muscular tissue were removed from a muscle, the sheaths and partitions would remain, just as they do in a squeezed lemon or orange. The connective tissue forms a framework for all the soft tissues of the body, and if their working cells were removed, the connective tissue would remain, and show more or less completely the form of the part. Connective tissue, therefore, may be called the skeleton of the soft tissues. Muscle consists, then, essentially of a collection of soft, transparent tubes, filled with the semi-fluid muscle substance. By scraping the surface of a steak with a dull knife the muscle substance may be obtained, leaving the connective tissue. This is a good way to get the nutritious part of beef for an invalid.

Importance of Muscles. — The different materials of which the body is built up are called tissues. Thus we find muscular tissue, bony tissue, nervous tissue, etc. The muscles make up nearly half of the weight of the body. This fact of itself should lead us to consider the muscles of high importance. Add to this the facts above noted, that the muscles are so largely concerned in the nutrition of the body, the chief agents for its protection, essential for the reception of ideas, and absolutely indispensable for the expression of ideas, and we can see the reason for beginning the study of physiology with the examination of the muscles and their action.

Laws of Muscle Action. — The chief characteristic of muscle is its ability to shorten; incidentally, it at the same time thickens and hardens. But it does its work by shortening, pulling on the bones by means of the strong, inelastic tendons, thus producing motion. The action of the muscle as a whole is the result of the characteristics of the cells of which it is composed. The individual cells and fibers shorten, and their combined action is seen in the muscular movement.

Extent of Muscle Shortening. — A muscle may be made to shorten one third of its length, but probably never shortens that much in the living body.

Duration of Muscle Shortening. — A muscle cannot be kept shortened for any great length of time. If one holds his arm out horizontally as long as possible he soon feels fatigue, later pain, and he may feel soreness in the muscle for several days. The law of muscle action is to alternate periods of rest with periods of action. In many exercises, as in walking, the limbs act alternately, one resting or recovering position while the other works.

Alternate Action of Flexors and Extensors. — If we consider the biceps and triceps of the arm, we see that they are compelled to act alternately if they would do effective work. They might both shorten at the same time, and are made to do so in such an attempt as that of holding the arm rigidly bent at a right angle; as, for instance, in wrestling "square hold," in which case one wishes to prevent his opponent from either pushing or pulling him. But while the two muscles act, no motion is produced. When the flexor shortens, the extensor lengthens, and *vice versa*.

Normal Condition of Muscle. — The muscles are always slightly stretched, as shown by the fact that when a cut is made into a muscle the wound gapes open; the tension of the muscle is further shown by the fact that when a bone is broken, as in the upper arm or thigh, the ends of the bones slip by each other, and the limb has to be strongly stretched to bring the ends back together. Muscles act better when slightly stretched, and probably need a slight resistant action of the opponent muscle.

Symmetrical Development of the Muscles. — The muscles of the two sides of the body are the same in number and arrangement. At birth they are probably about equal in size, weight, and strength. Most persons early become right-handed, and the greater use of the right hand and shoulder makes the muscles of this side larger and heavier. The muscles pulling on the bones slightly modify them in shape. The whole body may become noticeably unsymmetrical. Most persons step harder on one foot than the other, as shown by the sound of the footstep, and as shown by the constant wearing of one shoe sole or heel faster than the other. In many persons one shoulder is habitually carried higher than the other. Symmetrical development should be carefully sought, and any tendency to a one-sided development should, so far as possible, be avoided. We should use the left hand more. There are many advantages in being able to use either hand. In carving, in shaving, in bandaging, in administering medicine, it may be necessary to use the left hand skillfully. The pianist and the harpist use the two hands about equally, while the violinist puts much more skill into his left hand. Trainers of athletes often begin by developing the left side of the body till it equals the right in size and strength.

Muscles the Source of Strength. — Our strength depends on our muscles. It is a fine thing to have strong, well-developed muscles, not only because they give beauty of form, but because extra strength and endurance may be needed in case of accident, to save one's own life or that of others. In a case of fire the ability to climb, to go up or down a rope "hand over hand," may be all important. Any one's life may depend on his ability to run far and swiftly, to swim, to jump, or to lift a heavy weight.

Skeletal Muscles. — When we look at the skinned carcass of an animal in the market, we observe that the muscles almost completely cover the bones. Those which are attached to the bones are called skeletal muscles. They act upon them as levers, giving to motion strength, quickness, and precision. Without bones our motions would be like those of an earthworm or slug, slow and uncertain. The muscles, acting through the bones, can lift a weight that would crush the muscles if laid directly upon them, while a bone, able to support a heavy weight without being crushed, has no power in itself. The muscles have active strength, the bones have passive strength.

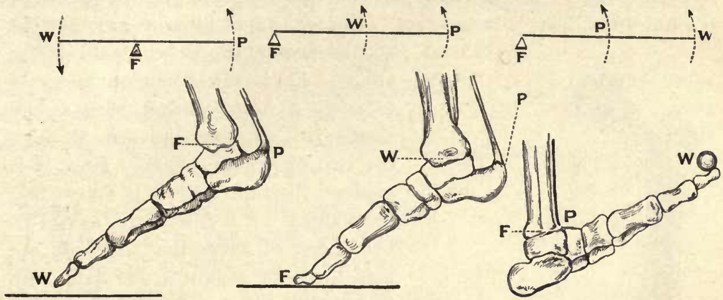
Relation of the Muscles and the Bones. — Suspend the skeleton from the ceiling in the most open space in the room. Let the pupils study it; not to learn the names of all the bones, but to get a general idea of the forms and relations of the parts. It is well to have the skeleton constantly at hand, to show the location of the various organs as they are taken up. If possible, supply the class with separate bones from another skeleton, and let the pupils place each separate bone alongside the corresponding one in the complete skeleton.

Pass to the skeleton, and locate the biceps muscle. After examining Fig. 2, show the points of its origin and insertion. Feel the biceps of your arm. Note that its thickest part is opposite the most slender part of the bone. But at the enlarged end of the bone the muscle has narrowed to a slender tendon, which passes over the joint to be attached to the next bone, thus giving more slenderness, flexibility, and freedom of motion to the joint. The muscle which closes the mouth, as in pursing up the lips, is not attached to any bone, but in shortening reduces the aperture.

Flexion of the Forearm. — Take the bones of the arm that are articulated (if there is not an artificial hinge at the elbow, one can readily be made of wire); put a strong rubber band in place of the biceps muscle; fasten this to the head of the humerus by cords, and by the lower end to the radius, where the rough place, an inch or so from the elbow joint, shows the insertion of the tendon. Have the rubber stretched so that when not held it will flex the forearm. This will serve to show the action of the biceps, though we must be careful to bear in mind that the muscle does not pull the arm up because it has been stretched, as is the case with the rubber. In the case of the muscle, we know that the live muscle has the power of shortening when stimulated, and in this respect is totally unlike the rubber. The live cells, or units, act in concert.

Levers. — The essentials of a lever are the point about which the lever turns, called the fulcrum, the place where the power is applied, called the power, and the part to be moved, called the weight. In the body, the fulcrum is some joint, the power is the place where the muscle is attached, and the weight is the part to be moved.

Kinds of Levers. — In flexing the forearm, the weight is the hand or the hand and what is in it; the fulcrum is the elbow joint; and the power is the point where the tendon of the biceps is attached to the radius. This kind of a lever is what the books call a lever of the third class. The triceps, on the back of the arm, pulls on the projection of the ulna (the inner bone of the forearm when the palm is up), back of the elbow. The elbow is here, also, the fulcrum, and the hand (or the object to be pushed by the hand) is the weight. This kind of lever, where the fulcrum is between the power and the weight, is called a lever of the first class. In raising the weight of the body, by standing on tiptoe, we use a lever of the second class. Here the ball of the foot is the fulcrum. The weight is the weight of the whole body, resting on the ankle joint, while the power is the calf muscle. We may find many examples of levers in the body if we look for them.



(1) Tapping on Floor. (2) Rising on Toe. (3) Lifting Weight.

Fig. 6. Three Kinds of Levers as shown by the Foot.
P — *Power.* W — *Weight.* F — *Fulcrum.*

Kinds of Levers shown by the Foot. — The different classes of levers may be further illustrated by different motions of the foot. In tapping the toes on the floor while the heel is lifted, or in pressing down the ball of the foot while running the treadle of a sewing machine, we have an example of a first-class lever. In raising the weight of the body on tiptoes, or as the foot is used in taking each step, the foot is used as a lever of the second class. When one lifts a weight with the toes, the foot is used as a lever of the third class. These three classes of levers are illustrated in the accompanying figures.

Advantages and Disadvantages of Levers in the Body. — The action of the bones of the forearm as a lever may perhaps be better understood by the following considerations: If the arm consisted merely of the biceps, suspended from the shoulder, it is evident that its only action would be a straight pull. Suppose the biceps, thus hanging alone from the shoulder, had a hook at its lower end, it could, when it shortened, lift a weight just as far as it shortened, and no farther. It could not swing the weight outward, or push it upward. But from the way in which the biceps is attached to the forearm, when the muscle shortens an inch it may move the hand a foot. Of course the hand moves much faster, and we have a great gain in speed by reason of this lever arrangement. But we cannot lift so heavy a weight at this faster rate, as we could at the elbow. For instance, suppose one were to carry a heavy basket with a bail handle by slipping the arm through the bail up to the elbow. Now, it is evident that the biceps is supporting the weight. If it is as heavy as can be held here, we know that we could not hold the same weight in the hand with the elbow bent at a right angle.

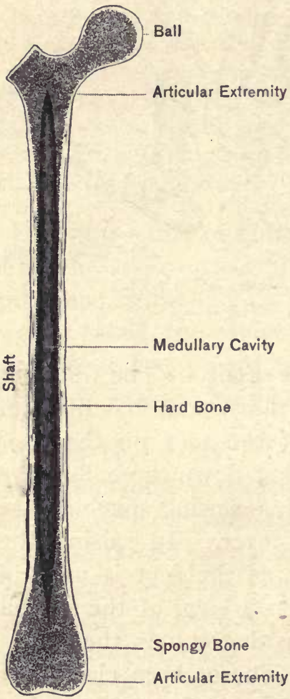


Fig. 7. Longitudinal Section of Femur.

Study of One of the Long Bones. — For this, take, preferably, a femur or a humerus. Let us suppose we have a femur.

1. Observe its shape, — cylindrical, somewhat curved, enlarged at the ends.

2. The ends have smooth places, where they fitted other bones.

3. Along the sides, especially near the ends, are ridges and projections, where the muscles were attached.

4. There are small holes in the bone, where blood tubes passed in and out.

5. Saw a femur in two, lengthwise, and make a drawing showing: —

(*a*) The central marrow cavity.

(*b*) The spongy extremities, noting especially the directions of the bony plates and fibers.

6. Observe the width of the lower end of the femur, where it rests on the tibia. Suppose these two bones were as narrow at their ends, where they meet to form the knee joint, as they are at their centers, what kind of a joint would they make? Illustrate by piling up a num-

ber of spools on end; the column is more lightened than it is weakened by the hollowing out of the sides of each spool. And the central hollow of the spool does not greatly weaken it. A given weight of material has more strength when in the form of a hollow cylinder. The bones combine well two very desirable qualities, lightness and strength. If in our column of spools we place a wide rubber band around the junction of two spools, we have something very similar to the capsular ligament, which surrounds the joints.

Joints. — The ends of the bones, where they fit together in the joints, are covered with a layer of smooth, elastic, whitish or transparent cartilage. The motion in the joints is made still more easy by the synovia, resembling white of egg. The ends of the bones are held together by tough bands and cords of ligament, a form of connective tissue very much like tendon. Bones are closely covered by a tough coat of connective tissue called the periosteum.

All these structures can easily be found by dissecting a sheep shank gotten from the butcher, or in the hind leg of a rabbit.

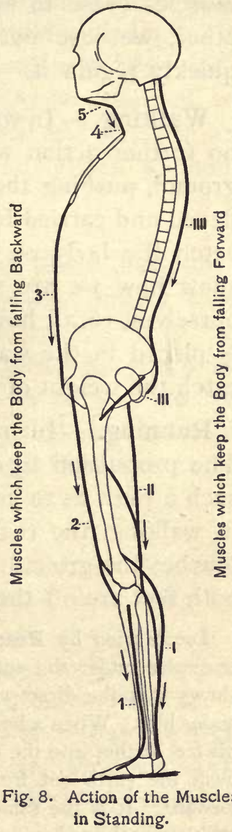


Fig. 8. Action of the Muscles in Standing.

Locomotion. — Locomotion is moving from place to place and should be distinguished from mere motion. By continuing such observations as we made when we began to study our motions, we can analyze and understand many of the common movements which we habitually make.

Standing. — Although we are not ordinarily conscious of the fact, when we are standing still we are using many muscles. The accompanying figure illustrates how some of the muscles act in keeping the body upright. Our weight, or, we would better say, the force of gravity, is continually trying to pull us down to the ground. The joints are all freely movable, and hence as soon as the muscles cease to act properly, in balancing against each other, we lose our equilibrium, and fall if we do not quickly regain it.

Walking. — In walking, we lean forward, and if we take no further action we fall. But we keep one foot on the ground, pushing the body forward, while the other leg is flexed and carried forward to save us from the fall. We catch the body on this foot, and repeat the action. To show how we are really repeatedly falling and catching ourselves, recall how likely one is to fall if some obstacle is placed in the way of the foot as it moves forward to catch the weight of the body.

Running. — In running, the action is more vigorous. The propulsion by the rear leg is now greater. It gives such a push as to make the body clear the ground, whereas in walking, the rear foot is not lifted till the front foot touches the ground. But in running there is a time when both feet are off the ground.

Locomotion by Reaction. — Take two broomsticks and place them crosswise under the ends of a board. Run along the board. This shows that the direct effort in running is to push one's support from under him. When a horse plunges forward in the mud, he only thrusts his feet farther into the mud. Our effort in progression is primarily to push the earth out from under us, and it is by reaction that we go forward. It is the same problem with the fish swimming forward by striking backward and sideways against the water, and with the bird beating downward and backward upon the air.

Bones combine Lightness and Strength.—The muscles, then, make use of the bones as levers. We carry these levers with us all the time. Hence the desirability of having them as light as is consistent with the requisite degree of strength. The body follows the same law of mechanics that we use outside of the body. A hollow pillar or hollow tube has a greater strength than the same amount of material in the form of a solid cylinder. The long bones of the limbs are hollow, and near their ends, where we have found that they need to be enlarged, we find a spongy structure, where lightness and strength are secured by the interlacing fibers and plates of bony material.

Uses of Bones. — The part that the bones play is of a passive nature; they support the tissues, protect some parts, and serve as levers on which the muscles act. We may not call the bones dead tissues, for they receive blood and grow. But the active muscles use them as a man uses a crowbar, as a mere tool. It will therefore be more interesting to return to the muscles, and learn the causes and conditions of their activity.

What makes Complex Muscular Action Harmonious. — Have you ever seen two persons, each using the right hand, try to sew, one holding the cloth, the other using the needle? Would they get along well? Suppose one were to hold the needle, and the other were to try to thread it, each using one hand? Why is it that the right hands of two persons cannot work so well together as the right and left hands of one person? What connection is there between the two, that one knows just what the other is doing and when it does it? Why can two individuals never, with any amount of practice, work so in unity as the parts of the individual?

Let us seek the answers to these questions in the following lessons.

Alcohol and Muscular Energy. — Alcohol does not increase the energy of the body so far as muscular work is concerned. Repeated experiments have been made which show that power to do muscular work is diminished as the result of taking alcohol. The person may, and often does, *feel* stronger, but the feelings are neither a sure test nor a safe guide. As one writer says, the drunken man thinks he is strong enough to hold two men, whereas he needs two men to support him in his weakness. Test of ability to do work shows the weakening effect of alcohol. It was formerly supposed that when men were called upon to perform unusually hard work they needed the sustaining power of alcoholic liquor, and such drink was furnished to men engaged in harvesting, etc. This belief has been thoroughly disproved.

The apparent liveliness of the tipsy person, and his more or less violent gesticulations, are no sign of added strength. We all know that restlessness and nervous activity are often a sign of weakness and not of strength.

Alcohol and Training. — It is a significant fact that men who are training for athletic contests (no matter what their ordinary habits or principles are) let alcoholic drinks alone. One of the famous pugilists said, " I'm no teetotaler, but when I have business on hand there's nothing like water and dumb-bells." No schoolboy or college student can hope to gain a place on any athletic team if he indulges in alcoholic drink.

READING. — *How to Get Strong and How to Stay So*, Blaikie; *Sound Bodies for Our Boys and Girls*, Blaikie; *Physiology of Bodily Exercise*, Lagrange.

Summary.— 1. Motion is involved in nearly every activity of the body.

2. The action of muscle is a shortening, accompanied by a thickening and hardening.

3. Muscle consists of fibers with a connective tissue sheath for each fiber, bundle of fibers, and for the muscle as a whole.

4. The skeletal muscle fibers are striated.

5. The muscles make about half the body's weight.

6. Muscles may shorten one third their length.

7. They cannot remain shortened long for a time.

8. The muscles should be developed symmetrically.

9. In the limbs the muscles are fusiform and have their greatest diameter opposite the central, or narrower, portions of the bones, concealing the fact that the bones are largest at the ends, as is so manifest in the skeleton.

10. The bones serve as levers by which the muscles exert their force.

11. The bones of the limbs are hollow cylinders combining lightness and strength.

12. The joints have a smooth motion due to the cartilage and synovia.

13. Locomotion is brought about by reaction.

Questions. — 1. What effect is produced by carrying a heavy satchel for a long distance without resting?

2. Which is more tiresome, standing still or walking? Why?

3. When the boy, who thinks he can strike a hard blow, says, "Feel my muscle," does he usually call attention to the muscle used in striking?

4. Find other examples of levers in the body.

5. Find examples of the three kinds of levers, not in the body, which we use often.

6. Why is it easier to sit with one leg crossed over the other?

7. What is the effect on muscles of light clothing?

8. How may the arms be used to illustrate the three kinds of levers?

9. Analyze and explain jumping, hopping, etc.

10. What is "curvature of the spine"? How caused and how avoided?

11. What makes people bow-legged?

12. Why are the sides of the body often sore after walking on icy pavements?

CHAPTER III.

THE GENERAL FUNCTIONS OF THE NERVOUS SYSTEM. — SENSATION AND MOTION.

What makes Muscles Shorten? — We have seen that the muscles have the power of shortening; that in shortening they act on the bones as levers to produce our varied motions. What makes the muscles shorten?

Voluntary and Involuntary Motions. — Some motions we will to make. We will to sit, to stand, to walk, to run, or to stretch out the hand. Such motions, originating in a brain activity, are called Voluntary. Other motions are Involuntary. The will does not control the heart beat. Most persons cannot keep from winking when a quick motion is made toward the face, even if they know they will not be hit. But all of these motions, whether voluntary or involuntary, are dependent upon the nervous system.

The Cerebro-spinal Nervous System. — This consists of the brain, the spinal cord, and the spinal nerves. The brain will be described later.

The Spinal Cord. — The spinal cord is a cylindrical body extending from the brain along the cavity of the spinal column. Its diameter is not uniform throughout. Between the shoulders is an enlargement called the cervical enlargement, where the large nerves are given off to

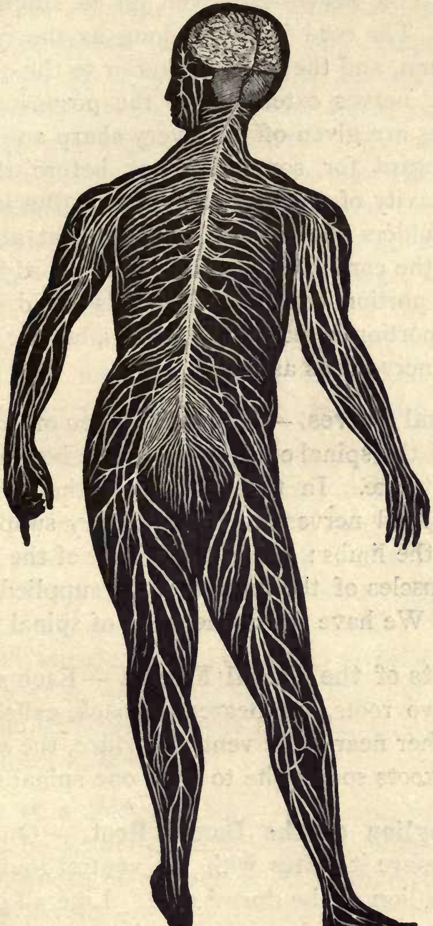


Fig. 9. Diagram showing Arrangement of Nervous System

the arms. In the region of the loins is the lumbar enlargement, where the nerves are given off to supply the posterior limbs. The cord is not so long as the cavity of the spinal column, and the space posterior to the cord is occupied by the nerves extending to the posterior limbs, and these nerves are given off at a very sharp angle, and continue backward for some distance before they emerge from the cavity of the spinal column. But in the region of the shoulders the nerves spring off at about a right angle with the cord. The outside of the cord is white, but the central portion consists of what is called gray matter. The white portion is made up of fibers, but the gray matter consists of nerve cells as well.

The Spinal Nerves. — These are given off in pairs from the sides of the spinal cord, passing out between the successive vertebræ. In the regions of the shoulders and loins the spinal nerves are large, as they supply the large muscles of the limbs; but in the middle of the back, where only the muscles of the body wall are supplied, the nerves are small. We have thirty-one pairs of spinal nerves.

The Roots of the Spinal Nerves. — Each spinal nerve arises by two roots, one nearer the back, called the dorsal root, the other nearer the ventral surface, the ventral root. These two roots soon unite to form one spinal nerve.

The Ganglion of the Dorsal Root. — On the dorsal root, just before it unites with the ventral root, is a swelling, the ganglion of the dorsal root. Like all ganglions, it is largely made up of nerve cells, being a center of control rather than a means of communication. This ganglion appears to control the nutrition of the adjacent nerve fibers, and is not concerned in the process of reflex action.

A Model of the Cerebro-Spinal Nervous System. — A plaster of Paris or papier-maché model of the cerebro-spinal nervous system will prove very helpful at this point. A study of it will show how the spinal cord is snugly and safely inclosed within the spinal column. At the joints between adjacent vertebras there are openings through which the spinal nerves pass out without danger of being crushed, or even pinched when the backbone bends. It will be noted that the nerves given off in the regions of the shoulders and hips are large, while in the middle of the back they are small. In the middle of the back only the body-wall is to be supplied with nerves, while we would naturally expect large nerves for the powerful muscles of the fore and hind limbs.

Structure of Nerves. — When we trace the sciatic nerve outward, we find that it is continually subdividing. This division continues until the branches are too small to be seen by the naked eye. Microscopic examination shows that a nerve is made up of a great number of fibers bound together in a common sheath of connective tissue, as is the case with muscle. When the nerve divides there is ordinarily no true branching or forking, but certain of the fibers simply separate from the rest, as in the separation of the fibers in floss silk.

Structure of a Nerve Fiber. — A single nerve fiber is too small to be seen by the naked eye, being only about one two-thousandth of an inch in diameter. It consists of the following parts: —

1. The *Axis Cylinder*, a central stand, or core, of semi-transparent, gray material.

2. The *Medullary Sheath* is a layer of white, oily material around the axis cylinder.

3. The *Nerve Fiber Sheath* is a thin, transparent outer sheath of connective tissue.

Function of Nerve Fibers. — The sole function of the nerve fiber is to convey nerve impulses. The nerve impulse passes along the axis cylinder as an electric current passes along an insulated wire.

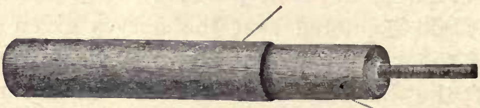


Fig. 10. Structure of a Nerve Fiber.

Gray Nerve Fibers. — In the sympathetic nerves there are many fibers which have no medullary sheath, but consist simply of the axis cylinder and the nerve-fiber sheath. These are called gray nerve fibers.

Cross-section of the Spinal Cord. — If a thin slice of the spinal cord be made as shown in Fig. 11, it will be seen that the central part is darker in color than the outer part. The central part is known as the gray matter, in distinction from the rest, which is called the white matter. The white matter of the nervous system is made up of nerve fibers whose structure and use we have just considered. But the gray matter has a different structure and a different function. Instead of being made up mainly of fibers it is composed of cells, one of the forms of which is represented in Fig. 12. Some of the branches of these cells are continued, and become the axis cylinders of nerves, and it is believed that every nerve fiber begins as a branch of some nerve cell. One of the best places to see these nerve cells is in the gray matter of the spinal cord, near the place where the ventral root of the spinal nerve arises. This part of the gray matter is called the ventral horn of the gray matter. If this portion be examined under a moderately high power of the microscope, there may be seen a number of cells with radiating branches.

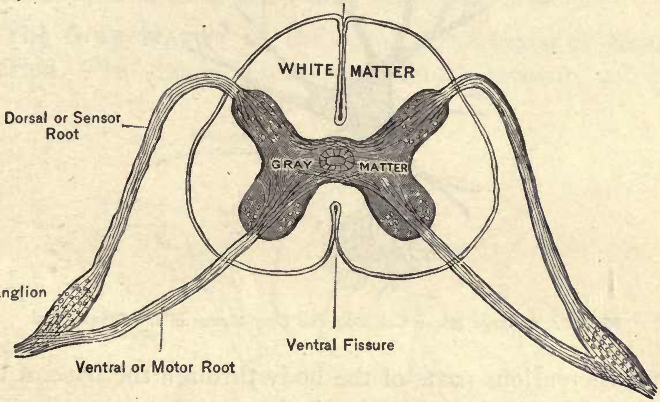


Fig. 11. Cross-section of Spinal Cord.

Functions of the Spinal Cord. — The spinal cord has two main functions: —

1. Its conducting power, by means of the white fibers which make up the outer part of the cord. These fibers may be regarded as connecting the gray matter of the brain with all parts of the body.

2. The gray matter is the center of the reflex actions of the cord.

Ganglia. — Masses of nerve cells make up nerve centers, or ganglia, such as are on the dorsal roots of the spinal nerves. These also would show under the microscope that their chief constituent is a collection of nerve cells which give off one or more branches.

The gray matter of the spinal cord is considered a collection of ganglions. We see that the outer layer of the brain is grayish in color. Within is white matter, consisting of nerve fibers that connect the cells of the gray layer

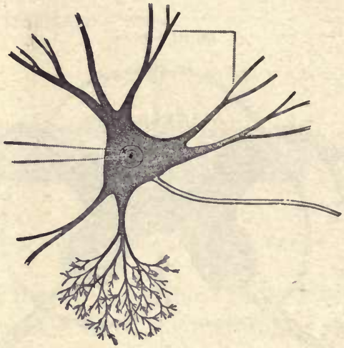


Fig. 12. A Large Nerve Cell from the Gray Matter of the Spinal Cord.

with the various parts of the body through the base of the brain, the spinal cord, and spinal nerves.

No Sensation without the Brain. — After a fowl's head is cut off it "flops" around for some time, and it may even jump clear from the ground. If one takes hold of its feet to pick it up, it may begin to struggle as if it were trying to escape.

Now, we know that the bird cannot feel anything after its head is cut off, because the body is completely separated from the brain, which is the center of sensation. So with the frog. After its head is cut off, it cannot feel anything.

Reflex Action of the Spinal Cord of the Frog. — A frog may be killed as directed on p. 9. Cut off its head and suspend the body from any convenient support, such as the ring of a retort stand.

1. On pinching the toes the foot will be drawn up.

2. The sciatic nerve should now be severed as before directed (p. 9). At the instant of cutting the nerve the muscles below will twitch, because the nerve fibers running to them are stimulated.

3. If the toes are again pinched, it is found that the uninjured leg will draw up, but not the one whose sciatic nerve has been severed.

4. If a wire be run down the spinal cavity, the spinal cord will be destroyed, and during the operation the uninjured leg will act spasmodically, because the nerve fibers going to its muscles from the cord are stimulated.

5. Pinching the toes no longer gives response, because the cord, which acted as the center of this reflex action, is destroyed.

The Gray Matter of the Cord the Center of Reflex Action.—In simple sensation of touch, pressure on the

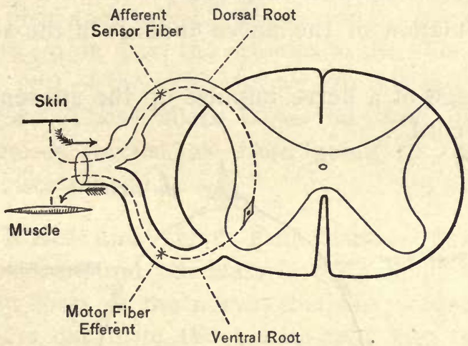


Fig. 13. Diagram of Reflex Action of the Spinal Cord. (After Landois and Stirling.)

toes starts a nerve current or nerve impulse which runs up to the brain. The sensation is in the brain, but is referred to the foot. Hence we should be careful not to speak of a sensation being carried. In voluntary muscular action the impulse starts from the brain, goes to the muscles, and makes them shorten or relax.

But in reflex action the current runs up the nerve to the spinal cord. The gray matter of the central part of the cord receives the message, and sends back a nerve impulse to the muscles to make them shorten and pull the foot away from the source of injury.

The Parts Essential to Reflex Action of the Spinal Cord: —

1. A sensitive surface (the skin, for instance).
2. Afferent nerve fibers.
3. A nerve cell, or cells, in the center of the spinal cord.
4. Efferent nerve fibers.
5. Working organ, as muscle or gland.

Phases of Reflex Action. — In the above experiment on the frog the steps in order were: —

1. Stimulation of the nerve endings in the skin of the toe.

2. Passage of a nerve impulse up the afferent fibers to the spinal cord.

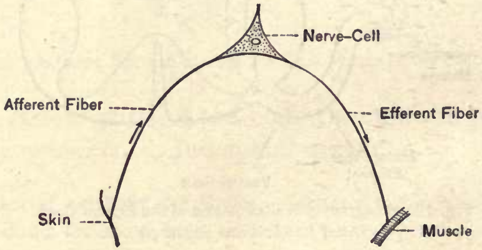


Fig. 14. Scheme of Reflex Arc.

3. Reception of the impulse by a cell, or cells, of the gray matter in the cord.
4. Sending back a nerve impulse
5. Along an efferent fiber, or fibers, to
6. Muscles which shorten and move the foot.

Importance of Reflex Action. — It is important that we understand the nature of reflex action, for very many of the processes of the body are regulated by it. Not only the more manifest motions, such as winking when anything comes quickly toward the eye, dodging, jumping when suddenly touched by anything hot or when pricked by a pin, but also the adjustments of the essential processes of life, circulation, respiration, and digestion, are brought about through reflex action.

Destination of Nerve Fibers. — The sciatic nerve is composed of many fibers. If this nerve is traced outward, it is found to be continually subdividing, and sending small branches to the muscles, and finally in the muscles one fine nerve fiber goes to each muscle fiber. (See Fig. 13.) Many fibers go on past the muscles to the skin. We can feel in any part of the skin, and we can tell just where we are touched. These fibers from the skin, then, carry nerve impulses inward, as those going to the muscles carry impulses outward.

Nerve Roots and their Functions. — Observations made on animals, and accidents in the case of man, show that all the fibers of the nerves that carry currents to the muscles pass out from the spinal cord into the ventral root, and that all the fibers that carry currents inward enter the spinal cord through the dorsal root. Hence, the dorsal root is often called the afferent root, and the ventral the efferent root. Since ingoing impulses produce sensation, the dorsal root is called the sensory root, while the ventral root, carrying currents outward to produce motion, is called the motor root.

Effect of Stimulating a Spinal Nerve. — Experiments have shown that if, in an uninjured animal, a nerve, or more properly a nerve trunk, — as the sciatic nerve, — be stimulated, for instance, by a suitable electric shock, two effects are produced: first, motion in the parts whose muscles are supplied by the nerve; second, sensation, which is referred to the parts of the skin supplied by the branches of the nerve.

Effect of Severing a Spinal Nerve. — If, instead of simply stimulating the nerve, the nerve is severed, the same two effects will be produced. After severing the nerve, if we stimulate the end of the nerve still connected with the limb, we get action of the muscles in that limb. If we stimulate the end of the nerve connected with the body, a sensation will be produced, and this sensation will be referred to the parts from which the nerve fibers arise, probably in the skin of the limb.

Effect of Stimulating the Ends of Severed Nerve Roots. — If we now turn to the roots of the nerve, and make similar experiments, we obtain the following results: Stimulating the dorsal root causes sensation referred to some outer surface, and no other effect is noticed. Cutting the dorsal root also causes sensation. Stimulating the end of this root still connected with the spinal cord causes sensation; but stimulating the end of the root connected with the nerve gives no appreciable result.

Stimulating or cutting the ventral root causes motion in the parts whose muscles are supplied by fibers from this root. After severing this root, if the end connected with the spinal cord be stimulated, no effect is noticed; but stimulating the end still connected with the nerve is followed by shortening of the muscles supplied.

Effect of Severing All the Spinal Nerves. — Severing all the spinal nerves destroys all power of sensation and voluntary motion in all parts of the body except the head. After severing all the dorsal roots, no sensation would be produced by stimulating any part of the body, and after severing all the ventral roots no act of the will can cause any of the muscles of the body to act. Severing all the nerves, or severing all the roots, cuts off all communication of the brain with the body, and so far as motion and sensation in the body generally are concerned, has the same effect as severing the spinal cord below the head.

Cramp. — Cramp is a spasmodic shortening of the muscles, attended with pain.

Tetanus. — Tetanus (or locked jaw) is a spasmodic and continuous shortening of the muscles, causing rigidity of the parts they supply. It is due to the disordered and excessive stimulation of the muscles through the nerves.

Crossing of the Fibers from the Brain to the Spinal Cord. — Both the brain and the spinal cord consist of two lateral halves connected by cross fibers. Each half of the brain is connected with the opposite half of the body. This is accomplished by the crossing of the fibers. The fibers that carry nerve impulses outward are now known to cross as they leave the brain, at the very beginning of the spinal cord, in the part known as the spinal bulb. The sensations arising from touching anything with the right hand, therefore, are in the left half of the brain, and the right half of the brain controls the left hand.

Voluntary Interference with Reflex Actions. — We have seen that the jerking of the hand away from a hot object is due to reflex action of the spinal cord. One might, by a powerful effort of the will, keep the hand on an object that is hot enough to burn the skin. One may command the foot to remain quiet when it is tickled; but as soon as the person is asleep, the same stimulations would be followed by the reflex actions such as we have considered.

In these cases of interference it is understood that the brain sends a nerve impulse down to the centers of the reflex action, and stops or diminishes their operation. This retarding influence of a group of cells is called inhibition. It is not always due to voluntary interference, but may be due to reflex interference, as we may see later.

The Nature of a Nervous Impulse. — Of the nature of a nerve impulse we know but little. It is convenient to compare the nervous system, with its conducting fibers and central ganglia, to a telegraph system. And electricity is the most convenient stimulus for exciting nerve impulses. Yet a nerve impulse is very different from an electric current. A nerve fiber is a poor conductor of electricity. An electric current may travel along a copper wire at the rate of between 100,000 and 200,000 miles a second, while a nerve impulse in a motor nerve travels only 170 feet in a second.

Transmission of Motor Impulses. — When a motor fiber is stimulated in the middle of its course we observe only one effect, — the shortening of the muscle at its lower end. But there is every reason to believe that the nerve current, or impulse, runs along the nerve in both directions from its starting point. But while the action of the muscle at the peripheral extremity manifests the existence of the current, there is nothing at the central extremity to give such evidence.

Transmission of Sensory Impulses. — Similarly, when a sensor nerve fiber is stimulated at some intermediate point, we have a sensation in the brain due to the current brought by the afferent fiber, and which we refer to the outer end of the nerve fiber. Probably a nerve impulse passed from the point of stimulation to the outer end of the fiber; but as there is nothing at the outer end of the nerve fiber to interpret it, we get no evidence of such impulse except by refined physiological tests.

Harmony in Muscle Action. — In throwing a stone a number of muscles are used. Each one of these must shorten in the right way and at the right time or the throw will not be accurate. Each muscle shortens under the influence of a nerve impulse started by the brain and brought by a motor nerve. If any muscle shortens an instant too soon, or a little too strongly, the stone goes to one side. In a tune on a piano we know that the right keys must be struck; that each must be struck at the right time, with the proper degree of force, and held for the right length of time, or we have discord instead of harmony. What the player is to the instrument, the brain is to the body.

Temporary Loss of Muscular Power. — It may have happened to you that after sitting long in one position you attempted to stand, but found that you could not do so. One leg failed to act at the bidding of your will. When the foot is "asleep" we get little sensation from it; we hardly know whether it is touching the floor or not. Pressing on it with the other foot causes no pain.

We try to stand when the foot is asleep, but we are unable to do so. The brain starts the nerve currents, and they run along the nerve as far as the compressed part; here they stop. They cannot reach the muscles of the leg below. Hence the muscles do not shorten, and we do not rise, no matter how strongly we will to do so.

Why is it that the nerves and muscles thus sometimes lose their ability to perform their natural activities?

Dependence of Nerves and Muscles. — This has been explained by saying that owing to external pressure, the nerve has temporarily lost its power of conducting nerve currents. But what beside the nerve has been compressed? What process in the limb has been interfered with by the pressure due to the position in which one has been sitting or lying? What is the temperature of the benumbed limb?

On what are the nerves and muscles so dependent for the maintenance of their activity?

Reading. — *Power through Repose*, Call; *The Technique of Rest*, Brackett; *Muscles and Nerves*, Rosenthal.

Summary. — 1. Motions are voluntary or involuntary, but all are under control of the nervous system.

2. The cerebro-spinal nervous system consists of the brain, the spinal cord, and the spinal nerves.

3. Each spinal nerve has two roots: the dorsal, which is afferent and sensory; the ventral, which is efferent and motor.

4. A ganglion is a nerve center largely composed of nerve cells.

5. Nerves are made up of nerve fibers.

6. A nerve fiber consists of the central core (or axis cylinder), which conducts the nerve impulse, the medullary sheath, and, outside, the nerve-fiber sheath.

7. The spinal cord has in its outer part white nerve fibers, in its center gray nerve cells.

8. These cells are branched, and at least one branch becomes the axis cylinder of a nerve fiber.

9. The gray matter of the cord is the center of the reflex action.

10. The nerve fibers from each half of the brain connect with the opposite half of the body.

11. The nervous system is comparable to a telegraph system.

Questions. — 1. Name as many involuntary motions as you know.

2. What other cases of reflex action do you know?

3. The story is told of a young Roman (Mucius Scævola) that to show his fortitude he thrust his hand into the fire and held it there until it was destroyed. What physiological action does this illustrate?

4. Why is a man partially paralyzed when he has broken his neck or back?

5. How does the nervous system differ from a telegraph system?

CHAPTER IV.

CIRCULATION OF THE BLOOD.

The Blood and its Work. — We know that if any animal is bled freely, it soon becomes weak, then unconscious, and soon dies, if the escape of blood be not stopped.

We observe the natural difference in color of different parts of our bodies; for instance, the lips and cheeks. We often note varying color, as in blushing and pallor.

We wish to understand these differences and changes; also to know what to do in case of fainting or bleeding from wounds. We may prolong and make more useful our own lives and those of others by knowing, in a practical way, something about the causes, prevention, and remedies of the colds, congestions, and inflammations to which we are subject.

Nearly every part of the body bleeds when cut. There is no bleeding when we trim the nails or cut the hair, and the outer skin has no blood in it. But the inner skin, and almost every tissue within it, if pierced even by the finest needle, yields blood. We see a little blood oozing from the surface of a fresh steak or roast.

What kind of a substance is the blood? Is it uniformly distributed through the tissues, like water soaked up into a cloth, or is it in distinct cavities? Why is it so essential to life? How does it do its work?

The Rate of the Heart Beat. — The heart beats about seventy-two times a minute in men; in women, about eighty. At birth the rate is from one hundred and thirty to one hundred and forty, and gradually decreases till about the age of twenty, when the average of seventy-two is reached. This rate holds till old age, when it increases. The rate is increased by muscular activity, food, external heat, internal heat (fever), pain, and mental excitement. Music accelerates the pulse rate. The pulse rate varies during the twenty-four hours, being lowest during the night, and highest about 11 A.M. Certain diseases increase the frequency of the pulse. Some drugs quicken the pulse rate, and others diminish it.

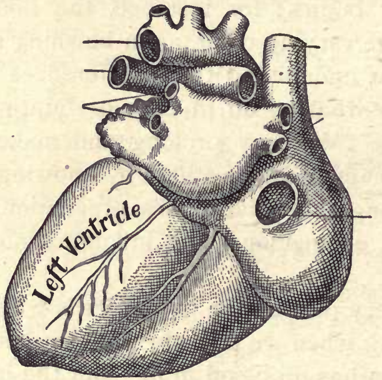


Fig. 14 A. The Heart, from the front.

The Position of the Heart. — The base of the heart is in the center of the chest, just back of the breast bone, but the apex points downward and to the left.

The Covering of the Heart. — The heart is inclosed in a loosely fitting membranous bag, the pericardium. Within the pericardium and around the heart is a small quantity of liquid, called the pericardial fluid.

The Size of the Heart. — A person's heart is about the size of his clenched hand.

The External Features of the Heart. — The heart is cone-shaped and the bulk of it is made up of the ventricles, the auricles being two ear-like flaps at the base, one on each side. There is a deep notch between the auricles and the ventricles. The line of division between the two ventricles is marked by a groove, which runs obliquely along the ventral surface. In this groove are blood tubes and usually considerable fat.

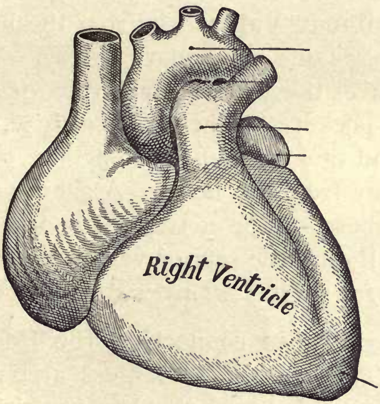


Fig. 14 B. The Heart, from behind.

The Internal Structure of the Heart. — The two halves of the heart are completely separated from one another by a partition. Each half, in turn, has valves which, part of the time, separate the cavity of each auricle (at the base) from the cavity of the corresponding ventricle (at the apex).

The Valves of the Heart. — Between the auricles and the ventricles are curtain-like valves, whose upper edges are attached to the inner surface of the walls at the upper margin of the ventricle. These flaps are somewhat triangular, and have strong, white, tendinous cords extending from their edges and under surfaces to the walls of the ventricle below. In the right half of the heart there are three flaps, and this valve is called the tricuspid valve. In the left side there are two flaps, which, together, constitute the mitral valve. As these valves are between the auricles and the ventricles, they are called the auriculo-ventricular valves, or, for short, the *aur-vent* valves.

The Semilunar Valves. — From the base of the right ventricle arises the pulmonary artery. Within its base, just as it leaves the ventricle, are three pocket-like valves, like "patch-pockets." They are in a circle, with their edges touching, and thus surround the opening, with their mouths opening away from the heart. A similar set of valves are within the base of the aorta, which arises from the left ventricle. Both these sets of valves are called ventriculo-arterial, or, for short, *vent-art* valves.

The Blood Tubes connecting the Heart with Other Organs. — The aorta (the largest artery in the body) arises from the base of the left ventricle, and supplies with blood every organ of the body except the lungs. The pulmonary artery springs from the base of the right ventricle and sends blood to the right and left lungs. Two large veins enter the right auricle, the precaval vein from the anterior regions of the body and the postcaval vein which brings blood from all the organs of the posterior portions of the body. The pulmonary veins return the blood from the lungs to the left auricle, two from each lung.

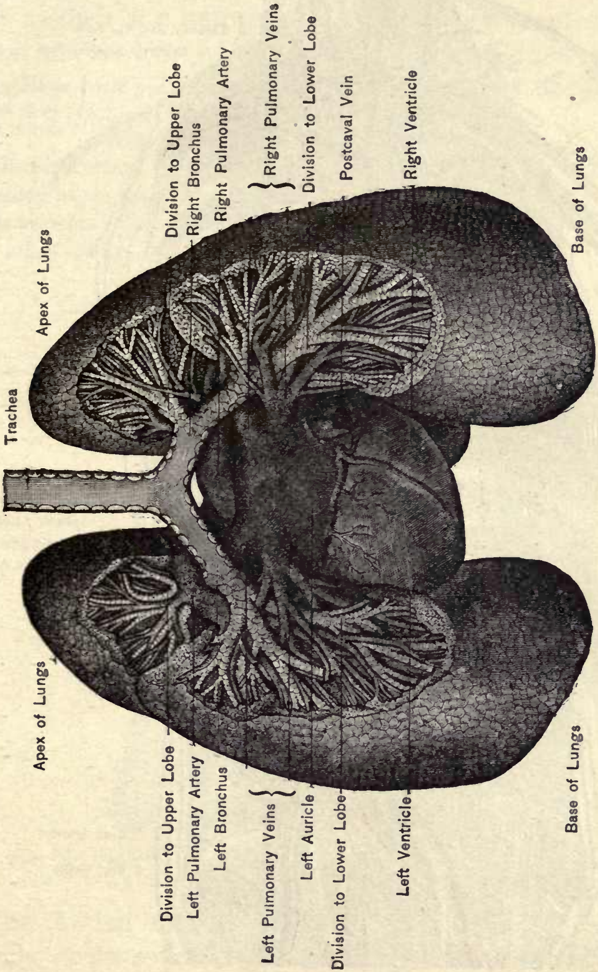


Fig. 15. Dorsal View of Heart and Lungs.

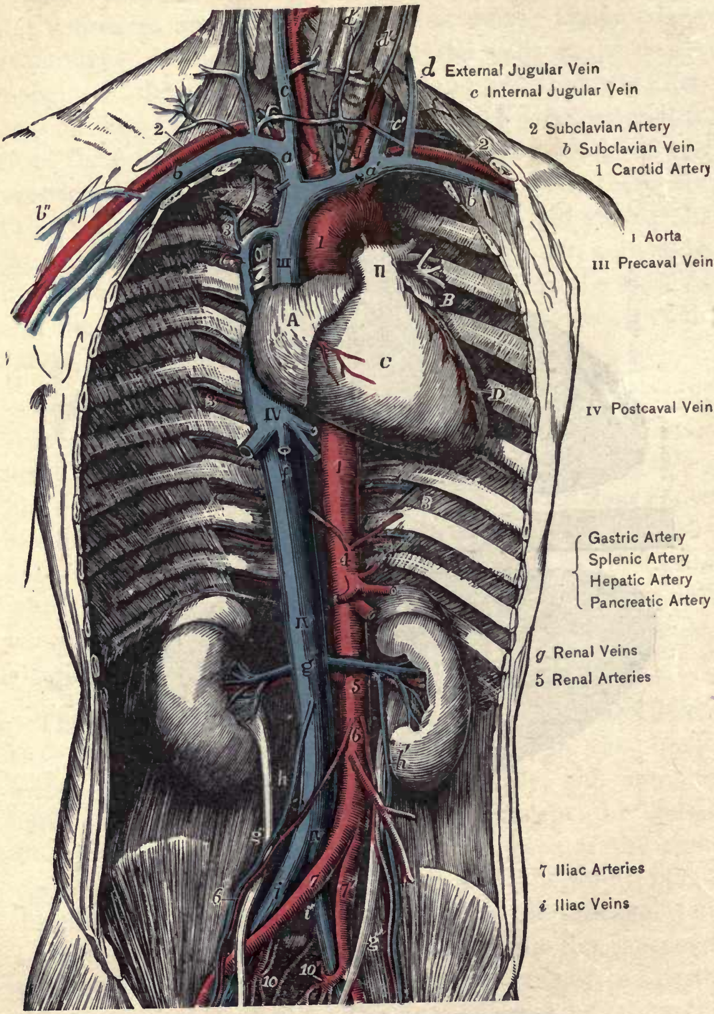


Fig. 16. Distribution of Arteries and Veins.

The Distribution of the Arteries and Veins. — The organs of the body receive a supply of blood in proportion to their size and activity. The artery supplying the blood and the vein which returns it usually lie side by side (see Fig. 16). The larger arteries are usually deep-seated and in protected places.

Demonstration of the Action of the Heart. — The heart may be mounted as shown in Fig. 17, and its action illustrated by compressing the ventricles with both hands. Instead of the apparatus here shown two retort stands may be used, though not so convenient.

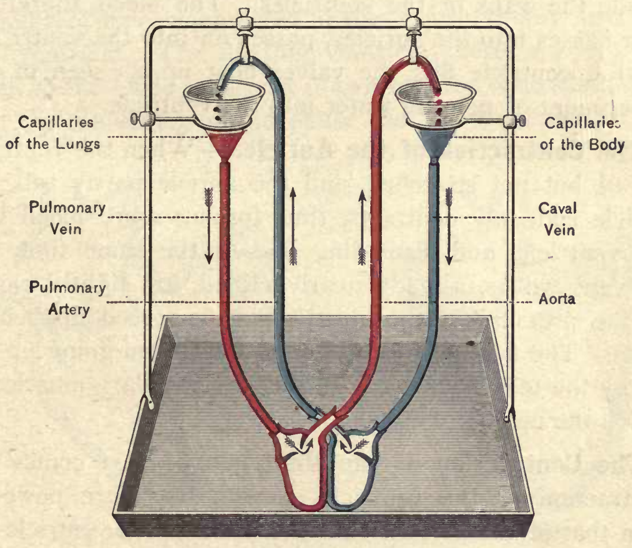


Fig. 17. Demonstration of the Action of the Heart (Heart Diagrammatic).

The Action of the Heart. — The heart consists of muscle fibers so arranged that they form a thick-walled bag, which stands expanded when the muscles relax. But when the fibers shorten the whole heart contracts, and the cavity is much reduced in size, if not entirely obliterated, and the blood is forced out.

The complete action of the heart consists of three parts, — the contraction of the auricles, the contraction of the ventricles, and the pause.

The Pause. — During the pause the blood is steadily pouring into the auricles; into the right auricle from the caval veins, into the left auricle from the pulmonary veins. At this time the curtain-like valves between the auricles and the ventricles are open, and their flaps hang loosely beside the walls of the ventricles. The blood, therefore, as it passes into the auricles, passes on into the ventricles. As the ventricle fills, the valves float up, as seen in the experiment of pouring water into the ventricle.

The Contraction of the Auricle. — When the ventricle is full, but not stretched, and the auricle partly full, the auricle suddenly contracts, thus forcing more blood into the ventricle, and distending it. At the same time the aur-vent valves, already nearly closed, are tightly closed by the pressure of the blood which is forced up behind them. The flaps of the valves are kept from going up too far by the tendinous cords and by the papillary muscles to which the cords are attached.

The Contraction of the Ventricle. — Next comes the contraction of the ventricle, slower, but more powerful than that of the auricle. As the walls of the ventricle are drawn together, the blood is under pressure. It cannot go back into the auricles, for the more it presses against the aur-vent valves, the more tightly they are closed. The semilunar valves are closed by back pressure in the aorta and pulmonary artery. But the pressure of the blood in the ventricles is so much greater that the semilunar valves are forced open, and nearly all the blood is driven out of the ventricles; from the right ventricle into the pulmonary artery, and from the left ventricle into the aorta.

While the ventricles are contracting and forcing their blood out, the auricles are slowly filling by the steady inflow through the veins.

Systole and Diastole. — The contraction of the heart is called the systole, and its dilation the diastole.

Dilation of the Ventricle. — As soon as the ventricle has completed its contraction it dilates, and most of the blood that has accumulated in the auricle simply falls into the ventricle. The dilating ventricle exerts a slight suction, so the blood is in part drawn into the ventricle. During the remainder of the pause the blood accumulates in

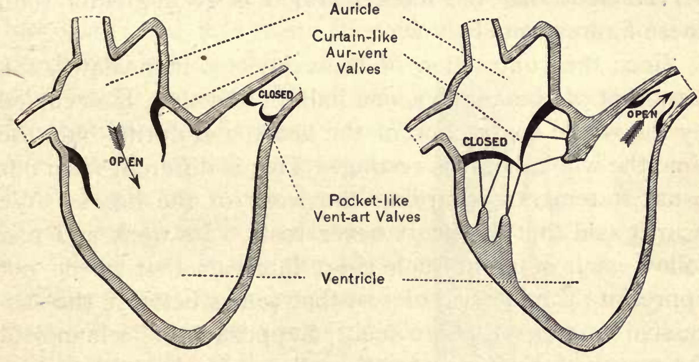


Fig. 18. Diagram of the Heart, showing the Action of the Valves.

the auricle and ventricle till the auricle again contracts and the cycle is repeated. This is true of both halves of the heart, which work simultaneously, the right heart pumping dark blood while the left heart pumps bright blood. The left ventricle is thicker walled and stronger than the right.

Work and Rest of the Heart. — The time taken by the different parts of the heart beat are about as follows: The auricle contracts about one eighth of the time and rests the other seven eighths. The ventricle contracts about three eighths of the time and dilates during about five eighths. If we suppose the whole period of the heart beat to be twenty-four hours (instead of eight tenths of a second), we can more easily see how much of the time the heart is actually at work, and how much of the time the heart is resting.

Auricle contracting (working) $\frac{1}{8}$ of the time — 3 h., resting 21 h.
Ventricle contracting (working) $\frac{3}{8}$ of the time — 9 h., resting 15 h.

No part of the heart, therefore, is working longer than a man would who only works nine hours a day. Some observers state that the resting period is even greater than these figures would show.

Since the contraction of the ventricles immediately follows that of the auricles, one half of the time is occupied by the whole contraction of the heart, and during half the time the whole heart is resting. This is different from our usual statements regarding the work of the heart. We hear it said that the heart never rests. Its work and rest follow each other at such short intervals that we do not appreciate the interval of rest that comes between the successive impulses that we feel. Suppose a policeman had the power of sleeping at will, and that he slept thirty minutes of each hour, and that in the remaining thirty minutes he made the rounds of a block. If we saw him passing regularly once an hour, every hour of the twenty-four, we might suppose that he did not sleep at all during the entire time. This ratio of work and rest is fairly constant in the varying rates of heart beat.

The Beat of the Heart. — The apex of the heart is always in contact with the chest wall. Consequently, it never strikes it. At each beat it pushes hard against the chest wall. This push may be felt and seen, and is called the heart beat.

The Sounds of the Heart. — There are two sounds of the heart: —

1. A short, sharp sound made by the closing of the semilunar valves.

2. Just preceding this sound a longer, duller sound may be heard during the contraction of the ventricles. This is supposed to be due to the vibrations of the walls of the ventricles and of the large valves.

Action of the Large Arteries. — The large arteries have in their walls a yellow elastic tissue. When the blood is forced into them, they are stretched. As soon as the ventricle ceases to contract, and sends no more blood into the arteries, they "stretch back." We should not say contract, for it is simply an elastic reaction. As the artery reacts it presses on the blood, and hence the blood tries to escape in every possible way. It cannot go back, for it fills the pockets of the semilunar valves, and closes them with a click. A rapid wave is sent forward that gives the pulse, and a slower but still rapid stream flows along the arteries, through the pulmonary artery to the lungs, and through the aorta and its branches to all the other parts of the body.

Fig. 19. Plain (Unstriated) Muscular Fibers from the Bladder.

The elastic reaction of the arteries thus helps to make steady the flow of blood, which is intermittent as it leaves the heart. The medium-sized arteries also have elastic tissue in their walls, and regulate the blood flow in the same way.

Variation of the Amount of Blood Needed. — Each organ requires a supply of blood in proportion to its activity. An actively working organ, like the brain, demands much more blood than bone, practically inactive. Further, working tissues, such as the brain and muscles, need a great deal more blood while they are at work than when they are resting. An organ needing a constant large supply of blood might secure this by having a large artery. But how can the supply be regulated so that an organ may receive, now more, now less, according to its needs?

Plain Muscle Fibers in the Walls of the Arteries. — This is regulated by the medium-sized and small arteries

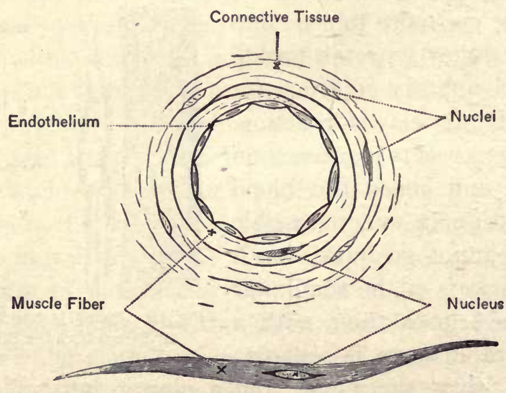


Fig. 20. Plain Muscle Fiber. Isolated and in Wall of Artery.

leading to the parts. In the walls of these arteries are muscle fibers of a different kind from those of the skeleton. These fibers are spindle-shaped cells, as shown in Fig. 19, with a nucleus near the center, and do not have the cross-markings of the fibers of the skeletal muscles; they are in consequence called nonstriated, smooth, or plain muscle fibers. They are arranged circularly in the walls of the arteries. These fibers have, in common with all muscle fibers, the power of shortening. When they shorten they reduce the size of the artery, and, therefore, for the time, less blood can flow through the artery. When the muscle fibers cease to shorten, the artery widens, and allows more blood to pass through it.

Illustration of the Action of Muscles in Arterial Walls. — To illustrate the action of the muscles in the walls of an artery, let the water run through a hose or large rubber tube. Now, if a row of persons take hold of this tube, the grip of their hands is like that of the muscles. When the hands tighten their grip, the caliber of the hose or tube is diminished, and less water is allowed to flow through it. When the hands relax, the tube, being elastic, allows more liquid to flow through it.

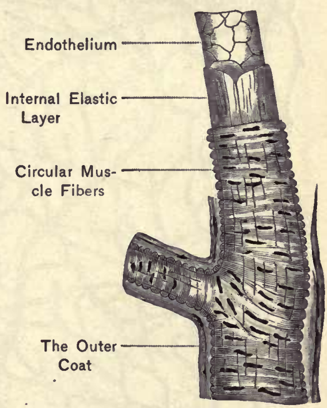


Fig. 21. Coats of a Small Artery.

Illustration of a Small Artery. — To represent a small artery, take a small, thin-walled rubber tube and wind a red thread around it. Now, if the thread could be made to shorten, it would diminish the caliber of the tube. The representation would be more exact if the thread were cut into many short pieces, and if each piece were thicker in the middle, and were then glued to the tube. If the whole were covered by a layer of tissue paper, the structure of the artery would be roughly represented.

Plain and Striated Muscle Fibers Compared. — These plain muscle fibers are further like those of the skeletal muscles in that they are under the control of the nerves, but they are involuntary in their action.

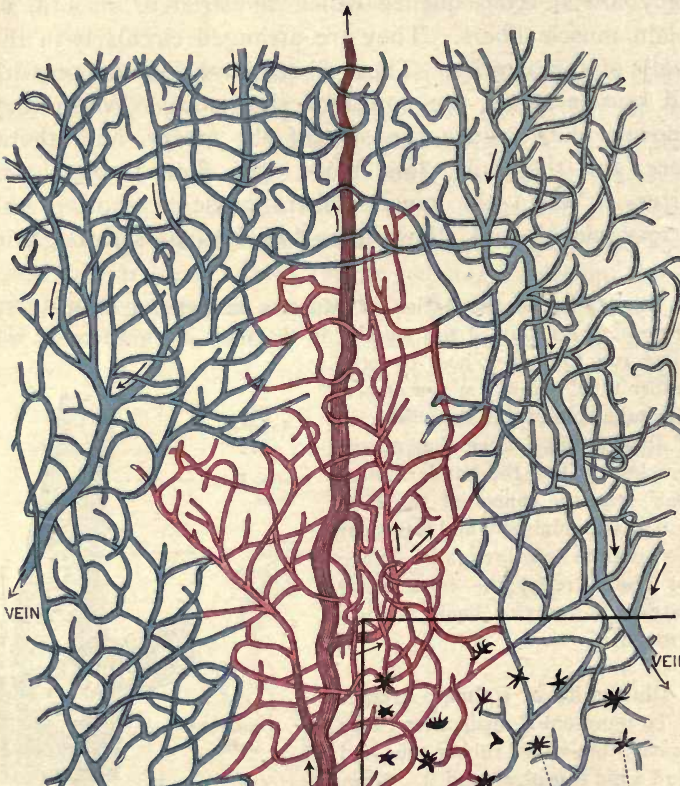


Fig. 22. Part of Frog's Web (low magnifying power).

We cannot interfere with the action of these muscles, no matter how strongly we may will to do so. Without our thinking about it, more blood goes to the muscles of the legs when we walk, more to the brain when we are studying, to the digestive organs after eating, etc. The

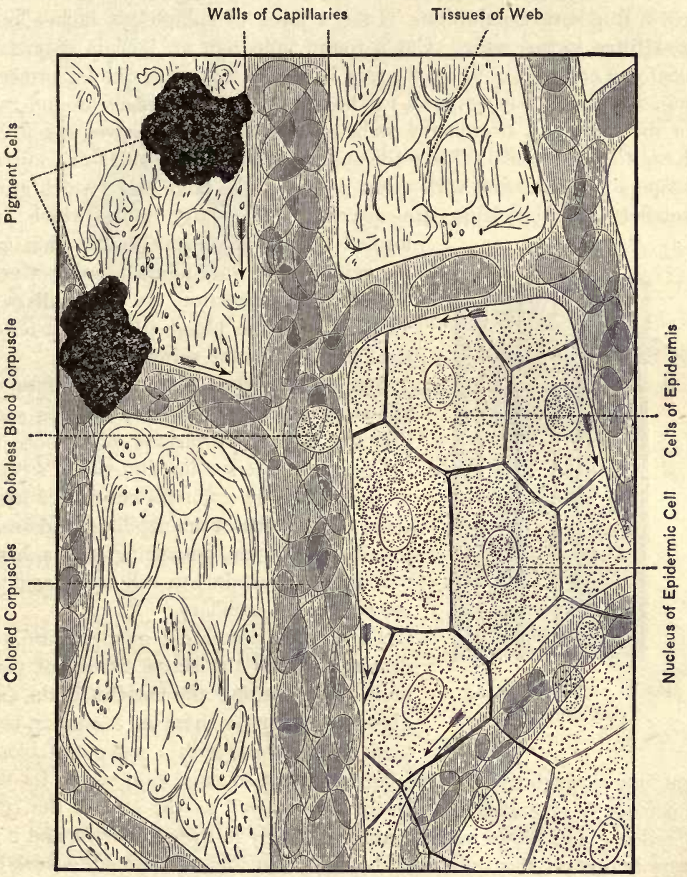


Fig. 23. Part of Frog's Web (highly magnified).

plain muscle fibers shorten at a much slower rate than the striated fibers. They are also slower in relaxing. Since the plain muscles are usually found in the walls of hollow organs such as the heart, blood tubes, digestive tube, etc., they are sometimes called visceral muscles in distinction from the skeletal muscles.

The Circulation of Blood in the Web of a Frog's Foot. — For this get a frog with a pale web. Take a piece of shingle six inches long and three inches wide. Cut a round hole, half an inch in diameter, near one end of it. Wrap the frog in a wet cloth, with one leg projecting, and tie it, thus wrapped, to the shingle. Tie threads around two of the toes, and stretch the web, but not too tightly, over the hole. Keep the web moist. Place the shingle firmly on the stage of a microscope. Examine first with a low power. The large tubes which grow smaller by subdivision are arteries. The large tubes which are formed by the union of smaller ones are the veins. The finer tubes, forming a network in every direction, are the capillaries. They receive the blood from the arteries and pass it on to the veins.

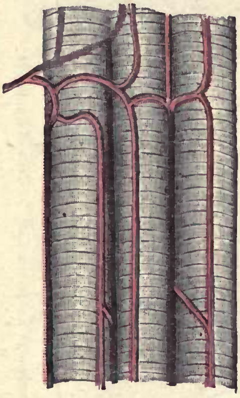


Fig. 24. Capillary Blood Tubes of Muscle.

Put on a higher power, a one-fifth or one-sixth objective. It may now be seen that the colored corpuscles float more in the center of the stream, and with a steady motion, while the colorless corpuscles keep close to the walls of the capillary, and seem to adhere to them, advancing with a hesitant motion, seeming to roll along against the wall of the capillary.

Close your eyes for a moment, and reflect that in all the active tissues of your body — for example, the muscles, brain, and digestive organs — there is a similar network of fine tubes with a current of blood running through them. The current is not so rapid as it seems, for the microscope magnifies the rate of flow as well as the size of the corpuscles. The blood really is moving slowly in the capillaries, and it is very important that it should be so, for in the capillaries the work of the blood is done. Part of the liquid of the blood soaks through the thin walls of the capillaries, and nourishes the surrounding tissues. All the other parts of the circulatory system exist for the purpose of sending a continuous, slow, and steady stream of blood through the capillaries. (See pages 72 and 73.)

The Blood Flow in the Capillaries. — The arteries divide and subdivide, and become capillaries, which have connecting branches, forming a close network of tiny thin-walled tubes. These penetrate nearly every tissue of the body. The blood cannot do its full work till it is in the tissues, and to reach the tissues it must soak through the walls of the capillaries. The work of the heart and arteries is to keep a steady flow of blood through the capillaries, that the tissues may be constantly supplied.

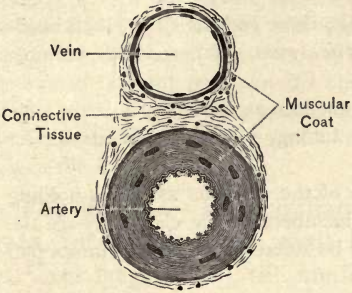


Fig. 25. Cross-section of Small Artery and Vein.

How is it that the jerky action of the heart, at each contraction sending a jet of blood into the arteries, — shown by a spurt when an artery is severed, and also indicated by the intermittent pulse, — how is this intermittent flow converted into the steady, uniform current that we have seen in the capillaries?

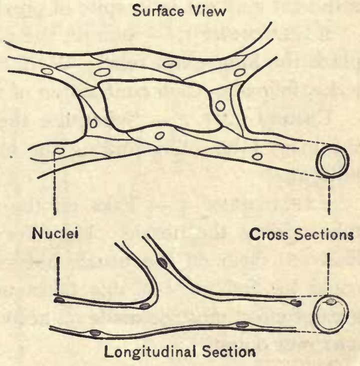


Fig. 26. Capillaries, composed of a single layer of cells.

Experiments illustrating the Blood Flow in the Capillaries. — A few experiments may make this matter more clear.

Material: — 1. A common rubber syringe.

2. A glass tube three feet long and seven sixteenths of an inch outside diameter.

3. Four inches of the same size glass tubing, for making connections.

4. Several nozzles, made of the same size glass tubing, all fine, but of varying degrees of fineness.

5. India-rubber tubing, twelve feet, three eighths of an inch inside diameter. This should be *black*, *pure gum*, rubber which is more highly elastic than the other kinds.

6. Three feet of rubber tubing, same size as above.

7. Four inches of white rubber tubing, same size as above, for making connections.

In all the experiments, have one of the students assist by holding the outlet tube, so that (1) all the members of the class may see the stream, and (2) that the stream may be suitably directed, as into a pail or sink.

Count aloud, to mark the exact time of each compression of the bulb, so the students can compare this with the time and duration of the jets of water.

Be very careful to use perfectly clean water, as any fine particles of sediment drawn into the tube are likely to clog the fine outlet of the nozzle. And it is well to take the further precaution not to let the supply tube touch the bottom of the water-supply dish, as some fine sediment may get in in spite of previous care.

Experiment 1. — Remove the nozzle of the syringe, and put in its place the long glass tube. Work the syringe, and note that the jet is jerky, following each contraction of the bulb.

Experiment 2. — Substitute the rubber tube, three feet long, for the glass tube. On working the bulb the stream will be found intermittent.

Experiment 3. — Take off the rubber tube and replace the glass tube, adding the nozzle. Here the pressure will be so great that it is likely to push off the nozzle unless the assistant holds it firmly. It could be tied on, but this takes more time. On working the bulb, greater effort must be made on account of the resistance caused by the narrower outlet.

Experiment 4. — Once more substitute the rubber tube, this time with a glass nozzle in its end. Now, on working the bulb, resistance will be felt, and the stream will be constant, or nearly so, and will continue for some time when the bulb is no longer worked. This is because the rubber has been stretched, chiefly laterally, and is now "stretching back." That is, by the elastic reaction of the rubber tube the jerky action of the bulb is converted into the steady flow that we see. In the first experiment we had a rigid tube and practically no resistance. In the second, although the tube was elastic, there was no resistance, so the elasticity was not brought into play. In the third, there was resistance, but the tube was inelastic. In the fourth, the resistance brought into play the elasticity of the rubber tube, and the elastic reaction of the tube continues (so to speak) the action of the bulb between two successive strokes. In this experiment the pulse can be felt in the tube.

The Veins. — The capillaries, after penetrating the tissues, reunite to form small veins, which in turn reunite to form larger ones, till finally two great veins, the caval veins, precaval and postcaval, return the blood to the heart. The veins, like the arteries, are smooth inside and elastic (though less elastic than the arteries). They are thinner than the arteries, and, in consequence, collapse when the blood flows out of them, whereas the larger arteries stand open, after they are emptied of blood.

The Valves in the Veins. — The only valves in the arteries are those which we have seen at the beginning of the aorta and pulmonary artery. Many of the veins have similar pocket-like valves, though less strong than those of the arteries. They are usually in pairs, but sometimes single or in threes. It is important to note that they all have the mouths of the pockets toward the heart, so that the blood flows freely toward the heart, but is prevented from flowing the other way on account of the filling of the valves by the reflow

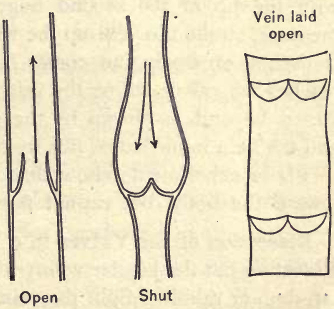


Fig. 27. Venous Valves.

of the blood stream. When the blood is flowing through the veins toward the heart the valves lie against the walls of the veins.

The valves are most numerous in the medium-sized veins, and especially in the veins of the extremities; more abundant in the leg than in the arm. Valves are absent from the caval and some other veins, and from the very small veins.

Illustration of Venous Valves. — Make a cloth tube (or take the lining of a boy's coat sleeve) and sew three patch-pockets on the inside, in a circle, *i.e.* with edges touching each other. Make the pockets a little "full." Pour sand, shot, or grain through the sleeve first in one direction and then in the other.

Evidences of Valves in our Veins. — With the forefinger stroke one of the veins on the hand or wrist toward the tips of the fingers. The veins swell out. The blood meets resistance in the valves of the vein. Their location may be determined by their bulging out during the experiment.

Stroke a vein toward the body, and the blood is pushed along without resistance.

Let the left hand hang by the side. Note the large vein along the thumb side of the wrist. Place the tip of the second finger on this vein just above the base of the thumb. Now, while pressing firmly with the tip of the second finger, let the forefinger, with moderate pressure, stroke the vein up the wrist. It may be seen that the blood is pushed on freely, but comes back only part way. It stops where it reaches the valves, filling the vein full to this point, but leaving it collapsed beyond, as shown by the groove. Remove the second finger, and the vein immediately fills from the side nearer the tip of the fingers.

These experiments show that the blood in the veins moves freely toward the body, but cannot flow outward to the extremities.

Dissection of the Valves in a Vein. — The valves may be seen by dissecting out the jugular vein (or any other large superficial vein) of a cat, dog, or rabbit. Split the vein and pin it out on a board.

Effect of Pressure on the Veins. — Since the valves in the veins open toward the heart, any intermittent pressure on the veins helps to push the blood on toward the heart.

The valves are most numerous in the superficial veins and those of the muscles. The pressure of the muscles during their action (thickening while shortening) produces pressure on the veins; and as the muscles act for a short time only, and then relax, this alternate compression and release aids very considerably in moving the blood on toward the heart. It is worthy of remark that this effect is more pronounced at the time the muscles need the most active circulation; namely when they are in action, and are using the most blood. The heart has power enough to pump the blood clear around from each ventricle to the auricle of the other side of the heart; but this outside aid comes in good play to relieve the heart at a time when it has an unusual amount of work to do, as when one is using a large number of muscles vigorously.

"Every active muscle is a throbbing heart, squeezing its blood tubes empty while in motion, and relaxing so as to allow them to fill up anew."

Rate of Blood Flow in the Arteries, Capillaries, and Veins. — The blood flows most rapidly in the arteries, slowest in the capillaries. Why is this?

When an artery divides, the two branches taken together are larger than the one artery that divided to form them. Stated more exactly, the sum of the areas of the cross-sections of the branches is greater than the area of the cross-section before branching. Hence as the blood flows on it is continually entering wider and wider channels; and we are told that the united cross-section of all the capillaries fed by the aorta is several hundred times that of the aorta itself.

The Flow of the Blood compared with the Current of a Stream. — If we walk along a stream, we see that the channel varies considerably in width and depth. Where the channel is large, whether from increased width or depth, there the current is slower, but wherever the channel is reduced, the current is more rapid. So the stream in the relatively narrow artery is swift. In the capillaries,

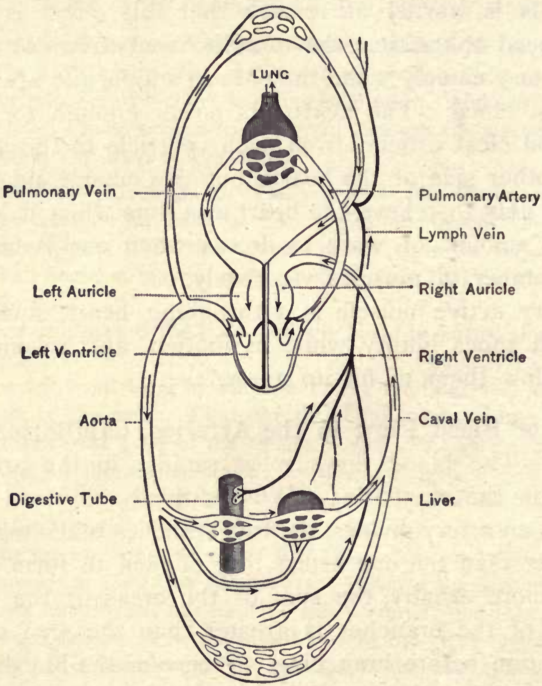


Fig. 28. Plan of Circulation. (Dorsal View.)

although any individual channel is small, these channels all together are wide; the result is the same whether a river widens out into a single lake, or divides into a great number of channels running past innumerable islands.

All the tissues of the body may be regarded as so many islands lying between the capillary streams.

The Blood Flow in the Veins. — When the blood re-collects in the veins it is entering narrower channels, and its rate is quickened; but as the veins are wider than the arteries, the stream does not enter the heart with the velocity with which it left that organ. The veins hold more blood than the arteries, and in dissecting the cat or rabbit it will be noticed that the arteries are emptied of blood; that the tissues of most of the organs are fairly free from blood; but that the great veins, such as the caval veins, are full.

Blood Tubes compared to Two Funnels. — If the blood tubes leaving the heart could all be united, they would be best represented by a funnel with its tube connected with the heart. If another funnel were placed with its mouth to the mouth of the first, their point of union, the widest point, would represent the capillaries; and if the second funnel had a wider tube than the first, it would fairly represent the veins which return the blood to the heart.

Nourishment of the Walls of the Heart and Blood Tubes. — The cardiac (coronary) arteries spring from the aorta just above the semilunar valves, and send blood into the muscular walls of the heart; and these arteries, like others, divide, forming capillaries, through which the heart muscle is nourished. The cardiac veins return the blood to the right auricle.

Influence of Gravity on Circulation. — Although the heart pumps the blood around through the body independent of the force of gravity, yet the circulation is influenced by this force. For instance, a person who has fainted should be laid flat on his back, that the heart may more easily drive blood to the brain. Many persons go to sleep more readily while sitting than while lying down. A sore hand feels less pain if held up, as in a sling, than when hanging by the side, and a sprained ankle does better rested on a chair, as less blood flows to it. Nearly every one has noted the pain following the pressure of blood when a sore hand, or foot, is suddenly lowered.

Experiments illustrating the Effect of Gravity on Circulation. — Let all the pupils in the class stand. Let one arm hang freely by the side. Hold the other arm straight up as far as the clothing will readily permit. Observe: —

1. The difference in the color of the two hands.

2. The difference in fullness, both in the feeling of fullness and in the prominence of the veins.

3. The difference in temperature; place the backs of the hands against the cheeks.

The position largely determines the amount of blood in the hand, and the amount of blood determines the temperature, the size, and the color.

The Heart Beat and the Pulse. — 1. The heart beat, felt at the left of the breast bone.

2. The pulse, felt at the wrist and at various parts of the body. Perhaps the most convenient place to study it is at the temple. Lay the forefinger lightly along the cheek just in front of the ear. Count the pulsations for a minute.

Let one or two pupils who are quick at figures step to the blackboard and put down the number of pulsations of each pupil, and divide by the number thus reporting, to get the average.

1. Let all in the class count the pulse while sitting. Probably it will be best to discard the first trial, as there are likely to be several failures from one cause or another. Then, too, there is usually a slight excitement at the beginning of a wholly new experiment. Get the average of the class.

2. Find the pulse while sitting; rise quickly, and immediately begin to count the pulse. Compare with the pulse as taken while sitting.

3. Compare the pulse before and after meals.

Summary. — 1. The heart beats about seventy-two times a minute.

2. The pulse is a wave running along an artery.

3. The pulse varies with age, health, food, etc.

4. The heart has two main cavities, one in each half of the heart, and two independent streams are flowing through it.

5. Valves allow the blood to flow through the heart in one direction, but prevent a reversal of the current.

6. The heart is a hollow muscle, and by contraction forces the blood out into the arteries.

7. The heart works rather less than half the time.

8. The large arteries, by elastic reaction, push the blood on while the heart is resting.

9. Circular muscle fibers in the walls of the medium-sized arteries regulate the blood supply to the organs.

10. In the arteries the blood flow is rapid and intermittent, in the capillaries slow and constant.

11. The thin walls of the capillaries allow the liquid part of the blood to soak out and nourish the tissues, and to soak back into the capillaries bearing waste matter.

12. The veins are thin walled, and collapse when empty, while the arteries are thick walled, and stand open when empty of blood.

13. Arteries carry blood *from* the heart, while veins carry it *toward* the heart.

14. The veins have valves which allow the blood to pass toward the heart, but not away from it.

15. Any intermittent pressure on the veins aids the blood flow.

16. The blood flow is most rapid in the arteries, slower in the veins, slowest in the capillaries.

17. Gravity influences circulation.

Questions. — 1. Why do the large arteries lie deep ?

2. In which direction should the limbs be stroked to promote circulation ?

3. How does slapping the hands around the body warm the fingers?

4. How can a horse or a cow be comfortable with the head down for a long time ?

5. Why are the walls of the left ventricle thicker than those of the right ?

CHAPTER V.

CONTROL OF CIRCULATION.—THE BLOOD AND THE LYMPH.

The Effect of the Emotions on Circulation.—In our every-day experience we have evidence of the control of the heart and blood tubes by the nervous system. We know that certain emotions affect the circulation of the blood and produce blushing and pallor. Certain emotions may also quicken or retard the action of the heart. Excessive grief or joy has produced sudden death by stopping the beat of the heart.

Let us look a little more closely at that part of the nervous system that has such intimate relation to the blood system.

The Rhythmic Action of the Heart.—In the first place, the action of the heart is automatic. The heart of the frog continues to beat a long time after it is removed from the body. This is regarded by many as due to the action of certain ganglia imbedded in the walls of the heart, especially in the auricles; while others say that since the ventricle, in which no ganglia have been found, may beat independently of the auricles, rhythmic contraction is characteristic of heart muscle, and that we are, at present, unable to explain it.

But while the impulses that *originate* the action of the heart arise within the heart itself, still the beat of the heart is constantly modified by nerve impulses reaching it from without.

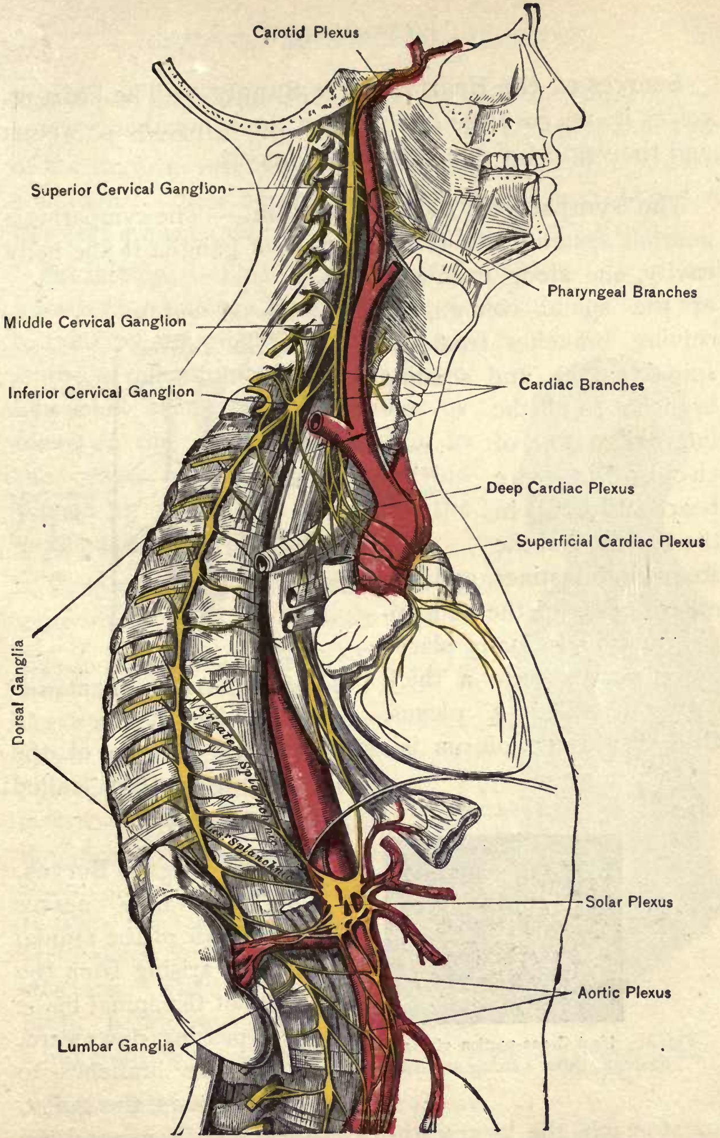


Fig. 29. Vertical Section of Body, showing Sympathetic Nerves and Ganglia of Right Side and their Connection with the Cerebro-spinal Nerves.

Sources of the Heart's Nerve Supply. — The heart receives its nerves from two sources, the sympathetic system and the vagus (or pneumogastric) nerves.

The Sympathetic Nervous System. — The sympathetic nervous system consists of two rows of ganglia in the body cavity, one along each side of the spinal column, receiving branches from the spinal nerves, and sending branches to all the internal organs of the body, — the heart and lungs in the thorax, and the stomach, intestines, and the other organs of the abdominal cavity. In many places these nerves form a thick network called a plexus. One very large plexus is on the dorsal surface of the stomach, and is called the solar plexus.

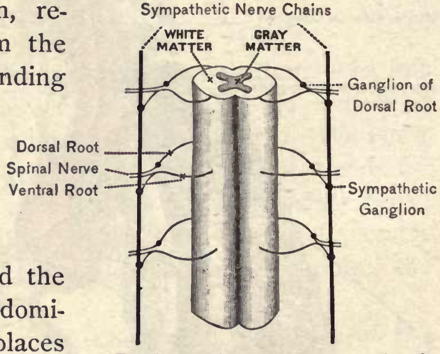


Fig. 30. Relation of Spinal Cord and Sympathetic Nervous System (Diagram).

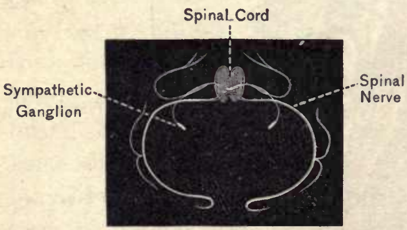


Fig. 31. Ideal Cross-section of the Nervous System. (After Landois and Stirling.)

The Vagus Nerves. — The vagus nerves are a pair of the cranial nerves arising from the sides of the spinal bulb; and passing downward, they give branches to the pharynx, the gullet, the stomach, the larynx, the windpipe, the lungs, and the heart. Now, whatever other function the vagus nerves may have, they seem to have the power of retarding, or stopping altogether, the beat of the heart; and stimulation of the vagus nerves may make the heart pause in a relaxed condition. Other nerves may quicken the heart beat, but the vagi are regarded as a break on the heart's action.

Inhibition. — This is a case of inhibition. It is well known that a severe blow over the stomach may cause one to faint by stopping the heart. This is due to reflex inhibition of the heart. The blow sends a nerve impulse by fibers of the sympathetic system to the center in the spinal bulb, and thence an impulse is taken by the vagus nerves to stop the heart.

Vaso-constrictor Nerves. — In an experiment with the rabbit's ear it has been shown that stimulating the sympathetic nerve in the neck causes the ear to become pale. This is due to the constriction of the arteries of the ear, because the nerves have made the muscle fibers of these arteries shorten. Such nerve fibers are called constrictors, or vaso-constrictors. They run in the sympathetic nerve, but have their origin and center in the spinal bulb.

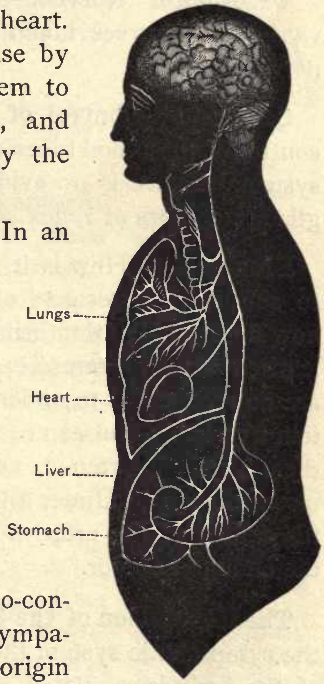


Fig. 32. Diagram of Vagus Nerve.

Vaso-dilator Nerves.—Other fibers may cause the opposite effect, namely, dilation, and are therefore called vaso-dilators. Examples of these may be found running to the arteries of the limbs. When the muscles of any organ, say the legs, act, they need a greater supply of blood. Now, at the same time that nerve impulses are sent to the muscles of the legs to make the muscles shorten, impulses are sent along other fibers of the same nerves to make the arteries dilate, and allow more blood to flow to these muscles.

Vaso-motor Nerves. — The vaso-constrictor and the vaso-dilator nerves taken together are called vaso-motor nerves.

Centers of Control of Circulation. — The centers of control of the blood tubes are in the cerebro-spinal nervous system. There is no evidence that the sympathetic ganglia are centers of reflex action.

Blushing. — How is it that the face sometimes flushes so suddenly? Because of some emotion, you say. But how does the emotion bring this about? We have already learned about the muscles in the wall of the arteries. We are now prepared to understand that in the normal condition nervous impulses are acting on these muscles, keeping them partly shortened, and so keeping the arteries of a moderate size. Under the influence of certain emotions, the caliber of the arteries is suddenly enlarged, and hence the change in color.

The Regulation of the Size of the Arteries. — Through the sympathetic system the blood supply of all the organs of the body is regulated. Any organ needing more blood sends a message (nerve impulse) to some nerve center, and in response nerve impulses are sent to the muscle fibers of the supplying artery, and the amount of blood sent to that organ is regulated. For instance, a piece of ice is laid upon the skin of the hand. The part becomes pale, as the arteries have become narrowed. If this action be continued, there may set in a decided reaction, and the part become more red than usual, when the reaction has widened the artery more than it was before the constriction.

Effect of Exercise on the Size of the Arteries. — As there is only a certain amount of blood in the body, it is evident that if one organ receives an extra supply, some other organ or organs must, for the time, receive less. For instance, one begins to walk vigorously. The large muscles of the lower limbs and trunk become active, and they need more blood. They therefore send messages to some nerve center (probably in the spinal cord), and by reflex action the arteries supplying the lower limbs are widened, and these muscles receive more blood. But these muscles make up a very considerable part of the weight and bulk of the body. While in action they take the lion's share of the blood. The brain, at such a time, would receive less, and it would be folly to expect the brain to work at its full capacity while the blood was called away to other organs.

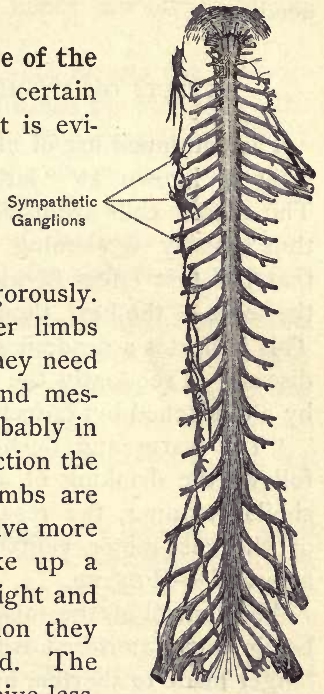


Fig. 33. Ventral View of Spinal Cord with Sympathetic Ganglions of One Side

Regulation of the Effects of Exercise. — When we exercise vigorously, the heart beats faster, and this of itself would tend to increase the blood supply to all organs.

But this mechanism for widening the channel leading to the working organs, while the arteries to the other organs are made smaller, or at least are not enlarged, solves the problem of supplying each part according to a greatly varying need, while not sending too much to a part not needing it.

EFFECTS OF ALCOHOL ON THE CIRCULATION.

The continued use of alcoholic liquors frequently causes what is known as "fatty degeneration" of the heart. The muscle cells are more or less replaced by fatty tissue, thus greatly weakening the heart. Experiments show that the first effect of alcohol on the heart is to weaken the force of the beat, though the rate is usually quickened. This indicates a deadening effect, such as is often seen in disease. Frequently the approach of death is indicated by a quickened but enfeebled heart-beat.

"The warm and flushed condition of the skin which follows the drinking of alcoholic fluids is probably, in a similar manner, the result of an inhibition of that part of the vaso-motor center which governs the cutaneous arteries." — FOSTER.

The control of the muscles in the walls of the arteries being thus interfered with, the circular muscles are no longer made to shorten, and the artery dilates, thus allowing more blood to flow into it.

We may thus account for the flushing of the skin of the face, which in many individuals quickly betrays indulgence in alcoholic drink. If this flushing is too often repeated, the arteries gradually "lose tone," and the condition becomes permanent. The circulation in the whites of the eyes may be affected, making them "bloodshot."

Similar congestion occurs in the mucous membrane of the stomach from the presence of alcohol, which may become a permanent inflammation followed in time by very extensive changes in appearance and function. It is said that most of the alcohol swallowed is absorbed directly from the stomach, and hence the intestines are not so directly affected.

Good authorities state that alcohol arrests the development of the corpuscles. It diminishes the size, alters the form, and reduces the number of the corpuscles. Since the work of the blood corpuscles is so important this reduction in their number and efficiency must very appreciably affect the nutrition of the body as a whole. When the blood is "out of order" the body is out of order.

The Blood. — The blood is composed of a clear liquid, the plasma, and the blood cells, or corpuscles. In a drop of blood under the microscope the plasma occupies the clear spaces between the corpuscles. The corpuscles make up one third of the bulk of the blood, and the plasma two thirds.

Microscopic Examination of the Blood. — To get a drop of blood from the finger, wind a cord around the finger, beginning at the base, drawing the cord moderately tight, until the last joint is reached. By this time the end of the finger is usually well distended with blood. With a clean needle make a quick, sharp, light puncture near the base of the nail; this ordinarily brings a small amount of blood. Put a small drop on each of several slides and quickly cover with coverslips. Examine with a high power.

The Colored Corpuscles. — These are often called the red corpuscles. But while in the mass they give the blood a red appearance, individually they are faint yellowish red. In shape they are seen to be circular disks, hollowed on each side like a sunken biscuit. As they are hollowed on both sides they are more accurately described as biconcave. These corpuscles tend to gather side by side, in rolls, like coins. They are cells without nuclei.

The Colorless Corpuscles. — In the open spaces between the rolls of colored corpuscles may occasionally be found some spherical corpuscles. They are usually

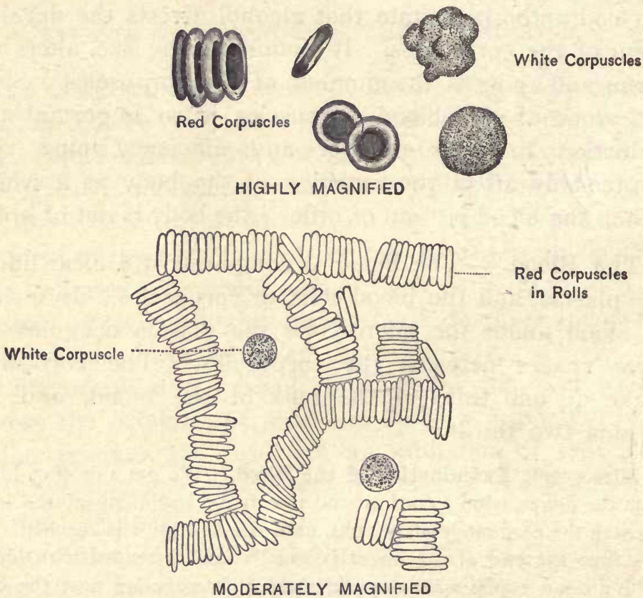


Fig. 34. Red and White Corpuscles of the Blood.

called the white corpuscles, but are better designated as the colorless corpuscles, since the others have only a slight color, and these have none. They usually have a dotted appearance. It is not so easy to distinguish the two kinds of corpuscles as it is in the case of the frog's blood, for the two kinds are more nearly of the same size in the human blood; and, further, when the colored corpuscles of human blood are seen flatwise they present a circular outline, while the frog's colored corpuscles are elliptical. But with a little study the two may be distinguished. As in the frog's blood, the colorless corpuscles have ameboid movements, though they are not very marked unless the blood be warmed to about the temperature of the human body.

Flexibility and Elasticity of the Corpuscles. — It will be well here to examine again the frog's web. (See p. 54.) It will occasionally be seen that when one of the colored corpuscles is pressed against an angle at the forking of the blood stream, it is sometimes bent, and that as soon as the pressure is discontinued the corpuscle springs back to its former shape, showing that it is elastic.

Frog's Blood. — A drop of frog's blood, mounted as the human blood was, will be helpful, as there is a very decided difference in the size and shape of the colored and colorless corpuscles. Further, the colorless corpuscles of the frog will show ameboid movements, *i.e.* slow changes of form, if watched a while.

The Plasma. — The plasma consists chiefly of water, having in solution various salts, including common salt; it also contains the nourishing materials for the tissues. These nourishing materials, obtained from the food by digestion, consist chiefly of proteids, fats, and sugar. The plasma also contains waste matters, from the working tissues, on their way out of the body. How the food is prepared for the building of tissue, and how the waste matter is removed from the body, we shall study a little later.

The Color of Blood. — The difference in color of an individual corpuscle and the blood in the mass may be better understood by comparing it with something that we see more frequently. A tumbler of currant jelly has a rich, red color, but a thin layer of the same jelly, as when one takes a spoonful on a plate, has a pale color, more yellowish. The colorless plasma with the colored bodies in it may be compared to a glass dish filled with cranberries and water.

Hemoglobin. — The coloring matter in the blood, then, is wholly in the colored corpuscles. Examination of these corpuscles shows that their color is due to a substance called hemoglobin. There is a small amount of iron in the hemoglobin, and the presence of this small quantity of iron appears to be essential to give the blood its color. When we come to the study of respiration we shall see that the hemoglobin in the corpuscles is the chief agent in picking up the oxygen from the air in the lungs and carrying it to the tissues in the body.

The Coagulation of Blood. — When the blood escapes from its natural channels it usually changes from a liquid to a jelly-like condition. This is known as coagulation. It is due to the formation of threads of fibrin from the plasma. These threads of fibrin entangle and inclose the corpuscles, and the two constitute the clot, or coagulum, as it is more technically termed. The liquid that afterward separates from the clot is the serum, and differs from the plasma only in the removal of the fibrin, which is exceedingly small in quantity, though of great importance in its action. Many experiments have been made, and much has been written about the coagulation of the blood, and perhaps its real cause is not yet clear. But we know that the coagulation often serves to stop the flow of blood from wounds, and this is its main use.

Fibrin. — If freshly drawn blood be stirred rapidly with a bundle of wires (perhaps the most convenient stirrer is a little roll of wire screen), there will soon collect on the wires a stringy substance. Thorough washing will soon leave this colorless. It is fibrin. If the stirring has been done thoroughly, the blood will no longer clot, no matter how long it may stand.

Liquid Blood and Coagulated Blood. — The following scheme shows the difference between the liquid blood and the coagulated blood: —

Liquid Blood	Plasma . . .	Serum		Coagulated Blood.
		Fibrin	Clot . .	
	Corpuscles			

Amount of Blood. — The blood constitutes about one thirteenth of the weight of the body. In a body weighing one hundred and fifty pounds this would be about six quarts.

Chemical Reaction of Blood. — Blood is alkaline.

Specific Gravity of Blood. — Blood is somewhat heavier than water, owing to the salts and other matters dissolved in it.

Quantity of Blood in Different Organs (approximately). — 1. One fourth is in the heart and the larger arteries and veins (including those of the lungs).

2. One fourth in the liver.
3. One fourth in the skeletal muscles.
4. One fourth in the other organs.

The Lymph Spaces. — We have seen that the capillaries have very thin walls. Through their walls part of the plasma of the blood soaks out, and is then called *lymph.* It passes into irregular cavities in the tissue called *lymph spaces.* Most of these lymph spaces are minute chinks or crevices in the connective tissues of the different parts of the body.

The Lymph Tubes. — Opening out of the lymph spaces are irregular passage ways called lymph capillaries, and these lymph capillaries are continuous with thin-walled tubes, the lymph tubes. These lymph tubes might be called the *lymph veins*, since they join still larger tubes closely set with valves, similar to those of the veins. But unlike the blood veins, the lymph veins do not gradually increase in size by confluence. They suddenly form a large tube, the *receptacle of the chyle*, beginning in the upper part of the abdomen. This tube soon narrows and passes through the diaphragm, close to the spinal column, and up along the column near the aorta, and empties into the veins of the neck at the junction of the left jugular and left subclavian veins. This tube is the thoracic duct, or the *main lymph duct*. It has numerous valves, and, like some of the smaller lymph veins, it presents a beaded appearance, due to the filling and bulging out of the valves. In the right side of the neck is a short right lymph duct which receives lymph from the right side of the head, neck, and thorax, and from the right arm. The lymph tubes, as a whole, are usually called the "lymphatics."

Lymph Spaces in the Frog. — In dissecting the frog, the looseness of the skin is very noticeable. The large spaces under the skin are lymph spaces. Sometimes considerable lymph is found here, so that in holding up a frog the sagging of the skin from the weight of the lymph may be easily seen.

Valves at the Mouth of the Lymph Tubes. — There are valves where these lymph ducts empty into the veins which prevent any reflow of liquid into the ducts, but allow the lymph to pass freely into the veins.

Muscle Fibers in the Walls of the Lymph Tubes. — There are plain muscle fibers in the walls of the lymph ducts

Lymphatic Glands. — In its course the lymph passes through many kernel-like masses, the lymphatic glands. Lymph contains corpuscles which are considered identical with the colorless blood corpuscles. It is thought that these corpuscles are formed in the lymphatic glands.

The Flow of Lymph. — The flow of lymph is partly due to the blood pressure in the capillaries; this pressure is caused by the heart. (In the frog there are two small hearts, — not, however, near the blood-pumping heart, — and these pump the lymph along.) In our bodies the flow of lymph is largely aided by any pressure that may be brought to bear on the lymph veins; for, on account of the valves, as in the blood veins, any pressure must push the liquid toward the heart. Thus the action of the muscles in the limbs, in the chest, in the abdomen, in the movements of breathing, and in the bending of the body, etc., all help in this flow, which is always, probably, very much slower than that in the blood veins.

Relations of Blood Flow and Lymph Flow. — It will now be seen that while the blood leaves the left ventricle by one tube, the aorta, it returns to the right auricle, not merely by the two caval veins, but that a part of the blood (*i.e.* of the liquid part of it) does not return by blood veins, but having left the blood system proper through the thin walls of the capillaries, it is brought back to the heart by the lymph veins, which, however, join the blood veins just before they empty into the heart. There is, in other words, only one set of distributing tubes, but there are two sets of collecting or returning tubes.

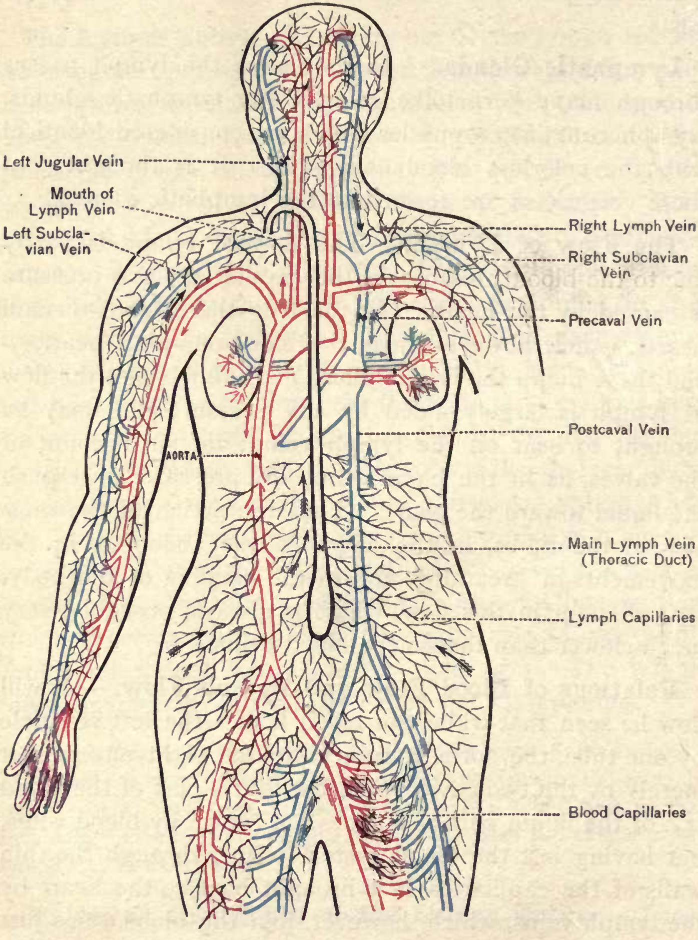


Fig. 35. Diagram of the Circulation of Blood and Lymph (Dorsal View).

The Lymph. — Lymph is a clear liquid. (Chyle and the lacteals will be considered when we study digestion.) It is more watery than the blood plasma, but contains a share of all its nutritious substances. Lymph may be defined as "*diluted blood minus red corpuscles.*" The blood proper never reaches the tissues.

The Cells of the Body live in Lymph. — The cells of the tissues are bathed in the lymph which fills the spaces in the connective tissue (and we have seen that the connective tissue pervades nearly all the tissues of the body), as water may fill the spaces left between stones built into a wall. The cells get all their nourishment from the lymph, and into the lymph they throw all their waste matter. Each cell may be compared to an individual ameba, which lives in water, and takes all its nourishment from that water, and throws all its waste product into the same water. As water is the medium in which the ameba lives, so we may say lymph is the medium in which the cells of the body live.

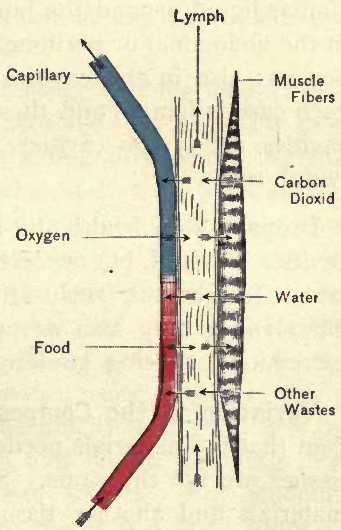


Fig. 36. Relation of Blood and Muscle. (Lymph being Middleman.)

Cells of the Body Aquatic. — The cells of the body, *i.e.* all the active, working cells, may, therefore, be said to live an aquatic life, and only dead cells, as of hair, epidermis, etc., live in air. We might also say that not only the human body, but all animal life is aquatic.

Importance of Lymph. — We can see that the movement and renewal of lymph are as necessary as the circulation of the blood itself; is, in fact, the most important part of it.

Lymph Cavities or Serous Cavities. — We have noticed the pericardial liquid. There is also a small quantity of similar liquid around the lungs in the pleural cavities, and in the abdominal or peritoneal cavity, around the digestive organs; also in the cavities of the brain. The liquid in each case is lymph, and these cavities, often called serous cavities, are lymph cavities. They communicate with the lymph tubes.

Dropsy. — In health the amount of the liquid in these cavities is small, but in certain disorders it may accumulate. In general, such affections are called "dropsy." The lymph may also accumulate in the tissues of the extremities, causing swelling of the limbs.

Variation in the Composition of Lymph. — It is evident that the materials needed by the cells of the different tissues are not the same. So, as one tissue takes certain materials and another tissue others, it is clear that the lymph will not be of quite the same composition in the different parts of the body. This difference is further due to the difference in the waste products thrown out by the different cells. Hence the composition of the blood varies considerably in different regions. But the lymph from all the tissues unites with the blood from all the tissues in the right heart, and on their way to it in the larger veins. So the constant slight differences in composition of the blood and lymph in the various tissues are counterbalanced by the mingling of the currents from these various parts in the large arteries and veins.

The Spleen. — The function, or functions, of the spleen are not well understood. It is believed to have something to do with the renovation of the blood, perhaps forming colorless corpuscles and destroying colored corpuscles. At any rate, the physiologists generally call it a blood gland. It is unlike true glands in that it has no duct, and forms no secretion to be poured into any cavity, like the glands of excretion and secretion. It has been found, in the case of accidents to man, and by observations on the lower animals, that life may continue after this organ has been removed.

Massage. — A system of pressing, rubbing, and kneading the muscles is known as massage. It helps the flow of the blood and lymph, thus aiding in washing out the waste products from the muscles and other parts of the body that are to be reached by pressure. We have seen that one of the benefits of exercise is to promote the circulation of the blood and of the lymph, and so to help get rid of the waste matters that are produced by the activity of the various organs. Many invalids cannot take active exercise. So this passive exercise may very fairly take its place, and assist in the nutrition of the tissue by accelerating the flow of blood and lymph, bringing new nourishment and carrying away wastes. For students who do not take sufficient exercise it is a good thing to rub the body thoroughly and briskly, not only after a bath, but often with the hands or with a dry towel.

Transfusion of Blood. — Transfusion of blood is the transfer of blood from the blood vessels of one animal to those of another. Transfusion may be direct or immediate, as when the blood vessels of the two animals are connected by tubing so that the blood passes from one to the other without exposure to the air; in indirect or mediate transfusion the blood is first drawn into a receptacle. In indirect transfusion the blood is often defibrinated before transference. The blood may be introduced either into an artery or a vein; if into a vein it is sent in the direction of the natural flow, *i.e.* toward the heart; if into an artery, in either direction. Soon after the discovery of the circulation of the blood the operation of transfusion began to be practiced, and high hopes were indulged in as to its value. But it was soon found to be attended by so much danger that it is now seldom used. It is resorted to (1) after great loss of blood, (2) after some forms of poisoning part of the blood is withdrawn and replaced by fresh blood, and (3) in certain disordered conditions of the blood. The chief dangers are (1) the introduction of air which forms minute bubbles and stops the blood-flow in the capillaries, (2) the introduction sometimes causes coagulation within the blood vessels, and (3) the serum of the introduced blood sometimes destroys the corpuscles of the blood to which it is added. In the earlier practice lamb's blood was employed, but now when transfusion is practiced on man only human blood is used. It has been found safer and better after great loss of blood from hemorrhage, to introduce a salt solution of about the natural degree of saltness of the blood; this restores the normal volume of circulating liquid, and avoids most of the dangers except that of introducing air. The numerous fatal results of this operation have shown that it should not be resorted to except in cases of extreme necessity.

For directions about stopping the flow of blood from wounds see Chapter XXIII. and the books named below.

READING. — *Prompt Aid to the Injured*, Doty; *Emergencies*, Dulles; *Emergencies*, Howe; *First Aid to the Injured*, Lawless; *First Aid to the Injured*, Morton; *First Aid in Illness and Injury*, Pilcher; *Sickness and Accidents*, Curran.

What other process keeps pace with the coursing of the blood through the body, being its running mate, so to speak?

Summary. — 1. Blushing, and other variations in blood supply, are under the control of the sympathetic nervous system.

2. The sympathetic nervous system consists of two rows of ganglia

in the body cavity near the spinal column, with fibers running to the internal organs. It is also connected with the cerebro-spinal nervous system.

3. The heart beat is automatic and rhythmic.

4. The heart beat is regulated by the sympathetic nervous system and by the vagus nerves.

5. The blood consists of a liquid, the plasma, in which float the colored and colorless corpuscles.

6. When blood is shed it coagulates, tending to check its own escape.

7. Lymph is like the blood diluted and lacking the colored corpuscles.

8. A set of lymph tubes conveys the lymph into the veins to join the flow toward the heart.

9. In its course the lymph passes through the lymphatic glands.

Questions. — 1. What makes the hands grow red and puff up on sitting in a warm room after snow balling?

2. How is a mustard plaster effective?

3. Why does light exercise before retiring promote sleep?

4. Why are the feet often cold after studying?

5. How does the application of ice, or cold water, relieve headache?

6. Why should the clothing be changed after getting wet?

7. What is the meaning of humor, in the expressions "good-humored," "bad-humored"? Have these expressions a real physiological significance?

CHAPTER VI.

RESPIRATION.

The Close Relation between Circulation and Respiration. — Is it not a very striking fact that we take one breath for every four heart beats? That whatever quickens the breathing also quickens the heart, so that the two always keep in almost the same ratio? Let us learn what are the many intimate relations of the blood pump and the air pump, the blood system and the air system, of Circulation and Respiration.

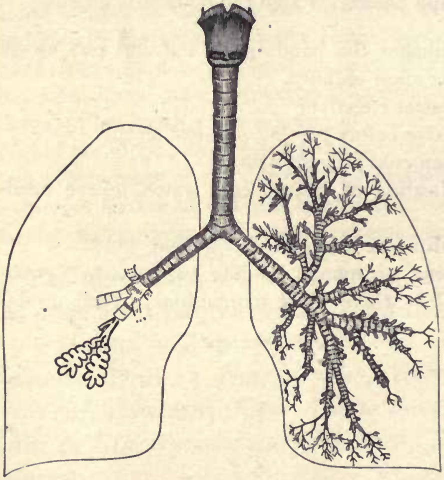


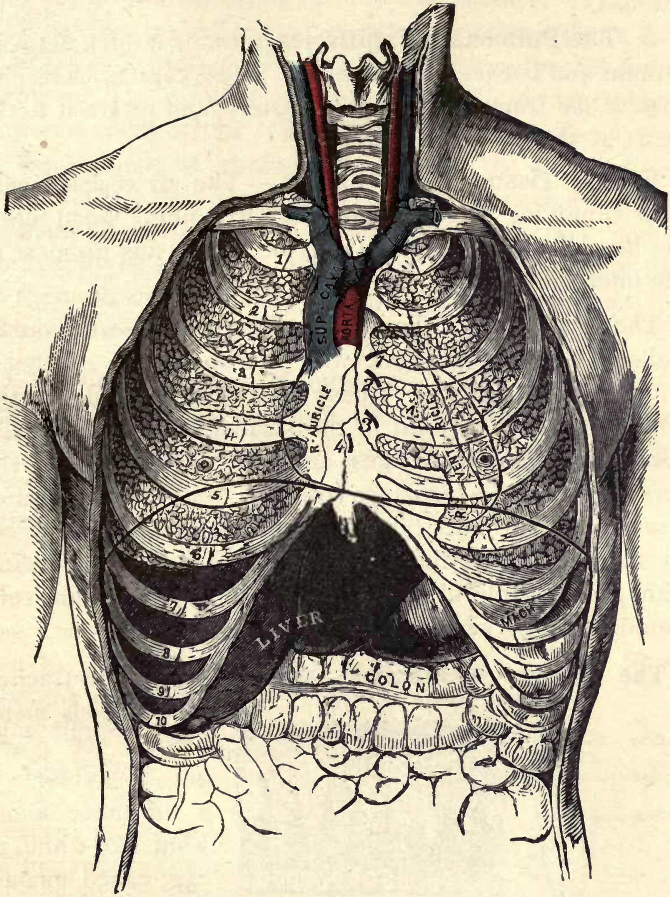
Fig. 37. The Trachea and Bronchial Tubes, showing Two Clusters (Alveoli)) of Air Vesicles.

The Organs of Respiration. —

1. The lungs and air tubes.

2. The structures which increase and diminish the size of the chest, principally the diaphragm, and the muscles acting on the ribs.

The Parts of the Lungs. — 1. **The Air Vesicles**, an immense number of small sacs, which communicate with



1. Pulmonary Orifice
2. Aortic Orifice
3. Left Auriculo-Ventricular Orifice
4. Right Auriculo-Ventricular Orifice

The heavy black line between the heart and the liver represents the diaphragm

Fig. 38. Front View of the Thorax. The Ribs and Sternum are represented in Relation to the Lungs, Heart, and other Internal Organs.

the outer air by the bronchial twigs, the bronchi, and the trachea.

2. **The Pulmonary Capillaries,** forming a thick network around and between the air sacs. These capillaries receive their blood from the pulmonary artery, and return it to the heart by the pulmonary veins.

Elastic Tissue in the Lungs. — The air vesicles, with their supplying air tubes and their surrounding blood tubes, are bound together by elastic tissue, which fills up most of the intervening space.

The Windpipe or Trachea. — The windpipe has in its walls C-shaped cartilages, with the open part of the C on the dorsal surface. These cartilages continue in the bronchi, and so on until in the smaller twigs they finally disappear. The cartilages are held together, and the dorsal gap of the cartilages (the gap would be like that of a series of horseshoes piled one on top of another) bridged, by tough fibrous tissue, with much elastic tissue, and with plain muscle fibers; the plain muscle fibers are very abundant in the smaller air tubes.

The Mucous Membrane. — The lining of the trachea is a mucous membrane. It pours out on its surface a substance somewhat like white of egg, called mucus. This keeps the air moist, and catches particles of dust that are in the inspired air. There is a constant slow current of mucus toward the throat, whence it is, from time to time, hawked up.

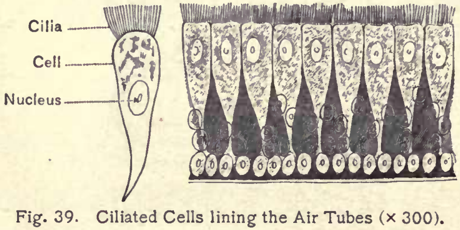


Fig. 39. Ciliated Cells lining the Air Tubes (× 300).

Cilia. — This current of mucus is caused by the cilia projecting from the lining cells of the trachea. They are little hairlike projections, in countless numbers, like a field of grass, each stalk having the power of bending back and forth, making a quick stroke toward the throat, then a slower recover stroke. Thus the united wavelike action of the myriads of lashing cilia paddles the mucus headward. It is a very common error to suppose that the cilia produce air currents. This is not their function, and it can readily be seen that they cannot create currents of air, as they are wholly submerged, like grass growing on the bottom of a shallow pond of slimy water.

Location of Mucous Membrane. — All the cavities and passages in the body to which the air has access, such as the digestive and respiratory passages, etc., are lined by mucous membrane (not all ciliated).

The Pleura.— The outside of each lung is covered by a thin adherent membrane, the pleura, which completely invests it, except at the root of the lung, where the bronchus and blood tubes enter. Here the pleura

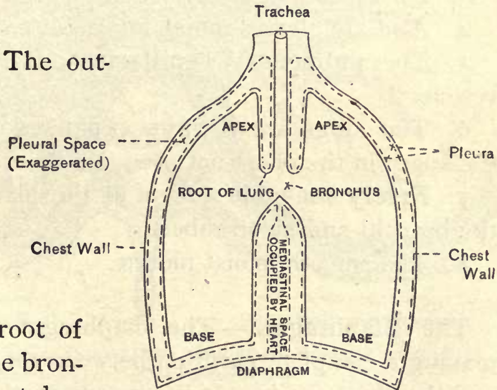


Fig. 40. Diagram of the Lungs and Pleuræ.

turns toward and adheres to the inner wall of the chest, forming its lining (still called the pleura), and below passes over the anterior surface of the diaphragm. The lung is thus free, except at its root, where the air and blood tubes enter. A very small quantity of liquid moistens the contiguous surfaces of the pleuræ on the outside of the lung and the inside of the chest wall, so they move easily one upon the other during respiration. As the lungs are always distended enough to fill the chest cavity, these two surfaces are always in contact. In pleurisy (inflammation of the pleuræ) pain is felt in breathing from friction or adhesion of these surfaces.

Important Facts concerning Respiration. — In studying respiration, let us constantly keep in mind these facts: —

1. The lungs are highly **elastic**, and

2. Highly **porous**, each air vesicle being in direct communication with the outer air by means of

3. Air tubes that always stand open

4. And are always **moist** internally.

5. The **pulmonary capillaries** closely invest each air vesicle.

6. The lungs are **always expanded** enough to fill all the space in the chest not occupied by other organs, and

7. **Freely movable**, except at the place of entrance of the bronchi and blood tubes.

8. The smooth, moist pleuræ.

The Diaphragm. — The diaphragm is a thin muscle making a complete partition between the abdominal cavity and the chest cavity. It is convex anteriorly, concave posteriorly; its ventral border is attached to the inside of the chest wall about opposite the lower end of the breast bone, thence obliquely along the border of the ribs (as felt in front), and the dorsal attachment is posterior to the ventral attachment. Its general position is shown in Figs. 38, 40, and 43.

To show the Action of the Diaphragm and Lungs. — MATERIAL. — Bell jar with stopper, sheet of rubber large enough to cover the mouth of the jar, toy rubber balloon, cork (rubber preferred), glass tube, strong rubber band (such as boys use for slung shots), marble.

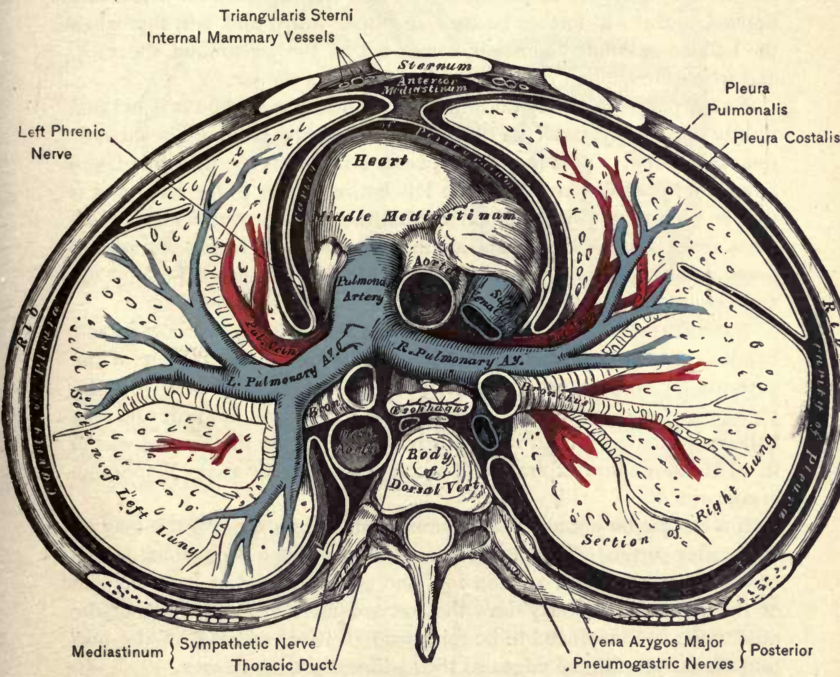


Fig. 41. A Transverse Section of the Thorax, showing the Relative Position of the Viscera and Reflections of the Pleuræ.

PREPARATION. — Lay the marble on the center of the sheet of rubber, double the rubber over it, stretching the rubber strongly over the marble, and tie the marble firmly in its place. Stretch the sheet of rubber over the mouth of the jar with the projection made by the marble on the outside, and fasten with rubber band. Bore a hole in the cork, and fix the glass tube snugly in it, so that the lower end of the tube will extend about half-way down the jar. Tie the balloon on the lower end of the glass tube.

EXPERIMENT 1. — Inflate the balloon. Consider that it requires some expenditure of energy to do this. When the mouth is taken away from the tube the balloon immediately collapses.

EXPERIMENT 2. — Insert the balloon and tube into the jar, but do not cork, and repeat Experiment 1. The same results as before are noticed, and it will further be seen, or rather heard and felt, that when the balloon is inflated some air comes out of the jar around the tube, and when the balloon collapses air again enters the jar.

EXPERIMENT 3. — Again inflate the balloon, and while it is inflated tightly cork the jar. If all the parts fit well, the balloon should now remain inflated. This may at first seem strange, as the mouth is taken away from the tube, and the tube left entirely open to the air. But it will be seen that to just the extent that the balloon contracts, so much more space is left in the jar outside the balloon. This means diminished pressure, and the pressure of the outer air presses the diaphragm up, and keeps the balloon partly distended, maintaining equilibrium.

EXPERIMENT 4. — Pull the diaphragm down, using the marble as a handle. This shows the expansion of the lung by the pressure of the external air when more space is given by the depression of the diaphragm. On releasing the diaphragm, it springs upward, and the balloon becomes reduced in size, driving out part of the air that was in it. This shows how expiration is accomplished, so far as the diaphragm is concerned.

If a bell jar be not at hand, a lamp chimney or a quart bottle may be used, after cutting off the bottom, as follows: File a deep notch across near the bottom; heat an iron rod, and apply the end of it to one end of the notch, and slowly draw the rod around to the other end of the notch (the rod may need to be reheated). After cracking off the bottom of the jar, file the edges so they will not cut the rubber.

Let each pupil make a drawing, showing the position of the parts in inspiration and in expiration.

Illustration of the Minute Anatomy of the Lung. — To illustrate the minute anatomy of the lung, take a rubber balloon, a glass tube, two rubber tubes, one dyed red, the other blue, a bag of netting, with one side dyed red and the other side blue. Tie the balloon on the end of the glass tube, slip the bag of netting over the balloon and tie it, with the ends of the rubber tubes on the corresponding sides of the bag. Slip a short piece of the rubber tube on the end of the glass tube, and when the balloon is inflated shut the air in by means of a

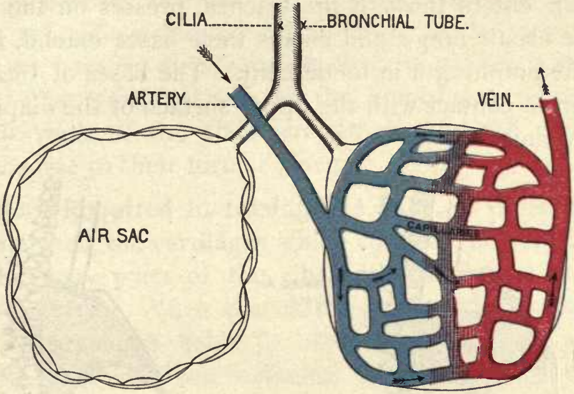


Fig. 42. Minute Structure of the Lungs, showing Air Vesicles and Capillaries.

pinchcock. The balloon represents an air vesicle, the glass tube a bronchial twig, the blue tube a subdivision of the pulmonary artery, the netting the capillaries around the vesicle, and the red tube one of the branches of the pulmonary veins.

The Movements of Respiration. — The process of respiration consists of two acts, inspiration and expiration.

Two Active Forces in Inspiration. — In inspiration the principal active forces in the body are, first, the diaphragm; and, second, the muscles which elevate the ribs.

Work of the Diaphragm in Inspiration. — The diaphragm is a muscle, and when its fibers shorten, the diaphragm is pulled down. In moving down it presses on the abdominal organs, and makes the abdomen protrude laterally and ventrally. This lowering of the diaphragm increases the space in the chest; the air already in the chest expands to fill this greater space. When expanded it exerts less pressure than before, and the air outside, having greater pressure, enters till equilibrium is produced. The air enters through the trachea, presses on the inside of the elastic lungs, and makes their bases extend, following the diaphragm in its descent. The bases of the lungs remain in contact with the upper surface of the diaphragm all the time.

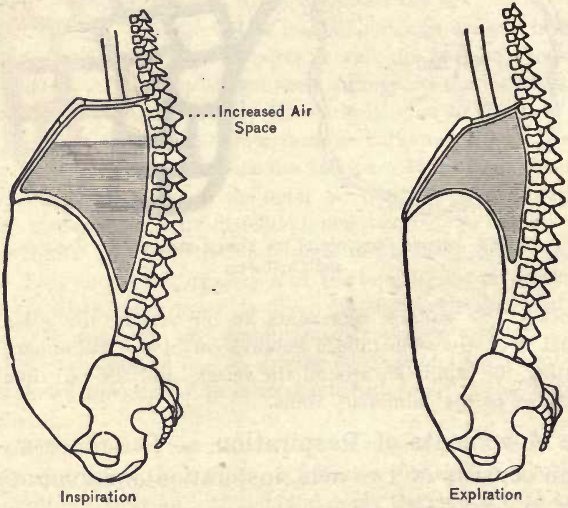


Fig. 43. Diagrammatic Sections of the Body in Inspiration and Expiration.

Work of the Chest Walls in Inspiration. — Certain muscles of the chest wall elevate the ribs and breast bone. This act widens the chest, and the air, as before, presses in through the open trachea, and keeps the sides of the lungs in contact with the inner surfaces of the chest walls.

Effort required in Depressing the Diaphragm. — Inspiration requires considerable effort, because the diaphragm in its descent presses upon the elastic organs of the abdomen (stomach, liver, etc.), and these organs, in turn, are pressed against the elastic walls of the abdomen. It is somewhat like pressing a pillow down into a rubber bag; the pillow springs up as soon as the pressure is stopped, because of its own elasticity as well as that of the bag. Therefore, as soon as the diaphragm relaxes, the elastic walls of the abdomen retreat, and the abdominal organs rise to their former place.

Effort Required in raising the Ribs. — When the ribs are elevated, the cartilages which connect the ventral ends of the bony parts of the ribs with the breast bone are slightly bent. When the muscles relax, the elasticity of the rib cartilages helps to bring the ribs back to their former position, thus reducing the chest to its former width.

Expiration Easy. — Thus we see why expiration is easy; in fact, "does itself" (in ordinary respiration) by elastic reactions. But inspiration is harder than it would be if it were not for the fact that the descent of the diaphragm meets resistance, and the ribs, in rising, have to overcome resistance in bending the costal cartilages, and in raising the weight of the chest walls and shoulders.

Potential Energy stored in a Door Spring. — When one opens a door that has a spring to shut it, he has to expend more energy to open the door than he would if he did not have to bend (twist or compress) the spring at the same time. But no effort is needed to shut the door. The door was opened and shut at the same time; *i.e.* when the door was opened force was stored in the spring (in the form of what is called potential energy), and this stored energy shuts the door while we pass on. We can better afford to employ more energy while opening the door than to take the extra time to shut it. If, then, a door with such spring were fastened open, it might remain open for a long time. When released it flies shut. If one, in this case, asks, "Who shut the door?" the answer is, "The person who opened it."

The Storing of Energy during Inspiration. — So in the act of inspiration we perform a double work in storing energy by which the expiration is performed without active muscular effort.

Review of Forces of Respiration: —

FORCES OF INSPIRATION.

1. Depression of the diaphragm.
2. Muscles elevating the ribs.
3. Pressure of the external air.

RESISTANCES TO INSPIRATION.

1. Compression of the abdominal organs and stretching abdominal walls.
2. Bending the rib cartilages and lifting the chest.
3. Stretching the lungs.

ELASTIC REACTIONS OF EXPIRATION.

1. Elastic reaction of the abdominal walls and contents.
2. Elastic reaction of the rib cartilages.
3. Elastic reaction of the lungs.

Forced Respiration. — Thus far we have been speaking of ordinary respiration. In forced respiration, as in shouting, many muscles are brought into play to expel the air rapidly and forcibly. In such an act as coughing there is vigorous action of the abdominal muscles.

Abdominal and Thoracic Respiration. — The main part of respiration is performed by the diaphragm, and the more common mode of respiration is therefore called abdominal or diaphragmatic respiration. In women of the civilized races respiration is more largely accomplished by the action of the thoracic muscles, and is called thoracic or costal respiration. In children the respiration is of the abdominal type.

The Rate of Respiration. — The rate of respiration in the adult varies from sixteen to twenty-four per minute, the average being about seventeen times a minute; about one respiration for every four heart beats. Light is favorable to respiratory activity. The rate is affected by the position of the body, state of activity, temperature, digestion, emotions, age, disease, etc. Ordinary inspiration takes slightly less time than expiration.

Modifications of Respiration. — Coughing is a forcible expiration, usually directed through the mouth, and for the purpose of getting rid of some foreign substance, or caused by irritation. In sneezing there is first a deep inspiration, and then the current of air is forced out, chiefly through the nose. Sneezing may be prevented by pressing firmly on the upper lip. Crying, laughing, sobbing, are modifications of respiration connected with certain emotions. Yawning and sighing are deeper breathings, caused by *ennui*, depressing emotions, or a deficient ventilation. Hiccuping is sudden inspiration, produced by spasmodic action of the diaphragm, accompanied by sudden closure of the glottis, and is often caused by some disorder of stomach digestion. Snoring is caused by breathing through the mouth and setting the soft palate into vibration. Sniffing is sudden inspiration: the diaphragm is suddenly pulled down, the air in the nasal cavity is thus drawn downward, and the air we wish to test, or the odor we wish to inhale, is thus drawn into the upper nasal cavities; whereas in ordinary inspiration most of the air passes along the lower part of the nasal passage. In hawking, the air is forced out through the narrowed passage between the root of the tongue and the soft palate to remove mucus. Gargling is forcing air up through liquid held between the tongue and the soft palate. Panting, whistling, blowing, spitting, sucking, and drinking are also modifications of respiration. In case of choking it is well to hold the head for-

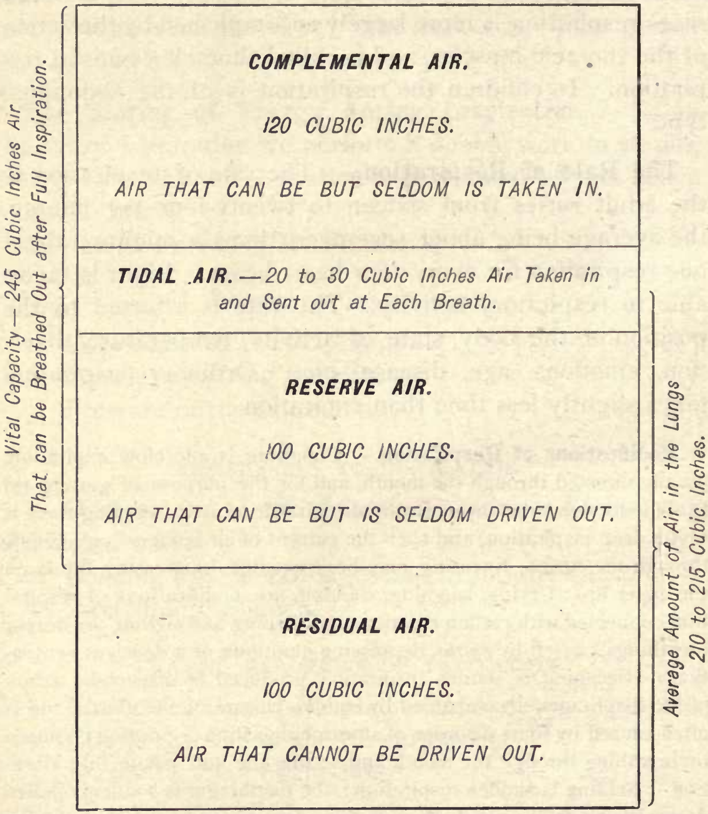


Fig. 44. Diagram of Lung Capacity.

ward, and perhaps downward. A smart slap between the shoulders sometimes helps dislodge anything stuck in the throat, and it may be necessary, in addition, to hold a child with its head downward.

Capacity of the Lungs. — Have the class stand, and each pupil raise his right hand.

1. **Tidal Air.** — Let all breathe together, at the ordinary rate and depth, and let the hand rise about three inches during inspiration, and fall again during expiration. The amount of air taken in at an ordinary breath is from 20 to 30 cubic inches, or about a pint. This is called tidal air.

2. **Complemental Air.** — As before, let the hand go up and down with the breathing, but at the end of the third inspiration, instead of stopping with the usual amount, keep on breathing in as much as possible, letting the hand rise accordingly. This air that can be taken in above the ordinary breath is called the complemental air, and it is estimated to be, on the average, about 120 cubic inches.

3. **Reserve Air.** — Begin as before, and at what would be the end of the third expiration continue to drive out as much air as possible, indicating the degree by correspondingly lowering the hand. This air that can be breathed out beyond the ordinary expiration is called the reserve air, and is reckoned at about 100 cubic inches.

4. **Residual Air.** — The air cannot all be breathed out. The remainder is called the residual air, and is computed to be about 100 cubic inches.

The Vital Capacity. — All the air that can be breathed out after a full inspiration, *i.e.* the sum of the complemental, tidal, and reserve air, would be about 240 to 250 cubic inches, and is called the vital capacity. Of course these figures represent only the average of certain experiments and observations. By practice any one can considerably increase his vital capacity.

A Test of the Capacity of the Lungs. — A simple method of measuring these stages of respiration is to take a gallon bottle and first carefully graduate it to pints by pouring in water and marking on the outside with a file. Then invert the bottle in a trough of water, and inhale from it by means of a rubber tube. Or fill the bottle, invert in water, and exhale into it.

Hygiene of Breathing. — Those persons who take constant exercise in the open air are likely not to suffer much from deficient respiration. But persons following sedentary occupations, such as that of the student, not calling for deep breathing (and often the air taken in is of poor quality), need to pay especial attention to the matter.

Breathing through the Mouth. — We should breathe through the nose, and not through the mouth. The nasal passages are fitted for the introduction of the air (1) by being narrow, but of large area; (2) by having their lining membranes richly supplied with blood; (3) by the abundant secretion of mucus by this membrane. The air, coming through this narrow channel, is warmed, and a large part of any dust it may contain is caught by the sticky mucus that covers all the walls of this passageway. If we breathe through the mouth (especially out of doors in cold weather), the air may not be sufficiently warmed before entering the lungs, and much more dust would be carried into the lungs. Then, too, the air has a drying effect on the throat, whereas the mucus of the nasal passages will moisten the air as it enters. The cilia, which extend from most of the cells lining the respiratory passages, are constantly causing the mucus to slowly flow toward the external opening, so a good share of the dust is gotten rid of. A further advantage of breathing through the nose is that we detect odors, and can thus judge of the quality of the air.

Breathing and Circulation. — The fact has been noted that breathing directly aids the circulation of the blood. This is due to the way air pressure is made to affect the large veins. Breathing also may very considerably aid the flow of lymph. Every deep inspiration brings pressure to bear on the main lymph duct as the diaphragm descends. Every forced expiration has the same effect. We must keep in mind that the tissues are fed directly by the lymph that surrounds them; that while the lymph is continually fed by the blood, there is not a great pressure given in this way. The lymph stream is largely dependent on the pressure of the surrounding organs. When one takes a good deal of muscular exercise the lymph is renewed with rapidity enough to supply the tissues with food, and to carry away their wastes. But in those who sit quiet a large share of the day, taking no more exercise than is necessary to take them to and from their places of business, the lymph becomes too nearly stagnant, the tissues are not well nourished, and the whole body suffers.

Deep Breathing. — It is a grateful relief to the whole system to stand. stretch, inhale deeply and slowly several times, and to repeat this every hour or so. Every one engaged in office work or studying should form this habit, especially if he does not give an hour daily to exercise in a gymnasium, or otherwise.

Respiratory Sounds. — During respiration sounds are produced by which the skilled physician can tell much as to the condition of the respiratory organs.

The Control of Respiration. — Breathing is an involuntary act. Still we can modify it. We can hold the breath for a time; but it is stated that one cannot hold the breath long enough to produce death by suffocation.

The muscles of respiration are under the control of nerves. The center of respiratory control is believed to be in the lower portion of the spinal bulb. This respiratory center is one of the most vital points in the body, for if it is destroyed, breathing is completely stopped, and death ensues. This center is affected by the condition of the blood. For instance, if the blood going to this center has not enough oxygen, the center hastens the process of breathing by nerve impulses sent to the muscles of respiration.

The Control of the Diaphragm. — The diaphragm is under the control of the phrenic nerves, which arise from the third, fourth, and fifth cervical nerves. If the neck is broken above the point where these nerves are given off, death almost always immediately follows, because the connection of the respiratory center and the diaphragm is broken.

Composition of Dry Air (by volume): —

Oxygen	21.00
Nitrogen	79.00
Carbon Dioxid	.04
	100.04

Experiments illustrating the Chemistry of Respiration. — EXPERIMENT 1. — If a piece of phosphorus be burned under a fruit jar inverted and with the mouth under water (for directions consult any chemistry), the oxygen will be consumed and water will enter part way to take its place. The remainder is nitrogen.

EXPERIMENT 2. — If a burning taper be lowered into this nitrogen, the flame will be extinguished.

EXPERIMENT 3. — If a chemical laboratory is at hand, some carbon dioxid should be generated and tested to show that it extinguishes flame.

EXPERIMENT 4. — Lime water is the test of carbon dioxid, and may easily be prepared by putting a piece of quicklime the size of a hen's egg into a quart of water.

EXPERIMENT 5. — Pour a little clear lime water into a jar containing carbon dioxid, and on shaking the contents the lime water will be rendered milky.

EXPERIMENT 6. — By means of a tube (a straw will serve) breathe through a small quantity of lime water to show that there is carbon dioxid in the expired breath.

EXPERIMENT 7. — If a jar be inverted over a lighted taper, the flame will soon be extinguished. Test the gas with lime water to see that carbon dioxid is produced by a burning candle.

EXPERIMENT 8. — By holding a clean, cold tumbler over a burning taper it will be seen that water vapor is produced by the burning.

EXPERIMENT 9. — Breathing into a clean, cold tumbler shows that water is produced also in the process of respiration.

EXPERIMENT 10. — A very brilliant experiment and one that is very instructive at this point is to burn a watch spring in oxygen. In this process the oxygen unites with the iron, forming iron oxid.

EXPERIMENT 11. — If a piece of watch spring be placed in water, it will soon rust. Rust is also an iron oxid, only the process is slow, instead of rapid as in the case of combustion, and just as much heat is given off, but not much at any given instant.

EXPERIMENT 12. — If a short piece of magnesium ribbon can be obtained, it may be burned in the presence of the class, though it is not well to look long at the excessively strong white light.

EXPERIMENT 13. — Magnesium will also rust in water, forming a white rust, or magnesium oxid, as in burning.

EXPERIMENT 14. — If a jar be filled with the slowly expired breath, capped tightly, and set in a warm place it will acquire a bad odor.

EXPERIMENT 15. — Hold a thermometer at arm's length. It indicates the temperature of the air — of the air that you are breathing in. Breathe for a few minutes upon the bulb of the thermometer, and the fact is clearly shown that the air we breathe out is much warmer than the air that we breathe in.

EXPERIMENT 16. — With a pair of bellows force the air of the room through a small quantity of lime water. By continuing this process a long time it may be shown that there is carbon dioxid in the air, but not nearly so much as in the expired breath.

Result of Experiments. — These experiments show that breathed air has gained: —

1. Heat.
2. Water vapor.
3. Carbon dioxid.
4. Waste products, or impurities, having no definite name, because not well known, highly putrescible, often called by the general name of "organic waste matter."

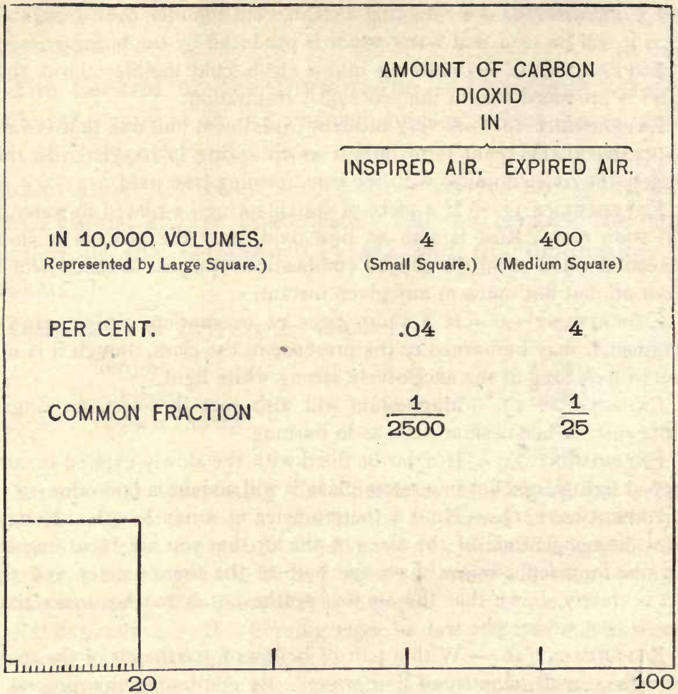


Fig. 45. Amount of Carbon Dioxid in Inspired and Expired Air.

The Composition of Inspired and Expired Air. —

	Oxygen.	Nitrogen.	Carbon Dioxid.
Inspired air . . .	21	79	.04
Expired air . . .	16	79	4.00

While the amount of nitrogen remains about the same, some oxygen has disappeared, and its place is taken by carbon dioxid, while the amount of carbon dioxid has increased a hundred-fold.

Exchanges between the Air and the Blood in the Lungs. — Whatever the air coming from the lungs contains that was not in the air entering them, it has taken from the blood, and what the air has lost it has given to the blood. The air in the air vesicle is separated from the

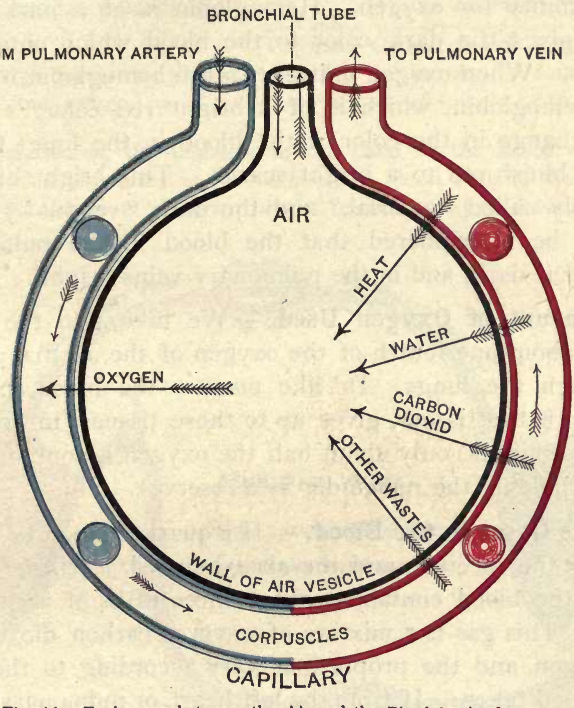


Fig. 46. Exchanges betw... the Air and the Blood in the Lungs.

blood in the pulmonary capillaries only by the thin wall of the air vesicle and the thin capillary wall. Carbon dioxid, water, and other waste matters pass from the blood through this thin partition into the air vesicle, to be sent out by later expiration. Oxygen from the air in the vesicle passes through these layers into the plasma, and most of it is quickly picked up by the colored corpuscles. The colored corpuscles are the carriers of oxygen.

Hemoglobin and Oxyhemoglobin. — As has already been stated, the hemoglobin in the colored corpuscles has an affinity for oxygen. Hemoglobin is of a dark color, and gives the dark color to the blood which enters the lungs. When oxygen unites with the hemoglobin it forms oxyhemoglobin, which is of a bright red color. Hence the change in the color of the blood in the lungs from a dark bluish red to a bright scarlet. This bright blood is usually called "arterial," and the dark "venous"; but it must be remembered that the blood in the pulmonary artery is dark, and in the pulmonary veins bright.

Amount of Oxygen Used. — We take into the blood only about one fourth of the oxygen of the air that passes through the lungs. In like manner the blood, passing through the tissues, gives up to those tissues (in ordinary circumstances) only about half the oxygen it contains (perhaps holding the remainder as a reserve).

The Gases in the Blood. — If a quart of blood be placed under the receiver, and the air exhausted, it will be found that the blood contained about three fifths of a quart of gas. This gas is a mixture of oxygen, carbon dioxid, and nitrogen, and the proportions vary according to the kind of blood taken. If from the left heart, or pulmonary veins, there will be more oxygen and less carbon dioxid; if from the right heart, pulmonary artery, or caval veins, there will be less oxygen and more carbon dioxid. Oxyhemoglobin blood ("arterial blood") contains about one fifth its volume of oxygen. Hemoglobin blood ("venous blood") contains about one tenth its volume of oxygen. Oxyhemoglobin blood holds about two fifths its bulk of carbon dioxid, while hemoglobin blood has nearly one half its bulk of carbon dioxid.

THE GASES IN THE BLOOD.

From 100 volumes of —	May be obtained		
	Oxygen.	Carbon dioxid.	Nitrogen.
Oxyhemoglobin (arterial) blood .	20 vols.	40 vols.	1 to 2 vols.
Hemoglobin (venous) blood . .	10 vols.	46 vols.	1 to 2 vols.

Illustration of the Changes in the Color of the Blood. — The changes that take place in the color of the blood, both in the lungs and in the tissues of the other parts of the body, may be illustrated as

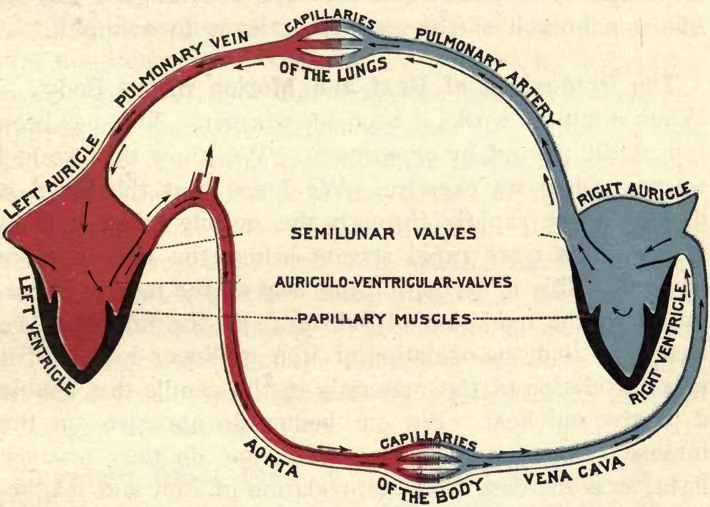


Fig. 47.

follows: Prepare a heart as directed on page 45. Use for the liquid a strong solution of litmus, neutralized or slightly alkaline; place in the throat of each funnel a small sponge. Saturate with ammonia the sponge in the funnel representing the capillaries of the body, and saturate with hydrochloric acid the one in the funnel representing the capillaries of the lungs.

Now, on working the heart the liquid will change from red to blue in the funnel representing the body, and from blue to red in the funnel representing the lungs.

"Anatomically there are two lungs, and the heart lies between them; physiologically, the lungs form a single organ, which is interposed between the two hearts." — WILDER.

The Changes in the Blood. — What does the blood do with the oxygen that it gets in the lungs, and where did it get the carbon dioxid and other impurities that it brings to the lungs? Let us follow the blood and see. From the pulmonary veins the blood goes to the left heart, and is pumped to all the tissues except the lungs. Let us follow a branch of the aorta that leads to a muscle.

The Production of Heat and Motion in the Body. — When a muscle works it becomes warmer. This has been repeatedly proved by experiment. We know that we feel warmer when we exercise. We know that the blood is flowing more rapidly through the muscle when it is at work. This more rapid stream brings the muscle more oxygen. This it needs, for the heat of the muscle is produced by the oxidation of substance in the muscle. We have seen that the oxidation of iron produces heat, and it is the oxidation of the materials in the candle that enable it to give out heat. But our bodies do not give out the intense heat of a burning candle, nor do they produce light, as is the case with the oxidation of iron and magnesium when those metals are burned. The slow oxidation of the metals, in the presence of moisture, is more like the oxidations in our bodies. It is by the oxidations of the muscle (or substance in it) that the muscles produce heat and that form of energy which gives motion. In the case of the rusting of the metals there is as much heat produced as when they are burned, but the heat is so slowly generated that it is given off about as fast as it is produced, and we do not notice it. The oxidation produces the waste matters, just as the burning of the various substances produces waste.

Oxidation of Live Tissues and Dead Matter. — In our experiments with oxygen we see that substances which burn in air will burn still more actively in oxygen. But we must not infer from this that in our bodies the oxidation of the tissues would be faster in pure oxygen. This is not the case. The tissues take as much oxygen as they need (if they can get it), and they will not take any more than they need, no matter how much is offered them. It does not injure the body, nor any part of it, to breathe pure oxygen. It does not make one feverish, it does not produce any more heat, nor make one "live faster." This point should be specially noticed, as it was formerly supposed that the oxidation of the tissues of the body was just like any combustion of dead material. But the tissues are alive. They know their own needs. Each cell takes what it requires and no more, just as it does of food brought to it by the blood. The amount of oxygen present does not determine the degree of muscular activity, but the degree of muscular activity determines the amount of oxygen consumed.

Increased Blood Flow is the Result of Exercise. — When we exercise, the muscles need more oxygen. They also need to have removed the waste matters that they are so rapidly producing at this time. How is the oxygen brought and the waste removed? By the blood, you answer. True; but what makes the blood come and go faster at this time? By reflex action, you reply. The muscles send a message to a nerve center, and this nerve center sends back a message to the blood tubes, making them widen, and the heart also may be made to beat faster. But would it do any good to have the blood flow through the muscles faster, if it could not bring more oxygen, and take away and get rid of more wastes? You will say no. To give the extra oxygen, and take out the carbon dioxid, the lungs cannot, of themselves, take in and send out air. The work of pumping air depends on the muscles of respiration, the diaphragm, and the muscles that elevate the ribs. These will not work faster unless they are ordered to do so. A message must be sent to these telling of the need in the muscles that we are considering, say one of the large muscles of the lower limbs. Thus, by a series of reflex actions, all these processes are kept in harmonious relation to each other. It must be borne in mind that increased blood flow is the consequence, and not the cause, of the increased activity of the tissues.

Temperature of the Body. — Insert the bulb of a thermometer into the mouth, and keep it there three or four minutes to find the temperature of the inside of the body. For this it is better to use a clinical thermometer, if one can be obtained. The average temperature of the tissues within the body is about 98.5° F.

How the Body is like a Stove. — The body may be compared to a stove. Into one we put fuel and produce heat. In the other we get heat from food.

How the Body differs from a Stove. — But the body is not like the stove in burning the fuel (food) *directly*. The food is first made into tissues, or "storage compounds" in the tissues. It is as though we were to build a stove entirely of coal, and then start a fire in it. In that case it would produce heat not merely by burning in one place within, but would be burning throughout the whole of its substance. This is the case with the body.

Oxidation in Tissue the Source of Heat in the Body. — We have seen that the muscles constitute nearly half of the weight of the body. We know, too, that they are more active than most of the tissues. We would now naturally infer, as indeed is the fact, that they are the chief source of the heat produced in our bodies.

The tissues of the body are oxidizing all the time. But when they are in vigorous action they oxidize very much more rapidly.

Next to the muscles, in importance as a heat producer, is the liver, which is the largest gland in the body, and, as we shall soon see, one of the most active. The blood, as it leaves the liver by the hepatic vein, is hotter than anywhere else in the body.

How the Body is like a Locomotive. — But it will be better to compare the body to a locomotive, as we produce not only heat, but motion as well.

If a visitor from another planet, unfamiliar with such creatures as we are, were to observe closely a man and a locomotive, he would see several points in common: —

1. Both are warm.
2. Both move.
3. Both use fuel (food or coal).
4. Both take in air, and (if it were a winter day)
5. Both give off "steam" (which is essentially the same in the two, carbon dioxid and water vapor being the chief constituents).

How the Body differs from a Locomotive. — By a closer examination he would find out some of the differences that we have noticed: —

1. That the body does not get hot enough to burn; *i.e.* the oxidation is relatively slow, and is not *combustion.*

2. That the oxidation of the body never produces light.

3. That the oxidation here is always in the presence of moisture.

The Amount of Carbon Dioxid given off. — When the breath is held for some time, the carbon dioxid in the expired air may reach 7 or 8 per cent. During violent exercise the amount of carbon dioxid given off may be from two to two and a half times as much as when we are at rest. The amount of carbon dioxid given off is increased in cold weather, and by taking food, and decreased from one fifth to one fourth during sleep. Oxygen is carried chiefly in the corpuscles, but the carbon dioxid is carried in both plasma and corpuscles.

Storage of Oxygen in the Tissues. — The activity of the tissues from their oxidation does not necessarily mean that the oxidation is direct; that is, that the oxygen is used as soon as it is brought to the tissue. For instance, in the muscles it is believed that the oxygen is stored in some form, probably in combination, so that it can be used when needed, perhaps much more rapidly than could be supplied by the respiration at the time. If we study the chemistry of explosion, we learn that it is a very rapid combustion. In the explosives are materials that unite instantaneously, instead of slowly burning, as in the case of ordinary combustibles.

The Action of Muscles like an Explosion. — Now, many physiologists hold that a sort of explosive compound is formed in the muscles, and that when the muscle acts it does so as the result of the explosion, so to speak, of this material. And, to carry out the figure, the nerve is compared to the match that ignites the explosive. A little heat is enough to cause the most violent explosion. So the force that passes along a nerve fiber is slight. But it rouses a great amount of energy that lay dormant in the muscle. It would seem to have "touched off" a lot of explosive material that was already there, rather than merely started an action that depends on the comparatively slow process of respiration at the time. We cannot follow this theory farther, as it takes us too deep into the study of chemistry in its most difficult branch, — physiological chemistry.

Summary of Respiration. — The tissues need oxygen; air is pumped into the lungs; this air gives oxygen to the blood; the blood carries it to the tissues.

In oxidizing, the tissues produce energy (heat and motion) and give off waste matter (water, carbon dioxid, etc.); these the blood carries to the lungs, the lungs give them to the air, and the air carries them out of the body.

The pumping of the air in and out may be called "mechanical respiration." The changes between the air and the blood in the lungs we will call the "ventilation of the blood," and the interaction of the blood and the tissues the "real, or internal respiration."

The Two Breaths. — "Every time you breathe you breathe two different breaths; you take in one, you give out another. The composition of these two breaths is different. Their effects are different. The breath which has been breathed out must not be breathed in again." — KINGSLEY.

Breathing Expired Air. — The air in the vesicles receives from the blood carbon dioxid, water vapor, and other impurities above mentioned. It has been believed for a number of years that the organic impurities constitute the most dangerous element in expired air. Carbon dioxid, though to some extent a poison, is not very injurious in such quantities as ordinarily exist in the air, even in poorly ventilated rooms; while the headache and drowsiness that one experiences in a close room where there are a number of people is due to the reabsorption of these organic matters. It is not due to lack of oxygen, for the oxygen may be reduced to 13 per cent without causing discomfort. A person may breathe air containing 1 per cent of carbon dioxid, with a corresponding reduction of oxygen, when the carbon dioxid is generated by ordinary chemical processes (as in a small room with a large kerosene lamp, or a gasoline stove); but air having 1 per cent of carbon dioxid produced by breathing is highly injurious, because it contains the organic impurities above noted, and the term "crowd poison" has been employed for this material. Later investigators, however, maintain that there is nothing injurious in the freshly expired breath.

Alcohol and Consumption. — At one time it was widely believed that alcohol was a cure for consumption. This is now known to be so far from the real facts of the case that it is well established that certain forms of consumption are directly attributable to the use of alcoholic drinks. Under the former mistaken view many consumptives used alcoholic liquors to their own injury. But time and experience have taught that they only exaggerate the trouble.

Summary. — 1. In the lungs the air and blood are brought very close together, only the wall of the capillary and that of the air vesicle intervening.

2. Through these two layers oxygen passes from the air vesicle into the blood. Carbon dioxid, water vapor, and other wastes pass from the blood into the air vesicle.

3. The mucous membrane of the air passages secretes mucus which is driven toward the nostrils by the cilia.

4. The chest is lengthened by the depression of the diaphragm, and widened by the elevation of the ribs, giving greater space, which is filled by external air expanding the lungs.

5. Inspiration acts in opposition to resistances, whose elastic reaction performs ordinary expiration without active effort

6. There are four heart beats for each respiration.

7. The lungs are never emptied.

8. Respiratory capacity may be increased by exercise and practice.

9. Respiration is controlled by the nervous system; the respiratory center is in the spinal bulb.

10. Internal respiration is an oxidation in the tissues, illustrated by the rusting of moist iron.

11. In passing through the lungs air loses oxygen, and gains water, carbon dioxid, and other wastes.

12. Oxygen is carried chiefly by the colored corpuscles of the blood; it unites with hemoglobin in the corpuscles, forming oxyhemoglobin, and gives the blood its bright scarlet color.

13. The energy of heat and motion in the body results from the oxidations in the tissues.

14. Air once breathed is unwholesome. The air of living and sleeping rooms needs constant renewal.

Questions. — 1. Is it a good thing to see how long one can hold his breath?

2. Should the head be covered by bedclothes?

3. What are the "lights" in an animal?

4. How is respiration affected by a stooping posture?

5. In what part of the lungs is the best air? Where the worst?

6. Can you explain how respiration affects circulation?

7. Is it easy to determine by the color of blood flowing from a wound whether it is arterial or venous? Why?

8. Of what advantage is it that the cartilages of the windpipe are C-shaped and not complete rings?

9. How is it that in respiration 5 per cent of the oxygen disappears while only 4 per cent of carbon dioxid appears in its place in the expired breath? (See p. 102.)

CHAPTER VII.

VENTILATION AND HEATING — DUST AND BACTERIA.

Need of Proper Ventilation. — When one is actively exercising his muscles he may keep warm outdoors through our winter days. For the heat of the body depends on its internal fires, the oxidation of its tissues. But if we are inactive, these fires burn feebly, and we need outside heat. While air is free, it really costs a good deal of money to have it properly warmed.

A Lack of Effective Systems of Ventilation. — Lung diseases are rare in the regions where the windows and doors may be kept open most of the days of the year. It is from shutting ourselves in so closely that we suffer. This is especially true where many people are housed in a comparatively small space, as in many public buildings. But in our private dwellings, even when the owners are amply able to secure the most sanatory appliances, defective apparatus is often put in. *Any system that does not provide for a constant renewal of the air is defective.*

Grates as Heaters and Ventilators. — Grates will aid largely in renewing the air. Although in themselves they merely have provision for sending radiant heat out into the room and much air up the chimney, yet, without any special provision for inlet of air to the room, they draw air in through every crack and crevice. It would probably be very much better to have special ducts for the admission of air, which is suitably warmed while on its way into the room, and to make the doors shut snugly, and to have double windows, as then both the admission of fresh air and the regulation of heat will be better secured. But it is a serious question whether, with all our modern appliances, conveniences, and luxuries, we have better air in our houses, and take cold less frequently, than our ancestors who depended more on the fireplace, even if they did "roast on one side while they froze on the other." Fireplaces are expensive as mere heaters, but they are excellent ventilators.

Ventilating Flues around a Smoke Flue.—If small ventilating flues could be built around the flue of the main heating apparatus, and connected with the various rooms of the house, air could be drawn from these rooms by ascending currents created by the heat of the central smoke flue. Such flues surrounding smoke flues, would have the added advantage of protecting the house from fire through the too common "defective flue."

The General Principles of Ventilation.—Of the forces that operate to renew the air two are natural, diffusion and the wind; and two are artificial, warm air shafts and fan systems.

Diffusion.—Gases tend to mix. We know that if a bottle containing an odorous substance be opened in a room where there are no air currents the odor tends to spread equally through the room. So if a person is in one corner of a large room, where there are no inlets or outlets, and no currents, as he uses the oxygen immediately around him, the oxygen farther away will diffuse toward him so that he will continue to get oxygen till the amount of oxygen in the room is nearly exhausted. So, too, the gases that he breathes out will not remain confined to the space directly about him, but will spread nearly evenly throughout the room. The same takes place in the open air, without wind. So, then, if the windows and doors are open, the air of the room will, by diffusion, be renewed.

Wind. — Motion of the air renews faster than mere diffusion. Strong wind forces its way through the cracks around windows, and when windows are open on opposite sides of a room there is usually enough breeze to renew the air. But during the greater part of the year this cannot be done.

Artificial Renewal of the Air. — The renewal of the air in most cases depends on the fact that heated air rises. Heat expands air. It is then lighter, bulk for bulk, than cooler air. The heavier surrounding air presses the lighter air upward. If there are outlets above and below, the heavier, colder air will press in at any opening left below, and push the lighter, warmer air out above.

The Common Stove. — In the case of the common stove we very well know that there are currents of heated air rising above the stove. Children make whirligigs and various toys to place in these up-currents above stoves. Air is, at the same time, flowing toward the stove along the floor and lower part of the room. Cold air can usually be detected entering around the windows and doors, which presses downward and toward the source of heat. The stove does not do much to renew the air in the room except in this general way; some heated air escapes at openings in the upper part of the room, and some is passed out through the stove, taken in as a draft. But in the main, the action of the heat of the stove is to make a current of warm air up from the stove, which current passes along the ceiling to the more distant corners of the room, then descends, joining the cold air, and repeating the round.

A Stove and Jacket. — In some cases a jacket is placed around a stove, and a duct from the outer air connects with the lower part of the space inside of the jacket and outside of the stove. Then as the air heated by the stove rises, fresh air is drawn in from outside to be warmed. In this case the direct heat from the stove is shut off from the room. Heat radiates in straight lines. When one holds out his hands beside a stove the heat he receives is radiant heat. Most of the heat from a grate is radiant heat. But in a jacketed stove the heating by air currents is called heating by convection.

The Furnace. — Now a furnace is practically a jacketed stove (almost always placed in a basement). Furnaces have this good feature that they are all the time sending fresh air into a room.

Foul-air Shafts and Fans. — Although in private dwellings heated by furnaces there is no special provision for the escape of foul air, there is ordinarily sufficient renewal of the air. But in public buildings there should be escape flues for foul air.

Frequently a large foul-air shaft is built in some central part of the building, and a small stove placed in it to create a sufficient up-current. In many public buildings the currents created by heat are insufficient to renew the air properly. Fans are used, which force the air, properly heated, into the room.

Direct Heating. — In heating by steam or hot water, if the radiators are placed in the room they give direct or radiant heat. This system is called direct heating. In itself it has no provision for renewing the air. It gives direct heat, and produces air currents within the room; and any change in the air is wholly incidental, from escape of heated air in the upper parts of the room and corresponding suction of outside air through such openings as the carpenters have left below.

Indirect Heating. — In indirect heating, coils of steam or hot-water pipes are placed in air shafts which lead up to the rooms above, and also have ducts to the outside. As the air is heated by the heat of the pipes it rises into the rooms above, and fresh, cold air presses in through the ducts, to be, in turn, heated and sent up. If there is at the same time a proper escape for the foul air, this makes an excellent system.

A Combination of Direct and Indirect Heating. — In many situations the direct and indirect may be advantageously combined. Where there is a grate in a room, it serves very well as a foul-air shaft, especially when there is a fire in the grate. It is well to have the flue from the grate in the same chimney with that from the smoke pipe, as then the heat from the smoke will cause a constant updraft in the grate flue, whether there is a fire going in the grate or not.

With a grate, in private houses, there is ordinarily no need of other foul-air shaft for any room. But it is very desirable to have at least some "indirect" heat, so that the fresh air introduced will be sufficiently heated.

If the introduction of air is thus provided for, it is then safe to put on double windows and make the cracks around the door very tight. Without any special provision for the renewal of the air these cracks are the means of safety.

In houses heated by furnaces, steam, or hot water, the floor is likely to be warmer from the escape of heat from the heater itself, and from pipes or air ducts under the floor.

Double Windows. — There is a very common misunderstanding as to the cold felt near a window in cold weather. It seems that air is entering; but a little reflection will show that even if the window were air-tight this effect would be produced, for the air near the window is cooled by losing heat to the outer air. The air next to the window, thus cooled, is heavier, and falls to the floor; and if there is any source of heat in the room, this cold air will pass along the floor to that source of heat, up from the heating body to the ceiling, and across the ceiling, and so on around again. There may thus be currents without any appreciable change in the quality of the air. It is economy to use double windows and prevent the loss of heat through the glass. So both economy and comfort suggest to us that we reduce as much as possible cracks around doors and windows, use double windows, make vestibules at entrances, and build special ducts by which fresh air may enter, and heat it properly on its way in.

DEAD DUST.

The Air is washed by Rain or Snow. — Every one will recall how delightfully refreshing the air is after a rain or a snowstorm. This is not due merely to the fact that the air is cool. It is clean because it has been washed. The rain and snow absorb a considerable amount of the various impure gases that are in the air. But raindrops and snowflakes bring down with them many particles of dust that were floating in the air. Take some of the snow that has fallen in a town. It looks pure in its almost dazzling whiteness. But melt some of it, and you will usually find a decided tinge darkening the water, showing that as the flakes sifted down through the air they caught myriads of particles of dust.

The Sources of Dust. — Where soft coal is used to any large extent it is one abundant source of this dust. In summer dust has many sources. The dust that blows into your face, and perhaps into your mouth, may be made of dry soil. Take a dry clod and drop it; it falls quickly to the ground. Pulverize it in your hand before dropping it, and considerable of it floats in the air for some time. Any substance that is easily dried and pulverized may form part of the common dust. The dust that you wipe from your eye, or is caught by the mucus of the nasal passages, may, instead of being made of clean soil, be from the excreta of horses, decayed leaves, wood, grass, etc. Indoors we are constantly making dust by wearing out our clothes. Many of the tiny particles that we see floating in the sunbeams are bits of cotton or woolen fibers. Shake any garment in a beam of light to see how much, and how easily, dust is given off. The worn-off particles of our shoes, books, floors, all contribute to the ever-present dust.

The Effect of Dust on the Lungs. — Now, this dust (so far as it is mere dead, dry matter, not considering it as a poison) is irritating to the lungs and respiratory passages. There is provision, as we have seen, for catching and getting rid of a good deal of it.

But still much is taken into the lungs. Examination shows that the lungs have many black specks from particles of carbon, etc., that have become lodged, and are of no benefit, to say the least.

LIVE DUST.

Composition of Live Dust. — Bad as this dead dust is, the injury from it is slight compared to that from live dust. We know that certain seeds float in the air, carried along by the wind. But these are comparatively heavy, and soon sink to the ground.

We all know pollen. At certain seasons it forms, in the vicinity of cornfields, for instance, a considerable part of the dust. This is alive. It will grow if it falls on the right kind of a surface, the stigma of the right plant at the right time. Such dust will not grow in our bodies. We do not furnish a soil in which it can grow. It merely adds to the amount of irritating dust.

Puffballs and Molds. — We have seen puffballs give off a cloud of dust when they are crushed. This dust is composed of live spores that will grow in suitable places and conditions. So, too, from a patch of mold, when brushed, we often see a little cloud of dust. These are a few instances of kinds of living dust that simply act on us like so much dead matter.

Yeast. — If we set a tumbler of cider on a table in a warm room, in a few days it ferments. This is due to yeast that has gotten into it. Boil the cider to kill any yeast that is already in it, and cork it securely so that air cannot get at it, and it will not ferment. Dried yeast germs float in the air, settle on the fruit or in the cider, and cause it to ferment. Cider is a good soil for yeast.

Disease Germs. — But there are floating in the air many kinds of spores that may grow in our bodies. We know that many of our contagious diseases are due to the growth in our bodies of some of these spores. Our bodies are a good soil for certain germs. The germs that cause consumption, typhoid fever, Asiatic cholera, erysipelas, diphtheria, and some forms of blood poisoning are well known. Microscopists know them when they see them as readily as we know peas from beans. And it is proved beyond all doubt that these germs get into our bodies by being breathed in, or by being eaten in food, or in drinking water, or by introduction into the blood in wounds. We have reason to believe that smallpox, yellow fever, measles, and scarlatina are caused by germs, but these diseases have not been studied so successfully.

How to avoid Germs. — How can we avoid or get rid of dusts of these kinds? To exterminate any plant, we try to keep the seeds from ripening, and to kill all that do ripen. Let us take a case that, while not pleasant to contemplate, is too terribly true to allow of being called an imagined case.

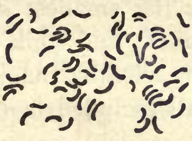
The Danger from Consumption. — A consumptive expectorates on the pavement. In this sputum are probably hundreds, if not thousands, of germs known as bacilli (*Bacillus tuberculosis*). They are alive. Now, so long as they remain on the pavement they do no harm. The sputum dries. But the bacilli are not killed by drying. With other dry material from the pavement they form part of the common dust. Any one of us may breathe some of this kind of matter any day, for there are persons afflicted with this dreaded disease in every community. Our bodies furnish the very best soil for the germs. We

Bacillus of Diphtheria (x 1000)

Bacillus of Tuberculosis (x 1000)

Bacillus of Typhoid Fever (x 1200)

Bacillus of Typhoid Fever (x 1200)
showing flagella



Bacillus (Spirillum) of Asiatic Cholera

Bacillus of Hog Cholera (x 1000)

Fig. 48. Types of Bacilli, showing Morphologic Characters and Arrangement.

do not need to go into the street to be exposed. Who knows what he brings into the house adhering to his clothing? These germs may be brought into the most cleanly houses in this way, or by the wind.

How to avoid the Danger. — Now, of course, all such material known to be highly dangerous ought to be destroyed. If those suffering from such diseases were careful to burn all such matter, most of the seeds of this disease would be killed. Thus in time we might stamp out the disease, as a scourge of Canada thistles. But so long as people expectorate upon the floors and pavements it will be difficult to prevent the spread of such germ diseases.

In hospitals such matters are now looked after with the greatest care, and in private houses where there is intelligence on these subjects. And it is encouraging to note the awakening of the public to the significance of the teachings of modern science on this subject, as shown by the fact that many of the railroad and street car companies now prohibit spitting on the floors of cars, not merely because it is uncleanly, but on the express ground that it is a means of spreading infectious diseases.

Bacteria. — These disease germs are the smallest and simplest of living things. They are plants; and while all of them that are well known have their scientific names, just as the larger plants have, they are all included in one general group designated as bacteria.

How to avoid Dust. — We need to learn a good deal more about avoiding and destroying dust, and the things that make dust.

Towns and cities need more sprinkling to keep the dust down. Much more of the refuse and street sweepings and cleanings ought to be burned. The dust of a house should always be burned, as we know not what germs of disease may be in it. If we burn it, we shall surely not have to sweep up that dust again. If we send it out of doors it may come back, and we may have to handle it again and again.

Sweeping and Dusting. — So far as possible let us avoid things that make dust. When we sweep a carpet, a considerable share of the dust comes from the carpet itself, especially if the carpet is old. Curtains and tapestries of nearly all sorts not only hold dust, but contribute a good deal to it. Those who write on such subjects recommend hard wood floors with rugs instead of carpets. The rugs can be taken out of doors and shaken, and the floors wiped with a moist cloth, so that little dust is left floating in the air of the room. Compare this with the condition that holds after the ordinary sweeping of a carpeted room with the common broom. The dust fills the air, only to settle back on the floor and furniture. Then comes the whisk broom, the so-called dusting. Well, it is dusting! It fills the air once more with dust. But do we get rid of it? Wiping off the dust with a moist cloth takes most of it away on the cloth. For those who cannot have hard wood floors a most excellent substitute (and in some respects better) is oilcloth or linoleum.

Sweeping the Sick Room. — The improved carpet sweepers are not only convenient, but sanatory. Many a well-meaning person will sweep a carpet in a sick room with an ordinary broom when the patient is suffering from lung disease, thoughtless of the fact that a little dust in sight, and perhaps on the shoes, is of much less significance than dust in the air we breathe. No one likes dust on the floor, but better a thousand times there than in our lungs.

Lung Diseases. — Statistics seem to show that one seventh of the deaths among the civilized races is due to lung diseases. The best authorities are now agreed that consumption is not hereditary. But it appears that there may be inherited a tendency to this disease, so that, if exposed, such persons are more likely to contract the disease than those not so predisposed.

Probably anything that lowers the general vitality makes the system more ready to succumb to any of these contagious diseases. We have all noticed what a difference there is among individuals in the readiness with which they "catch" contagious diseases.

Destruction of Germs by Colorless Corpuscles. — It is believed by some physiologists that the colorless blood corpuscles may take these germs of disease into their substance, and destroy or change them so that the disease is warded off. In other words, they may be compared to a cat that catches and eats the mice which invade a house.

How to ward off Contagious Diseases. — A good general condition of the body helps greatly to ward off diseases of this nature. A cheerful condition of mind and body should be cultivated. In times of widespread contagious disease, if one is terrified into the belief that he is going to have the disease, he is more likely to take it.

Thorough cleanliness, plenty of direct sunshine, care in diet, and the keeping of the body in good tone, all these reduce the chances of "taking" contagious diseases.

An open-air life, abundant nutritious food, and freedom from anxiety are probably the best restoratives for incipient consumption.

The Bacteria of Putrefaction. — Besides the disease-producing bacteria, there are others that cause decay and putrefaction of various kinds. They cause our richer foods to "spoil," milk to turn sour, butter to become rancid, etc.

While these bacteria do not cause disease in the human body, they often make food poisonous. The cases frequently reported of poisoning from eating ice cream, cheese, sausage, etc., are in many cases due to bacteria in them. We should, in the first place, be careful to get good, fresh material. In the second place, it should be so kept as to prevent the introduction and development of bacteria in it. Bacteria need heat for their growth (as we so well know is the case with the higher plants). They also need moisture.

The Preservation of Foods. — So our principal modes of keeping foods from spoiling are to keep them in a cold place, or to dry them. Or we heat them, and shut them away from the air, as in our various modes of canning and preserving foods. Salting and smoking meats, etc., preserve them by preventing the growth of bacteria. Cold does not usually kill bacteria. So milk that has been kept in a refrigerator, and that seems sweet, may have in it a stock of bacteria, and after we drink the milk the heat of our bodies favors their development. There are now known ways of killing the bacteria in milk and other liquids, known as "sterilizing," that make us safe from this danger.

Although the main subject of this chapter is air and ventilation, it has been thought best to touch briefly the subject of bacteria in food, as the bacteria are so widely disseminated by the air. One of the earlier and still interesting works on this subject is Tyndall's *Floating Matter of the Air*.

But let us now turn from the air and respiration to another, yet closely allied subject.

The Need of the Removal of Waste. — When we awaken on a cold winter morning we are likely to find that the fire in our hard coal stove has burned low. Not enough heat is given out. What is the trouble? Is it merely that more coal is needed? We put another hod of coal in the magazine (though some usually remains). Does this bring the desired result? No. We open the draft. Is this sufficient? It is not. We must shake down the grate and clean out the clinkers. The removal of waste is often more necessary than the addition of a fresh supply of material. It is often a more serious matter to have the waste pipe leading to the sewer clogged than to have the water supply cut off. It is often more to be desired that the garbage cart take away decaying matter than that the bread wagon arrive. The demands of nature for the expulsion of excreta are imperative, while we can withstand the cravings of hunger for a while. So we shall turn our attention for the present to the immediate demand for the removal of wastes, and later consider the equally important, but less importunate, question of supply and renewal.

READING. — (1) *Bacteria*, (2) *Dust and Its Dangers*, (3) *Drinking Water and Ice Supplies*, Prudden; *Ventilation and Warming of School Buildings*, Morrison; *Sanitary Conditions of Schoolhouses*, Lincoln (American Public Health Association); *Disinfection*, Sternberg (American Public Health Association); *Micro-Organisms and Disease*, Klein; *The Wilderness Cure*, Marc Cook.

Summary. — 1. Lung diseases usually accompany close confinement, but are rare with those living in the open air.

2. Air in rooms needs constant renewal.

3. Grates are good ventilators, but not economical heaters. Grates heat very unevenly.

4. Stoves are economical heaters, but poor ventilators. Stove heat is also very uneven.

5. All crowded rooms, as schoolrooms and churches, need special inlets for fresh air and outlets for foul air.

6. The most common means of withdrawing the air is by foul-air shafts. Heat is the force relied on, but the removal of foul air is usually inadequate, on account of the slowness of the current or the narrowness of the outlet, or both combined.

7. Fans are much more certain to be effectual.

8. Steam and hot water may heat directly (by radiation) or indirectly (placed in flues). A combination of direct and indirect heating favors economy and efficiency.

9. Dust as mere dry dead matter is irritating.

10. Disease germs may form part of the dust of the air.

11. Most of our contagious diseases are known to be due to bacteria.

12. Burning is the surest method of destroying germs.

13. Carpets, tapestries, and cloth-upholstered furniture add largely to the dust in houses.

14. Putrefaction is caused by bacteria.

15. Preservation of food depends on destroying, or excluding, or retarding the growth of the bacteria of putrefaction.

Questions. — 1. How can we renew the air of a room without having unpleasant drafts?

2. Should bedroom windows be open at night? Is night air bad?

3. What dangers in the use of hard coal?

4. Should there be a damper in the smoke pipe of a hard coal stove?

5. What do miners mean by "choke damp"?

6. What is hay fever? Asthma? Bronchitis? Pneumonia?

7. Compare stove and furnace heating.

8. Compare heating by steam and by hot water.

9. Is the air in the mountains or on the seashore better than elsewhere?

10. What regions are recommended for consumptives? Why?

CHAPTER VIII.

EXCRETION.

THE SKIN AND ITS FUNCTIONS.

The Skin throws off Perspiration. — The energies of the body — heat and motion — are produced by the oxidation in its tissues. During this process waste products are formed, which if retained in the body would cause very injurious effects.

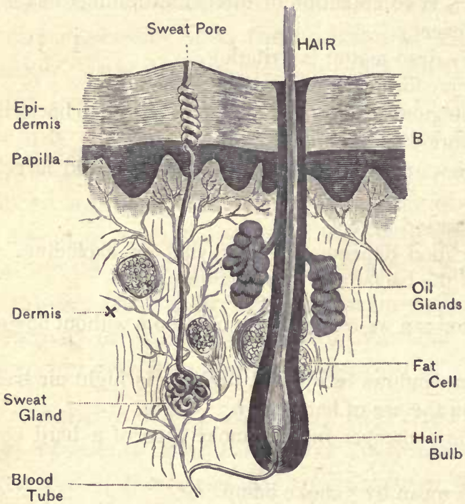


Fig. 49. Vertical Section of the Skin.

How does the body get rid of these substances? We have learned that the lungs throw off carbon dioxid, water, and certain putrescible organic matter.

The skin is constantly throwing off wastes, collectively called sweat, or perspiration.

The Structure of the Skin. — The skin has two layers, the inner, or dermis, and the outer, or epidermis. A bruise often loosens or breaks off a piece of the epidermis, but seldom removes the dermis. The epidermis is thick over the palms of the hands and soles of the feet; elsewhere it is thin. Not often seeing the whole thickness of the skin, we do not easily obtain an idea of its real thickness. The skin constitutes about one-fifteenth of the body's weight, and if tanned makes a moderately firm and thick leather very much resembling the pigskin used for covering footballs, striking bags, etc.

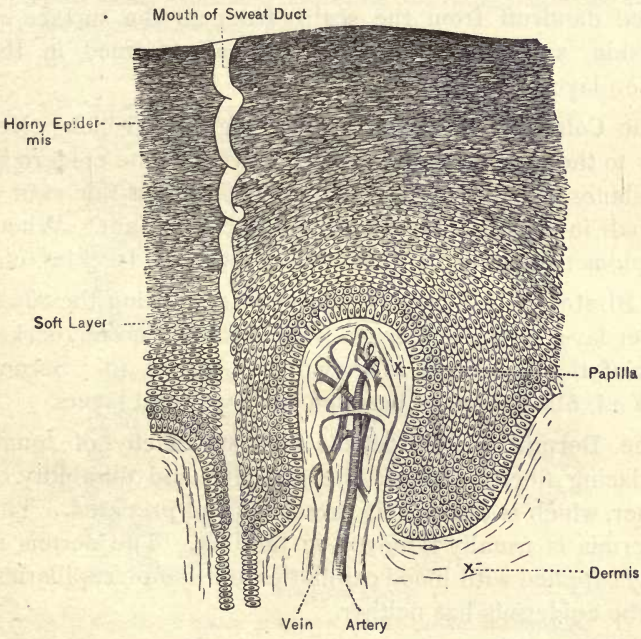


Fig. 50. Section of Epidermis, showing Papilla. (Highly magnified.)

The Epidermis.—The epidermis consists of many layers of cells packed closely together. The deepest cells may be compared to grapes with their cell walls plumply filled out by the liquids of the cell. Suppose, for the inner layer, grapes set on end, and so closely packed together as to press each other into elongated prisms. Then layers less closely pressed, more nearly spherical; then layers of cells with less liquid in them, and somewhat shrunken, like raisins; then still dryer cells, flattened parallel with the surface of the skin; and last, in the outer part, layers of cell walls, dry and empty, pressed flat like empty grapeskins. The flat cell walls come off in flakes (called dandruff from the scalp) from all the surface of the skin, and new cells are continually formed in the deeper layers.

The Color of the Skin.—The pigment, which gives color to the skin, lies in the deeper layers of the epidermis. In albinos this is wanting; in persons with a fair skin it is small in amount, in dark skins more abundant. Where the pigment is irregularly scattered it causes freckles, etc.

A Blister.—A blister is caused by separating the outer, harder layer of the epidermis from the inner, softer, darker layer of the epidermis, as shown at *B* in Fig. 49. Serum, or blood, fills the space between the separated layers.

The Dermis.—The dermis consists chiefly of tough interlacing fibers. Hence the strength and durability of leather, which is the dermis preserved and prepared. The epidermis is usually removed in tanning. The dermis is richly supplied with blood capillaries and lymph capillaries, but the epidermis has neither.

Papillæ.—The outer surface of the dermis has numerous conical elevations. Over most of the skin there is no evidence of these papillæ, as the epidermis envelops them. But on the palm and sole the papillæ are in rows, and these rows are indicated by the fine ridges.

Hairs and Nails. — Hairs and nails are outgrowths of the epidermis. Their deeper parts are embedded in the dermis, through which, from the blood, they derive their nourishment. Like the epidermis, they are dead in the outermost part, and are supplied by growth from beneath.

Examination of the Skin with a Lens. — Place a linen tester, or good pocket lens, on the palm of the hand, and note the openings of the ducts of the sweat glands, or sweat pores. Count the pores within the square shown. Measure this square, and then estimate the number of sweat glands to a square inch of the palm.

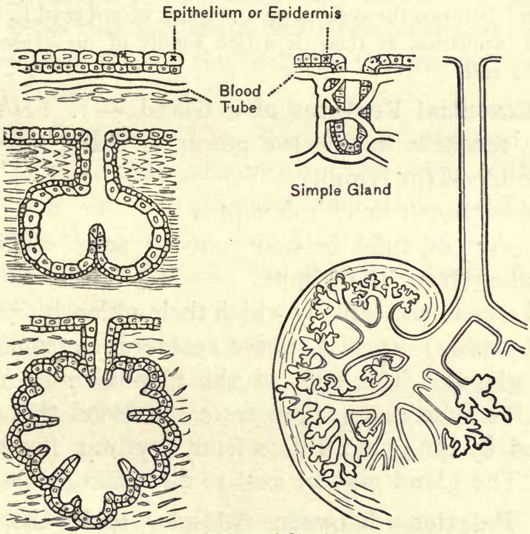


Fig. 51. Evolution of Glands. (After Landois and Stirling.)

The Sweat Glands. — The sweat glands are minute tubes whose inner ends are closed, and whose outer ends open upon the surface of the skin. The tube going inward pursues a corkscrew-like course through the epidermis, then becomes straighter, and, having passed through the dermis, is coiled up in a ball in the connective tissue lying just underneath the inner skin. The cells forming the walls of the coiled part differ from those of the duct, or straighter part of the tube. As the blood flows around the coil it gives off lymph, and from the lymph the cells of the gland take certain waste matters, which are passed out to the surface of the skin. There is also some muscular tissue around the walls of the gland.

Model of a Sweat Gland. — Take a small rubber tube a foot long; close one end; tie the half with the closed end into a globular knot; around and between the coils place a network of red cord to represent the blood capillaries, as there is a rich supply of these blood tubes around the coil.

The Essential Features of a Gland. — 1. *Cells lining a cavity*, the cells having the power of taking something from the blood (or lymph).

2. *Blood supply* or lymph supply.

3. A *duct* or tube to pour out on some surface the liquid taken from the lymph.

4. *Nerves* to the cells by which their action is controlled.

5. (Probably) Special nerve centers controlling the various glands. The cells of the glands in many cases so alter the substances taken from the blood that what is produced by the gland differs from anything found in the blood. The gland may be said to manufacture the liquid.

The Relation between Glands and the Blood Supply. — The sweat glands, like all glands, are largely dependent on the amount of blood supply. In exercising, the skin is usually redder from the greater blood supply, and at the same time the glands are more active; for, during exercise, and immediately after it, there is more waste matter to be thrown out. But the activity of the gland is not a mere filtering process, due to the greater blood pressure. There may be a cold sweat; *i.e.* when the skin is pale. Here is evidence that the activity of the glands is, primarily, due to the nerve impulses from some nerve center to the gland cells.

Sweat Glands are Simple and Excretory. — The sweat glands rid the body of certain waste matters that can no longer be used. They are excretory glands. In structure they are simple glands.

Distribution of Sweat Glands. — The sweat glands are thickly distributed over the whole surface of the body, but are especially numerous and large on the palms of the hands and the soles of the feet. In the armpits the glands are very large.

The Oil Glands. — The oil glands of the skin are distributed over all the surface except the palms of the hands and soles of the feet. The oily matter is usually poured out around the hairs as they emerge from the skin. It serves to oil the hair and the skin, and keep them from becoming too dry.

Composition of Sweat. — Sweat is mostly water; about one per cent is solid matter, including salt and certain matters which, like the organic waste matter from the lungs, easily putrefy, and some oily matter from the oil glands of the skin.

Experiment to show Insensible Perspiration. — Thrust the hand into a glass jar, preferably a jar that has been in a cool place. Note the moisture that soon gathers on the inside of the jar from the insensible sweat of the hand. A common fruit jar will do for a small hand, but a candy jar is better, having a larger mouth and clear glass.

Kinds of Perspiration. — Ordinarily the sweat is evaporated as fast as it is poured out; in distinction from this insensible perspiration, there is the so-called sensible perspiration — when it accumulates enough to be perceptible. These are not two distinct kinds of sweat, but it is convenient to distinguish between the perceptible and the imperceptible. Sweat varies greatly in its wateriness, and hence in the *relative* amount of solid matter contained.

The Amount of Perspiration. — There is about one quart in twenty-four hours. It varies with: —

1. Temperature, dryness, and rate of renewal of air.

2. Condition of the blood; *e.g.* if watery from drinking much water.

3. Muscular exercise.

4. Certain drugs — some exciting perspiration, *e.g.* camphor; others diminishing it, *e.g.* belladonna.

5. The nerves exercise great influence on the activity of the cells of the gland.

The Functions of the Skin.

1. Protective.
2. Excretory.
3. Absorptive.
4. Sensory – organ of touch.
5. Heat-regulating.

Next to its excretion, the heat regulation by the skin is the most important for our present consideration.

Regulation of the Temperature of the Body by the Skin. — It is a striking fact that, except in disease, the temperature of the body varies only a little from 98.5° F. in summer and winter, during exercise and rest. The rate of heat production varies greatly. The rate of giving off heat must therefore vary accordingly.

The Body gives off Heat. — In considering the regulation of the body's temperature, we must bear in mind that the body is surrounded by air almost always considerably cooler than itself. The body is, therefore, almost always giving off heat. Our clothes do not warm us: we warm them, and they keep us from warming the air too fast; *i.e.* keep us from losing too much heat. Indoor heat in winter in the cooler parts of the United States is kept at about 70° F. by artificial heat. This air does not warm us. We, being about 30° F. warmer, are warming it.

Ways of Giving off Heat. — The skin gives off heat by —

1. *Radiation:* heat is given off in every direction.

2. *Conduction:* whatever we touch that is cooler than our bodies is warmed. We warm chairs, clothing, etc.

3. *Convection:* the air in contact with the skin is warmed and rises. Our bodily heat is thus carried off by convection.

4. *Evaporation:* the evaporation of the sweat is a much more important factor in heat regulation. Any liquid, in evaporating, absorbs heat. The cooling effect of alcohol or ether on the skin is due to the fact that heat is taken from the body in converting the liquid into a gas.

Experiments in Evaporation. — Let the teacher, with a medicine dropper, place a drop of alcohol, ether, or cologne on the back of the hand of each pupil. Notice two facts: (1) It produces a cooling effect. (2) The liquid soon disappears. To prove that it is not merely that the liquid is cool, try the following: Tie a piece of cheese cloth around the bulb of a thermometer; dip the bulb into a dish of alcohol or ether, and note its temperature (if these are not at hand, gasoline serves very well, or even water, though the evaporation is slower); then lift the bulb out of the liquid, and note any change in temperature. The evaporation of the liquid takes heat from the bulb, and causes the thermometer to register a lower temperature. We sponge the face and hands of a feverish patient to reduce the amount of heat. We sprinkle the floor in hot weather, and, by the absorption of heat in evaporating the water, cool the air of the room.

Heat and Exercise. — When we exercise, we produce more heat: we sweat more; more heat is taken from the body to evaporate this sweat. If we are not exercising, and are in cooler air, we sweat less, and less heat is given off. So the temperature of the body is kept uniform.

This should also be observed: When we exercise, more blood is in the skin, and more heat is given off in the other ways mentioned; when we exercise less, the skin, especially in a cool air, becomes paler; *i.e.* has less blood in it, and heat is economized.

Distribution of Heat in the Body. — If more heat is produced in one part of the body than in the others, the circulation of the blood tends to equalize the temperatures of the different parts. So, too, if one part is cooled, — that is, is losing heat faster than the others, — the blood brings heat from other organs to that part.

For instance, if one holds his hands in the snow, or puts a piece of ice on his wrist, the whole blood stream is affected. So if the hands and the feet are exposed to the cold, it may do little good to have the rest of the body covered. A pair of wristers and a pair of leggings may often add more to one's comfort than a heavy overcoat.

Regulation of Bodily Temperature by Food and Clothing. — When subject to the influence of cold we eat more; we choose more heat-producing foods, as fatty food-stuffs; we take more vigorous exercise; we put on more clothing, and especially of the non-conducting kinds, — woolens. In warmer weather we eat less fatty matter, wear less clothing, and are less disposed to exercise actively; we fan ourselves to help get rid of heat; we take ices and cold drinks. For most persons it seems better to wear woolen most of the time, as even in summer we are subject to sudden changes in the air, and with such covering one is less likely to take cold.

The Effect of Wet Clothing.—In getting the clothing wet, the greater loss of heat is not from the coolness of the water, but the loss of heat in evaporating the water from the clothing. Of course it is desirable to put on dry clothing as soon as possible; but a person in good health is not likely to take cold, except in very cold weather, if he continues active exercise till he can change the wet garments for dry ones. Children do not often take cold from wading in water so long as they are barefooted; but if the shoes and stockings are wet, they are likely to take cold.

Alcohol and Heat. — The usual effect of a moderate dose of alcohol is to make the person feel warmer. There is more blood in the skin, where the nerve endings perceive the effect. More heat is brought to the surface and more is given off from the body. A thermometer has no "feelings" by which it can be deluded. The thermometer says that the body is losing heat. It is as though one were to open a window, and as the warm air rushes out by him, were to say, "It is getting warmer," not recognizing the loss of heat. There is some heat produced in the body by the oxidation of the alcohol, but this is overbalanced by the loss as shown by a thermometer. The fact is, as clearly shown by experiment, that alcohol deadens the senses, and neither heat nor cold is so readily perceived as before. And this deadening of the senses also makes one fail to notice fatigue; hence the delusion that the fatigue is gone.

THE KIDNEYS.

The Work of the Kidneys. — One important part of the work of the lungs, as we have seen, is to throw out carbon dioxid. The skin also throws off certain wastes. The kidneys have the special task of excreting a waste product of the body called urea. Urea is the nitrogen-containing waste.

The Parts of the Kidneys. —The kidneys are attached to the dorsal wall of the abdominal cavity. The depression in the kidney corresponding to the stem scar on a bean is called the hilum. From the hilum issues a white tube, the ureter, which conveys the urine to the bladder.

The Blood Supply of the Kidneys. — Entering the kidney alongside the ureter is the renal artery, a branch of the aorta, and from near the same point the renal vein returns the blood from the kidneys, and pours it into the postcaval vein. Through the kidneys is pouring a continuous stream of blood, varying in amount at different times and in different conditions. The kidney receives a very large amount of blood for its size, as compared with other organs. The flow to it is made easy by the fact that the renal arteries are relatively wide and short, and take the blood directly from the main current of the aorta. The blood leaving the kidney, especially when in full activity, is still bright red; it is probably the purest blood in the body.

Urine. — From the kidney, through the ureter, urine is continually passing to the bladder. Urine is mostly water containing urea, salt, and various other substances in small amounts. Urea is a waste matter brought in the blood. If the kidneys are stopped in their action, urea accumulates in the blood, and death soon results; to just the degree that the kidneys fail in performing their duty, just so far must the body suffer.

Microscopic Structure of the Kidney. — If microscopic sections of the kidney are at hand they should be examined; but the kidney is so complicated in structure that a diagram is needed in connection with the sections and the descriptions. The unit of structure in the kidney is a tube which takes material from adjacent blood capillaries. The relation of the capillaries to the tube is peculiar. The inner end of the tube is enlarged into a ball; this ball is deeply depressed opposite the point where the tube leaves it. Into this depression is fitted a globular tuft of capillaries. The arrangement may be illustrated by the common toy known as the "cup and ball." The handle of the cup should be hollow to represent the tube; the cup should be double walled, the space between the inner and outer layers continuous with the hollow of the handle.

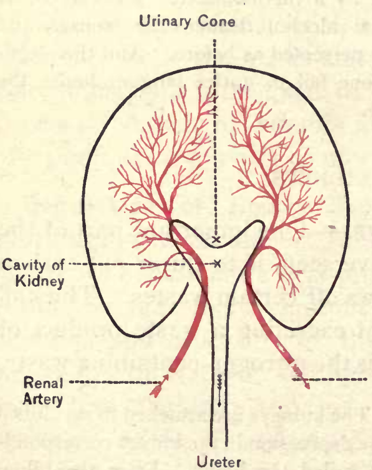


Fig. 52. Cross Section of Kidney.

Instead of a solid ball held by one string, there should be a yarn ball with two large strings attached to one side, one representing the artery, the other the vein; the yarn ball represents the dense cluster of capillaries.

Another Illustration. — A still better illustration of the urinary tube and capsule may be made thus: Take a thistle tube (used in the chemical laboratory), let down into its bulb a rubber balloon or bag of sheet rubber or cloth, fastening the margin around the rim of the bulb; put a little ball of red yarn in the depression of the bag hanging in the bulb; have two ends of the yarn projecting to represent the artery entering and the vein leaving the capsule. The vein, soon after it emerges, breaks up into another set of capillaries which extend around the tube. A number of these primary tubes unite, and many of the common ducts open at the apex of each of the urinary pyramids, emptying their secretion into the cavity of the kidney. As the blood flows through the tuft of capillaries in the capsule at the end of the tube, a large amount of water, together with salt and some other substances, pass through the thin partition into the cavity of the capsule, and thence down the tube. The walls of the tube are thicker than, and its cells are different from, those of the capsule. These cells take the urea and some other substances from the blood, and pass them into the tube to join the more watery material from the capsule.

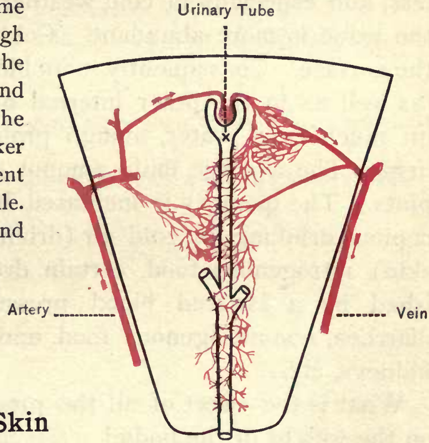


Fig. 53. Urinary Cone Enlarged. (Diagram.)

Comparison of the Skin and the Kidneys. — The kidneys, then, are not very different from the skin. Imagine a piece of skin rolled up with the outer surface of the skin turned inward. Its glands then would pour their secretion into a cavity where it might accumulate, instead of evaporating as fast as it is poured out. Of course the kidneys have a somewhat different work from the skin, but in its general plan of working we might say they are skin turned outside in. The kidney unit (the tubular gland) has branches; *i.e.* is compound. The kidney is a compound gland of excretion, internal in position. Both skin and kidneys excrete a large amount of water, with salt and some other matter in common.

Relation between the Work of the Kidneys and that of Skin. — There is a very immediate relation between the work of the kidneys and that of the skin. In warm weather, and when exercising actively, we perspire freely, and the amount of urine is reduced; when we exercise less, and especially in cold weather, we perspire less, and the urine is more abundant. Cold drives the blood from the surface. Consequently more blood goes to the kidneys (as well as to the other internal organs), and they throw off much more water, though probably little if any more urea. The average daily amount of urine is about three pints. The quantity is increased by high blood pressure, copious drinking, by cold air (driving the blood from the skin), nitrogenous food, certain drugs, etc. It is diminished by a lowered blood pressure, profuse sweating, diarrhea, non-nitrogenous food, and some diseases of the kidneys, etc.

What is the effect of all the processes thus far studied on the weight of the body?

Reading. — *The Skin and Its Troubles,* D. Appleton & Co.

Summary. — 1. The skin throws off sweat, which is water containing waste matter.

2. The tubular sweat glands take the wastes from the lymph which soaks out through the walls of the capillaries in the skin.

3. The activity of the glands is under control of nerves and nerve centers, as is also the supply of blood to the skin.

4. The amount of sweat depends on temperature, exercise, amount of liquid food taken, drugs, etc.

5. The temperature of the body is regulated chiefly by the evaporation of sweat.

6. In cold weather we eat more of heat-producing foods, such as fats.

7. The kidneys excrete urea, a nitrogen-containing waste.

8. There is an intimate relation between the workings of the lungs, skin, and kidneys.

Questions. — 1. Does cutting hair make it grow faster ?

2. Do cows, dogs, and cats sweat ?

3. Why is thirst relieved by immersion, even in salt water ?

4. Why should clothing worn during the day be removed at night ?

5. How does the body lose heat, except by the skin ?

6. Why should the blood still be red after passing through the kidney ?

7. What is "skin grafting" ?

8. Why is it considered a good sign when the skin becomes moist during a fever ?

9. Can food, medicine, or poison be absorbed through the skin ?

CHAPTER IX.

FOODS AND COOKING.

Necessity of Food. — Thus far we have been studying processes by which the body's weight is reduced. We have studied the oxidation in the tissues and the removal of the wastes. Unless the tissues receive a corresponding supply the heat and energy of the body cannot long be maintained.

Food Defined. — Foods are substances that build tissues or produce energy without injuring any organ or function of the body. Certain substances that do not become part of any tissues, nor in themselves produce energy, are useful in aiding the processes going on in the body. These may be called *accessory* foods, *e.g.* condiments; some accessory foods, such as coffee, seem to retard the waste of tissues.

Foods and Foodstuffs. — Most of our articles of food consist of two or more different kinds of materials. For instance, milk consists (1) chiefly of water; in this are (2) the substance that makes cheese (casein); (3) cream, from which we get butter (fat); (4) sugar, which gives milk a sweet taste; (5) salts, such as common salt, lime salts, etc. These different materials are *foodstuffs*. We have many kinds of foods, but few foodstuffs, which we find occurring over and over again, in various forms, in the numerous things we eat.

Kinds of Foodstuffs.

1. Proteids (example, casein).
2. Fats.
3. Carbohydrates (example, sugar).
4. Water.
5. Salts.
6. Oxygen.

Oxygen is by some authors called a food, but it is more convenient to treat of it elsewhere.

The Proteids. — The chief substance in the white of an egg is albumen, a typical proteid. Of the many proteids some of the more commonly known are casein (the curd of milk), gluten (in grains), legumin (in peas and beans), fibrin (in blood), myosin (in muscles). Gelatin (obtained from connective tissue and bones by prolonged boiling) differs considerably from the proteids in composition, but may be counted in with them. It is less valuable as a food than the true proteids, although in certain circumstances more desirable from the fact that it is very easily digested.

Characteristics of Proteids. — The proteids are —

1. Composed of carbon, hydrogen, oxygen, nitrogen, a little sulphur, and, in some, traces of phosphorus.
2. Jelly-like, and do not easily diffuse through animal membranes (a characteristic to be kept in mind when studying digestion).
3. Coagulable (usually) by heat, acids, alcohol, etc.
4. Easily putrefy when moist and warm.

Importance of Proteids. — The proteids are of special importance as foods because the most active tissues, muscle, nerve, and gland, and the most important liquids of the body, *e.g.* blood and lymph, have proteid as a chief constituent. Proteid food, therefore, must be taken to make good the losses of these tissues during their oxidations.

Proteid-containing Foods. — The principal proteid-containing foods are lean meat, fish, eggs, milk, cheese, and some seeds which abound in the vegetable proteids.

Meat. — Lean meat has about twenty per cent of proteid, the rest being chiefly water. Beef and mutton are more easily digested than veal and pork. It is better to buy meat from a very fat animal than from a lean one, for, although there is slightly less proteid in the meat from a fat animal, this loss is more than made up by the addition of fat, which takes the place of water in the meat from a lean animal. There is more nourishment in a round steak than in tenderloin.

Fish. — Fish, when fresh, is a good food. Although, as a rule, salted meats are less easily digested than fresh, salted codfish is a nourishing and economical food.

Eggs. — Eggs contain considerable proteid, but their value as food has been overrated. The yolk has a large amount of fat. Although the egg has all the material needed to form a chick, it is not a perfect food for man.

Milk. — Milk, as we have seen, is an ideal food in that it contains all the kinds of foodstuffs, and in the right proportion for the young mammal. But the proportions are not right for the adult. An adult would need four quarts and a half daily, and then he would not get enough carbohydrates (represented in milk by the sugar). The oily material in milk is in the form of minute globules, which can easily be seen under the microscope. Each of these oil droplets is supposed to be surrounded by a thin envelope of albuminous matter, by means of which it is enabled to remain suspended for some time instead of rising quickly to the surface. Such a mixture of oil in a liquid is called an emulsion. When cream is churned the albuminous covering is removed and the butter "gathers."

Cheese. — Cheese is very rich in proteid, much more so than lean meat. Yet, as it is rather difficult of digestion, we do not use it largely as food; we regard it more as a luxury, while in many parts of Europe it is largely used as food, taking the place of meat. It is a cheap food, and might well be used more extensively, especially by laboring men. When taken with milk it is said to be more readily digested.

Vegetable Proteids. — Peas and beans (dried) contain as much proteid (legumin) as meat, and all the cereals contain some proteid (gluten).

Fats. — Fats are composed of carbon, hydrogen, and oxygen. The oxygen is small in amount, so these foods yield a great amount of energy by the oxidation of their carbon (forming carbon dioxid) and hydrogen (forming water). The fats most used are animal fats, including butter. But some vegetable oils, such as olive and cotton-seed oils, are used.

The Carbohydrates. — Starch and sugar are the chief carbohydrates. Starch is used in larger quantity than any other foodstuff except water. Sugar is usually regarded as a luxury, yet it is an important food. It is quickly absorbed.

Carbohydrate-containing Foods. — The principal carbohydrate-containing foods are the grains, vegetables, and fruits.

The Grains. — The most important grains are wheat, corn, rice, oats, rye, and barley.

Wheat. — Wheat furnishes the principal breadstuff among the more civilized nations. It is especially adapted to the temperate zones. Taking into consideration its composition, digestibility, and other characteristics, it is the most desirable of all the grains for civilized man.

Wheat Flour. — In ordinary white flour nearly all the gluten has been removed with the bran or "middlings." While wheat or bread made from the whole grain of the wheat may support life, one would starve if he attempted to live on common white bread alone. It is almost entirely starch. In the "entire wheat flour" it is claimed that all the gluten is retained, only the very thin outer husk of the grain being removed. It does not make so white a flour, but it is better adapted to use as a food. If we use white bread, having thrown away the nitrogenous part of the wheat, we need to take more proteid from other sources than if we used the entire wheat flour. This is not economy. And it is claimed that the entire wheat bread is more wholesome as well as more nutritious. The part thrown away has in it phosphates as well as the nitrogenous material. This flour is ground fine so that it has not the coarse particles which are in Graham flour, and which are a source of irritation to the mucous coat of the digestive tube in some persons.

Corn. — Corn is one of the most nutritious of the grains. Although somewhat less readily digested than similar preparations of wheat, and, consequently, less desirable for indoor workers, it is a fact that, for a given amount of money, more nutriment can be obtained in corn meal than in any other food known. Corn furnishes food to a large part of the human race.

Rice. — Rice forms a larger part of human food than the product of any other plant, being often an almost exclusive diet in India, China, and the Malayan islands. Rice has a larger proportion of starch, and less of fats and albuminoids, than the other grains. It is best adapted for the food of warm climates.

Oats. — This grain was first used as food for man by the Scotch, but the use has extended and become prevalent in this country. In point of nutrition it is ranked higher by some than ordinary grades of wheat flour.

Rye. — Rye grows farther north than other grains, and is largely used for bread in Russia and parts of Germany. It is a valuable food, though less nutritious and less digestible than the corresponding preparations of wheat.

Barley. — This grain has wide range of cultivation, and, while inferior to wheat, is considerably used where other grains cannot be raised.

Potatoes. — Potatoes contain about twenty per cent starch, two per cent of proteid, and no fat, the remainder being chiefly water, with some useful salts, especially potash salts. In spite of its relatively low food value, the potato is our most useful vegetable on account of its abundance, the ease with which it can be preserved, its mild flavor, and the readiness and the variety of ways in which it can be cooked.

Other Vegetables. — The chief nutrient in vegetables is starch, though in many the starch is present in small amounts. The salts and acids present are of value, and care should be observed not to remove too much of these salts in cooking. The fibrous matter, cellulose, while indigestible, is of value in adding bulk to the mass of food to be digested. Formerly sailors were subject to scurvy;

this is now attributed to a diet of fat and salt meat, to the exclusion of fresh vegetables, vegetable acids, etc. The disease is avoided by a greater use of vegetables, lime juice, etc.

Fruits. — Many of the fruits, such as bananas and apples, have considerable starch and sugar. But the fruits are probably more useful to us on account of their flavor, due to aromatic bodies, and to their salts and the peculiar fruit acids.

Water. — Water constitutes about two thirds of the entire weight of the body. It constitutes the bulk of the liquids we have studied, blood, lymph, sweat, saliva, bile, etc. Water is the solvent and carrier of all the material of the body. Hence we need a large amount of it; of course we must remember that we get a good deal of water in most of our solid foods.

Rain Water. — Water, as it comes from the clouds, is pure. After enough rain has fallen to wash the air, rain water is pure, and if caught on a clean roof (especially a slate roof) and kept in a clean cistern, it is good drinking water.

Well Water. — Falling upon the earth, the rain water soaks down until stopped by some impervious layer, such as clay. This water is the supply of our wells and springs. It always has more or less earthy matter in solution, and is therefore more or less "hard." Unless a large amount of mineral matter or some special material is dissolved in it, it is, ordinarily, good drinking water. Such water is not pure, in the strict sense of the word, but is pure for drinking purposes.

Impurities in Water. — The great source of danger is from what are called "organic" impurities. Bacteria will not live and grow in pure water. They must have something on which to feed and grow. But in water containing a large amount of decaying animal or vegetable matter they are likely to abound. And the most dangerous sources of contamination are cesspools and sewers. Water may be contaminated by such material and not have bacteria in it, but is very likely to harbor such foes.

Contamination from Cesspools. — The ordinary cesspool is a grave source of danger. Because the well may be on higher ground than the cesspool does not give assurance that the water may not be polluted. Often when the surface of the ground slopes in one direction, the strata underneath may slope in just the opposite direction, and the well may be the reservoir into which the cesspool is drained.

Good authorities say that a cesspool should not be allowed within a hundred feet of a well.

Abolish the Cesspool. — But it is better and safer to have no cesspool. Where a sewer system is not to be had, it is better to allow no great accumulation of such material. A deep pit in which a quantity of semiliquid matter gathers is not only a nuisance, but a source of danger. Privies should have a very shallow pit, or none, and should be cleaned often. There should be a little dust sprinkled in each day, and occasionally some "chlorid of lime" or sulphate of iron.

Typhoid Fever. — Typhoid fever is now known to be usually caused by drinking water. The dejecta of some one who has had the disease find their way into the source of the drinking water. In many cases this has been clearly proved. Of course the dejecta of all such patients should be either destroyed or thoroughly disinfected.

Ice Water. — Although bacteria will not develop in a cold place, they are not killed when frozen in water, as was formerly supposed. Further, ice, in forming, does not throw out all the impurities, as was formerly stated. So it is not safe to drink water formed from melted ice unless the water of which that ice was made was good water. The ice taken from ponds is not safe. If ice is made artificially from suitable drinking water, of course the melted product will be essentially unchanged so far as the composition is concerned. Water may be cooled by placing any ice around it, and we may have the desired temperature without any admixture of a dangerous element.

Boiling Water. — When one cannot get good drinking water, or when away from home where the water is of doubtful purity, it is better to boil the water before using it, either as a drink or in preparations of food that are not to be thoroughly cooked. It seems to be proved that it is better to heat the water twice nearly to the boiling point than to boil hard once only. The first heating may start the resistant germs into more active life, causing them to sprout (so to speak), and a *second heating several hours later* may easily kill them; whereas it has been proved that one hard boiling will not always kill the germs.

Cautions as to Drinking Water. — Or if one uses tea and coffee, it is safer to content one's self with these, and not drink much water till that which is safe, as from deep wells, can be obtained.

In hot weather, and especially for those who are engaged in hard work, it has been found that a little oatmeal stirred in the water is beneficial.

When overheated, avoid drinking much cold water. Repeatedly rinse the mouth with cool water, and swallow very little. This is the way trainers manage a horse at a race, and it is sensible to treat a man as carefully.

Salts. — Salts include many substances besides common salt. They aid in the solution of various substances during digestion and in other processes. We cannot live without salt.

Lime in the form of calcium phosphate and calcium carbonate is essential, especially in the bones and teeth. Iron is associated with hemoglobin.

Necessity of a Mixed Diet. — Our experience, together with the results of the experiments on animals, teaches that we could not live long if fed on any one class of foodstuffs alone. We must take a representative of each of the groups. We have noticed that most of our foods already contain more than one foodstuff. We so combine them as to get suitable proportions. Thus we eat bread and butter (a small amount of fat with a large quantity of starch and a little gluten), meat and potato, crackers and cheese, pork and beans, egg on toast, bread and milk, rice and fowl, macaroni and cheese; they "go well together" chiefly because they are complementary.

Disadvantages of a One-sided Diet. — In order to get enough nitrogen from bread alone, one would have to eat about four pounds a day; meanwhile twice as much carbon as is needed would be taken, thus throwing an undue amount of work upon the digestive organs. Again, one would need to consume about six pounds of meat to get the requisite amount of carbon, and six times as much nitrogen as is needed would be taken; to get rid of this extra nitrogen would severely tax the kidneys and liver.

Effect of Cold on Appetite for Fats. — In cold climates a large amount of fat is consumed, while in the tropics starch is the chief food. Our appetites call for more of the fatty foods during the winter season.

Proper Diet. — While common experience has led people to adopt a mixed diet, the proportions of the different foodstuffs is not always what it should be. The proportions of the foodstuffs (exclusive of water) may be roughly stated as about 1 part of proteid, 1 part of fat, 3 parts of carbohydrates. But this will vary somewhat with the amount of work done, and other varying conditions.

Vegetarians. — The so-called "vegetarians" recognize the need of proteid food, and most of them seek proteid in eggs, milk, and cheese. But these are animal products, and the name "vegetarian" is inconsistent. They are merely "anti-meat eaters." If they do actually succeed in getting enough proteids from the legumes and the grains, the complete digestion of which is difficult, they are, as Professor Martin says, to be congratulated on having digestive powers that can stand such a strain. That we are adapted for using flesh as part of our food is indicated in at least two anatomical features: (1) we have canine teeth, though not so fully developed as in the carnivora; (2) the intestine in carnivora is very short, that of the herbivora very long, but in man intermediate. Nevertheless, it is undoubtedly true that many persons eat too much meat.

Tea. — Tea owes its stimulating effects to a substance called *thein.* This is a stimulant to the nervous system, but if not too strong is not followed by a subsequent depression. Tea that is too strong is likely to produce nervousness and dyspepsia. Boiling the tea leaves also brings out the tannic acid that they contain, and produces bad effects.

Coffee. — Coffee owes its stimulating effect to a substance called *caffein*, which is considered identical with thein. Coffee acts as a restorative after hard labor, seeming to retard the wastes of the tissues and food. It is used in the army (also in penitentiaries), not as a luxury, but as a matter of economy in the matter of food supply. Coffee, used to excess, frequently causes palpitation of the heart.

Malted Milk. — Malted and peptonized milk makes a valuable drink for invalids and dyspeptics.

Cocoa and Chocolate. — Cocoa contains a stimulant called *theobromin*. But unlike tea and coffee, cocoa and the preparation from cocoa known as chocolate are true foods by virtue of the fat contained.

Beef Tea. — Beef tea and various beef extracts are very beneficial. There is not enough nourishment in them to maintain strength without other food. Their nutritive value has been somewhat overestimated. Their value is probably much more in their stimulating than in their nourishing effect. But many of the soups and drinks made from these preparations are very beneficial. They refresh the tired system wonderfully. If the man who feels "fagged out" and takes a drink of liquor to "brace him up," as he says, were to take a cup of hot bouillon, he would find himself braced up for the time, without any bad reaction, or permanent injury to the system, which follow the use of alcohol.

Cooking. — Cooking is designed to make food more palatable and more digestible. Some foods, such as eggs, are as digestible before they are cooked as after, often more so, as they are very frequently badly cooked. But many foods in the raw state are unattractive, or even repellent, whereas cooking usually develops an agreeable odor and taste. Cooking should soften the harder and tougher tissues, such as cellulose in vegetables, and the connective tissue of animal foods. Cooking starch causes the starch grains to swell and burst, and makes the starch much more digestible.

Making Soup. — If meat be cut into small pieces and put into cold water, and the water gradually warmed, the soluble material of the meat may be extracted, and this is the principle followed in making soups.

Boiling Meat. — But if we wish to cook the meat itself, the juices should be retained instead of withdrawn. For this purpose boiling water is poured over the meat to coagulate the outer layer, and prevent the extraction of the juices.

Baking, Roasting, and Broiling. — The same principle applies to baking, roasting, and broiling. The outside is subjected to high heat at the beginning of the cooking, which forms a layer nearly impervious to the nutritious material inside. In these modes of cooking it is very desirable to reduce the heat applied after the first few minutes, so that the interior may be more gradually cooked; this is, perhaps, especially true in broiling.

Frying. — Frying, as ordinarily done, is not a good mode of cooking; in fact, is often very bad, as the food is frequently penetrated by fat and rendered very indigestible. But true frying, that is, by immersion in boiling fat, is a good mode of cooking. This coagulates the albuminous substance on the outside, keeps in the nutritious juices, and prevents soaking with the fat. Often the food to be thus cooked is first coated with white of egg, which is very quickly coagulated, and helps form a protecting outside crust.

READING. — *Practical Sanitary and Economic Cooking*, Abel (Public Health Association); *The Science of Nutrition and the Art of Cooking*, Atkinson; *Chemistry of Cookery*, Williams; *Chemistry of Foods aud Nutrition*, Atwater (*Century Magazine*, 1887–88; also Department of Agriculture); *Eating for Strength*, Holbrook; *Foods*, Smith; *Philosophy of Eating*, Bellows; *Handbook of Invalid Cooking*, Boland.

Summary. — 1. Food builds tissue and maintains energy.

2. The simpler constituents of foods are called foodstuffs.

3. The foodstuffs are water, salts, proteids, carbohydrates, and fats.

4. Water is essential to life, making two thirds of our weight.

5. Salts are essential to life.

6. The chief proteids are lean meat, eggs, cheese, gluten, etc.

7. The chief carbohydrates are starch and sugar, derived from the grains, vegetables, and fruits.

8. Fats and oils are obtained from plants and animals.

9. The chief source of impurity in water is from bacteria, which thrive when decaying animal and vegetable matter are present.

10. Boiling water may destroy these germs of disease.

11. Ice water is not a wholesome drink.

12. A mixed diet is necessary, as no one food contains all the needed material in the right proportions to maintain life well.

13. Tea and coffee are slightly stimulating, but, if used moderately, ordinarily without any bad reaction.

14. Cooking is to make food more palatable and digestible.

Questions. — 1. Which class of foodstuffs is most expensive? Why?

2. Make a list of all the common foods, naming the foodstuffs in them.

3. Why do we not eat buckwheat cakes and sirup in summer?

4. At what price are eggs an expensive food?

5. How do flour and potatoes compare in economy at ordinary prices?

6. Why are foreigners prejudiced against corn?

7. Why is broiling better than frying?

8. Why do Englishmen in India so generally suffer from "liver complaint"?

CHAPTER X.

THE DIGESTIVE SYSTEM.

The Object of Food. — The tissues are worn out by their oxidations. They are built up again by the blood, and the blood is renewed by the food.

All food must be reduced to the liquid condition, if it is not already liquid.

The Digestive Tube. — The chief organ in this work of liquefying the food is the *digestive tube*, or "alimentary canal," as it is called. As the food passes through the digestive tube it is subjected to various mechanical and chemical processes which liquefy it and bring it into such a condition that it can be absorbed through the mucous lining of the digestive tube and passed into the blood.

The Work of the Digestive Tube. — To take a special instance, a muscle is in part worn out by the oxidation during its activity; to replace the loss suppose we take a piece of steak. We cannot substitute this directly in the place of the worn-out tissue. In digesting the steak we must tear it all to pieces, and reduce it to a liquid form by the action of the teeth and by the various liquids from the glands along the digestive tube. In short, the muscle, as such, must be thoroughly destroyed; in the liquid produced by the digestion of the beef there is no trace whatever of the structure of the beef. But the blood, taking this material, builds muscle which can hardly, if at all, be distinguished from the original beef.

If the food taken be all ready to build tissue, for example, certain forms of sugar, liquid, soluble, and of the proper chemical composition, it will not need to go through these changes.

In order to understand the process of digestion let us first turn our attention to the anatomy of the organs of digestion.

The Organs of Digestion. — The organs of digestion are the digestive tube and the accessory parts, the masticatory organs, the glands in, and alongside of, the walls of the tube.

The parts of the digestive tube are the mouth, the pharynx, the gullet (or esophagus), the stomach, the small intestine, the large intestine.

Brief Description of the Digestive Organs. — At the back of the mouth may be seen the soft palate with the cylindrical uvula hanging from its center. Beyond this is the cavity of the pharynx, which narrows below into the gullet, a red-walled, muscular tube, extending along the dorsal side of the windpipe, and close to the spinal column. It extends the length of the thorax, and then passes through the diaphragm and widens into the stomach, at the upper left end of the latter. The stomach is somewhat pear-shaped, with the larger end to the left. At the right end it tapers into the small intestine, the first foot or so of which is called the duodenum. Then comes a long coil of the small intestine, which joins the shorter large intestine, ending in the rectum. Just below the diaphragm is the dark-colored liver, overlapping a large portion of the stomach. Between two of the lobes of the liver is the bile sac whose duct enters the duodenum a short distance from the stomach. The pancreas is a pinkish organ of irregular shape lying along the stomach and duodenum. Its duct enters the duodenum at the same point as the bile duct. The intestine is held in place by the mesentery, a thin fold of transparent membrane folded closely around it, and supported from the dorsal wall of the abdominal cavity. Between the two layers of the mesentery are the branches of the artery supplying the walls of the intestines, and the veins that convey the absorbed food from the intestine to the liver.

Digestive Organs of a Cat or Rabbit. — The digestive organs will be much better understood if a cat or rabbit be dissected, as the organs have essentially the same form and relations. The animal may be killed by putting it in a tight box, or under a washbowl with a small sponge holding a tablespoonful of ether or chloroform. It may then be opened by a slit along the middle line of the ventral surface, from the chin to the pelvis. The diaphragm should be noted as forming a partition between the cavity of the chest and that of the abdomen.

To Illustrate the Mesentery. — To illustrate the relation of the mesentery to the intestine, suspend the arm in a sling made of a handkerchief; press the two thicknesses of the cloth together just above the arm to represent the two layers of the mesentery.

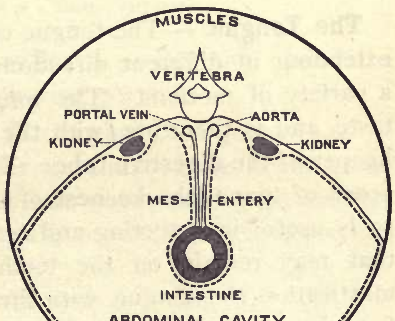


Fig. 54. Cross-section of Abdomen.

Model of Intestine and Mesentery. — A more complete representation may be made as follows: Material: piece of large (one inch or more in diameter) rubber tubing, eight inches long; sheet of thin white court plaster, six inches by twelve inches; red, blue, and white cord. Lay the tube across the middle of the court plaster; gum the plaster snugly around the tube; between the two adjacent layers of the court plaster, where they meet after passing around the tube, lay the three kinds of cord, each frayed out at one end, the frayed ends resting upon the tube. Moisten the court plaster and press the layers firmly together. The court plaster should now adhere so closely to the tube as hardly to be seen, and the two layers should seem as one, in which appear the cords representing the arteries, veins, and lacteals.

The Mouth. — In studying the mouth and contained organs, the student should not content himself with mere reading, but should carefully examine his own mouth cavity by means of a hand glass. We are apt to think of the mouth as a cavity of considerable size, as indeed it is when fully opened; but we are not so likely to think how completely the cavity is obliterated when the mouth is closed. If one notes the sensations from the mouth when it is closed, he will perceive that the tongue almost entirely fills the space, touching the roof of the mouth, and the teeth in front and at the sides.

The Tongue. — The tongue consists chiefly of muscles, extending in different directions, thus giving the tongue a variety of motions. The tongue is the chief organ of taste, and is therefore (with the sense of smell) the gatekeeper of the digestive tube. The tongue has also a keen sense of touch (the keenest of any part of the body), and so is useful in detecting and removing any food particles that may remain on the teeth after a meal. During mastication the tongue, with the lips and cheek, keep the food between the teeth. When the morsel of food is sufficiently masticated, the tongue pushes it back into the pharynx to be swallowed.

The Teeth. — The teacher can usually obtain a lot of teeth from the dentist for the asking. These should be cleaned before using them in the class. Use pearline or any washing soda. If there be enough time, let each pupil make a drawing of one of each of the four kinds of teeth; and it would be well to draw both a front (outer surface) and a side view (surface adjacent to another tooth) of each of the four kinds.

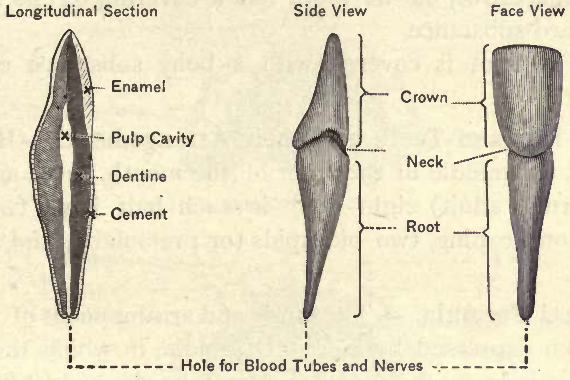


Fig. 55. Parts of a Tooth. (Incisor.)

External Features of a Tooth. — Examine one of the front teeth. It has the following parts:—

1. The crown, the part that is above the gum.
2. The root, the part that was buried beneath the gum.
3. The neck, a more or less constricted part, dividing the crown from the root; it is normally at about the surface of the gum.
4. A hole at the tip of the root.

To make a Section of a Tooth. — Let each pupil prepare a longitudinal section of a tooth as follows: Imbed a tooth in a little sealing wax on the end of a spool, cork, or block of wood. With a grindstone grind away one half, showing the pulp cavity to the tip of the root as in Fig. 55. Make a drawing of the surface thus exposed, naming the parts. If human teeth cannot be obtained, almost any kind will serve. Let each pupil keep his preparation.

Structure of a Tooth. — 1. The pulp cavity, communicating with a hole in the tip of the root, through which the nerve and blood tube entered.

2. The bulk of the tooth is made up of a substance called dentine (ivory).

3. The crown of the tooth has a covering of enamel, a very hard substance.

4. The root is covered with a bony substance called cement.

The Kinds of Teeth and their Arrangement. — Beginning at the middle of the front of the mouth, there are (in the normal adult) eight teeth in each half jaw: two incisors, one canine, two bicuspids (or premolars), and three molars.

Dental Formula. — The kinds and arrangement of teeth are often expressed by a dental formula, in which the numerators indicate the upper jaw and the denominators the lower, thus: $I\frac{2}{2}$, $C\frac{1}{1}$, $PM\frac{2}{2}$, $M\frac{3}{3}$ (for one side of the head).

Incisors. — The crown of an incisor is chisel shaped; but the root is flattened in the opposite direction, *i.e.* at right angles to the jaw, instead of parallel to it, as is the case with the crown. Look at a skull from which the teeth have been extracted in order to see the cavities into which the teeth fitted.

Canines. — The canine tooth has a conical crown, and a longer root than the incisor.

Bicuspids. — The bicuspid has two points.

Molars. — The molar has a cuboidal crown, and usually two or three roots.

The Milk Teeth. — The thirty-two teeth of the permanent set were preceded by a temporary set of twenty milk teeth. Because the first set is temporary it should not therefore be neglected. Cavities in these should be filled and the teeth kept clean. Before the temporary set has gone the first of the permanent set appear. The first of

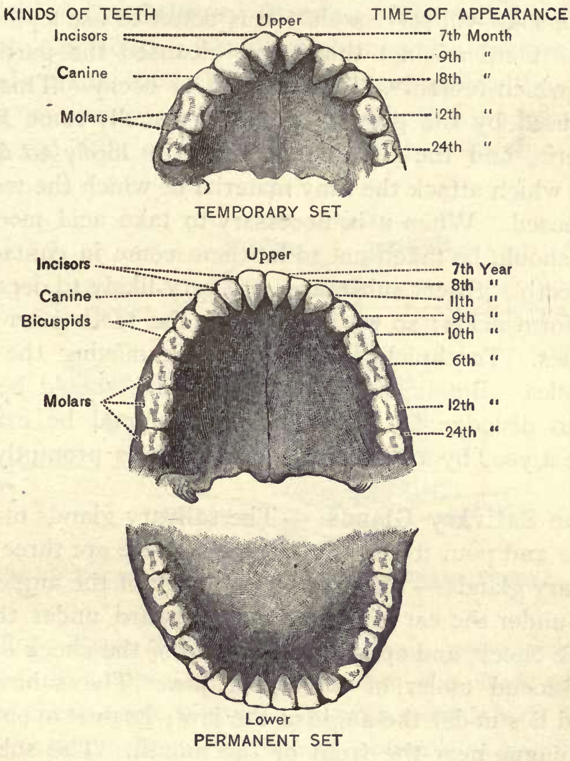


Fig. 56. TEETH: Kinds, Arrangements, and Times of Appearance.

these, often called the "six-year molars," are just back of the hindermost "milk molars." These should receive especial care, as they will never be replaced. Any beginning of decay in them ought to receive prompt attention.

The Care of the Teeth. — The teeth need careful attention. They should be thoroughly brushed at least twice a day, on rising and on going to bed. It would be better to clean them after each meal also. If a tooth powder, recommended by a reliable dentist, is not used, a good white castile soap will serve well. It is better to use tepid water. If the teeth are not thoroughly cleansed the particles of food which remain will soon begin to decay. This decay is caused by the growth of germs, usually some kind of bacteria, and the decay thus begun is likely to develop acids which attack the limy material of which the teeth are composed. When it is necessary to take acid medicines, care should be taken not to let them come in contact with the teeth. Sweet substances are very likely to decompose and form acids; so we must clean the teeth after eating candies. Toothpicks are useful in removing the larger particles. But in using toothpicks care should be taken not to dislodge fillings. The teeth should be examined twice a year by a dentist, and any cavities promptly filled.

The Salivary Glands. — The salivary glands make the saliva and pour it into the mouth. There are three pair of salivary glands — the parotid, just back of the angle of the jaw, under the ear; its duct runs forward under the skin of the cheek, and opens on the inside of the cheek opposite the second molar of the upper jaw. The submaxillary gland lies under the angle of the jaw; its duct opens under the tongue near the front of the mouth. The sublingual gland is in front of the submaxillary and empties near the same place as the submaxillary.

Dissection of the Salivary Glands. — The salivary glands of a rabbit or cat may be found near the base of the ear and under the angle of the jaw by removing the skin from the side of the head and neck.

Salivary Ducts in Our Mouths. — If the inside of one's cheek be examined by the use of a hand mirror, the opening of the duct from the parotid gland may be seen opposite the second molar of the upper jaw. It usually looks like a pink and white spot, resembling a wound of a bee sting. Sometimes saliva may be seen issuing from it.

Action of the Salivary Glands. — The salivary glands pour into the mouth a liquid which they manufacture from materials taken from the blood. In structure the gland may be compared to a bunch of grapes, the grapes representing the little cavities, with a wall of cells that make

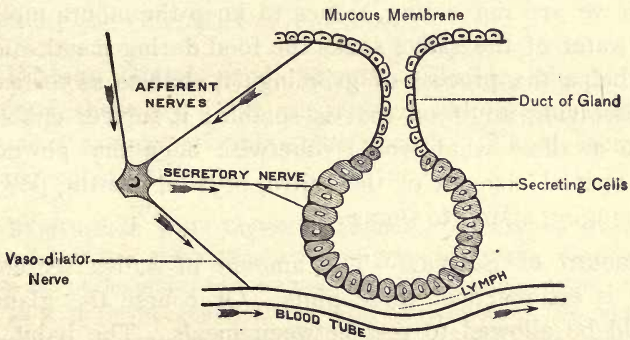


Fig. 57. Diagram of a Salivary Gland. (After Landois and Stirling.)

the saliva. From these cavities the liquid passes into the individual duct, represented by the stem of a single grape; many of these unite to form the main stem, which corresponds to the main duct. A rich network of capillaries surrounds the gland; when the gland is at work it receives more blood; the liquid part of the blood (plasma) soaks out through the capillary walls and surrounds the gland; it is now called lymph; from the lymph the gland directly obtains its material.

Nerve Control of Salivary Glands. — The glands are doubly dependent on nerve control: —

1. Through the control of the arterial muscles by the nerves the amount of blood sent to the glands is regulated.

2. Nerves also go to the cells of the gland to control their activity. When we taste, smell, see, or even when we think of, some delicious food the mouth may "water," as we say, *i.e.* the salivary glands are, by reflex action, stimulated to activity; on the other hand, some emotions, such as fear, check the flow of saliva.

Saliva and its Uses. — The saliva is mostly water, and, when we are not eating, serves to keep the mouth moist. The water of the saliva soaks the food during mastication and helps the process of grinding; it enables us to taste by dissolving any food that is soluble; it further enables us to swallow what would otherwise be a dry powder. The special element of the saliva, ptyalin, has the power of changing starch to sugar.

Amount of Saliva. — The amount of saliva secreted daily is estimated at three pints. Of course the glands should be allowed to rest between meals. The habit of chewing gum, though supposed to aid digestion, undoubtedly does far more harm than good. During the resting period the glands accumulate material for the active work of secretion, for there is no sac in which to store the saliva, and it must be made as fast as it is needed.

Character of Salivary Ferment. — "The character of action of salivary ferment is further defined by experiments showing: 1, that it is destroyed by boiling; 2, that its action is delayed or suspended at a low temperature, most pronounced at about body temperature (37° C.); 3, that it acts best in a neutral or in a faintly alkaline medium, not at all in an acid medium, or in too strong an alkaline medium; 4, that it has almost indefinite power, if the product of its own action (sugar) is not suffered to accumulate. In all these respects, with the exception of the third, the salivary ferment resembles ferments in general, which are destroyed by heat, delayed by cold, and are limited in their action only by the accumulated product of such action." — WALLER.

Enzymes. — Ptyalin is a type of a group of bodies called unorganized ferments, or enzymes. These ferments are the agents that produce the peculiar chemical changes that are the chief part of digestion.

Mucous Glands and Mucus. — Besides the salivary glands, there are great numbers of simple glands in the mucous membrane lining the mouth. These secrete a glairy substance called mucus.

Experiments with Digestive Liquids. — It may be proved by experiment that saliva turns starch to grape sugar in an alkaline solution and at the proper temperature. Also that pepsin dissolves proteids in an acid (hydrochloric) at the right temperature. The proteid is turned to peptone, and becomes soluble and diffusible, capable of absorption through the walls of the stomach and intestine. We find that the different elements of the pancreatic juice can, in alkaline solution, and at the right temperature, emulsify fats, turn proteid to peptone, and convert starch into grape sugar.

The Pharynx. — The cavity back of the mouth, beyond the soft palate, is the pharynx. The pharynx is a funnel-shaped cavity, communicating above with the passages from the nostrils; in front it opens into the mouth; below it connects with the windpipe, through the glottis, and with the gullet, which, as we have seen, lies just back of the windpipe.

Position of Organs during Respiration. — In quiet respiration the tongue nearly fills the mouth. The base of the tongue is nearly covered by the soft palate, which curves downward from the hard palate, and by the epiglottis projecting upward from below. The glottis is open and the gullet is closed. Air enters the nostrils, passes along the nasal passages above the hard palate, back of the soft palate and epiglottis, through the open glottis into the windpipe, and on to the lungs.

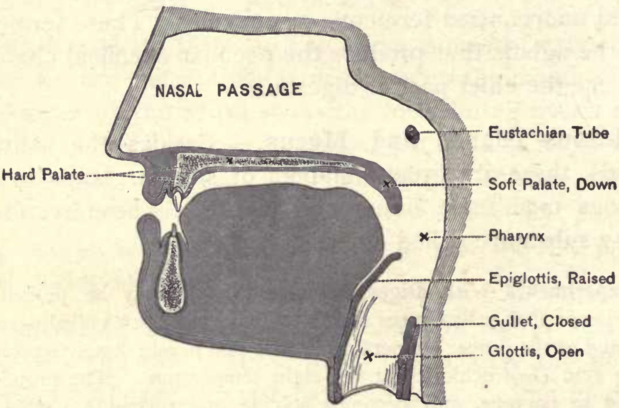


Fig. 58. Diagram, showing the Positions of the Organs of the Mouth and Throat during Breathing.

The Process of Swallowing. — When the morsel of food is ready to be swallowed the tongue pushes it back into the pharynx; the soft palate is raised to shut off the passage into the nasal cavity; the larynx is pulled upward and forward; the epiglottis is pulled down over the glottis, or opening of the windpipe; and the base of the tongue extends back over the epiglottis; thus the air passages, above and below, are shut off, and the food passes over the epiglottis into the gullet. The muscles of the pharynx also do their part in pushing the food along. As soon as the food has passed over the epiglottis, the epiglottis rises to its upright position, and the soft palate drops back to its place, leaving the air passages again open.

Breathing and Swallowing. — It is to be observed that the food tube and the air tube cross, and that the pharynx is their crossing. As we are swallowing only a small part of the time, the passageway naturally stands open to the air; and when we swallow, the parts are, by muscular

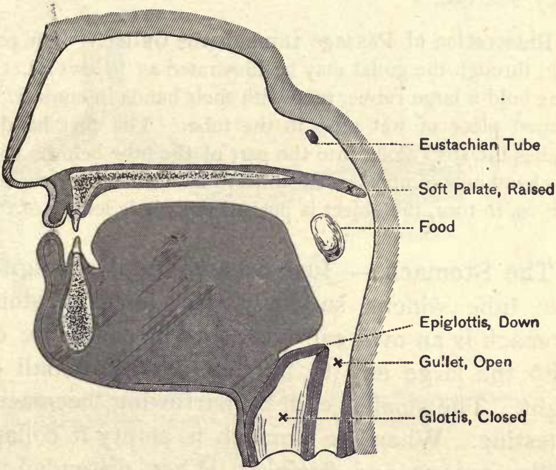


Fig. 59. Diagram, showing the Positions of the Organs of the Mouth and Throat during Swallowing.

effort, temporarily adjusted for this work. There is a spring switch (to borrow a term from the railway) which keeps the track open for the air, which is all the time passing; but when the food comes along, the switch must be held open for it until it has passed.

Structure and Action of the Gullet. — The gullet has an outer muscular coat and an inner mucous coat. The muscular coat has two layers, an inner with circularly arranged fibers, and an outer layer with longitudinally arranged fibers. When the food enters the gullet the muscle fibers, especially the circular fibers, shorten, and by a wave-like action push the mass rapidly along into the stomach. The first part of swallowing is voluntary; but after the bolus has entered the gullet the action is involuntary. The mucous lining of the gullet has many mucous glands which lubricate the passageway by the mucus which they secrete.

Illustration of Passage through the Gullet. — The passage of the food through the gullet may be illustrated as follows: Let several persons hold a large rubber tube with their hands in contact. Put an egg-shaped piece of wet soap in the tube. The first hand is shut and pushes the soap along into the part of the tube held by the next hand; this hand now compresses the tube, while the first hand remains clinched; and so, in turn, the object is pushed the whole length of the tube.

The Stomach. — Just beyond the diaphragm the digestive tube widens suddenly, forming the stomach; the stomach is an oval sac lying just beneath the diaphragm, with the large end to the left and the small end to the right. The smaller end, by narrowing, becomes the small intestine. When the stomach is empty it collapses, as its walls are soft and flexible. When distended it may hold three pints, or when abnormally distended even more.

The Coats of the Stomach. — The stomach and intestines have four coats, in the following order, beginning at the outside: the peritoneum, the muscular, the submucous, and the mucous coats. The muscular coat of the stomach consists of three layers, distinguished by the arrangement of the fibers, a circular layer, a longitudinal layer, and an oblique layer. The mucous lining is somewhat loosely attached to the muscular coat by the intervening submucous coat, and when the stomach collapses the mucous coat is thrown into folds, usually running lengthwise.

The Gastric Glands. — In the inner surface of the mucous membrane are many holes. These are the mouths of the ducts of the gastric glands. If a duct is traced inward, it is found to divide into several branches, usually two or three. These gastric glands vary somewhat in their structure in different parts of the stomach.

The Gastric Juice. — The liquid secreted by the different glands also varies considerably, but the liquid as a whole is called the gastric juice. The gastric juice is

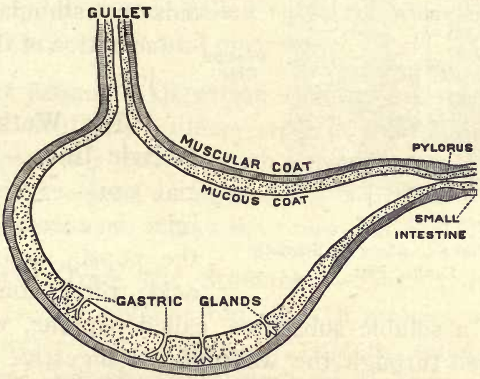


Fig. 60. Longitudinal Section of Stomach, showing Gastric Glands in Position. (Dorsal View. Mucous Coat Unduly Thickened.)

chiefly water, containing a ferment, or enzyme, called pepsin, and a small amount of acid. The amount of gastric juice secreted daily has been estimated at from five to ten quarts. Of course, we must bear in mind that nearly all of this is again absorbed from the digestive tube, and is not a permanent loss to the body.

Blood Supply of the Stomach. — The mucous membrane is abundantly supplied with blood tubes, but during the time of its rest the blood flow here is diminished, and the membrane is comparatively pale. But as soon as food is introduced into the stomach the blood flow is greatly increased, and the mucous membrane becomes red. This blood supply gives the glands the materials with which they manufacture the gastric juice. At the same time the cells of the glands are stimulated to action, and the secretion is poured out rapidly. The alkaline saliva also aids in stimulating the secretion of the gastric juice.

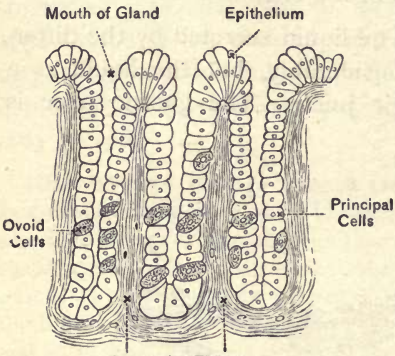


Fig. 61. Three Glands of the Stomach — Cardiac Part.

The Work of the Gastric Juice.—The special work of the gastric juice is accomplished by the pepsin, aided by the acid; these convert proteids into a soluble substance, called peptone, which can be absorbed through the walls of the digestive tube into the blood.

Rennet and Rennin. — Rennet, used in cheese making, is a familiar substance obtained from the fourth stomach of the calf. When milk enters the stomach it is curdled; that is, the casein previously dissolved in the liquid milk is coagulated. This curdling, or coagulation, is attributed to a ferment in the gastric juice called *rennin*, and it seems to be entirely distinct from pepsin.

Churning Action of the Stomach. — At the same time all the food is soaked by the gastric juice, the process being greatly assisted by the churning motion of the stomach caused by the action of the muscular coat. The food is thus gradually reduced to a pulpy mass called chyme.

During the first part of digestion in the stomach the thick ring of circular fibers called the pylorus (gatekeeper) around the opening of the stomach into the intestine keeps the passage nearly closed, leaving a small orifice for liquids only. But as the food is reduced to the proper condition the pyloric muscles relax and allow the chyme to pass into the intestine. And at last any indigestible substances are usually allowed to pass.

Sphincter Muscles. — Such rings of muscular fibers, guarding openings, are called sphincter muscles. There is a similar one at the anal opening.

Time of Stomach Digestion. — The time required for the digestion of any ordinary meal is from three to four hours, though this may be much longer if very indigestible substances have been eaten, or if the condition of the body or mind is such as to retard the process of digestion.

Absorption from the Stomach. — Some parts of the food that are already digested, or such matters as are soluble, *e.g.* water containing sugar, peptone, salts, etc., may be absorbed immediately through the walls of the mouth and stomach into the blood capillaries. Recent experiments show that the amount of absorption from the stomach is much less than was formerly supposed; water, for instance, "when taken alone, is practically not absorbed at all in the stomach. As soon as water is introduced into the stomach it begins to pass out into the intestine, being forced out in a series of spurts by the contractions of the stomach."

Chyme. — The rest of the food, now called chyme, is passed on into the small intestine. It is acid, and in a liquid or semiliquid condition. Chyme, as it enters the intestine, is a mixture of digested, partly digested, and un-digested materials. Some of the starch has been changed to sugar, but only a small part, owing to the short time of mastication. The bulk of the starch is unchanged. Some of the proteid is already changed to peptone. Part is still proteid, while part is in an intermediate stage between proteid and peptone. Fat is essentially unchanged, but is melted by the heat of the mouth and stomach, and is more or less divided into small drops by mastication and the movements of the stomach. For instance, in eating bread and butter, the melting butter will be finely mixed with the bread as it is chewed. The water in the chyme was partly taken as such, and partly derived from the saliva and gastric juice. There are also present ptyalin, pepsin, mucus, salts, and some indigestible substances. At intervals the sphincter muscles of the pylorus relax, and the contractions of the stomach send the liquid mixture into the intestines by spurts.

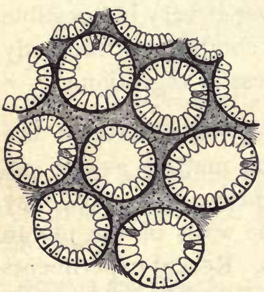


Fig. 62. Horizontal Section through the Mucous Membrane of the Intestine, showing Intestinal Glands in Transverse Section. (Highly Magnified.)

The Intestine. — The small intestine has essentially the same structure as the parts of the digestive tube already studied, namely, a mucous lining beset with an immense number of tubular glands, called intestinal glands. These secrete a liquid collectively called the intestinal juice, whose exact work is not well known, but which may be said to complete the work of the other secretions. The intestine has also a muscular coat with circular and longitudinal fibers. And the muscular coat does the same work of mixing the juices with the food and of moving it along.

Bile and Pancreatic Juice. — Soon after the chyme enters the small intestine it has poured upon it two liquids, which enter the intestine in one common stream; these are the bile and the pancreatic juice. These juices come from two large compound glands, the liver and pancreas,

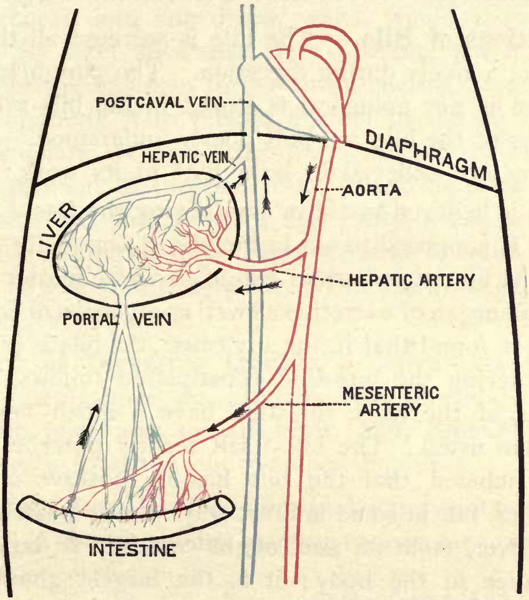


Fig. 63. Diagram of Portal Circulation.

that lie close to the stomach. Their ducts join before they enter the intestine into which these juices are emptied a few inches beyond the stomach.

The Portal Circulation. — The liver receives blood from two sources, — a branch of the aorta and the portal vein. The portal vein is formed by the union of veins from the stomach, intestine, pancreas, and spleen. Unlike other veins, the portal vein divides and subdivides, forming capillaries which ramify through the liver. The blood is again collected by veins, forming the hepatic vein which empties into the postcaval vein close to the diaphragm. From the blood the liver manufactures at least two important substances, — the bile and liver starch, or glycogen.

Functions of Bile. — The bile is secreted all the time, but more actively during digestion. The part made while digestion is not going on is stored in the bile sac. The functions of the bile are still poorly understood. But the following are believed to be a part of its work: —

1. It is believed to aid in emulsifying the fats.

2. It is supposed to aid in the absorption of fat.

3. The bile, to a certain extent, is waste matter; so the liver is an organ of excretion as well as an organ of secretion.

4. It is found that if, for any cause, the bile is prevented from entering the intestine, constipation follows, and the contents of the large intestine have a much more fetid odor than usual. The bile itself readily putrefies; hence it is concluded that the bile has no positive antiseptic properties, but in some indirect way retards putrefaction.

The liver, from its size, ought certainly to be of great importance in the body; it is the largest gland in the body, and receives one fourth of the blood.

The Work of the Pancreatic Juice. — The pancreatic juice acts on all the principal classes of foodstuffs: —

1. A ferment in it called amylopsin acts on starches, changing them to sugar, even more energetically than the ptyalin of the saliva.

2. Another constituent of pancreatic juice is trypsin; like the pepsin of gastric juice, this ferment has the power of changing proteids to peptones.

3. The pancreatic juice also acts on the fats in two ways: —

(*a*) It emulsifies them, *i.e.* the fat is divided into exceedingly fine drops, each enveloped in a coating of albuminous substance. An emulsion can be made artificially by shaking together water, oil, and white of egg. The shaking breaks the oil into fine drops, which would soon gather again if no other substance were present; but it is supposed that the albumen forms a thin coating around each droplet, enabling it to remain distinct in the liquid.

(*b*) The fats are also acted on chemically by steapsin, another ferment of the pancreatic juice; they are decomposed with the formation of free fatty acids, and thus more fully prepared to be absorbed and to build up the tissues. These free fatty acids aid in the work of emulsifying the rest of the fat.

Review of Digestive Liquids. — Saliva acts only on starch, gastric juice on proteids, bile on fats, whereas pancreatic juice acts on all three, and, probably, more energetically than the above-named liquids.

Intestinal Juice. — The intestinal juice contains a ferment, called invertin, which changes cane sugar to dextrose which is a variety of grape sugar.

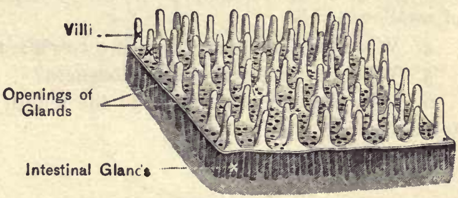


Fig. 64. Mucous Membrane of Small Intestine

Acids and Alkalies in Digestion. — The bile and the pancreatic juice are alkaline, and overcome the acidity of the chyme, as the acidity of the gastric juice in the stomach overcame the alkalinity of the saliva.

Summary. — 1. The chief work in digestion is to render the food liquid, soluble, and in condition to be absorbed and become part of the blood.

2. The digestive system consists of a long tube, through which the food passes, being subjected to mechanical and chemical processes to liquefy and otherwise make the food ready to become blood.

3. The teeth grind the food.

4. The food is soaked and acted on by the saliva, gastric juice, intestinal juice, bile, and pancreatic juice.

5. These liquids are formed from the blood by glands. A gland is a structure, usually tubular or saclike, surrounded by capillaries, which give off lymph around the gland. The gland cells take part of the lymph and form the "secretion," which is usually poured out on a surface by means of a narrow tube, or duct.

6. The salivary glands, pancreas, and liver are compound glands. The gastric and intestinal glands are simple.

7. The first part of swallowing is voluntary. Through the gullet the food is pushed by the shortening of the circular muscle fibers.

8. The liver receives blood from the hepatic artery and from the portal vein, but is drained by one vein, the hepatic, which empties into the postcaval vein.

9. Saliva acts only on starch, gastric juice on proteids, bile on fats; pancreatic juice acts on all three of these foodstuffs.

Questions. — 1. Why does the physician examine the tongue of his patient?

2. What is the "mumps"?

3. Why is one more likely to choke if he thinks about the process of swallowing?

4. What are the peculiarities of a cow's stomach?

5. What is the meaning of biliousness?

6. Why is there a difference in the length of the intestine in a cat and a sheep?

7. What is colic?

CHAPTER XI.

ABSORPTION — DIGESTION COMPLETED.

Absorption. — The mucous membrane of the small intestine is thrown into ridges, but, unlike those of the stomach, they run transversely. Again, while the folds in the lining of the stomach are temporary, these are permanent. They serve to increase the surface of the lining, and to retard the passage of the food material, and so to aid the process of digestion and of absorption.

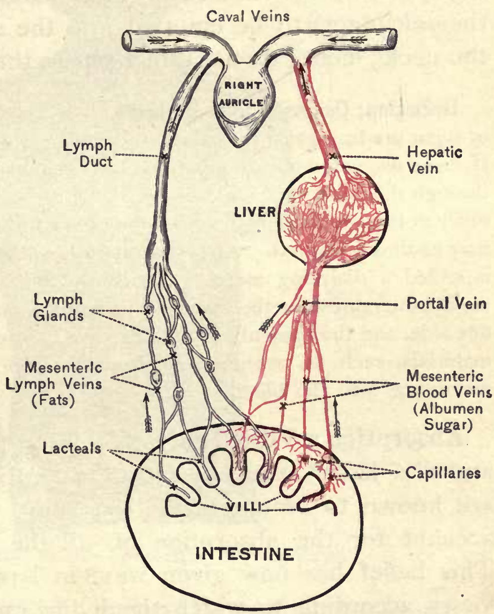


Fig. 65. Plan of Absorption.

Villi. — Further, the surface of the mucous membrane of the small intestine is thickly beset with little cylindrical projections, like the "pile" on velvet. These projections are called villi (singular, villus). The villi greatly increase the absorbing surface of the small intestine. In each villus is a network of blood capillaries, and the beginning of lymphatic capillaries called lacteals.

Routes of Different Foods after Absorption. — In the villi the largest part of the work of absorption is done. The fats are absorbed by the lymph capillaries, or lacteals, and the rest of the foods by the blood capillaries. It should be carefully noted that nearly all of the foods but the fats go at once to the liver, through the portal vein; but the fats are carried by the main lymph duct (the thoracic duct) to be emptied into the subclavian vein in the neck; hence do not directly pass through the liver.

Diffusion, Osmosis, and Dialysis. — If a solution of salt and one of sugar are brought into contact, they will gradually mix by *diffusion*. If these two solutions are separated by parchment, they will still diffuse through the membrane and mingle. This is *osmosis*. Since substances differ in the readiness with which they pass through a membrane, they may be thus separated. Such separation is *dialysis*, and the membrane is called a dialyzing membrane. In the digestive tube the mucous membrane represents the dialyzing membrane with blood or lymph on one side, and the contents of the digestive tube on the other. Soluble materials, such as peptones, sugars, etc., pass through the mucous membrane into the blood.

Absorption a Vital Process. — "The process of osmosis, and to a lesser extent of filtration and imbibition, as they are known to occur outside the body, were supposed to account for the absorption of all the soluble products. This belief has now given way, in large part, to newer views, according to which the living epithelial cells take an active part in absorption, acting under laws peculiar to them as living substances, and different from the laws of diffusion, filtration, etc., established for dead membranes.

"Unlike sugars and peptones, fats are absorbed chiefly in a solid form — that is, in an emulsified condition. There can be no question, in this case, of osmosis. It has been shown by nearly all recent work that the immediate agents in the absorption of fats are again the epithelial cells of the villi of the small intestine. The fat droplets

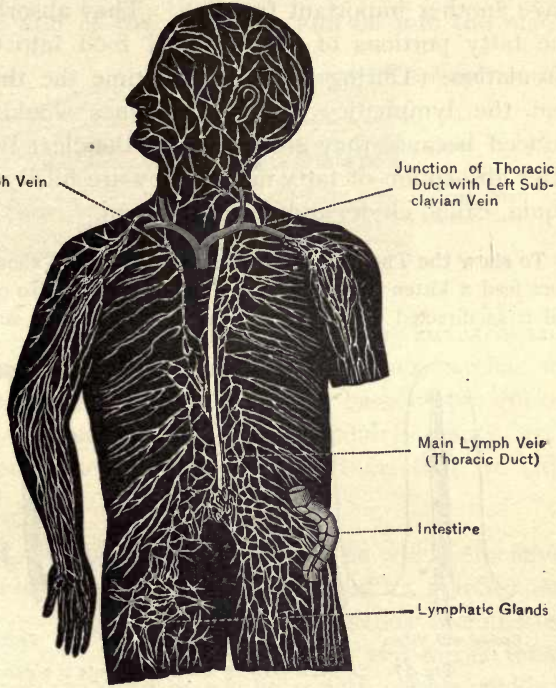


Fig. 66. Lymph Veins — Lymphatics. (Ventral View.)

are taken up by these cells, and can be seen microscopically after digestion in the act of passing, or rather of being passed, through the cell substance. The epithelial cells, in other words, ingest the fat particles lying against their free ends, and then pass them slowly through their cytoplasm into the substance of the villus." — HOWELL.

The Lacteals and Lymphatics. — While the main work of the lymphatics, as we have seen, is the carrying of lymph from the tissues of the body generally to empty into the veins of the neck, the lymphatics of the intestines have another important function. They absorb and carry the fatty portions of the digested food into the general circulation. During most of the time the thoracic duct and the lymphatics of the intestines would hardly be noticed because they are filled with the clear lymph. But after absorption of fatty matter they are filled with a white liquid, called chyle, and are easily seen.

To show the Thoracic Duct and Lacteals. — To show the thoracic duct feed a kitten or puppy on rich milk, and after two or three hours kill it as directed on page 27. As soon as you are sure it is dead,

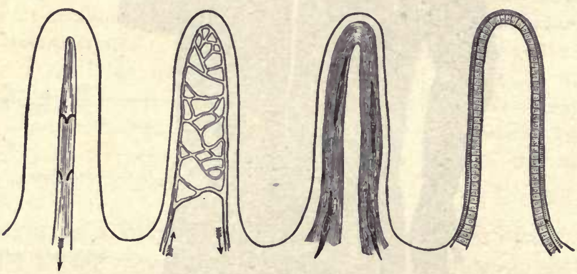


Fig. 67. Elements entering into the Structure of a Villus.

open the abdominal cavity and spread out the mesentery. The white lacteals, filled with chyle, will be seen radiating through the mesentery. Press on some of these, and it will be seen that they are thin tubes filled with a white liquid. They converge toward the place of attachment of the mesentery to the dorsal part of the abdomen. On the dorsal wall of the abdomen, just posterior to the diaphragm, the receptacle of the chyle, or the beginning of the main lymph vein (thoracic duct), should be found. Trace it anteriorly through the chest alongside the aorta to its mouth, near the junction of the left subclavian and jugular veins.

Action of the Villi. — In each villus there are plain muscle fibers. When these shorten they squeeze the chyle, that has already been absorbed, into the lymph tubes of the wall of the intestines, and on into the main

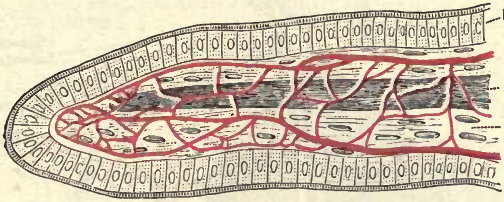


Fig. 68. Intestinal Villus.

lymph duct. The chyle cannot return to the lacteal when the muscles relax, on account of the valves, similar to those of the veins, in the lacteal at the base of the villus. Then, when the muscles relax, the lacteal is empty, and ready to absorb more of the emulsified fat that we call chyle.

Review of the Digestive Tube. — The whole digestive tube may be briefly and roughly described as a muscular tube of varying diameter, lined by mucous membrane. The muscular coat propels the contents and mixes them with liquids; the mucous coat is beset with glands, making liquids, some of which merely soak the food, others act on it chemically, while mucus serves to lubricate the surface. It seems that these myriads of simple glands are not enough, so several large compound glands lie alongside the food tube and empty their secretions into it by ducts; these supplementary glands are the salivary glands, the pancreas, and the liver.

Length of the Intestine. — The length of the small intestine is about twenty-five feet, and of the large intestine

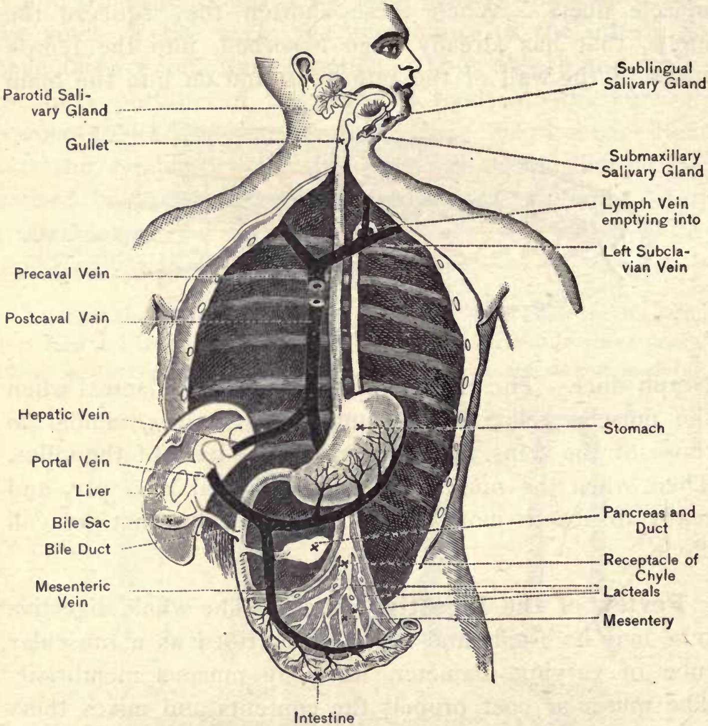


Fig. 69. Diagram of the Organs Concerned in the Conversion of Food into Blood.

five or six feet. The large intestine is not a direct continuation of the small; that is, the small intestine opens at a right angle into the large near the beginning of the latter, so that there is a short blind end called the cecum.

In some animals this is large and has considerable length, but in man it is very short. It seems to have been longer in man's ancestors, for there is a closed prolongation of the cecum, the vermiform appendix. This appendix is frequently the seat of serious or fatal inflammation, called appendicitis.

PARTS OF DIGESTIVE TUBE.	MECHANICAL PROCESSES.	GLANDS.	LIQUIDS.	CHEMICAL CHANGE.	ABSORPTION.	
					MATERIAL	BY
MOUTH.	Cutting and Grinding.	Salivary.	Saliva.	Starch to Sugar.		
PHARYNX.	Raising Soft Palate. Depressing Epiglottis.					
GULLET.	Food carried to Stomach.	Mucous.	Mucus.			
STOMACH.	Churning and Mixing.	Gastric.	Gastric Juice.	Proteid to Peptone.	Water. Salts. Sugars. Peptones.	Blood Capillaries.
SMALL INTESTINE.	Mixing and Moving Food.	Liver. Pancreas. Intestinal.	Bile. Pancreatic Juice. Intestinal Juice.	Starch to Sugar. Proteid to Peptone. Fats { Emulsified. Decomposed.	Water. Salts. Sugar. Peptone. Fats.	Blood Capillaries Lacteals.
LARGE INTESTINE.	Food Forced on.	Mucous.	Mucus.		Water.	

Fig. 70. Outline of Digestion.

The Colon. — The small intestine joins the large near the lower right side of the abdomen. The main part of the large intestine is called the colon. It runs upward (ascending colon), crosses over to the left side (transverse colon), and descends the left side (descending colon), and, after curving somewhat like a letter S (sigmoid flexure), terminates in the rectum. It is well to know the course of the lower bowel, as pressure may be so applied as to push the contents along in case the bowels become torpid.

The Work of the Large Intestine. — Most of the absorption is accomplished in the small intestine; but as the food passes on into the large intestine the work of digestion and of absorption are carried somewhat farther. If the residue be not soon expelled, there may be absorption of some of the results of putrefactive changes, and a sort of general poisoning of the whole body. Hence the great importance of regularly and thoroughly emptying the lower bowel. The matter thus expelled is largely made up of indigestible material, with some real waste substances.

Taking up again our comparison of the body and a furnace, we see that the feces are not true waste products, but are rather clinkers, or material that has not been burned or oxidized in the body. The real wastes of the body are the carbon dioxid, urea, water, etc., that are thrown off by the lungs, kidneys, and skin.

Constipation. — This is a very common disorder, and the evils attendant upon it are many. Of course, if any trouble is long continued or severe, a physician should be consulted. But it is well known that certain foods tend to bring on such a condition, and that other foods have the opposite tendency. Thus, cracked wheat and oatmeal are generally considered as somewhat laxative in their effects. The fruits generally are laxative. The coarse particles of graham flour are irritating to the mucous lining of the stomach and intestines, and for many persons serve well to stimulate the action of the bowels. But in many persons the mucous coat is so sensitive that it cannot bear such irritation. For these the "entire wheat flour" may serve the same purpose. Of course each person finds out by his own experience what is best for him, and no rules can be laid down that will apply to all cases. But it may be well to know what is the usual effect of some of the common articles of food, as perhaps some persons may habitually partake of certain articles and do not suspect that they are the cause of the trouble. The following list is taken from Stockham's *Tokology*: —

LAXATIVE.	CONSTIPATING.
Rolled and cracked wheat bread, gems, biscuit, griddlecakes.	Hot bread.
Crackers and mush from flour of the entire wheat and graham flour.	White bread.
Granula.	White crackers.
Bran gruel and jelly.	Black pepper and spices.
Fruit puddings.	Pastry made of white flour and lard.
Fruit pies.	Bread, rolls, dumplings, etc., made with baking powder.
All fresh acid fruits, including tropical fruits, like bananas, oranges, lemons, etc.	Cake.
Dried fruits.	All custard puddings.
French prunes and prunellas, eaten raw.	Salted meats.
Stewed dried fruits containing hydrocyanic acid, of which peaches, plums, and prunes are the best.	Salted fish.
New Orleans molasses.	Dried meats.
Rhubarb.	Dried fish.
Onions.	Smoked meats.
Celery.	Poultry.
Tomatoes.	Cheese.
Cabbage, raw.	Chocolate.
Corn.	Cocoa.
Squash.	Boiled milk.
Cauliflower.	Tea.
Green peas.	Coffee.
Spinach.	Coffee made of wheat, corn, barley, toast, etc.
Beets, etc.	Beans (dried).
Liver.	Potatoes.
Oysters.	Farina.
Wild game.	Sago.
	Starch.
	Tapioca.
	Rice.
	Raspberries.
	Blackberries.

Hygiene of Digestion. — A prime requisite for a good digestion is a tranquil condition of the whole body, especially of the nervous system. We see that the blood must be massed in the digestive organs at the time of digestion. As there is a limited amount of blood in the body, it is evident that if more is sent to one part, other parts must at the time receive less. If we try to study hard immediately after eating, we are calling the blood away from the organs of digestion, and to that extent interfering with the process of digestion. If we exercise the muscles too vigorously soon after eating, we call the blood to the muscles, and so call it away from the stomach and intestines. If, after prolonged study, one is unable to obtain sleep, it may sometimes be efficacious and very desirable to eat a little of some very simple food for the purpose of drawing off the blood to the stomach, and thus relieving the brain. A little muscular exercise may accomplish the same result, or a footbath may be employed. For many persons it would probably be better to take a simple lunch than to go to bed hungry, although one should be careful not to abuse the stomach.

It is exceedingly difficult to lay down general rules in regard to diet. To a certain extent each person must be a law unto himself, for what agrees well with one may act almost as a poison to another. Moderation should always be observed, especially in taking foods to which we are not accustomed.

Solid Foods digest Slowly. — Suppose one were to sit down to eat dinner when ravenously hungry. If in such a condition one begins with solid food, he is likely to eat too fast. Hunger is a demand of the system for food. It takes some time for solid food to go through all the processes of digestion, and be absorbed into the system and appease hunger.

Value of Soup. — But if a soup be first taken, which is readily absorbed, the demand of the system will begin to be met, and there will not be the same tendency to rapid eating. Further, a warm soup stimulates the blood flow in the mucous membrane, and thus prepares for more thorough digestion. It is more easy after a soup to deliberately masticate the solid portion of a meal.

Desserts. — Dessert and sweatmeats, following a meal, are often very helpful by further stimulating the secretion of the glands. Nuts, which are not very digestible, are beneficial if eaten sparingly. The agreeable taste stimulates the salivary glands, and the alkalinity of the saliva stimulates the gastric glands to increased activity. The same may be said of cheese.

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

Pie. — The average pie needs some extra help for its digestion. Donoghue, formerly champion long-distance skater, when asked if he dieted in preparation for a race, said he avoided pastry. If the vigorous digestion of a man skating for hours daily in zero weather cannot profitably manage pie, how in the case of sedentary persons? If pie is eaten, it should be masticated with very great thoroughness. Undoubtedly most persons would be better off if they did not eat puddings and pastries. Fruit is best taken before meals, especially before breakfast.

Hot Drink at Meals. — Hot drink, with a meal, whether it be tea or coffee, or simply hot water, is usually beneficial; especially to a weak digestion when taken before meals.

The Bad Effects of Imperfect Mastication. — If we swallow food before it is thoroughly ground and mixed with the saliva, the stomach and other parts of the digestive organs will require much more time to reduce the food to a liquid form. Further, when eating hastily, we are very apt to eat too much. Thus we may give the stomach a double amount of material to handle, and the material may not be half so well prepared as it should be. The work thus thrown upon the stomach may easily be made fourfold. Of course the organs suffer, and, sooner or later, if this treatment is continued, they must break down.

Effect of Repose on Digestion. — Not only mastication, but the whole process of digestion, goes on better when the body and mind are at rest and in a peaceful and contented condition, as not only the salivary glands, but all the glands, are under the control of the nervous system, and are greatly influenced by the condition of the body. During a meal, and for a short time before and after, all thoughts of one's occupation, and especially all anxiety, should be absolutely dismissed from the mind. For those whose digestion is not strong, it is especially desirable to secure a period of rest after each meal, taking a lounge or easy-chair, closing the eyes, and, as nearly as possible, closing the mind; for some, even a short nap is very helpful.

Conversation at Meals. — During a meal there should be conversation on topics of general interest. "Chatted food is already half digested."

Deliberation in Eating. — It is said that the people of the United States are nervous, and eat, as they do nearly everything, hastily. Deliberation in eating adds to dignity as well as health, and properly may be considered an evidence of culture.

Time of Eating. — Probably our almost universal custom of three meals a day, resulting from experience, is well adapted to the needs of our people. Theoretically the chief meal should be near the middle of the day, as is the custom in the country; for the bodily powers are higher than later in the day. But for city people, and others who are very busy in the middle of the day, it is undoubtedly better to take the chief meal after the rush of the day's work is over, when there is time for a deliberate meal and when the mind is free from business cares. For many, too, this is the only time when the whole family can leisurely meet at the table.

Eating between Meals. — The stomach should have time to rest and prepare for the work of digesting another meal. Many find two meals a day sufficient. There are some persons, however, for whom it would be better to have more meals, with less food at each meal. Meals should be regular.

Amount of Food Needed. — This varies greatly with the individual, age, the kind and amount of labor, etc., so that no very helpful rule can be given. Each person must find by experience what is best for himself. It is the opinion of many leading physicians that the majority of mankind eat too much. The fasting enjoined upon some is undoubtedly hygienic; and it would be a valuable lesson for more persons to experiment in the line of fasting.

Errors of Diet. — Sir Henry Thompson, one of the foremost authorities in the world on the subject of foods, says: "I have come to the conclusion that more than half of the disease which embitters the middle and latter part of life is due to avoidable errors of diet; and that more mischief, in the form of actual disease, of impaired vigor, and of shortened life, accrues to civilized man from erroneous habits of eating than from the habitual use of alcoholic drink, considerable as I know that evil to be."

Effects of Alcohol on the Digestive Organs.— While it is a popular delusion that alcoholic drinks aid digestion, careful experiments show that alcohol retards this process; the fact is that alcoholic dyspepsia is one of the most common effects of moderate drinking. The stomach is first acted upon by alcohol; it usually becomes inflamed, and this condition may become chronic. The liver, under the influence of alcohol, develops an abnormal growth of connective tissue, and takes on the characteristic appearance by which it is designated as the "hob-nailed liver."

READING. — *Disorders of Digestion*, Brunton; *Indigestion and Biliousness*, Fothergill; *A Plea for a Simpler Life*, Keith.

Summary. — 1. The hairlike villi lining the small intestine absorb the liquefied food.

2. Sugars and peptones are carried away by the blood capillaries and pass through the liver, but the fats are taken by the lacteals into the lymph stream to join the blood in the subclavian vein.

3. Digestion is greatly influenced by the condition of the nervous system.

4. Mastication should be thorough.

5. Chat at meals is hygienic.

6. Rest after meals.

7. Soups and desserts have a physiological justification, though the latter often become harmful.

8. There is a great amount of suffering from intemperance in eating as well as in drinking.

CHAPTER XII.

NUTRITION.

Ledger Account of the Body and its Organs.—Through the digestive tube and lungs the body receives additions, and there is a corresponding loss through the lungs, skin, kidneys, and intestines. So a ledger account might be kept with the body, and it should balance in the long run, since in adult life the weight remains practically constant.

So we might take a single organ, say the liver, and balance its accounts. It receives a large amount of blood. To offset what it takes from the blood, it gives to the intestines a large quantity of bile, and to the blood it gives glycogen.

It is especially interesting to note the losses and gains of the blood as it passes through the various organs of the body. A river, flowing past one State after another, will take some of the soil of each and deposit some of its muddy particles on the banks of each State. Of course, the blood is unlike the river, in that it empties into itself; *i.e.* it is truly a circulation. The blood takes something from, and gives something to, each organ as it flows through it. From the intestine the blood gets the chief part of its new material in the newly digested food. To the muscles the blood gives nutritive material and oxygen, and receives water, carbon dioxid, and other waste matters. The account would be similar with the brain. In the skin and the kidneys the blood has great losses and little gains.

The accompanying diagrams may help in presenting the main points in the blood circuit, and the losses and gains in its course.

Blood a Mixture of Good and Bad. — In the common blood streams are combined the good and the bad. The

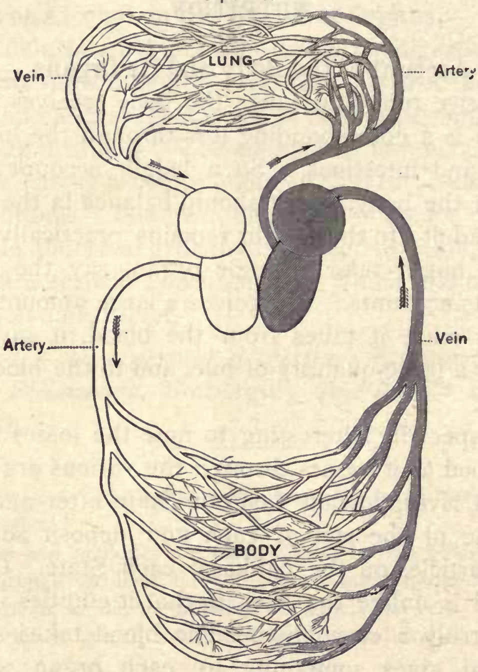


Fig. 71. Diagram of the Heart and Blood Tubes (Dorsal View).

newly digested food is received into a current of impure blood in the postcaval vein. The blood from the kidneys, probably the purest blood in the body, joins the same impure stream. From the aorta, red blood, usually called pure—the same kind that goes to the brain—is sent to the kidneys and to the skin to be purified. Yet, as this mixed blood flows through each organ, that organ, so long as it is in health, takes from it only what it should take

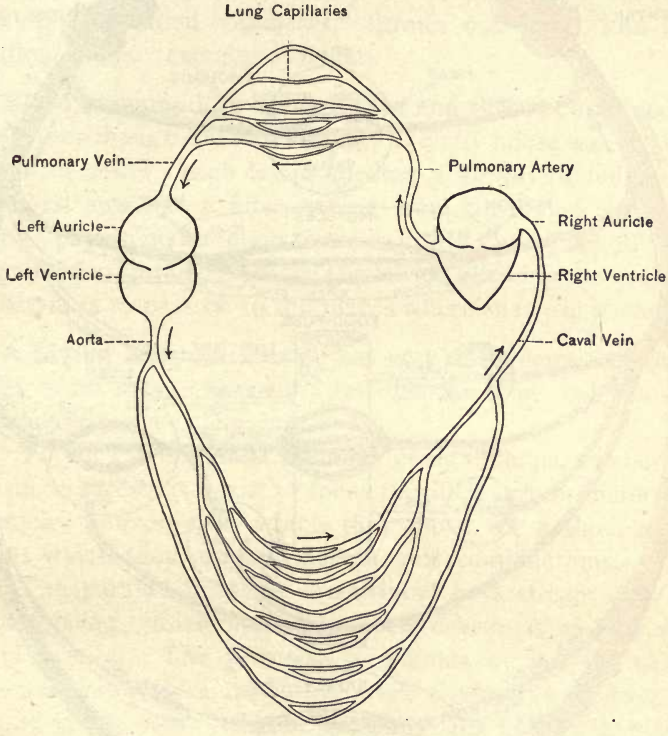


Fig. 72. Diagram of the Circulation, representing the Right and Left Halves separated (as they are in reality), showing that the Blood makes but One Circuit.

Action of Diseased Kidneys.—The kidney takes, during health, only the waste matters, leaving the valuable nourishing material. But, in disease, the kidneys may

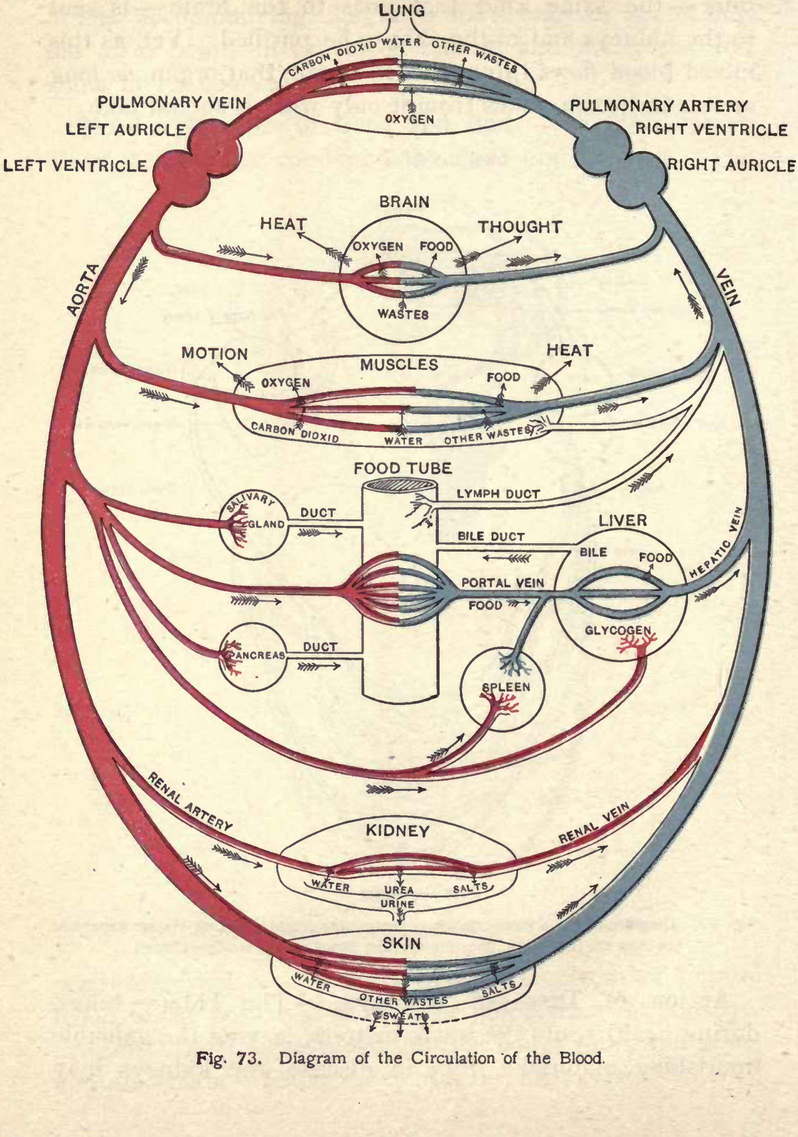


Fig. 73. Diagram of the Circulation of the Blood.

take out some of the most valuable portions of the nutriment. Suppose that in a mill, a workman, whose business is to shovel out wastes, becomes crazy, and shovels wheat or flour out of the mill into the stream below. The diseased kidney may be said to have become crazy, and in the disease called "diabetes" throws out sugar, and in "albuminuria" excretes albumen.

Blood Streams like Water Pipes and Sewer Combined. — It is as though the water supply of a city house was taken from the sewer; each organ needing a supply of building material acts like a filter, taking from the blood what it needs, paying no attention to the impurities present, and the organs of excretion select the impurities, allowing the useful substances to pass on to the places where they are needed.

A Living Eddy. — Huxley has very aptly compared the body to an eddy, whose form remains the same, but whose particles are ever changing.

"To put the matter in the most general shape, the body of the organism is a sort of focus to which certain material particles converge, in which they move for a time, and from which they are expelled in new combinations.

"The parallel between a whirlpool in a stream and a living being, which has often been drawn, is as just as it is striking. The whirlpool is permanent, but the particles of water which constitute it are incessantly changing. Those which enter it on the one side are whirled around and temporarily constitute a part of its individuality; as they leave it on the other side, their places are made good by new comers.

"Those who have seen the wonderful whirlpool, three miles below the Falls of Niagara, will not have forgotten the heaped-up wave which tumbles and tosses, a very embodiment of restless energy, where the swift stream hurrying from the falls is compelled to make a sudden turn toward Lake Ontario.

"However changeful in the contour of its crest, this wave has been visible, approximately in the same place and with the same general form, for centuries past. Seen from a mile off, it would appear to be a stationary hillock of water. Viewed closely, it is a typical expression of the conflicting impulses generated by a swift rush of material particles.

"Now, with all our appliances, we cannot get within a good many miles, so to speak, of the living organism. If we could, we should see that it was nothing but the constant form of a similar turmoil of material molecules, which are constantly flowing into the organism on the one side and streaming out on the other."

Importance of Renewal of Blood and Lymph. — It will be well here to recall some facts noted in connection with the study of the blood and lymph. We then learned that the lymph (the supply and renewal of which depends upon the blood) surrounds the individual cells which make up the tissues of the body; and that, to a certain extent, every cell lives an independent life, each taking its nourishment directly from the lymph around it. The importance of an abundant supply of good lymph is now more apparent. If digestion is not good, or the food be insufficient or of poor quality (whether naturally or from being badly cooked), good blood cannot be made, and the lymph will not be good. The cells are more or less starved, or poisoned if wastes are not properly removed, and the general tone of the body will soon be lowered; for the health of the body as a whole depends on the average condition of the cells composing the body, just as the condition of any community depends on the average condition of the individuals of that community.

Fat as a Tissue. — As a tissue fat serves as a stored-up food. The camel's hump is a well-known instance. In some of the savage races fat is stored in a very similar hump. But in most persons it is distributed more evenly over the body, though there is a tendency to deposit rather more over the abdomen. A fat person can endure starvation longer, other things being equal, than a thin person. A layer of fat under the skin serves also as a heat saver.

Hibernation. — Hibernating animals are fat when they enter upon their winter sleep, but are lean when they come out in the spring Remaining inactive they have produced very little energy, their only motions being a slow and feeble breathing and a correspondingly reduced heart beat. They have consumed the fat, using it mainly in maintaining the necessary heat. In short, they have burned their fat to keep them warm.

The Hibernation of a Bear. — In one of Captain Mayne Reid's stories (*The Plant Hunters*) we are told how the hunters followed a bear into a cave. At the innermost end of this very long cave they finally killed the bear. Just at this time they find that their candles are all burned out, and they are left in complete darkness, lost in the bowels of the earth. Failing to grope their way out, they are at last driven to this expedient: With what combustibles they can gather together, including their gunstocks and some of the fat of the bear, they melt some of the fat, they use the gun barrels for molds, take strips of their clothing for wicks, and make two long candles. With these they finally light their way out to the upper world.

Respiration and Oxidation of Candle. — Now we have seen that when we burn a tallow candle one of the chief products of the combustion is carbon dioxid. Another product of the burning is common water. If, then, these hunters had left this bear to his winter's nap, he would have consumed this fat in the slow process of breathing, and it would have given off the same products, as we have proved that two of the waste matters of the expired breath are carbon dioxid and water.

Glycogen. — As stated above, glycogen is formed in the liver. This is indicated by the fact that there is more sugar in the blood in the hepatic vein than in the portal vein, except during digestion. Glycogen is formed by and stored in the liver, and is doled out to the tissues. That muscles use sugar in their action is indicated in the fact that the arteries bring to the muscles more sugar than is carried away from them by the veins. As fat is a reserve food, so glycogen serves as a temporary carbohydrate reserve.

Nutrition. — All the changes that take place between the reception of food and the excretion of waste are

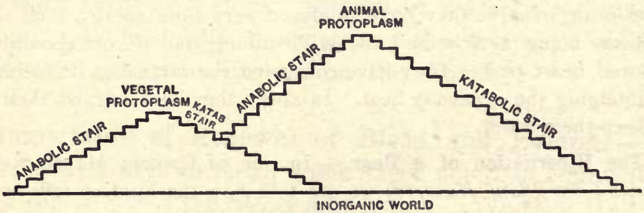


Fig. 74. Animal and Vegetable Protoplasm.

included under the term *nutrition.* The materials taken as food are usually more complex and unstable, the waste products more simple and stable; just as the products of combustion are, as a rule, simpler and more stable than fuels. In both combustion and the processes of nutrition the final result is oxidation, more or less direct.

Muscular Exertion and Excretion of Urea. — Since muscles are the engines of motion, and also are largely composed of proteid (nitrogen-containing) material, we would naturally expect that increased muscular exertion would increase the excretion of urea (the only nitrogen containing waste). But experiment shows that increased muscular action, such as mountain climbing, hardly increases the amount of urea excreted. Such work, however, does largely increase the amount of carbon dioxid excreted. It is thought, therefore, that our energy is largely derived from carbohydrate foods and fats, and this view is strengthened by the fact that our beasts of burden depend chiefly on carbohydrate foods.

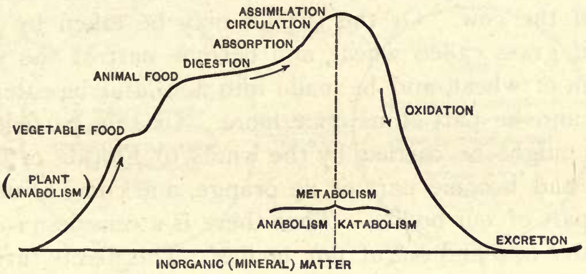


Fig. 75. Life Processes.

While increased muscular action does not very perceptibly increase the amount of urea excreted, an addition to the amount of proteid food taken does increase the amount of urea.

Metabolism. — The building-up or constructive processes are included under anabolism, while katabolism designates the tearing down or destructive processes. All the processes of nutrition, both of building up and tearing down, are included in the term metabolism.

The Indestructibility of Matter. — We are agreed that we cannot destroy matter. We may demolish a house, but the material is all there. We may burn it, but if we could gather the ashes and that part of the smoke and gases furnished by the material of the house, the weight would all be recovered.

In the continual wasting away of our bodies there is no real loss of matter. Our weight is reduced, but the wastes are still part of the earth or air, and are used again. For instance, a particle of carbon in the carbon dioxid of the expired breath may be taken in through a blade of grass in an adjoining field. A cow may eat the grass, and we may soon take the very same particle of carbon in the flesh or milk of the cow. Or the carbon may be taken by that kind of grass called wheat, and become part of the seed or grain of wheat, and be made into flour and be eaten as bread, and be part of us once more. Or this particle of carbon might be carried by the winds to Florida or California, and become part of an orange, and come again to make part of our bodies. Thus there is a ceaseless round of matter into and out of our bodies. The plants furnish food for us, and we help to make food for them by the wastes of our substance. No one has a monopoly of any portion of matter; it is now ours, now some one else's. A particle may pass from one animal to another animal, as when we eat flesh or other animal food. But more often the wastes of our bodies go to make part of the air or the soil, and are then taken by some plant before again becoming part of our tissues. But we are as unable to destroy matter as we are to create it.

The Indestructibility of Force.—So with energy. We cannot create it and we cannot destroy it. We derive our energy from the food we eat. And this food we get directly or indirectly from the vegetable kingdom.

An engine gets energy from the combustion of fuel. In the growth of the plant under the influence of sunlight the plant has stored energy. Now that the wood or coal are burned the energy is given out, primarily as heat. But we may convert the heat into electricity, the electricity into light, or back again into heat if we wish. We get our energy from food as the engine gets its energy from fuel. This is saying nothing against the superiority of the human body, and is not in the least degrading. We are

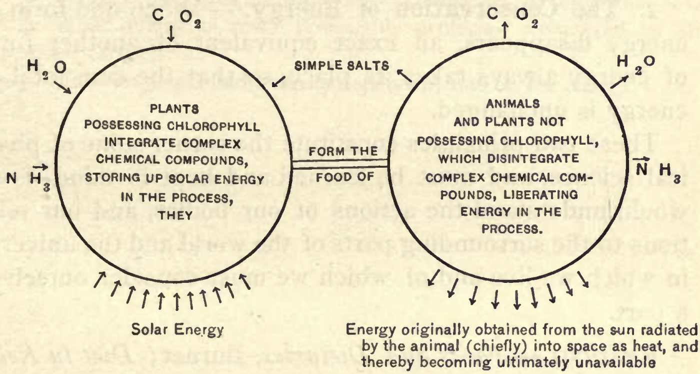


Fig. 76. Relation of Plants and Animals.

self-maintaining, self-directing, growing, living machines. Still, starvation soon puts an end to our ability to produce energy of any kind.

The Utilization of Energy in the Body and in Machines. — Now, it is a well-recognized fact that in very many machines only the smaller part of the energy is directed to the end sought. Take a common candle. We wish to get light from it. But most of the energy of the candle is devoted to making heat, which in this case we do not desire. In many machines there is great loss from friction, from radiating heat, etc. Physiologists tell us that the human body utilizes a larger portion of its energy than most machines. While energy may fail to be used for the desired purpose, it is never destroyed nor really lost.

CORRELATION AND CONSERVATION OF ENERGY.

1. **The Correlation of Energy.** — All kinds of energy are so related to one another that energy of any kind can be transformed into energy of any other kind.

2. **The Conservation of Energy.** — When one form of energy disappears, an exact equivalent of another form of energy always takes its place, so that the sum total of energy is unchanged.

These two principles constitute the corner stone of physical science, and must be learned and kept in mind if we would understand the actions of our bodies, and our relations to the surrounding parts of the world and the universe in which we live and of which we must consider ourselves a part.

READING. — *Foods and Dietaries*, Burnet; *Diet in Relation to Age and Activity*, Thompson.

Summary. — 1. The blood flow is a true circulation; that is, the blood moves in a circuit, being more or less altered by every organ it passes through.

2. The body is an eddy into which particles are constantly entering, forming part of it a while, and then passing out.

3. Fat as tissue is stored food, and consequently stored energy.

4. Glycogen is a carbohydrate reserve stored temporarily in the liver.

5. Nutrition includes all the processes of the body from the time matter enters as food until it leaves as waste matter.

6. The building-up processes of the body are called Anabolism, the tearing down are Katabolism, and both of these are included under Metabolism.

7. We can create neither matter nor force, but are dependent on food as the engine is dependent on fuel.

8. We are dependent on the green plants for our food.

9. The animal body utilizes more of the energy contained in food than the engine utilizes from fuel.

Questions. — 1. Why is it that some persons eat a large amount of food yet remain thin ?

2. What is meant by "lymphatic temperament" ?

3. Classify the organs shown in Fig. 73 according to their functions.

4. What animal is most thoroughly protected from cold by an envelope of fat ?

5. How are plants and animals dependent one on the other ?

CHAPTER XIII.

ALCOHOL.

Fermentation. — If a glass of sweet cider is set in a warm place for a day or two, it will probably be observed that bubbles of gas are given off and it will now have a sharp, pungent taste. The gas is carbon dioxid, and the new taste is chiefly due to alcohol, though attributable in part to other substances that have been produced and also to the loss of sugar. The same change would be likely to occur in a moderately strong solution of sugar, and in many fruit juices, especially if sweet. Sweet liquids undergoing this change usually become frothy, or "work," as we say, and at the same time acquire a sharp taste. This change is due to a process called fermentation.

Yeast. — Any substance in which alcohol is produced in this way is found to contain yeast. Yeast is a microscopic, one-celled plant, oval or elliptical in outline, which acts as a ferment. Common baker's yeast represents one group of these ferments.

It has been clearly proved that yeast is the cause of the above changes, some of the more manifest evidence being as follows: (1) Yeast may always be found in liquids undergoing alcoholic fermentation. (2) Yeast is killed by boiling. If such liquids as have been mentioned are thoroughly boiled and placed, while boiling hot, in a perfectly clean jar and sealed air-tight, they will keep indefinitely without any fermentation of this kind. (3)

Yeast added to such sweet liquids hastens, or makes more certain, this form of fermentation.

Yeast cells are not killed by drying. They become dry and float as part of the common dust of the air. They are still alive, and if they fall into a sweet liquid, especially if the liquid is not saturated with sugar, they begin to grow. In their growth they break up, or decompose, sugar and form at least two substances, carbon dioxid and alcohol. Yeast, therefore, is called a ferment, and this change is called alcoholic fermentation. A small quantity of yeast has the power of changing a large amount of sugar into carbon dioxid and alcohol. Then, too, we must remember that its growth is so rapid that a small quantity of yeast soon becomes a large quantity.

Ferments. — Besides yeast there are many other ferments which, when introduced into liquids, cause various changes, *i.e.* there are many sorts of fermentation. For instance, putrefaction is a kind of fermentation of substances containing nitrogen, during which process offensive gases are given off. Most of the ferments belong to a group of very simple, one-celled plants called Bacteria. (Yeast is an exception, not belonging to the Bacteria.)

Fermented Drinks. — All the alcoholic liquors are the result of alcoholic fermentation of various substances. Such liquors may be classed in three groups, — wines, malt liquors, and distilled liquors.

Wines. — The wines are the result of fermentation in the juice of the grape or other fruit which is rich in sugar. This fermentation was, in all probability, discovered very early by the human race, for we find it in use among nearly all races of men, and accounts of it in the early records of history. But it was not until the microscope was invented that its cause was known.

When alcohol accumulates in the fermenting liquid to the amount of 14 per cent, it kills the yeast germs; consequently no natural wine can contain more than this amount. Wines are classed as light wines and heavy wines. The light wines contain from 5 to 12 per cent alcohol. The heavy wines include all wines with more than this amount and have had brandy, or other spirit, added to them, having from 16 to 25 per cent, or even more, alcohol.

The Danger in Wine-drinking. — Because some of the wines contain a relatively small per cent of alcohol, there is a common delusion that there is not much harm in drinking them. Let us consider three points regarding this. (1) We do not argue or act in the same way in regard to other substances that are known to be poisonous. We do not venture to take small doses of arsenic or phosphorus, saying "Oh! a little will not hurt me." The poison is there just the same and will have its effect. (2) In small quantities the alcohol in the wine has the power to fix the alcohol habit, which is cumulative and leads to a desire for more which is almost impossible to resist. (3) Because of the very fact that the percentage of alcohol in wines is low, enough more of the liquid is taken to introduce into the system actually more alcohol than is taken by those who drink stronger liquors.

Wine-drinking cannot be too strongly condemned, either on the ground of the effects it directly produces or the fact that it leads to the use of stronger liquors.

Vinegar. — After sweet cider has fermented — or become "hard" as we call it — it usually passes on to become vinegar. This change is another form of fermentation, due to another kind of ferment. This formation of vinegar is likely to take place in any weak solution of alcohol-fermented liquor. In this fermentation acetic acid is produced, hence it is called the acetous fermentation. It is interesting to note that the word "vinegar" comes from the French *vin* (wine) and *aigre* (sharp or sour), as vinegar was formerly made by this secondary fermentation of the lighter wines.

Cider. — Besides the ordinary cider obtained from apples a cider made from pears, and called perry, is used. It is not a good thing to keep sweet cider about the house. It is pretty sure to ferment soon, forming alcohol. Hard cider contains from 2 to 10 per cent of alcohol. It is not only decidedly intoxicating, but experience has proved that some of the worst forms of disease result from the habitual drinking of this alcoholic drink. It also leads to the desire for stronger drinks.

"Temperance Drinks." — Many well-meaning persons use the various preparations called "root beer," perhaps without realizing that most, if not all, of them are made with yeast and in their preparation undergo fermentation, thereby producing alcohol, though not ordinarily in large amounts. By giving such drinks (often called "temperance drinks") to children, an appetite for alcohol may be cultivated and the beginning of a terrible habit made. It may be well here to call attention to the real meaning of the word "habit," *that which holds us.*

Malt Liquors. — These are obtained from the small grains, especially barley, by soaking the grain and then allowing it to sprout. During this process most of the starch is converted into grape sugar. The sugar is extracted by boiling, and then, by the addition of yeast, alcohol is produced. The chief product is beer, which contains from 2 to 5 per cent of alcohol. Hops and other substances are usually added. Although the per cent of alcohol in beer is low, the effect of beer-drinking is marked. As in the case of wine, often the drinker takes such enormous quantities of the liquor that the total amount of alcohol introduced into the system is large, and the effect correspondingly pronounced. In the case of many beer drinkers there is apparent a continual state of heaviness or lethargy, a sort of perpetual stupefaction, which points significantly to the narcotic effect of alcohol. It is said on good authority that in the city of Munich it is rare to find a sound heart or sound kidneys; and perhaps this is typical of many large cities where beer-drinking is so widely prevalent.

Distilled Liquors. — Distilled liquors, or *spirits*, are obtained from the wines and fermented liquors by the process of distillation. This process depends on the fact that alcohol boils at 173° F., while water boils at 212° F. The *still* consists of a large boiler with a large tube rising from the top, and this tube extends through, and is coiled about in, a reservoir which is kept filled with cold water. On heating the fermented liquid in the still up to 173° F., the alcohol is converted into vapor. As this vapor passes along the coil (known as the worm) the vapor is condensed by the cold, and thus the alcohol is separated from the water and other liquids, which boil at a higher temperature. By distilling wine a large part of the water is left behind, and brandy is the result. Whisky is made by distilling the fermented grains, especially rye and corn, while rum is manufactured by the distillation of fermented molasses. Most of the distilled liquors contain from 40 to 50 per cent of alcohol. By repeated distillation and rectification pure alcohol is obtained. Pure alcohol is not largely used, the ordinary commercial alcohol being about 91 per cent alcohol. The effects of alcohol on the human system will be treated a few paragraphs later.

Physical Properties of Alcohol. — Alcohol is a clear liquid of .79 specific gravity. It boils at 173° F., and does not freeze above 200° F., hence is often used in thermometers. Alcohol dissolves gums and resins, and many substances which are insoluble in water.

Chemical Properties of Alcohol. — Alcohol is composed of carbon, hydrogen, and oxygen (C_2H_6O). In composition the alcohols (for there are many kinds of alcohol) resemble fats. In both there is only a small proportion of oxygen to the amount of carbon and hydrogen. For this reason both burn with great readiness and produce a large amount of heat. Alcohol burns with a nearly colorless, but very hot, flame, and does not produce soot; hence the alcohol flame is very useful in delicate work, such as watch-making, etc.

Physiological Effects of a Moderate Dose of Alcohol. — A moderate dose of diluted alcohol or ordinary alcoholic drink usually has about the following effects, especially upon those not accustomed to its use. First, a dilation of the blood tubes of the face and of the mucous lining of the stomach; for a very short time a quickened, and perhaps more forcible, heart beat; nervous excitement, shown by restlessness and talkativeness; followed by more or less dullness or drowsiness, usually followed by a depressed feeling on the next day.

Effects of Larger Doses of Alcohol. — Larger doses of alcohol, or more than what might be called moderate drinking, are usually followed by more giddiness, diminished sensibility of the skin, partial loss of control of the muscles, as shown in speech and gait; the eyes cease to work in harmony, and the person may see double; nausea is a common effect; and (without attempt to dwell on such offensive details) after a time stupor comes on. In such drunken sleep the temperature has been known to fall as low as 75° F. From this it is very evident how foolish it is for one who is exposed to severe cold to drink alcoholic liquor to keep himself warm, and the extreme danger of such a course. Members of exploring parties in cold climates have lost their lives by ignorance of, or disobedience to, this well-known rule. In the unconsciousness of drunken sleep the full narcotic effects of alcohol are seen. And it is very significant that the word by which we designate this condition (a word that was applied long generations before there was any systematic study as to how drugs affect the body), this word — *intoxication* — *means poisoning*.

Alcohol formerly regarded as a Stimulant. — Until late years nearly all authorities considered alcohol a stimulant. Its effects were apparently such as to rouse the organs of the body to a higher degree of activity. But recent experiments have shown that this effect, which is of a very short duration, is not its real characteristic action. In from ten to twenty minutes this preliminary excitement begins to abate, and is followed by a period of diminished activity. Its essential action is that of a narcotic or paralyzing agent.

Alcohol as a Narcotic. — Many of the later writers who have investigated the subject say that alcohol is not a stimulant, but always a narcotic. The effect on the capillaries is explained as follows: In ordinary conditions of circulation, when only a moderate amount of blood is needed in any given organ, the circular muscle fibers in the walls of the arteries leading to that part are kept shortened by nervous impulses sent to them from the nerve centers which control them, hence a moderate supply of blood. A narcotic has a paralyzing effect on these nerve centers; hence the usual impulses which would have been sent are no longer sent, the muscle fibers relax, the artery widens, and the part becomes flushed.

In regard to the effect on the action of the heart, it must be remembered that in the first place there are ganglia imbedded in the walls of the heart, and that the heart tends to beat rhythmically; second, that there are two sets of nerve fibers reaching the heart from without, the sympathetic, which bring impulses which quicken the activity of the heart, and the vagus nerves, which slow its action. The sympathetic fibers are *accelerators*, while the vagus fibers *retard;* the vagus nerves exert an *inhibitory* effect, *i.e.* they act as a brake on the heart's action. If they were strongly stimulated, the heart would stop. If impulses are not continually sent to the heart along these fibers, the heart begins to beat faster, just as a wagon going down hill begins to go faster when the brake is taken off.

The action of the narcotic is to paralyze the nerve center from which the restraining impulses normally are sent to control the heart. Hence the rapid beat. As to the force of its beat there is difference of opinion; many maintain that it has less force than before.

Under the influence of alcohol the person says and does foolish things; he violates confidence; he proposes, and engages in, rash undertakings; his higher nerve centers in the brain are more or less paralyzed; his judgment is weakened; in short, he has lost self-control.

Alcohol in the Army. — Colonel Alfred A. Woodhull, surgeon United States army, says in regard to this matter, "I do not think any of our medical officers would seriously advocate the issue of alcohol as a measure of health."

Captain Woodruff, assistant surgeon United States army, says, "Spirits can never be used in the army as a regular issue; the practice is thoroughly vicious, and was virtually abandoned sixty years ago."

Dr. Frank H. Hamilton said: "It is earnestly desired that no such experiment ever be repeated in the armies of the United States. In our own mind the conviction is established by the experience and observation of a lifetime, that the regular routine employment of alcoholic stimulants by men in health is never, under any circumstances, useful. We make no exceptions in favor of cold, or heat, or rain."

General Kitchener prohibited all drinks containing alcohol in the Soudan campaign, and of the result a war correspondent said: "Of one thing I am sure — that the mortality from fever and other diseases during the Atbara campaign and the final Omdurman campaign would have been infinitely greater than it was if alcoholic liquors had been allowed as a beverage, or even as an occasional ration.

"The men who grumbled a little when General Kitchener emptied out into the street a cargo of Scotch whisky that had been smuggled into Berber for sale to the troops, soon discovered for themselves that the Sirdar was right. According to official reports nearly four thousand of the soldiers now in South Africa are total abstainers."

Alcohol and Mountain-climbing. — Statistics have been collected from mountain-climbers, and a large majority testify that alcoholic drinks are injurious or at least not helpful. This testimony is all the stronger from the fact that it comes largely from Englishmen and Germans, who are more likely to have the habit of moderate drinking when at home. Mountain-climbing calls for a greater expenditure of energy than is probably realized by any who have not tried it. Aside from the natural exhaustion of such severe exertion, there is likely to be giddiness or nausea as a result of the rarefied air. The keeper of the house on the summit of Pike's Peak says that such symptoms are almost invariably aggravated instead of being relieved by taking alcoholic drink.

Testimony of a Naturalist. — W. T. Hornaday, author of *Two Years in the Jungle*, who has had years of experience as collector in many lands, has the following to say as to the use of alcoholic drink: "Above all things, however, which go farthest toward preserving the life of the traveler against diseases and death by accident, and which every naturalist especially should take with him wherever he goes, are *habits of strict temperance*. In the tropics nothing is so deadly as the drinking habit, for it speedily paves the way to various kinds of disease which are always charged to the account of 'the accursed climate.' If a temperate man falls ill or meets with an accident, his system responds so readily to remedies and moderate stimulants that his chances of recovery are a hundred per cent better than those of the man whose constitution has been undermined by strong drink. There are plenty of men who will say that in the tropics a little liquor is necessary, 'a good thing,' etc.; but let me tell you it is no such thing, and if necessary I could pile up a mountain of evidence to prove it. The records show most conclusively that it is the men who totally abstain from the use of spirits as a beverage who last longest, have the least sickness, and do the most and best work. As a general rule, an energetic brandy-drinker in the jungle is not worth his salt, and as a companion in a serious undertaking, is not even to be regarded as a possible candidate."

Is Alcohol a Food? — Alcohol certainly cannot build up muscle or brain or nerve, because these tissues must have nitrogen as a constituent element, and alcohol contains no nitrogen.

Undoubtedly the best test of a food is its ability to maintain working power. Does alcohol do this?

In the above paragraphs are given the results of much experiment and observation. Alcohol has been tried in the army and navy, on the march and in camp, in hot and cold climates, in mountain-climbing, in training for boxing, boating, and other athletic contests, and as a result the uniform testimony is that it fails to sustain energy, that is, *as a food it is a failure.* Experience shows that men can endure more cold and more hard labor without alcohol than with it. This has been repeatedly proved in Arctic expeditions, in the army and navy, during the hardships and exposures of forced marches and deprivations in all climates. Neither in hot nor in cold climates is alcohol necessary to health, and even its moderate use does more harm than good. The explorers in the arctics and in the tropics are alike better off without alcohol than with it.

This testimony as to the uselessness of alcohol is all the stronger on account of the chemical nature of alcohol and the claims made for it. Alcohol contains but little oxygen and burns readily and yields a large amount of energy in the form of heat. It seems very natural, therefore, to jump to the conclusion that it will oxidize in the body and produce heat and, perhaps, other useful energy. It does oxidize in the body, but, as already shown, it causes the body to lose more heat than it furnishes, and the work accomplished during the period of its influence is less than that accomplished without it.

The fact of the oxidization of alcohol in the body does not necessarily prove that it furnishes the body energy that can be utilized, for other substances, everywhere recognized as poisons, such as muscarin and carbolic acid, are also oxidized in the body.

It has been claimed that alcohol spares the tissues of the body, but it is doubtful if this is true, many experiments going to show that instead of retarding loss it actually causes an increased loss of tissue.

The fact, then, seems clear that alcohol does not furnish the body with available energy with which to carry on its daily work.

On the other hand, we can see how the readiness with which alcohol is oxidized in the body is plainly injurious. It is well known that most persons eat more than is needed; in fact, some of the best authorities state that the larger part of the ills of the body, especially in later life, come from overeating, or as an adage puts it, "one half of what we eat enables us to live, the other half enables the physicians to live." Now when, in addition to a surplus of food, alcohol is also taken, the ready oxidation of the latter prevents the complete oxidation of food, and favors the accumulation of incompletely oxidized waste products, which are very harmful in the system. They clog the excretory organs, especially tending to overwork, and consequently to break down, the liver and the kidneys.

The Danger of Moderate Use of Alcohol. — Thus far we have mainly considered the question whether alcohol is or is not useful in supporting the energies of the body. It is time to ask another question, What effect does the continued use of alcohol have upon the body?

No one denies that the use of alcohol may, and often does, create an appetite for more, and that this appetite frequently becomes uncontrollable. If one eats a sufficient amount of bread to-day, he does not, in consequence, crave a larger amount to-morrow. But the appetite for alcohol grows. The law of its use is the law of increase, until the terrible alcohol habit is formed. History is full of accounts of men who thought they could stop it when they chose. The man who says that he can take it or let it alone usually takes it. The grip of the alcohol habit is well nigh as relentless as the grip of death.

There is one safe rule: *Touch not, taste not, handle not.*

Alcohol as a Poisonous Drug. — Alcohol should be classed with the poisonous drugs (*e.g.* opium, arsenic, chloroform, belladonna, strychnine, etc.). We know that they are very dangerous substances.

Diseases produced by Alcohol. — The organs most directly affected and altered in structure by alcohol are the stomach, heart, liver, kidneys, lungs, and nervous system. Even moderate drinking may affect any of these organs. Tremor of the muscles, especially noticeable in the hands, is often observed. This tremor reaches its extreme in the terrible disease known as delirium tremens. The heart often undergoes fatty degeneration, fat replacing part of the muscle. The arteries may undergo the same change. The kidneys are disordered, and one form of resulting disease is known as Bright's disease. This is often caused by moderate drinking. One form of consumption has been proved to be due to the use of alcoholic drink. But the most positive, and the most serious, effects of alcoholic drinks is on the nervous system, of which more will be said later.

Predisposition to Disease caused by Alcohol. — In many cases where the use of alcoholic drink has not actually shown a diseased condition there is marked weakness and inability to resist or throw off disease. Drinkers are much more subject to sunstroke and to many of the infectious diseases. Yellow fever is almost surely fatal to the intemperate. Some forms of pneumonia are more likely to attack the intemperate. The insidious nature of alcohol and the evil effects of moderate drinking appear when the body is attacked by disease. The body is found to be undermined and sapped of its strength at the very time when a reserve fund of vitality is needed to ward off the attack of disease.

Inheritance of the Effects of Alcohol Drinking. — The evil is great enough when seen only in the individual who indulges in the drink habit. But the inherited results are often worse. First the craving for liquor is often inherited. This craving may take a mild form, and a person of good will power may resist it. But sometimes the inherited craving takes the form called dipsomania, in which at intervals the craving is so strong that it cannot be resisted, while there may intervene considerable periods when there is no desire whatever for strong drink. Then, too, idiocy, imbecility, and epilepsy are common in the children of intemperate parents.

Alcohol and Poverty. — No one needs to be told that a large share of the poverty, everywhere so common, is due to the drinking of alcoholic liquors. Much of the earnings are frequently spent for liquor; the man's working capacity is diminished, his work becomes irregular, and so unreliable that the drinker often fails to obtain employment when he is sober.

The Business Man's View. — Many firms and corporations now refuse to hire any one who is known to indulge in alcoholic liquors or to frequent saloons. Drinking makes men *unreliable*, and the wise business man will not intrust matters of importance — and all business is important — to those on whom he cannot rely. No boy or young man can afford to risk his position and his reputation by taking a single drink of liquor.

Alcohol and Character. — Serious as are the effects of alcohol on bodily health, and prejudicial as it is to all business prospects and what we usually call success, still more fearful are the effects, through the nervous system, on the mind and character. Although a later chapter gives some attention to this matter, certain phases of the subject may be treated here.

Alcohol and Crime. — Every one knows from observation and newspaper reports that much of our daily crime is due to alcohol. Without quoting figures it may be stated that carefully collected statistics show that a large per cent of the inmates of our jails, reformatories, and penitentiaries are brought to such places through the influence of alcohol.

The Delusive Nature of the Effects of Alcohol. — Alcohol is one of the most delusive substances known to man.

It *seems* to give warmth to the cold, strength to the weak, activity to the sluggish; it *seems* to refresh the weary, to quench thirst, and to satisfy hunger; it *seems* to rouse the mental faculties to a higher pitch of activity, bringing forth a greater degree of wit and wisdom than the individual ordinarily displays. It *seems* to banish fear and make the timid brave.

Let us glance over these *seemings* and try to get at the real facts in the case.

The feeling of increased warmth after taking alcohol is due to the greater amount of blood in the skin where the nerve endings are affected, or to the deadened sensibility to cold, or to both; test by the thermometer shows that the body's temperature is lowered.

After taking alcohol a person may feel stronger; actual test of strength shows diminished muscular power.

Fatigue seems to have been done away with because sensibility is blunted; any form of drowsiness would produce the same result.

Hunger appears to be satisfied through the action on the nerves of the stomach; but the body's need of food has not been satisfied. Thirst may seem to have been allayed; but only soon to return intensified. What usually passes for wit, under the influence of alcohol, is ordinarily the silliness of the tipsy; under this influence the person overestimates his wisdom, while others can easily see that his judgment is warped. He may fear danger less than before, but it should not be called bravery; he is less sensible of danger, and he has become rash or even reckless.

In all these cases sensibility is lowered, and the nerve centers, especially the higher centers, have become more or less paralyzed. For a short time the blood and the brain run riot, the reins of judgment having been thrown overboard. Power has not been gained, but *control has been lost.*

Alcohol is not the "elixir of life," it is the "fountain of death."

The Danger of using Alcohol. — The danger is especially great where there is a latent hereditary tendency to inebriety or insanity. Many individuals, on finding a drug which exhilarates and banishes the weight of oppression by which they are borne down, are tempted beyond their power of resistance, even though they know that the reaction will bring them into a worse condition than the one from which they sought relief. The pressure of modern life, and the intensity of the struggle for a living, brings about a condition of nervous strain that is fraught with great danger. Every *thinking* man should see that to use alcoholic drink for the relief of such a condition is like venturing out in a boat above the Falls of Niagara — he knows not when the rushing, mighty power will gain the mastery and dash him to destruction.

Reading. — *The Temperance Teachings of Science*, Palmer; *The Foundation of Death, a Study of the Drink Question*, Gustafson; *The School Physiology Journal.*

Summary. — 1. Alcohol is a very dangerous drug and should be used only when prescribed by a physician.

2. Athletes avoid alcohol when training.

3. A large per cent of crime is due to alcohol.

4. On account of its rapid absorption alcohol is a quick recuperative after collapse.

5. In small amounts alcohol is oxidized in the body, producing energy.

6. Alcohol usually lowers the temperature of the body through the increased skin circulation.

7. It is especially dangerous to take alcoholic drink when exposed to severe cold, as in Arctic explorations.

8. In the army alcoholic drink as a regular ration did more harm than good; hence was discontinued.

9. More hard work can be endured without alcohol than with it.

10. The precise effects of alcohol are hard to determine. But everybody knows that its effects are generally bad.

11. Alcohol is now classed as a narcotic and not as a stimulant.

12. Alcohol deludes by deadening the senses, giving the false impression that heat and strength have been gained and fatigue banished.

13. If thirst *seems* quenched, the deception is revealed by the fact that the *thirst quickly returns intensified.*

14. Alcohol is not a true food.

Questions. — 1. Why do some persons think that alcoholic drink makes them warmer?

2. What do statistics show as to "expectation of life" among abstainers and alcohol users?

CHAPTER XIV.

EXERCISE AND BATHING.

How Exercise is Beneficial. — The full significance of the benefits of muscular exercise could not be understood when we studied the muscles, and before we had studied the blood and its work in the tissues of the body generally. Now we can comprehend how exercise stimulates the cells to activity, renews the lymph around the cells both by quickening the blood flow and by pressure on the lymph tubes; how the glands of excretion are set to work more actively, and the more rapid blood stream brings away the material to be thrown out.

Exercise for General Health. — Exercise is not merely for the muscles. It quickens the action of the whole body by increasing cell activity. It helps clean out the system and clear the brain as well. We read Blaikie's admirable book, *How to Get Strong*, and learn not merely to strengthen the muscles, but how to get strong to do the work we have to do daily, how to feel well every day, how not only to do our work, but to do it gladly, and with a little extra good cheer that may radiate from us and inspire others. We have no right and no need to carry the sour visage of a devitalized body. Good health is attainable, and ought to be attained, by nearly all. Attention must be paid to the laws of our being. It takes some effort, mental as well as physical, to adopt and observe regular hours for exercise and relaxation and to be careful in diet.

Nature's Rewards and Punishments. — But nature rewards for obedience by the delight of a healthy body; and she never forgets and never forgives, nor fails to punish every violation of every one of her laws. Nature makes no threats beforehand. She does not even tell us her rules. But we may find what they are by careful observation.

Exercise prolongs Life. — Many men would live longer, feel vastly better, and do greater good in the world if they would take regular and systematic exercise or recreation (and this should be, literally, re-creation). It is a short-sighted policy to say, "I cannot afford the time." Not to take time for exercise is to mortgage one's future. Lord Derby says, "He who does not take time for exercise will have to take time for illness." The latter half of every person's life ought in many respects to be by far the most productive of good. But many cut off this half, or render it less productive through breaking down in health as a consequence of violating the laws of hygiene. Thus one defeats his own ends in life, and robs the world of the debt he owes it, that of returning to it, in his riper years, something for the help it gave to him in his early years while he had not yet reached the fullest mental maturity. It is sad enough that so magnificent a structure as the human body must perish and become part of the common clay. But it is infinitely more sad to think that it has not fulfilled its purpose when the end comes in what should be mid-career. Each of us should leave the world better than he found it, and our ability and opportunities for doing this increase as we reach middle life.

Forms of Exercise. — In selecting the kind of exercise the old lines fit well: —

> "In whate'er you sweat, indulge your taste;
> The toil you hate fatigues you soon,
> And scarce improves your limbs."

Of course this does not mean that a boy should refuse to saw wood because he dislikes it, and spend all his time playing ball. But for older persons, especially those of sedentary occupation, exercise that exhilarates is far more beneficial than that which is not enjoyed. One may take a walk and carry all his cares and anxieties with him, but he is not likely to think of such matters when playing tennis with a good opponent. Whether it be horseback riding, cycling, boxing, boating, skating, or other form of exercise, choose, whenever a choice is possible, that which you thoroughly enjoy. Exercise should be taken out doors whenever possible. The gymnasium is a substitute in bad weather.

Games of School Children. — Most of the games of school children are excellent kinds of exercise. Cases have been reported of injury from excessive skipping the rope. But in moderate degree it is a good exercise. Tag, snowballing, racing, the various games of ball, jumping, hopping, and other games may be played on the school grounds.

Tennis. — Tennis is a fine game, and suitable for girls as well as boys. It has the great advantage over baseball that it does not require a large ground (which often means going some distance from the school grounds or from home). Two can make up a game, and a little time can be better utilized than with the games requiring more players. The exercise, too, is more evenly distributed.

There is no long waiting, as in some games, but a constant interchange of play, active but not severe, with practically no danger of injury.

Baseball and Football. — For those who can pursue the more vigorous games of baseball and football they are admirable, and should not be objected to because occasional injury comes from them. No vigorous exercise is wholly unattended by risk, though it is usually slight when the proper care is used. All these games calling for great activity and strength develop manly qualities in boys, and do much to make them active, fearless men, men who in time of danger have not only strength and endurance, but well-trained muscles, cool heads, and brave hearts, men who know what to do and how to do it in an accident, as at fires, upsetting of boats, etc. A few strong, cool-headed men, by their presence of mind, often stop a panic and save many lives when there is an alarm of fire, which often proves false. The Duke of Wellington said that it was on the football fields of Eton and Rugby that the battle of Waterloo was won.

Boxing. — Boxing is a splendid exercise. It calls into play nearly every muscle of the body. Many pieces of apparatus in a gymnasium are for the especial purpose of working certain muscles. But a pair of boxing gloves may be said to contain a whole gymnasium. Many kinds of work in a gymnasium are likely to be overdone, especially if not under the direct supervision of a good director. One may overlift or overstrain himself. But in boxing there is little tendency in this direction. Boxing makes one quick on his feet, trains to quick movements of the arms, trains the eye, keeps the body in an erect position, and especially develops the muscles of the legs and back.

Boxing brings out the chest and shoulders. It develops the "wind," and keeps one in constant action. It teaches control of the temper more than almost any form of exercise. It develops a degree of self-reliance that is worth much. Instead of developing a tendency to become involved in quarrels, it prevents getting into such disgraceful affairs. The man who knows that he can defend himself when it becomes necessary is far less likely to pay serious attention to idle bluster and slight provocation than one not so trained. And it may prove valuable to know how to defend one's self from the attack of a ruffian, or bully, or drunken brute, or other infuriated animal. The coolness of head, the quick judgment, and prompt action of a trained boxer frequently saves one from serious injury, and adds not a little to personal comfort. Like tennis, boxing calls for little apparatus, little space, and only two persons. In many places where ordinary gymnasium work is out of the question, boxing is available. It is indeed a "manly art," and the doctrine taught in *Tom Brown's School Days at Rugby* is as wholesome as can be given to boys to make them strong and active, to give them physical and moral health.

Bicycling. — This is an excellent exercise, as it is in the open air and exhilarating. There is danger of overexertion, and it is bad for one to yield to the temptation to make long runs. There is danger of overtaxing the heart. The handle bar should be adjusted to allow a fairly upright position. The saddle should be such as not to sustain the weight on the perineum.

Exercise for Middle-aged Men. — For men in middle life, in most cases, milder exercises are preferable, such as shooting, fishing, and horseback riding. Every person should have some form of exercise that takes him into the open air daily. The English are more given to their "constitutionals" than their American cousins, and are the better for it. Doubtless if we paid more attention to these matters, we should lose something of our national reputation as a "nervous people." English women are noted walkers, and do not seem to pride themselves on the smallness of their feet. The signs of the times would appear to show that we are improving in this respect. Probably Americans make too much use of street cars. Walking is the cheapest exercise, and every one can afford to take it. For those who can afford it horseback riding is admirable. As Dr. Holmes expressed it, "saddle leather is in some respects even preferable to sole leather; the principal objection to it is of a financial character." Lord Palmerston said "the outside of a horse is the best thing for the inside of a man." Perhaps livery bills would prove cheaper and more agreeable than doctors' bills.

"Taking Cold." — So long as one is actively exercising, he is not likely to take cold. But if one rests in a cool place, especially when he is warm, he is, as we all too well know, likely to take cold. As we saw when we were studying the circulation of the blood, the application of cold to the skin causes the arteries (through reflex action) to become smaller. Thus when resting in a cool place the skin becomes pale and cold.

During a "cold" there is fever. The regulation of the heat by the skin is interfered with. At the same time it is often noticeable that the urine is more abundant than usual. As cold may lead to fatal lung disease, so it may be the beginning of some disease of the kidneys that may, in the end, bring fatal results.

Diarrhea. — Diarrhea, which is a catarrhal condition of the intestine, may follow, or be associated with, a cold, and as a result of this the process of absorption is often largely checked. There is a great increase in the secretion of mucus by the mucous glands in the intestinal wall. As the various liquids of digestion are all taken from the blood, it is evident that if some returns are not soon made, the system must become bankrupt. It is, then, more easy to understand the excessive weakness and feeling of utter prostration that we experience during an acute attack of diarrhea. We can now understand where all the material comes from to make the profuse discharges, especially after we have ceased eating for some time.

It is a significant fact that diarrhea is usually called "summer complaint." During the warm summer nights we are tempted to go to sleep with very little covering over our bodies. But it almost always grows cool before morning. The common summer diarrhea is, in many cases, due to bacteria taken in food; but, on the other hand, may be simply a "cold in the bowels."

Bathing. — One purpose of bathing is to cleanse the skin. For this purpose warm water is best, and it is desirable to use soap, especially on those parts which are especially exposed to contamination, such as the hands, the feet, the armpits, and groins.

Cold Baths. — Another important function of bathing is to act as a systemic tonic. For this purpose cold bathing is better, but this should not be too long continued, and must be followed by brisk friction to give the skin a ruddy glow. For this kind of bath a tub is not necessary, and hardly desirable. The water may be quickly applied by means of a sponge, and the body thoroughly rubbed with a coarse towel. The whole process should be completed very quickly, especially if the room be not warm.

Bath Mits. — Instead of the sponge and the ordinary form of towel, it may be found more convenient to use bath mits made of Turkish toweling. These are easily made, and are somewhat more convenient, as thus friction may be more readily applied than with a towel, which is apt to slip in the hand. The two hands may be used at the same time, and the whole time of the bath need not exceed two or three minutes. At the beginning of a bath, cold water should be applied to the head and face.

Time for Bathing. — For students, or others who do not take a great deal of vigorous exercise, which keeps the skin active, this means of keeping the skin active is especially valuable. The use of warm water for cleansing seems best adapted (for busy people) to the time of going to bed. But the best time for the cool bath is on getting up in the morning.

Warm Baths vs. Cold Baths. — Prolonged warm baths are debilitating, and probably increase a tendency to take cold, whereas cold bathing is one of the very best means of fortifying against cold, and especially against the tendency to take cold on slight exposure. For most persons a cool sponge bath, on rising, will act as a most excellent tonic; but if it seems to produce neuralgia, it should be used with caution.

Exercise of Arterial Muscles. — We have learned that the blood supply to any organ is regulated by the action of the plain muscle fibers in the walls of the small arteries. Now, when we are subject to changes in temperature these muscles get exercise, and one writer has well called the cold bath the *gymnastics of the plain muscle fibers*, and we can understand how the system can be trained to adjust itself to cold, and enabled to avoid "taking cold" so frequently.

Habit of Cold Bathing acquired Gradually. — There are undoubtedly many persons who do not profit by cold bathing, but probably many of these would soon adapt themselves to it by beginning with tepid water and gradually using cooler. To stand stripped in a cold room, of course, is not a safe thing to do. And the great secret of the benefit that may be expected from the operation, as most people are situated, is to be very brisk, the whole process occupying only a few minutes. Many are opposed to cold sponge bathing, and condemn it without reserve, when, probably, they have never really given it a fair trial.

Let it be repeated, with emphasis, that for students it is one of the *very best means of preserving health.*

READING. — *Baths and Bathing* (Health Primers, D. Appleton & Co.).

Summary. — 1. Exercise stimulates the activity of all the organs, by promoting cell activity and assisting excretion.

2. Exercise should be in the open air as much as possible.

3. Exercise is more beneficial when it exhilarates.

4. Exercise should be taken regularly.

5. Warm baths are best for cleansing, and a good time is at bedtime.

6. Cold baths stimulate the circulation of blood in the skin, and serve as a tonic to the whole system. Just after rising is a good time for the cold bath.

7. The cold bath fortifies against taking cold.

Questions. — 1. Should exercise be carried to the point of fatigue ?

2. How can one avoid taking cold after exercise ?

3. Do girls need exercise as much as boys ?

4. What is the condition of the body during a "cold" ?

5. How may a cold be caused ?

6. How may a cold be cured ?

7. How may a cold be prevented ?

8. Why do some persons take cold so much more readily than others ?

9. Why does the same person take cold more readily at one time than at another ?

10. How often should a person bathe ?

11. What hour is best for sea bathing ? Why ?

CHAPTER XV.

THE BRAIN.

THE muscles are the executive organs; but the seat of the will is the brain.

If models of the brain can be obtained, they should be carefully studied. If not, the accompanying figures may be used in their stead.

The Coverings of the Brain. — There are two readily distinguishable coats of the brain, the *dura mater*, a tough membrane, adhering more or less closely to the inside of the skull; and the *pia mater*, next to the brain, a much thinner membrane, traversed by blood tubes, and dipping down into the grooves between the convolutions of the cerebrum.

The Parts of the Brain. — The larger and upper part of the brain is the cerebrum; below and back of this is the smaller cerebellum; the part of the spinal cord within the cranium is generally reckoned as part of the brain.

The Cerebrum. — The cerebrum consists of two lateral hemispheres, separated by a deep median groove. The surface of the cerebrum is in irregular ridges, the convolutions. The outside of the brain consists of gray matter, whereas the outside of the spinal cord is white. The inner part of the brain is white, and the two halves are connected by a broad band of white matter, which consists of many white fibers.

The Cerebellum. — The cerebellum is much smaller than the cerebrum, and has fine transverse ridges and grooves in place of the convolutions of the cerebrum. It is also of a deeper color, a reddish gray. The cerebrum overlaps the cerebellum so that the latter could not be seen from above if the whole brain were laid bare. But in the lower animals the parts of the brain are more in a series, one behind the other, and in a line with the spinal cord.

The Spinal Bulb. — The enlarged beginning of the spinal cord, often called the medulla oblongata, is the spinal bulb. It is white like the rest of the cord.

The Brain of a Cat or Rabbit. — The brain of a cat or rabbit may be exposed by first mounting the specimen as directed for showing the spinal cord (see p. 27). After removing the skin from the upper part of the head, the bone should be cut away between the eyes with a pair of bone forceps. Cautiously working backward, the whole of the brain may be unroofed. Great care must be exercised, for here we have one of the softest tissues of the body lying very closely beneath one of the hardest. It is possible to do this with a strong knife, but the bone forceps save a great deal of hard work. The bone must be broken away bit by bit. To remove the brain, it will be necessary to cut through the tough dura mater that covers it.

Removing this, there will be found an inner covering, the pia mater, a membrane richly supplied with blood tubes, from which the brain gets its nourishment. After the dura mater has been removed, the anterior end of the brain may be gently lifted with the handle of the scalpel and the under surface studied, following the description of the cranial nerves.

Preservation of the Brain. — The brain may be studied while it is fresh, but it is more easily handled after it has been hardened. Lay the brain in weak alcohol, about 25 per cent. It should rest on a layer of cotton, otherwise it may be very much flattened by its own weight. Later transfer it to 50 per cent alcohol, and then to 75 per cent. When it is well hardened, it may be sliced with a sharp scalpel as directed. A better and quicker method is to use a solution of alcohol and formalin as follows: 95 per cent alcohol, 60 parts; 2 per cent formol, 40 parts. The liquid need not be changed if used in sufficient volume.

The Brain of the Rabbit (*Alcoholic Specimen*). — The brain of a cat or dog is better, being larger. Take a brain well hardened, and review the parts as named above. It is very desirable to have a specimen in which the arteries have been injected.

1. Press down the cerebellum to see the deep groove between it and the cerebrum. The thin membrane covering the brain and dipping into the groove is the pia mater.

2. Press down the spinal bulb and tear away the pia mater where it passes from the cerebellum to the spinal bulb. Note, between the bulb and the cerebellum, a space covered by a thin membrane. Cut through this membrane; the cavity is the *fourth ventricle* of the brain. Observe the two ridges bounding the sides of the fourth ventricle. At the point of their divergence, observe the opening of the *central canal* of the spinal cord.

3. Gently separate the cerebral hemispheres, and note the transverse band of white fibers connecting them.

4. Examine the under surface of the brain, and find the roots of the cranial nerve.

The Cranial Nerves and their Functions. — 1. The *olfactory lobes* extend forward under the fore part of the cerebral hemispheres. They are the nerves of smell.

2. The *optic nerves*, or nerves of sight, join each other before reaching the brain. Only the first and second pairs of cranial nerves directly enter the cerebrum.

3. Back of the optic nerves, near the middle line, is the third pair of nerves. The third, fourth, and sixth pairs of cranial nerves control the muscles of the eyeballs.

4. The fourth pair extend up on each side into the groove between the cerebrum and the cerebellum.

5. Back of these is the larger fifth pair, the *trigeminal*. This pair supplies part of the face, and sends branches to the teeth. It is the nerve affected in neuralgia of the face. Besides being the nerve of sensation for most of the

head and face, this nerve has motor fibers which control the muscles of mastication. Unlike the other cranial nerves, the trigeminal resembles the spinal nerves in having two roots, one sensory, the other motor.

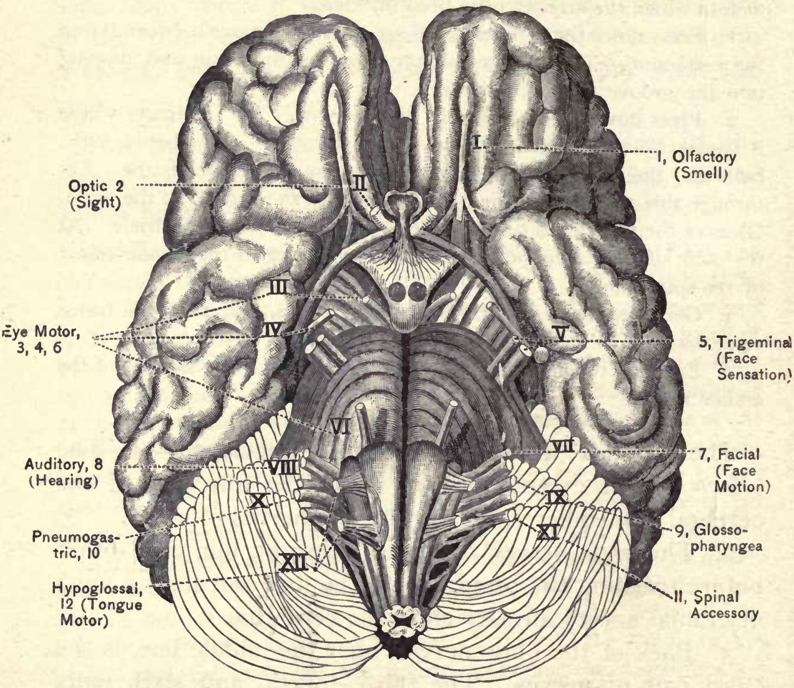


Fig. 77. The Base of the Brain, showing the Origin of the Cranial Nerves.

6. Back of and inside of the fifth pair is the sixth pair.

7. The nerves of the seventh pair are larger, and are farther back and outward. These are the *facial nerves,* and control the muscles of the face and the facial expression.

8. Close to the seventh are the eighth, or *auditory nerves.*

9. The ninth, tenth, and eleventh arise close together, farther back and well up on the sides of the spinal bulb. The ninth supplies the back of the tongue and the pharynx, and is called the *glosso-pharyngeal* nerve. It gives the sense of taste from the base of the tongue.

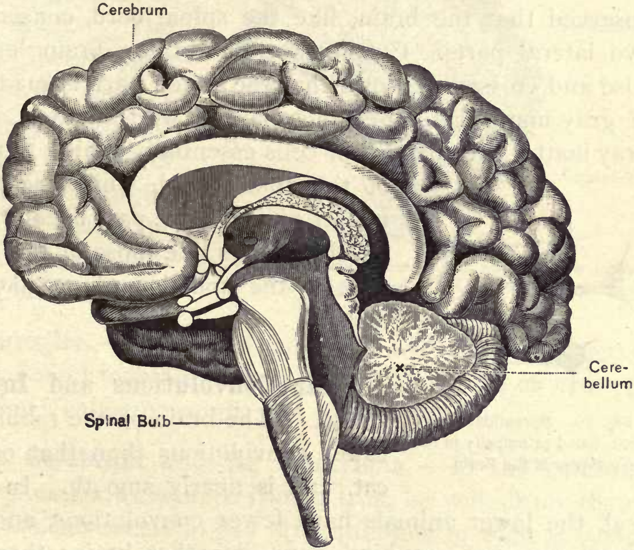


Fig. 78. Vertical Section of Brain.

10. The tenth pair, or *vagus nerves* pass down out of the brain cavity, give off branches to the pharynx and larynx, and are distributed to the heart, lungs, and stomach. The vagus nerves are so widely distributed that their functions cannot be briefly stated.

11. The eleventh pair arise in part from the spinal cord outside of the cranial cavity, enter the skull, and pass

out again to supply certain muscles of the neck and shoulders.

12. The last pair of cranial nerves, the twelfth, arise near the middle line of the spinal bulb. This pair supply the muscles of the tongue, and are called the *hypoglossal nerves.*

Brain composed of Two Hemispheres. — It will be observed that the brain, like the spinal cord, consists of two lateral parts. Cutting sections of the brain lengthwise and crosswise shows that the outer part is made up of gray matter and the inner part of white matter. The gray matter is composed of cells essentially similar to those of the spinal cord, while the white matter of the inner part is composed of white fibers like those of the outer part of the spinal cord, or like the nerves.

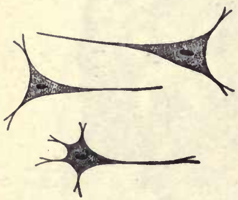


Fig. 79. Pyramidal Nerve Cells, found principally in the Gray Matter of the Brain.

Brain Convolutions and Intelligence. — The brain of the rabbit has fewer convolutions than that of the cat, and is nearly smooth. In general, the lower animals have fewer convolutions, and the lower races of mankind have smoother brains than the higher races. In the earlier stages of development man's brain is smoother, but with growth the convolutions appear, and increase in number with the growth of the brain. As we know that intelligent action depends on the gray matter of the surface of the brain, we infer that to accommodate its increase in the brain case it is thrown into folds, as the surface of the lining of the intestines is increased by folds and villi.

Gray and White Matter of the Brain.—The gray matter of the convolutions of the adult human brain is about one fifth of an inch thick, the larger part of the brain consisting of the white matter. Sections will show that there are several masses of gray matter in the brain deeper than the convolutions. These are the ganglia of the brain. The white fibers inside the brain connect the gray matter of the convolutions and these ganglia with all parts of the body through the spinal cord.

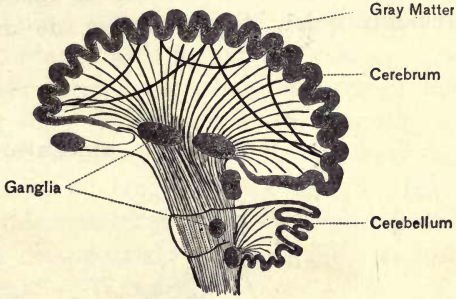


Fig. 80. Diagram of the Brain, showing the Spinal Cord, Ganglia, and Course of the Fibers.

Neuroglia.—The brain consists of nerve cells and nerve fibers, bound together and supported by a form of connective tissue called neuroglia.

The Cerebrum and its Functions.—If the cerebral hemispheres are removed from a frog, he will sit up about as before, but seems to pay little attention to what is going on around him. If placed on his back, he will turn over and sit up. If pinched, he may jump away, and may show that he can see by avoiding anything that may come in his way. If placed in the water, he will swim, and if he swims against anything that he can climb upon, will do so and remain quiet. If placed on a board, and the board be slowly tilted, he will move along and keep his equilibrium, climbing over the end of the board if necessary to keep his balance. If left alone, he will not move, but will die in his tracks, though he will eat food if it is put in his mouth. He seems to have lost the power of *willing* to do anything, or what we call the power of *volition.* He originates no action.

A Pigeon with Cerebrum Removed. — A pigeon with its cerebrum removed acts in about the same way. It remains quiet, stupid, paying no attention to ordinary

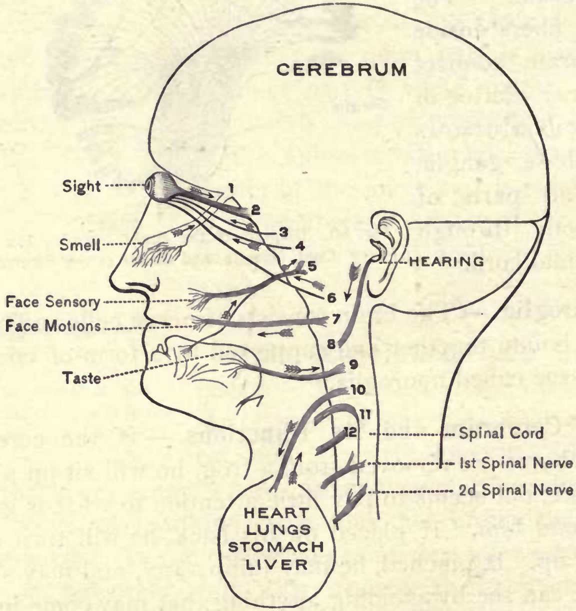


Fig. 81. Diagram of the Cranial Nerves and Sense Organs.

events. A sudden loud noise may cause it to start. If its tail be pulled, it moves forward to regain its balance. If thrown in the air, it flies for a distance. It swallows food placed in its mouth, but would starve surrounded by food.

Placed on its back, it will right itself, but it does not show the usual degree of *intelligence* and *will power*.

Function of the Cerebral Cortex. — " Experimentally, we learn that after the removal of the cortex (gray matter) an intelligent animal is reduced to the state of a non-intelligent automaton, responding indeed to stimuli, internal as well as external, but failing to interpret the significance of present events in accordance with bygone experience. A brainless dog is stupid; he may see a bone in front of his eyes without showing signs that he knows the meaning of a bone or the use to which it may be put; he may hear the crack of a whip, but he no longer shows signs of fear, for he does not remember its sting; his former purposeful behavior has entirely disappeared; in short, he has lost memory and judgment." — WALLER.

The Center of Sensations itself Insensible. — The gray matter of the outside of the brain is the central organ of intelligent sensation and motion. The functions of *volition*, of *consciousness*, of *intelligence*, seem to reside in, or rather to depend upon the activities of, the cells of the gray matter of the convolutions of the cerebrum. This we have learned from experiments on the lower animals, and from accidents and disease in the case of man. All sensation seems to be in the gray matter of the convolutions of the cerebrum, and yet it is itself insensible; it may be cut and cause no sensation. But when the nerve impulses from the various parts of the body reach the gray matter of the cerebrum they rouse the cells here to an activity that gives us what we call sensation. It is never a sensation until it reaches this part and is properly interpreted.

Crossed Control of the Body. — While each hemisphere mainly controls the muscles of the opposite half of the body, it also, in part, has control of its own side. Paralysis of one side (hemiplegia) is due to injury of the opposite cerebral hemisphere.

Location of Brain Functions. — Much has been learned of late years as to the location of special functions in the brain. Many of the motor centers have been determined

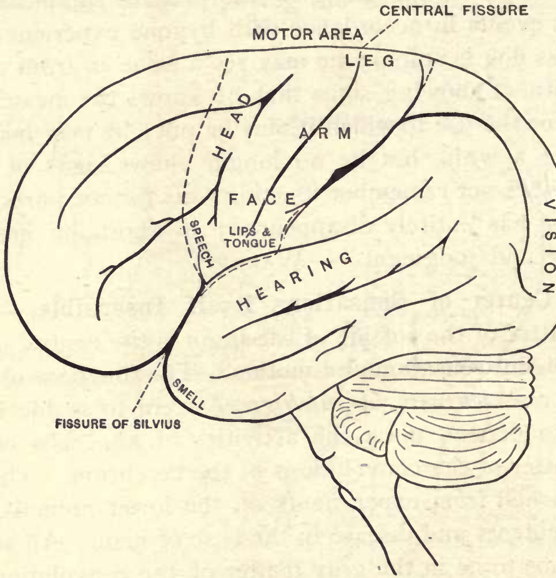


Fig. 82. Location of Brain Functions.

in the following manner: In some of the lower animals the brain has been exposed, and on stimulating certain portions with an electric current the movements that followed were noted. In monkeys, "particular movements of the arm, forearm, hand, and thumb can be produced by excitation of particular spots, almost as regularly as definite notes can be sounded on a piano by touching particular keys." In the case of man we infer that there is a similar location, and many cases of accident and disease have helped in locating the functions. But these areas are not sharply defined..

Left Hemisphere Better Developed. — The "speech center" is in the left hemisphere; the right eye and ear, which connect with the left brain, are better developed than the left, and in general the left hemisphere seems superior (in right-handed persons) to the right.

Location of Centers of Sensation. — It is not so easy to locate the centers of sensation as those for motion. For we can see the resulting motion, but a sensation can only be felt by the individual in whom it occurs. Still, some of the sensation centers have been located, and it is likely that in time we shall know much more on this subject. The accompanying diagram shows some of these centers.

The Functions of the Cerebellum. — The cerebellum is the center for regulating the actions of the skeletal muscles. When we walk or run, or even stand still, a number of muscles must act, and act in concert. The nerve impulses originate in the cerebrum, but the cerebellum is the center for harmonizing the action of these various muscles, or *coördinating* them. When the cerebellum has been removed from a pigeon the bird flutters, and, while possessing the power to move, does not seem capable of any regular and orderly movement. There is no loss of intelligence, no paralysis. Of course, in this experiment there is great disturbance of the system, and perhaps too much is inferred from it.

Functions of the Spinal Bulb. — The spinal bulb is the connection between the spinal cord and the brain. The bulb may be said to be that part of the spinal cord which is within the cranium. It is enlarged, hence its name, *spinal bulb.* From it arise all the cranial nerves except the first five pairs. The spinal bulb is also the center for the control of respiration, of circulation, of deglutition, and perhaps for many other processes.

Brain Work and Brain Rest. — Sleep is not merely rest for the body; it should be complete rest for the brain. In so far as there are dreams, it would seem to indicate a partial activity; that is, incomplete rest. The brain worker especially needs plenty of sleep; excellent authorities say at least eight or nine hours. The brain, like the muscles, needs exercise, and it also needs regular periods of rest. If a nerve cell is not kept active by the passage of nerve impulses through it, it usually atrophies, and may degenerate.

Sleeplessness. — Intense brain work, without sufficient sleep, is likely to lead to sleeplessness, as when one has some subject of special study in hand and either will not or cannot throw it off. Perhaps inventors are as prone to this sort of trouble as any one class of men. Keeping the blood continually in the brain, or in any organ, is likely to lead to a permanent congestion or inflammation that may cause serious, if not fatal, results.

Fatigue. — It is stated that brain workers need more sleep than those who work chiefly with the muscles. Fatigue of the voluntary muscles is much more a matter of nervous than of muscular origin. When one is completely "tired out," as he would say, if his mind can be aroused, as by some excitement, he will be found able to expend a good deal more muscular energy. So, too, many persons of slight muscular build, but of great "will power," are able to do more work with the muscles than others with larger muscles and less will. During fatigue the cell bodies are found to decrease in size, but there is no discernible change in nerve fibers as a result of fatigue.

Control of Mind. — But the brain worker should not only be able to sleep regularly and long enough; he ought to be able to throw off his mind any subject, and take rest while he is awake. If one allows himself to think about mental work while eating, the process of digestion will not go on well.

Habit of Resting the Brain. — The student should acquire the power and cultivate the habit of having, so far as possible, regular hours for work, and of completely throwing aside his work and worry at stated times. In seeking recreation it is well to choose that which will necessitate giving the attention to something entirely different from the daily work. For this reason chess may be no real recreation for the student, while a game of tennis, boxing, or other competitive exercise is likely to accomplish this very desirable object. A walk may put the muscles into play, but if the mind is still intent upon the line of work maintained throughout the day, the exercise may prove of little benefit. He may return more tired than when he set out. The exhilaration of horseback riding may prove far better, though perhaps involving much less muscular exertion.

Nervous Tissue least affected by Starvation. — It is worthy of note that in fasting the nervous tissue is less reduced than any other tissue, being scarcely diminished by complete starvation.

Blood Supply of the Brain. — Blood is supplied to the brain through four arteries: the right and left internal carotid arteries, and the right and left vertebral arteries. These arteries are so connected by cross-branches that if any three of them should be compressed, or the blood flow in them otherwise stopped, the fourth would still be able to give the brain blood enough for its work. When the brain is more active it receives a larger supply of blood. During sleep it is paler.

Fainting. — If the supply of blood to the brain is shut off, unconsciousness quickly follows. In the ordinary faint the blood supply has been reduced, owing to the diminution of the blood pressure or heart's force. It may be due to inhibition of the heart from some emotion, or bad odor, as in a close room; severe pain may be the cause; a blow over the pit of the stomach may stop the heart by reflex action. Fresh air should be supplied, and the body laid flat on the back. This position makes it easier for the blood to reach the brain and restore consciousness. Smelling salts (or ammonia) may stimulate respiration and circulation. Sprinkling a little cold water on the face may have the same effect, but it is not necessary to pour a large quantity of water over the person. Rubbing the limbs toward the heart promotes the flow of blood, and tends to start the heart to activity.

Apoplexy. — Apoplexy is caused by rupture of a blood tube and the formation of a clot that presses on the brain.

Meningitis. — Meningitis is an inflammation of the membranes immediately surrounding the brain or spinal cord or both.

The Water Cushion of the Brain. — Between the coats surrounding the brain and spinal cord there is a layer of liquid, comparable to that around the heart or lungs. When an undue amount of blood is sent to the brain, it is supposed that part of the cerebrospinal fluid is pressed out into the spinal cavity, thus relieving the pressure in the brain cavity.

Relative Activity of Gray and White Matter. — The gray matter is, physiologically, more active than the white, and in keeping with this is the fact that the capillary network is closer in the gray matter than in the white. This is true of the spinal cord as well as of the brain.

READING. — *Brain-work and Over-work*, Wood; *The Brain and its Functions*, Luys.

Summary. — 1. The outside of the brain consists of gray matter, the inside of white matter.

2. The twelve pairs of cranial nerves are distributed to the head, with the exception of the tenth and part of the eleventh.

3. The cranial nerves include all the special senses but that of touch.

4. Each hemisphere of the brain is connected with, and has chief control of, the opposite half of the body.

5. The gray matter of the cerebrum is the seat of the will, sensation, thought, and emotion.

6. The cerebellum regulates voluntary motion.

7. Many of the cerebral functions have been located.

8. The brain needs rest. In sleep less blood flows through the brain.

9. Work reduces the size of nerve cells. During rest they increase again.

Questions. — 1. Is there any special reason why the "speech center" should be in the left cerebral hemisphere?

2. Why does a light lunch sometimes enable one to go to sleep after mental work?

3. Why is it uncomfortable to hold the head down?

4. How does the nervous system resemble a telegraph system? In what respects are the two unlike?

5. Name some remedies for sleeplessness.

CHAPTER XVI.

EFFECTS OF ALCOHOL ON THE NERVOUS SYSTEM.

"Oh, that man should put an enemy into his mouth to steal away his brains!"

The Effects of Alcohol on Nervous Tissue. — The physiological effects of alcohol which have been considered in connection with the muscles, circulation, digestion, etc., are quite subsidiary to its effects on the central nervous system.

It is difficult to understand the extreme delicacy of organization of the nervous system. We can readily see how thoroughly nature has guarded this tissue by placing it in the most protected places in the body. But even after we have considered this point, we are not yet ready to comprehend the fine texture and sensitiveness of this tissue above all others. It is this high degree of susceptibility of the nervous system that renders it peculiarly subject to the effects of alcohol. The injury done to the brain by alcohol may not be readily discernible; but as it is so delicate we cannot expect to trace the changes in structure as we might in some of the coarser organs of the body. For instance, the rupture of a small blood-tube in most of the tissues of the body results in a small clot, which ordinarily is a matter of no special consequence; it forms a "black-and-blue spot," which is hardly more than a temporary inconvenience, for it does not ordinarily interfere with the function of the organ. It is soon absorbed, and all traces of it pass away. Not so with the brain: a clot produces pressure on the delicate nervous tissue, which results in paralysis — more or less complete — or death.

Effects of Small Doses of Alcohol on Mental Operations. — The common, but erroneous, idea is that alcohol stimulates the brain to a higher degree of activity. There does appear to be an exhilaration for a short time, but this is undoubtedly due to the increased flow of blood to the brain; for the liquor has paralyzed the smaller blood-tubes, thus allowing the brain to be flushed with blood. But careful experiments show that any temporary increase in mental activity, following small doses of alcohol, is always at the expense of accuracy and power, and that its effects cannot truly be called stimulating. And this period of exhilaration is extremely short-lived. In describing his methods of work, Helmholtz said that slight indulgence in alcohol instantly dispelled his best ideas. Professor Gaule states that once during the strain of an examination he suddenly stopped his wine and beer, and was surprised to find how much better he could work. An eminent professor in Leipsic once said that the German students could do twice as much work if they would let their beer alone. Dr. August Smith has found that moderate, non-intoxicant, doses of alcohol lowered his ability to memorize as much as 70 per cent.

Permanent Effects of the Continued Use of Alcohol. — "The long-continued use of quantities not immediately so disastrous, produces various structural changes, which are often markedly perceptible; and in chronic alcoholic disease, hardening of the brain structure, increase of the connective tissue, with diminution of the proper brain cells, thickening of the membranes, and effusions of serous fluid into the ventricles or cavities, are among the appearances often found. All these changes are usually accompanied with inflammatory and other degenerative processes, with a lowering and perversion of function, and with premature decay of all the mental and physical powers." — PALMER.

Dr. Clum in his work entitled *Inebriety, its Causes, its Results, its Remedy,* says: "The most important part of man is his nervous system; the cerebrospinal, sympathetic, and vasomotor being intimately interwoven and connected, composing the whole. The great nervous center, the brain, with its hemispheres, its gray and white matter, is the most complex of all complexities. The nerve fibers not only connect every cell with every other cell, but unite all nervous structures into one, making the entire body a complete whole, and forming close and direct sympathy between the intellect and the physical organization.

"The mind and body are so intimately connected that exhausting excess of either acts and reacts on the other. Excessive work, either intellectual or physical, the sudden loss of property, intense disappointment, great trouble, unrequited affections, etc., may impart a shock to the senses through the mind, which, extending to the molecules of the brain, disturbs their normal action; and a sufferer thus worn and debilitated with the cares of life, with an enfeebled will power, the result of nervous exhaustion, experiences a craving for some form of stimulant to 'brace him up.' He is on the verge of inebriety, or of insanity, or both, and if he indulges in alcoholic beverages he becomes an inebriate. Any disease inherited or acquired, acting either directly or indirectly upon the nervous system, may act as the predisposing, exciting, or complicating and protracting cause of alcoholic inebriety."

"Inebriety is often, too often, observed to flourish in the richest and most promising soil. The clergyman, the lawyer, the editor, the student, and all others who use their intellectual faculties to *excess*, as well as the mechanic, the laborer, and those who excessively exert their physical system, have unnatural longings for something to restore the exhausted energies of mind and body.

"The excessive worry of one man, the exhausting excesses of another, and the overwork of others, lead to organic lesions and nervous defects, and the disease inebriety, an ungovernable craving for alcoholic drinks, is the result."

Dr. Crothers, author of *Diseases of Inebriety*, says, "I have often been made impatient in listening to the lecturer presenting the 'scientific aspects of the alcohol question' to an audience, to see him illustrate extensively with charts, and spend hours to show the effects of alcohol upon the coats of the stomach, and upon the structure of the liver and the kidneys, and never allude once to *the brain;* when the fact is, alcohol's principal effect is upon this organ, and the functions of this organ so far transcend the functions of all the others, that I might say, there is no comparison."

MORAL DETERIORATION PRODUCED BY ALCOHOL.

[PROFESSOR H. NEWELL MARTIN.]

"One result of a single dose of alcohol is that the control of the will over the actions and emotions is temporarily enfeebled; the slightly tipsy man laughs and talks loudly, says and does rash things, is enraged or delighted without due cause. If the amount of alcohol be increased, further diminution of will power is indicated by loss of control over the muscles. Excessive habitual use of alcohol results in permanent overexcitement of the emotional nature, and enfeeblement of the will; the man's highly emotional state exposes him to special temptations, to excesses of all kinds, and his weakened will decreases the power of resistance; the final outcome is a degraded moral condition. He who was prompt in the performance of duty begins to shirk that which is irksome, energy gives place to indifference, truthfulness to lying, integrity to dishonesty; for even with the best intentions in making promises or pledges there is no strength of will to keep them. In forfeiting the respect of others, respect for self is lost and character is overthrown. Meanwhile the passion for drink grows absorbing; no sacrifice is too costly which secures it. Swift and swifter is now the downward progress. A mere sot, the man becomes regardless of every duty, and even incapacitated for any which momentary shame may make him desire to perform.

"For such a one there is but one hope,— confinement in an asylum, where, if not too late, the diseased craving for drink may be gradually overcome, the prostrated will regain its ascendency, and the *man* at last gain the victory over the *brute*."

NARCOTICS.

Definitions of Narcotics. — Gould's *Dictionary of Medicine*, one of the very best authorities, thus defines narcotic: "A drug that produces *narcosis*," and narcosis, as "the deadening of pain, or the production of incomplete or complete anesthesia by the use of narcotic agents, such as the use of anesthetics, opium, and other drugs." It is common, however, to treat of chloroform, ether, chloral hydrate, etc., in a group by themselves under the designation Anesthetics.

The Century Dictionary thus defines narcotic: "A substance which directly induces sleep, allaying sensibility and blunting the senses, and which, in large quantities, produces narcotism or complete insensibility. Opium, *Canna-*

bis Indica, hyoscyamus, stramonium, and belladonna are the chief narcotics, of which opium is the most typical. Direct narcotics . . . either produce some specific effect upon the cerebral gray matter, or have a very decided action on the blood supply of the brain."

Some authorities class alcohol with the narcotics.

OPIUM.

Opium. — Opium is the dried and thickened juice of the head, or capsule, of a species of poppy. Incisions are made in the partially ripened heads; the milky juice exudes; after about twenty-four hours the partially dried and thickened material is scraped off with a dull knife. Most of the opium comes to this country from Smyrna, with a smaller quantity from Constantinople. As gathered it is a reddish brown, sticky substance of peculiar odor. It is soluble in water, alcohol, and dilute acids, to all of which it gives a deep brown color. It is a very complex substance, but the chief constituent is *morphia*, or morphine, to which the properties of opium are due. One fourth of a grain of morphine is equal to a grain of opium of the average strength. "Opium was known to the Greeks, but was not much used before the seventeenth century; at present it is the most important of all medicines, and its applications the most multifarious, the chief of them being for the relief of pain and the production of sleep. Its habitual use is disastrous and difficult to break up. It is classed as a stimulant narcotic, acting almost exclusively on the central nervous system when taken internally; in large quantities it is a powerful narcotic poison, resulting in a coma characterized by great contraction of the pupils, insensibility, and death." — *Century Dictionary.*

Properties and Uses of Opium. — The United States Dispensatory makes the following statements as to its medical properties and uses: "Opium is a stimulant narcotic. Taken by a healthy person in a moderate dose, it increases the force, fullness, and frequency of the pulse, augments the temperature of the skin, invigorates the muscular system, quickens the senses, animates the spirits, and gives new energy to the intellectual faculties. Its operation, while thus extending to all parts of the system, is directed with peculiar force to the brain, the functions of which it excites sometimes even to intoxication or delirium. In a short time this excitation subsides; a calmness of the corporeal actions, and a delightful placidity of mind succeed; and the individual, insensible to painful impressions, forgetting all sources of care and anxiety, submits himself to a current of undefined and unconnected but pleasing fancies, and is conscious of no other feeling than that of a quiet and vague enjoyment. At the end of half an hour or an hour from the administration of the narcotic, all consciousness is lost in sleep. The soporific effect, after having continued for eight or ten hours, goes off, and is often succeeded by more or less nausea, headache, tremors, and other symptoms of diminished or irregular nervous action, which soon yield to the recuperative energies of the system, and, unless the dose is frequently repeated, and the powers of nature worn out by overexcitement, no injurious consequences ultimately result. Such is the obvious operation of opium when moderately taken; but other effects, very important in a remedial point of view, are also experienced. All the secretions, with the exception of that from the skin, are in general either suspended or diminished; the peristaltic motion of the bowels is lessened; pain and inordinate muscular contraction, if present, are allayed; and general nervous irritation is composed, if not entirely relieved."

Cocaine. — Cocaine is an alkaloid extract of a shrub native to the Andes. It is much used by the natives for sustenance during long journeys. It is a cerebral stimulant, developing a remarkable power of enduring hunger and fatigue. Its effects are similar to those of coffee, but are more intense. Large doses have a narcotic effect and cause hallucinations. Its long-continued use is followed by insomnia, decay of moral and intellectual power, emaciation, and death. Locally, it is a powerful anesthetic in a limited area of surface, hence is valuable for minor surgical operations.

Chloral Hydrate. — This drug is frequently, but incorrectly, called chloral. It is a powerful hypnotic, antispasmodic, and depressant to the brain and spinal nerve centers, and, to a limited extent, is an anesthetic. It is very useful in fevers accompanied by cerebral excitement, and in convulsions. Its hypnotic effects have led to its use by individuals without a physician's prescription, and often with fatal results. No drugs of this class should be used except under the advice of a physician.

Chloroform. — In a similar way this anesthetic, whose discovery is one of the greatest importance in modern surgery, is abused for the sake of its effect on the system, and the hold such a habit gets over the user is similar to that of the alcohol or opium habit.

The Use of Narcotics. — The use of anesthetics and narcotics may all be said to be typified by the use of alcohol. Not that they are all stimulants, though many of them are, in small doses, or in the earlier stages of their effects. They all act on the nervous system. They produce a pleasurable effect or they bring relief from pain. The use of many of them is begun during illness, when they are administered to relieve pain, as in neuralgia. The habit, once formed, is hard to break. Others, having heard of the soothing effects of these drugs, are unwise enough to experiment on themselves. Only the confessions of such victims, and the degrading effects on character, show how powerful is the sway which this class of drugs gains over those who yield to their influence. Let no one flatter himself that he has a strong will and can control himself. The history of their use is ever the same. They enslave. They destroy.

Tobacco. — The use of tobacco is needless. Man gets along well enough without it. It is injurious to many. It is an expensive habit. Many a man spends enough on tobacco to send a boy through college. With the excellent cheap printing of to-day, many of the very best books may be bought for the money that is paid for as many cigars. Even for those who can abundantly afford it, it seems extremely selfish, when it is needless, and there is so much good that might be done with the money. Another very selfish feature is that so many men do not seem to consider the fact that the air is public property, and they have no right to fill the air with any gas or smoke that is offensive to others. Very likely many men derive great comfort from the use of tobacco after they have once formed the habit, but most of these were made sick in learning, showing that the use is unnatural.

Nicotine. — The active material in tobacco is a substance called nicotine. It is a violent poison. A drop of it in concentrated form will kill a dog.

General Effects of Tobacco on the System. — Tobacco usually diminishes the natural appetite for food and interferes with digestion. It often affects the stomach and induces a craving for alcoholic drink. The eyes are frequently affected. Smoking often irritates the mouth and throat sufficiently to make the voice husky. The heart also is very frequently affected, the beat becoming unsteady. The muscles are in some cases weakened and affected by trembling.

Cigarette Smoking. — It seems to be clearly proved that cigarette smoking is very injurious, especially to boys. And if men smoke cigars, the example is set for the boys to smoke cigarettes. Some of the cigarettes are said to be steeped in preparations of opium, so that the use of cigarettes is often subjecting the user, not only to the tyranny of tobacco, but that of opium as well.

Perhaps Robinson Crusoe might have been excused for using tobacco, having no one to save money for, no unfortunates to aid, no children to educate, no one to whom he might set a bad example, no one whose breath of air he could contaminate, no one to smell his breath, no one to see the offensive results. But a man, living in the society of so many to whom this habit, in all its features, is so disgusting and in every way offensive, ought seriously to *consider whether he is doing right* in continuing such a practice.

Many boys seem to think it is manly; they wish to do as others do. It is not manly to imitate any one. Do nothing simply because some one else does it. To do this is to be a slave, to be led. And one bad feature of the tobacco habit is that one makes himself a slave to the weed. For, like other narcotics, it has a powerful influence on the system, and the habit, once formed, is hard to break.

How many men have been heard to say, "I wish I had never formed the habit."

Has any one in middle or later life ever been heard to say, "I wish I had formed this habit"?

READING. — *The Nature and Effects of Alcohol and Narcotics*, Luce; *Diseases of Inebriety*, Crothers; *Inebriety, its Causes, its Results, its Remedy*, Clum; *Inebriety*, Palmer.

Summary. — 1. The most important physiological effects of alcohol are on the nervous system.

2. Many physicians regard inebriety as a disease.

3. The use of alcohol weakens the will power.

4. Narcotics produce anesthesia, or loss of feeling.

5. Hence narcotics are useful in deadening pain, but their use is dangerous.

6. Opium is one of the most widely used of the narcotics.

7. Tobacco is needless and in many cases harmful.

8. Cigarette smoking is very injurious, especially to the young.

Questions. — 1. Why is cigarette smoking more injurious than cigar smoking?

2. How does the opium habit often begin?

CHAPTER XVII.

GENERAL CONSIDERATIONS CONCERNING THE NERVOUS SYSTEM.

Nerve Stimuli. — Natural nerve impulses that run outward are ordinarily started by the action of some nerve cell or cells, as from the gray matter of the brain or of the spinal cord.

Nerve impulses coming inward may be started in several ways. Ordinarily by some one of a few forces that are capable of affecting the nerve endings. Mechanical force, as pressure, acts on the nerve endings of the skin, and starts nerve impulses which are carried to the brain and rouse certain cells to activity, and give us the sensation of touch. The vibrations known as light excite the special nerve endings in the retina, but affect no other nerve endings. Sound is appreciated only by the endings of the auditory nerve. Certain gases or fine particles affect the olfactory nerve endings, and certain substances may give the sense of taste by acting on the ends of nerves in the mouth. Different nerves, then, are adapted to receiving impressions from the action of different forces.

Kinds of Nerve Stimuli. — There are four kinds of nerve stimuli, — electrical, mechanical, thermal, and chemical. In experiment, electricity is usually the best stimulus; mechanical stimuli, as used in the experiments with the muscle-nerve preparation from the frog, by cutting or pinching the nerve, may be employed; heat, as in touching the nerve with a hot wire, or holding a hot wire near the nerve, may be used as a stimulus; chemical stimuli, as acids, strong salt solution, etc., may also be used.

Essential Similarity of All Nerve Fibers. — It is to be noted that while special stimuli act on specially modified nerve endings, all nerve fibers are essentially alike, and the nerve impulse, however started, is probably the same kind of force. For instance, cutting the optic nerve, or severe shock, as a blow on the head, causes a sensation of light not quite so definite, but essentially the same as though light had acted on the retina, and thus started the nerve impulse, instead of a mechanical stimulus acting on the nerve fibers between the retina and the brain.

Relation of Stimulus and Sensation. — If we apply a stimulus of a given intensity, as of an electric current, whose intensity can be measured, it causes a sensation of a certain degree. Doubling the stimulus, or increasing it by a definite amount, does not increase the intensity of the sensation to the same degree. The sensations do not increase at the same rate as the stimuli. To increase the sensations arithmetically, the stimuli must increase geometrically.

Reaction Time. — "Reaction time" is the time between the application of a stimulus and the signal given as a response to show that the stimulus has been "felt." Thus a blindfolded person gives a signal as soon as he is touched. This interval between the stimulus and response varies with the individual, mode of stimulation, health, attention, etc. It is from one tenth to one fifth of a second; is shortest for touch; longer for sight than for hearing. The total reaction time is occupied by (1) the time of conducting the nerve impulse to the brain, (2) the time occupied in the cerebral cortex in the perception of the sensation and the formation of the volition, (3) the time of conducting the motor impulse and giving the signal. The greater part is in the middle interval, *i.e.* the central elaboration, during which the entering impression gives rise to an outgoing impulse.

Reflex Action. — In a previous diagram of reflex action, a single cell was represented as receiving the afferent im-

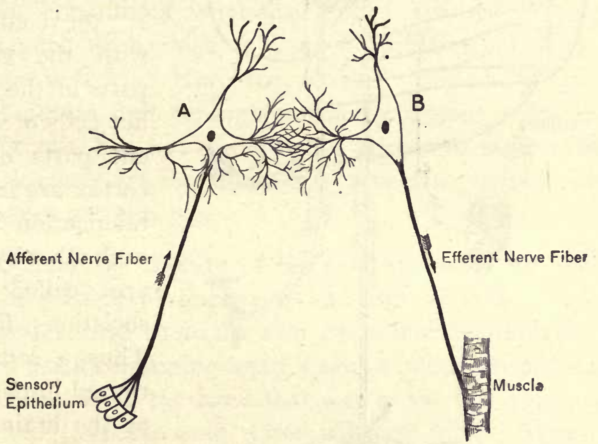


Fig. 83. Diagram of Reflex Action.

pulse and sending out an efferent one. It is more probable that at least two cells are concerned in such an act, one receiving the incoming impulse, and influencing, by means of fine connecting branches, a second cell which sends out the motor impulse, as shown in Fig. 83.

Connection of Brain Centers. — We have seen that the brain functions are more or less localized. We also know that the cortex receives impressions through the channels of the different sense organs, and we can respond through various channels, — speech, writing, facial expression, etc. We would therefore expect, theoretically, that the various parts of the cortex of the brain are connected. As a matter of fact, we find anatomically that this is the case. Not only are the cells of the gray matter connected with the various parts of the body, but cells of different parts of the cortex are in communication with each other by what are called "association fibers." Thus a sensation roused in one part of the brain gives rise to the sending out of an impulse from another part of the brain to produce the response.

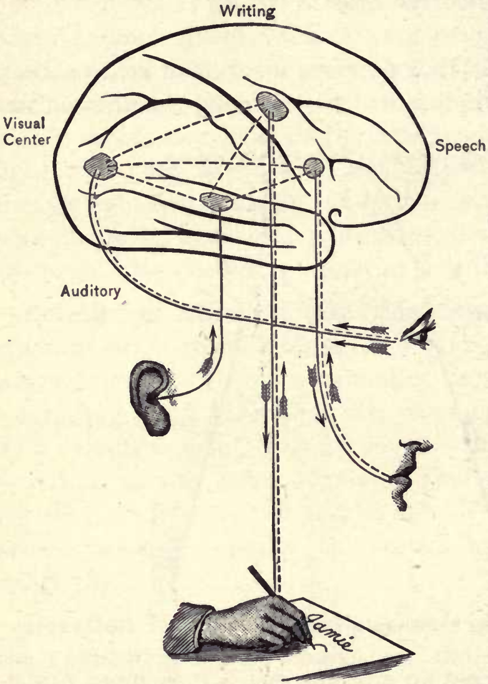


Fig 84. Connection of Brain Centers by Association Fibers. (After Landois and Stirling.)

(The dotted lines from the hand, mouth, and eye represent afferent fibers from the skin, muscles, and joints of the hand, lips, orbit, etc.)

The Nature of Sensation. — Of the real nature of sensation we know but little. Like consciousness, we call it a condition of the gray matter of the cerebral convolutions.

Perhaps the most practical definition of sensation that we can give is that it is the *interpretation that the cells of the gray matter of the brain give to the nerve impulses that come from without.* This will apply to ordinary sensations.

Subjective Sensations. — But sensations may be *subjective;* that is, they may exist without any corresponding external exciting cause. For some unexplained reason the cells of the brain are active, and their activity, however caused, constitutes what we call a sensation. Certain drugs, such as hashish, may excite an unusual degree of cerebral activity. Here the action is roused through afferent nerves, but through unusual channels; that is, the subject *sees,* but not through the nerves of sight. Many *hallucinations* are explainable to a certain degree; others we cannot account for.

The Relative Nature of Sensations. — If one hand be held in a basin of hot water and the other in a basin of cold water, and then the two be suddenly plunged into a third basin containing tepid water, a sensation of cold will be received from the hand that was in the hot water, while the hand from the cold water will feel heat. Sensations depend on comparison and contrast. After listening to low sounds, a sudden loud noise is painful; and after hearing loud noises, it is difficult to detect slight sounds. We hardly notice the gradual fading of the light at sunset. And the nose does not usually detect the slow fouling of the air in a room; but let one come in from the fresh outside air, and the contrast is striking. A constant current of electricity usually causes a muscular contraction at the time the current enters the muscle and at the time when the current is stopped, that is, at the "making" and the "breaking" of the current; but the muscle ordinarily remains inactive while the current is passing.

Induction Current used in Physiological Experiment. — The interrupted current, or induction current, is therefore commonly employed as a stimulus in physiological experiment. A sudden change seems to be requisite for producing the nerve impulse necessary to rouse a sensation in ordinary circumstances. Pressure may be applied so gradually that we fail to notice it. The art of the pickpocket, of the ventriloquist, of the sleight-of-hand performer, depends largely on this fact. Attention is called to something else, and the work is either quickly done when attention is completely absorbed on something else, or the act is so gradual that no sudden change is noted. In smelling it is often necessary to sniff; the sudden rush of particles of air bearing the odorous particles against the surface bearing the nerve endings seems to be necessary.

Dreams. — Dreams, due to more or less perfect brain activity, are often traceable to nerve impulses brought from the digestive tract, from the respiratory organs, from the skin (heat and cold and pressure), from sound, from any internal organ, according to the condition of the blood, pressure, etc. It seems to be well settled that dreams seeming to cover long periods of time really take place in a very short space of time, just as sometimes during waking hours thoughts fly through the mind in countless numbers and with incredible swiftness.

Ignoring Nerve Currents. — Do we have dreams when we recall none? Without attempting to answer this question it is well to note that the brain undoubtedly is constantly receiving nerve currents to which it pays no heed, or at least of which we are not conscious. For instance, our clothing is touching nearly the whole of the surface of our bodies, and, plainly, the surfaces thus touched are affected. Undoubtedly currents go to the brain, but as they are of no significance in ordinary circumstances, we learn to disregard them. If a savage were suddenly clothed as fully as we are, he would, for a long time, be continually conscious of the fact.

Judgment. — In what is called Aristotle's experiment, the experimenter crosses the first and second finger, and feels an object with the fingers thus crossed and eyes shut.

If a marble be rolled about by the two fingers thus crossed, it seems to be two. Here we use *judgment* with the sensation. Ordinarily, we could not feel, at the same time, one simple solid object with the outside of the first and the inside of the second finger. This illustrates how we are constantly using our judgment in interpreting our sensations. We see few things as they are in themselves. We see nearly everything in the light of past experiences.

Lingering Effect of Sensations. — We have noted the lingering effects of sensations, how sights and sounds linger and are fused one with the other. So we get continuous light from a series of flashes if they follow each other in sufficiently rapid succession, and continuous sound from a series of sounds that would be heard separately if they are more than about a sixteenth of a second apart. So with touch, if the finger be held against the teeth of a revolving wheel, if the wheel revolve slowly, the touch of each tooth may be felt, but when it whirls more rapidly the sensation becomes that of continuous pressure. Experience and experiment both go to show that probably nothing is wholly forgotten. Whatever acts upon a cell of nervous matter makes its mark. It may become dim, but it is never completely obliterated. The testimony of persons rescued from drowning, and other similar experiences, goes to show that the record was yet in the mind. We may fail to recollect, but we ever remember.

Habits are Acquired Reflex Actions. — The work of the spinal cord is that of a subordinate officer, whose duty is to relieve his superior, the brain, of many small tasks, and to afford him relief from having all the details constantly on his mind. If we learn to do many things mechanically, we save the effort of doing them by conscious effort and act of will. Whatever we do for the first time requires careful attention. To learn any new muscular action, such as a new step in marching, fingering a musical instrument, or typewriting, requires effort; they produce more or less fatigue. Subsequent effort in doing the same thing is very much less, showing that, in many cases, fatigue is mental rather than muscular. What we do from habit, and cheerfully, is easily done. Hence the desirability of forming good habits, that we may, without unnecessary effort, — that is, without loss of energy, — do what is needed for our well-being.

Fatigue from Standing. — We are not conscious of expending energy in standing until we begin to be weary; but the fact that a blow on the head causes one to fall reveals the fact that the brain is constantly sending messages to the muscles to make them act. The shock of the blow has stopped the sending forth of these messages, and so the body is no longer supported. None of the muscles that support the body have been injured or even touched.

The Usefulness of Resting. — We have, in youth, such a boundless store of energy that we do not sufficiently consider these matters. But if one wishes to follow the intellectual life long and successfully, he must learn to economize energy, and to direct his forces into useful channels. And one important part of this knowledge is learning how to rest. It is an art that very few have well learned.

Nervous System compared to a Telegraph System. — The brain is like a telegraph office in both receiving and sending out messages. Unlike the telegraph office, it has one set of fibers to bring currents in (afferent), and another to carry currents outward (efferent).

Efferent Currents. — We have concerned ourselves thus far chiefly with efferent nerve fibers and efferent currents. These efferent currents are sent mainly to muscles, to make them shorten or to relax, or to gland cells, to control their activity. The only other efferent currents, so far as known, are those which possibly go to the cells of the tissues to regulate their nutrition or their heat production.

Having given so much attention to the outgo of nerve impulses, let us ask the question, "What about the incoming nerve currents?"

Afferent Currents. — "All life long the never-ceasing changes of the external world continually break as waves on the peripheral endings of the afferent nerves; all life long nervous impulses, now more, now fewer, are continually sweeping inward toward the center; and the nervous metabolism, which is the basis of nervous action, must be at least as largely dependent on these influences from without as on the mere chemical supply furnished by the blood. We must regard the supereminent activity of the cortex and the characters of the processes taking place in it as due not so much to the intrinsic chemical nature of the nervous substance, which is built up into the cortical gray matter, as to the fact that impulses are continually streaming into it from all parts of the body; that almost all influences brought to bear on the body make themselves felt by it. To put the matter in a bald way we may ask the question, What would happen in the cortex if, its ordinary nutritive supply remaining as before, it were cut adrift from afferent impulses of all kinds? We can hardly doubt but that volitional and other psychical processes would soon come to a standstill, and consciousness vanish. This is, indeed, roughly indicated by the remarkable case of a patient whose almost only communication with the external world was by means of one eye, he being blind in the other eye, deaf of both ears, and suffering from general anesthesia. Whenever the sound eye was closed he went to sleep." — FOSTER.

Let us turn from the consideration of outgoing, or efferent, nerve impulses and their resulting action to the incoming, or afferent, nerve impulses and the activity which they rouse in the gray matter of the cerebrum — sensation.

READING. — *Wear and Tear*, Mitchell; *Power through Repose*, Call; *Technique of Rest*, Brackett.

Summary. — 1. Nerves may be stimulated by mechanical force, chemical action, heat, and electricity.

2. Electricity is the most convenient nerve stimulus for physiological experiment. The induction current is usually employed.

3. To increase sensations arithmetically stimuli must increase geometrically.

4. Reaction time is the interval between the application of a stimulus and the response.

5. Sensations are relative.

6. Habits are acquired reflex actions.

7. The nervous system is unlike the telegraph system in using one set of fibers for receiving and another for sending messages.

Questions. — 1. Is the difference in "reaction time" in individuals of any significance?

2. Why are slight wounds in a battle often unperceived?

CHAPTER XVIII.

THE GENERAL SENSES.

The Body a Collection of Organs. — We have been considering the body as a collection of organs working together to serve the brain, the mechanism through which the mind operates.

We have especially studied the muscles as the only means by which the mind manifests itself to the outer world.

Influences from the External World. — But how much mind would we have if we did not receive something from the outer world? Read the story of Kaspar Hauser. We are continually getting knowledge of the outer world and of the condition of our own bodies through the afferent nerves. We may never know fully what consciousness and thought are, but we can understand that to the brain are continually streaming nerve impulses that convey messages which the brain more or less completely interprets.

Classification of the Senses. — These incoming currents pass along myriads of nerve fibers. But the nerve fibers are all essentially alike. And the kinds of sensations that these currents arouse in the brain are but few. It is difficult to classify the senses, but it will serve our convenience to divide them into two groups.

General Sensations and Special Senses. — In distinction from the special senses, sight, hearing, etc., are the general sensations already referred to, such as hunger, thirst, fatigue, nausea, satiety, faintness, etc. They are often called "common sensations," and Martin designates them as "sensations which we do not mentally attribute to the properties of external objects, but to the conditions of our own bodies."

General Sensations. — Nerve endings in different parts of the body may be affected by the blood and the lymph, and give us sensations of comfort, discomfort, restlessness, fatigue, faintness, etc. These are called general sensations. They are probably due to the condition of the blood, or to the condition of nutrition of the various parts of the body. Thus after muscular exercise the muscles are acid in their reaction, while they are alkaline after resting; after exercise carbon dioxid accumulates in them to a certain extent. Hunger and thirst come on after abstinence from food and drink, or after work exhausting the tissues. The presence of the various waste products, or the condition of the cells as the result of their activity, acting through the nerve endings in the tissues, keep the nerve centers informed as to the condition of the parts of the body. If these conditions are extreme, we may have definable sensations, but ordinarily the sensations are of an undefinable sort which we designate as "general sensations."

The Muscular Sense. — As an example, we will take the case of estimating the weight of an object by holding it in the hand. Our estimate is thought by some to be the result of (1) direct consciousness of the degree of effort put forth; but probably it is (2) a sensation, or complex of sensations, aroused by nerve impulses from the organs used. There are afferent nerve fibers with endings in (1) the skin, (2) the muscles and tendons, (3) the joints.

In extending the arm and moving it up and down, all three of these sets of nerve endings are probably stimulated, and impulses thence conveyed to the brain.

Muscular Sense and General Sensibility. — It is a matter of doubt whether or not the impulses from the muscles are predominant, and consequently whether the term "muscular sense" is the most appropriate. Peculiar nerve endings have been found in the tendons, and the joints are believed to have an especially rich nerve supply. It is not necessary that we actively use the muscles to have sensations of this kind. In passive moments, as the raising of the arm by another person, we have a "sense of position" of the parts, a considerable share of which is probably due to the tension of the skin and changes in the joints. There is, of course, some tension of the muscle, even in this passive movement, that might affect nerve endings in it. The muscular sense is closely related to the general sensibility already mentioned, if not a modified form of it.

Importance of Muscular Sense. — It is difficult to realize the importance of this sense in our daily experience. We probably underestimate it, and attribute to sight too much of our knowledge of the external world. The fundamental facts concerning the objects about us are not obtained through sight alone. Such knowledge is based on complex judgments concerning the meaning of auditory and visual phenomena, according as they have, in past experience, been interpreted by tactile and muscular perceptions. That is, when reduced to its simplest terms our most practical and important knowledge of the world is the outgrowth of tactile and muscular perceptions; by and with them all other sense perceptions have been corrected and compared.

Dependence of Sight on Muscular Sense and Touch.— An illustration of the assistance which touch and the muscular sense give to the sense of sight is furnished in the case of a boy who had been blind from birth, and received sight at the age of twelve years by means of a surgical operation. At first he could not distinguish a globe from a circular card of the same color until he had touched them. He knew the peculiar features of the dog and the cat by feeling, but not by sight. Happening one day to pick up the cat he recognized for the first time the connection between the new sense of sight and the old familiar ones of touch and the muscular sense. On putting the cat down he said, "So, puss, I shall know you next time."

Pain. — When a heavy weight is laid on the hand it may cause pain. It would at first seem that the ordinary pressure sense, when unduly exaggerated, becomes pain. But there seem good reasons for considering pain as a distinct sense from that of touch intensified. It is thought that there are, throughout all parts of the body, nerves of "common sensibility" or "general sensibility," which keep the nerve centers informed as to the condition of all the various tissues, and that ordinarily we have no sensation resulting from the impulses; to use the language of the psychologist, "they do not rise above the threshold of consciousness." They may have some influence in adjusting the action of the different parts. We have seen how the bloodflow to any part is continually adjusted without our knowing anything about it. But we are usually more or less conscious of the general condition of the body. We call by the name of "common sensations" such feelings as hunger, thirst, nausea, fatigue, depression, melancholy, restlessness, such as many experience preceding a thunderstorm, the feeling of general discomfort known as malaise, and its opposite, the feeling of general well being. The body seems to have a set of nerves to give information as to the state of nutrition of the body, and as to its condition generally. These nerves, when the system is disordered in any part, may bring messages that cause intense pain. Of course, they are warnings (they are more than mere warnings; probably if the earlier indications of simple discomfort had been heeded the later more emphatic messages of pain would not have been necessary). These messages of pain *demand* attention.

The Extent of Pain. — In reference to pain in the skin, it is held that the skin, too, has its nerves of general sensibility, and that these are distinct from those of touch and temperature sense. That when they are unduly stimulated they give rise to painful sensations. It is to be noted that the internal organs are ordinarily devoid of feeling, and that the skin is especially sensitive. The skin senses stand guard at the outposts, so to speak, of the body's camp, and give warning of approaching danger. No enemy may enter without being discovered by these keen sentinels, and the alarm is given. If it is not heeded, great harm may follow. And it is a comfort to know that the more severe wounds do not cause pain in proportion to their extent. When a person says his "lungs are sore" the pain is usually in the muscles of the chest from coughing. While there may be acute pain from the lungs, as in pleurisy, there is often deep-seated lung disease without pain from the lungs themselves. The muscles of the chest and back may be strained by lifting, and the soreness is erroneously attributed to the lungs or kidneys. Hence there is frequently a wholly needless apprehension of deep-seated disorder, whereas in reality there is merely a strain of superficial muscles. In amputating a limb the chief pain is in cutting through the skin. Some excellent authorities still hold the view that pain is merely the result of intensifying any of the simple sensations; but it is generally held that it results from the excessive stimulation of the nerves of general sensibility; as Foster puts it, "the constantly smouldering embers of common sensibility may be at any moment fanned into the flame of pain."

Pain a General Sense. — In the real "special senses," — sight, hearing, smell, taste, touch, and temperature sense, — we refer the sensation to some external object, whereas general sensations are subjective, referred to our bodies. Ordinarily we do not localize the common sensations, and a further indication of the relationship of pain and general sensation is in the lack of complete localization of pain. Slight pain, especially in the skin, may be closely located, but severe pain tends to become indefinite and diffuse. So we may class both the muscular sense and pain with the "general" rather than with the "special" senses.

Hunger and Thirst. — The cause of these sensations in a healthy body is plainly the need of food and water throughout the system generally. The sensation of thirst manifests itself in the throat, and the longing may be temporarily relieved by merely moistening the throat. So hunger may, for the time, be appeased by filling the stomach with indigestible material. But the sensation soon returns. The system has a crying need, and it is not to be put off by any such frauds. That these sensations are really demands made by the body as a whole may be shown by the fact that they are permanently relieved by introducing food and water into the body (by the rectum, for instance), in which case the throat and stomach have nothing given them directly. Since, however, food and drink naturally enter by the throat and stomach, the mucous membrane of these organs has become spokesman of the body for its demands.

Reading. — *Pain*, Corning.

Summary. — 1. Brain action depends, in the long run, upon impulses from without. If we had no *impressions*, we could have no *expressions*.

2. General sensations are referred to our bodies and their condition; special sensations are regarded as attributes of external objects.

3. The "muscular sense" probably depends chiefly on impulses from the tendons and joints.

4. The muscular sense is necessary for the full interpretation of sight. It enables us to judge of the degree of effort put forth or force resisted.

5. Pain is a general sensation. It is a warning — the cry of a sentinel that an enemy has passed the picket line.

6. Hunger and thirst indicate the need of food and drink. They are local signals of a general want.

Questions. — 1. If we had no sense of pain, what might result?

2. If we pass by a meal time without eating, why does the sense of hunger disappear?

CHAPTER XIX.

THE SPECIAL SENSES—TOUCH AND TEMPERATURE SENSE.

What we learn by touching Objects. — Let one person rest the hand flat on the table, palm upward, and close the eyes. An object placed on the palm, by another person, may give rise to various sensations, so that it may be described as rough or smooth, light or heavy, hot or cold, wet or dry, etc. If the object is very heavy or very hot, it may cause pain. If now the thumb and fingers are raised and applied to the object, more definite information will be gained as to its shape, size, surface, etc. Now raise the object in the hand, and further appreciation will be gained as to its weight.

These experiments show that several sensations are involved in the handling of objects, and that the knowledge so gained is complex.

Cutaneous Sensations. — The sensations from the objects resting on the skin of the passive hand may, probably, all be referred to impressions made on nerve endings in the skin, and are called *cutaneous sensations.* They include: (1) the pressure sense, or touch proper, (2) the temperature sense, and (3) pain.

Nerve Endings in the Skin. — The skin consists of two layers, the epidermis and the dermis. We need now to recall those conical elevations of the dermis that we call papillæ. In these papillæ are certain important nerve endings. There are several kinds of nerve endings in the skin and underneath it that receive the impressions which, carried to the brain, give us sensations of touch (and allied sensations to be considered soon). Pressure on the skin affects these nerve endings, and starts impulses that pass along the sensor fibers to some nerve center, probably in the spinal cord, spinal bulb, or brain.

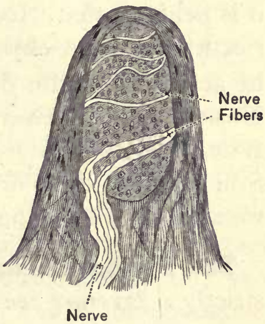


Fig. 85. Papilla of Skin with Touch Corpuscle.

Touch Corpuscles. — These "touch corpuscles" are not regarded as essential for producing the sensation of touch, but some nerve endings in the skin do seem necessary; for if a nerve fiber be touched, not at the end, but somewhere along its course, we get, not a sensation of touch, but a sensation of pain. Except in the mouth and nose, we get little, if any, sense of touch from any organ but the skin. The lining of the digestive tube and the internal organs generally are devoid of this sense.

The Sense of Touch. — Of the special senses the most general is that of touch. Seeing and hearing, taste and smell, belong to very limited parts of the outside of the body, but we have the power of feeling all over the surface of the body.

Touch the most General of the Special Senses. — Not only is the sense of touch the most general in being distributed over the whole of the body, but it is the most widely distributed sense throughout the animal kingdom

As we descend the animal scale we find many of the lower animals lacking some of the senses that we possess. In many of the simpler forms of animal life there is no evidence of a sense of hearing, and it is extremely likely that if they have taste and smell, these senses are in a very rudimentary state of development. But in all these forms it is believed that "feeling" exists. Contact of their exterior with foreign objects is so often immediately followed by action that little doubt remains about their having the sense of touch. Even ameba may have, in a rudimentary state, the power to distinguish light, to taste, and to hear. Still we have little or no evidence on these points, while we are pretty sure that it feels.

The Pressure Sense. — The sense of touch, proper, is strictly a *pressure sense*. If we test the skin to find what regions are able to detect the least pressure, it is found that the forehead is most sensitive, and nearly equally so are the temples, back of the hand, and forearm.

Ability to detect Differences of Pressure. — The ability to detect differences of pressure is tested by finding what is the least addition to a weight required to make it seem heavier. For instance, if a weight of 11 grains is just perceptibly heavier than one of 10 grains, it does not follow that 1 grain added to a weight of 100 grains will give any palpable increase. To 100 grains must be added 10 grains before additional pressure is felt; that is, whatever the weight, there must be the *same ratio* of increase to increase the sensation. This is part of the law, already stated, of the relation of stimulus and sensation. The law is true only in a general way and will not apply in extreme cases. It is stated that the forehead, the lips, and temples appreciate an increase of one fortieth to one thirtieth of the weight estimated, while the skin of the head, the fingers, and the forearm require an increase of one twentieth to one tenth for its perception.

After-Pressure. — The lingering effect of pressure, or after-pressure, may be noticed after taking off a tight hat, skate strap, shoe, or glove.

Local Sign. — "If a point of the skin is touched, certain tactile corpuscles are irritated; these, in turn, set up impulses in sensory nerve fibers, and these impulses are carried by the fibers, first to the spinal cord, and then to the brain, where the fibers end in ganglionic masses in the gray matter of the cerebral cortex. There are thus projected, as it were, on the cortex of the brain, tactile centers for the hind leg, fore leg, neck, eye, ear, trunk, etc.; and it follows that each point of the skin has a corresponding point in the cerebral cortex. Thus for each stimulation of a point of the cerebral cortex there is a *local sign*, and so we localize tactile impressions."

Accuracy in locating Touch Sensations. — The accuracy varies, and is ordinarily keenest where the nerves are most numerous. Where the sense of locality seems to be improved by cultivation, this appears to be due to keener discrimination in the brain cells, and not to changes in the nerves or nerve endings. This is indicated in the fact that if the fingers of one hand become more discriminating by practice, it will be found that the fingers of the other hand, without special training, are also improved.

Test by Compass Points. — The delicacy of localizing touch is usually tested in this way. The blunted points of a light pair of compasses are allowed to rest gently on the skin of various parts of the body. If the two points are very close together, they will be *felt as one* pressure. That part which can best distinguish, as two points of touch, these blunt points, is considered the most sensitive. By this test the tip of the tongue is the most sensitive, being able to distinguish, as two separate points of contact, the tips of the compasses when only one twenty-fifth part of an inch apart. Following is the order of degrees of sensitiveness: tip of tongue, tips of fingers, lip, tip of nose, eyelid, cheek, forehead, knee, neck; while the middle of the back seems least sensitive, the two points not producing two distinct sensations until they are more than two and a half inches apart. In general those parts which are most used, and those parts which are more freely movable, are most sensitive; for instance, the knee is much more sensitive than the middle of the thigh or the middle of the leg, and the elbow than the middle of the arm or forearm. If the compass points, about half an inch apart, be passed from the palm to the tips of the fingers, it will at first seem one line gradually separating into two diverging ones, owing to the keener localizing power as the finger tips are approached.

Reference of Sensation to the Region of Nerve Endings. — If the "funny bone," or "crazy bone," be hit, *i.e.* if the ulnar nerve be bruised against the bone, sharp pain may be felt in the wrist and hand, and soreness of these parts may be felt for days, though they are not in the least injured, but only the nerve at the elbow. The currents along this nerve rouse sensation that we have learned to localize at the endings of the nerve fibers. So, too, after amputation of a hand or foot, there may for years be sensations referred to the missing member, probably due to irritation of the nerves of the stump. There is, then, no certainty of getting rid of a corn by amputating a toe.

The Temperature Sense. — Many cases are on record in which, from accident or disease, the pressure sense was lost and the temperature sense retained, or *vice versa*. Such facts have led to the belief that the temperature sense is distinct from that of touch, and has its own nerve fibers and nerve endings.

Two Sets of Nerve Fibers for Distinguishing Heat and Cold. — Since heat and cold are only differences in the degree of heat, we would expect both of these kinds of impressions to be received through one set of nerves. There seems, however, to be good evidence of two sets of nerve fibers, one for heat and the other for cold. In the common experience of the foot "going to sleep" by pressure on the sciatic nerve, or the arm from compression of the brachial nerve, the skin may be found, at a certain stage, to be only slightly sensitive to warmth, while distinctly sensitive to cold. In some diseases of the spinal cord the skin may be affected by warmth, but not by cold. The sensations of cold and pressure seem to be usually lost or retained together, while those of warmth and pain have a similar connection. But more accurate results are obtained by touching the skin with a blunt metal pencil, warmed or cooled.

Warm Spots and Cold Spots. — If this be applied at regular close intervals, it is found that some places feel the warm point, while others feel the cold. In this way the skin has been mapped out into "warm spots" (warmth-perceiving spots) and "cold spots" (cold-perceiving spots), and still other areas seem not sensitive to temperature.

Heat or cold, if applied directly to a nerve trunk, does not rouse sensations of temperature, but, if strong enough, produces pain. If the elbow be dipped into water at the freezing point, a sensation not of cold but of pain is caused, and is felt in the hand. Heat and cold are not felt in the digestive tube except at or near the openings. If very hot liquid be swallowed, it may cause pain in the gullet and stomach. If a considerable quantity of warm liquid be taken, it may give a feeling of warmth from its effect on the skin of the abdomen, by conduction of heat outward. As with other senses, a sudden change in the degree of the stimulus is more certain to rouse sensation than a gradual change.

READING. — *The Five Senses of Man*, Bernstein.

Summary. — 1. The cutaneous sensations are touch proper, temperature sense, and pain.

2. There are touch corpuscles in the papillæ of the dermis.

3. Touch is the most general of the senses, both in its extent in our bodies, and in the number of animals possessing it.

4. Touch proper, or pressure sense, is tested by discrimination of additional pressure.

5. Touch localization is tested by discrimination as to the distance of two points of contact.

6. Temperature is discerned by a special set of nerve fibers.

7. Touch and muscular sense are necessary adjuncts of sight to give correct perceptions of size and form.

Questions. — 1. What is the explanation of tickling?

2. Where does the change occur by which we become more discriminating in the sense of touch?

3. Why does an emotion, such as shame, make one feel hot?

CHAPTER XX.

THE SENSE OF SIGHT.

The Sense of Sight. — In the fable of the blind man carrying the lame man whose eyes were good, we have an illustration of the dependence of the various organs on each other. We have considered how all our knowledge, both of the condition of our bodies and of the external world, comes through the nervous system. Now, so far as the senses we have studied are concerned, we learn almost nothing of the external world except from actual contact. But sight reveals objects at a distance. Without the eye the body is comparatively helpless. The lame man that the body carries is a slight burden in comparison with the assistance which he renders. We can well afford to carry with us all the time two of these lame men to keep posted as to the objects beyond our reach. Of course touch is a great aid to our interpretations of what we see. But sight is evidently the main avenue of knowledge, the royal road along which come the messages which bring us the most news, which give us the keenest delight; which makes us aware of most that we know of this world, and the only means of knowing that there are other worlds than the one we inhabit.

Protection of the Eye. — The eye is set well back in its socket and guarded by three projecting bony prominences, — the brow, cheek bone, and the bridge of the nose. It is further protected by the eyelids and eyelashes.

The Lacrymal Secretion. — The lacrymal gland, or tear gland, is just above the outer angle of the eye, and pours its secretion over the eyeball in weeping, or when there is need of an unusual supply of tears. The lids serve as curtains to admit or shut out light, and, by winking, wash the eye with their own secretion, a fluid mixture of salt water and mucus. It is as though a man were kept all the time in front of a plate-glass window, with water and rubber scraper, to keep it clean and bright. The lacrymal secretion is, ordinarily, carried off as fast as it is made, by two ducts beginning at the inner angle of the eye, one on each lid; these two ducts soon unite and empty by one outlet into the nasal cavity. If these ducts are stopped, or if the secretion be formed very rapidly, the liquid overflows on the face as tears.

The External Parts of the Eye. — The "white of the eye" is the sclerotic coat. It has blood tubes, but ordinarily they are not conspicuous. The front part of the eyeball is covered with the cornea. This is transparent, and the color of the iris shows through the cornea. In the center of the iris is the hole, or pupil, by which light enters the interior of the eye.

The Conjunctiva. — The front of the eyeball is covered by a thin, transparent, mucous membrane, the conjunctiva, which turns back and lines the inside of the eyelids. It is highly sensitive.

The Muscles of the Eyeball. — There are six muscles which move the eyeball, — four straight muscles (the recti) and two oblique. The four straight muscles arise from the deepest part of the eye socket and pass forward to be attached to the top, bottom, and sides of the ball. Where they are attached, they are flattened out like straps. The inferior oblique arises from the inner front part of the orbit and passes outward to attach to the under surface of the eyeball. The superior oblique arises, like the recti, at the deeper part of the eye socket and passes forward through a fibro-cartilaginous loop or pulley near the inner, upper angle of the orbit, and then runs outward and is attached to the upper surface of the eyeball.

Movements of the Eye.—These six pairs of muscles move the eyes to right and left, up and down, and give rotary movements. Normally the two eyes move in the same direction at the same time, though in looking at near objects the two eyes both point inward, so that one appears cross-eyed, and in looking at an object that is moving away from one, the eyes are gradually diverging, though this is slight.

Dissection of an Eye.—The muscles and external parts of the eye may readily be seen by examining the eye of a rabbit in its natural position and then dissecting it out. A beef eye should be obtained from the butcher and the structure of the eye learned by following the description below.

The Coats of the Eye.—There are three coats, the outer or sclerotic, the middle or choroid, and the inner called the retina.

The Sclerotic Coat.—This is of a dull white color, constituting the "white of the eye." It is thick and tough, holding all the contained parts firmly and furnishing sufficient strength for the attachment of the muscles that move the eyeball.

The Choroid Coat.—The middle layer of the eye coat is the choroid. It is thinner than the sclerotic and of much more delicate structure. It is permeated by blood tubes, and has an inner lining of dark color to prevent the reflection of light in the eye, just as most optical instruments are painted black on the inside.

The Retina.—The retina is a continuation and expansion of the optic nerve and forms an inner coat that lines all but the anterior part of the eye. It is a thin, translucent film, somewhat like the film that forms over the white of an egg when it is first dropped into hot water. It is exceedingly delicate and easily torn. The retina is the only part of the eye that is sensitive to light, and on it the images must be formed to produce distinct vision.

The Cornea. — The clear front part of the eye is the cornea. It is a continuation of the sclerotic coat and is

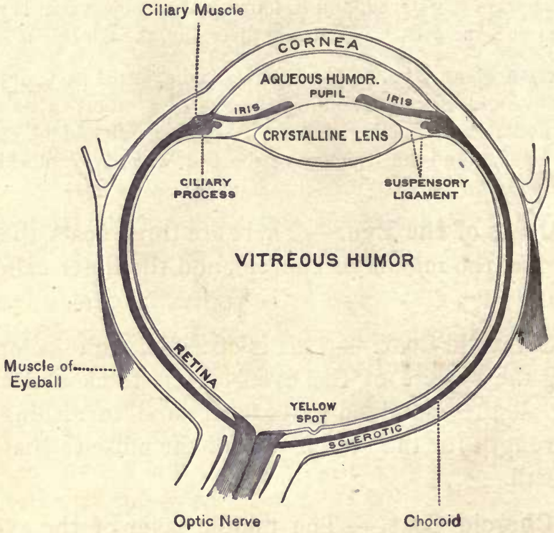


Fig 86. Horizontal Section of Right Eye.

more bulging than the rest of the front of the eye, as can be seen by taking a side view of the eye, or by noticing some one who closes the eyelids and rolls the eyes about.

The Iris. — This is the part that gives the color to the eye, or if the pigment that gives the color is lacking, the blood gives the pink color seen in albinos. The iris is a forward continuation of the choroid coat.

The Pupil. — Most of the light that passes through the transparent cornea is stopped by the opaque iris. But in the center of the iris is a round hole through which light enters the interior of the eye. The pupil looks dark because it is the only opening into a dark room.

Regulation of the Amount of Light admitted into the Eye. — Hold a hand glass between the face and a well-lighted window. Note the size of the pupils. Quickly turn toward the darkest part of the room. We see, what we have all noticed in watching the eyes of a cat, that when subject to a bright light the pupil is small, but with less light the pupil is larger. The iris has circular muscle fibers that reduce the pupil when there is too much light for the eye, and when the light is feeble the pupil opens wider.

The Refracting Media of the Eye. — The media that refract the rays of light to form the images on the retina are the cornea, the aqueous humor, the crystalline lens, and the vitreous humor. The cornea has already been described.

The Aqueous Humor. — In looking at the entire eye it is not easy to realize that there is a space between the cornea and the iris. In this space is the clear, watery aqueous humor.

The Vitreous Humor. — All but the front part of the space within the coats of the eye is filled with a clear, jellylike substance, the vitreous humor.

The Crystalline Lens.— Just back of the iris is a double-convex lens, clear as crystal, and of about the consistency of a gumdrop. It is less convex on the front surface.

The Lens Capsule. — The lens is completely enveloped in a thin, transparent membrane called the lens capsule.

The Hyaloid Membrane. — A thin membrane, the hyaloid membrane, lines the inner surface of the retina. As it continues forward toward the lens capsule it is called the suspensory ligament.

The Ciliary Muscle. — Arising from the sclerotic coat, just within the outer border of the iris, is the ciliary muscle. It is inserted in the margin of the lens capsule by means of fibrous strands that form an intimate part of the capsule.

Experiment with Lens to show Inversion of Image. — Take a double-convex lens, two of which are in the common "tripod lens," or

Fig. 87. The Formation of an Image on the Retina.

any hand magnifier. Hold this up in front of a window and catch the inverted image of the window on a piece of paper held back of the lens. This illustrates how the image of an external object is formed by the crystalline lens upon the retina of the eye. If two lenses of different thickness can be obtained, it will be seen that the thicker lens (if both have the same diameter) will make an image closer to the lens than the thinner one.

Experiments to illustrate the Adjustment for Distance. — (1) Stick a pin at each end of a book cover. Hold the book at about the usual distance for reading, so that the two pins are in a line with the eye. Look closely at the nearer pin, and the second pin will appear indistinct. Now look closely at the head of the farther pin. The nearer one may be seen, but not sharply. (2) Hold the tip of a pencil in a line with any object, say a picture, on a wall opposite. In looking at the tip of the pencil the picture is dim. Now look by the pencil at the picture, and the point of the pencil will be blurred.

Adjustment of the Lens for Seeing at Different Distances. — If we look up from a book we are reading, we do not realize that any change is necessary in the eye for us to see a distant object. But the above experiments prove that we cannot, at the same time, see distinctly a near and a distant object. When the photographer places his camera, he moves the ground-glass plate back and forth till the image is distinctly formed on the plate. We cannot move the retina back and forth, so we change the shape of the lens. When we look at a near object the lens becomes thicker, and when we look at a distant object the lens becomes less thick. This adjustment is called *accommodation.*

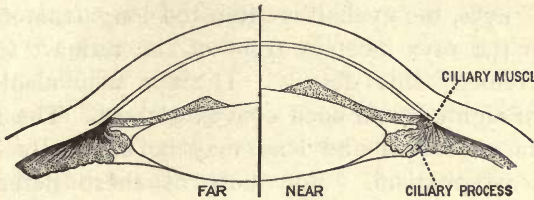
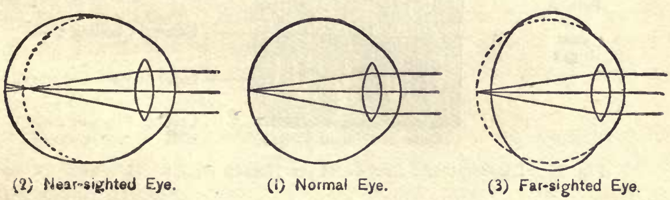


Fig. 88. A Diagram to illustrate Accommodation.

Action of the Ciliary Muscle. — In looking at a near object, the ciliary muscle pulls on the hyaloid membrane, and draws it forward (since the muscle is fastened at the point where the iris joins the cornea). When the hyaloid membrane is pulled forward, the lens is released from pressure that was given it by the lens capsule. Now the lens becomes thicker because it is elastic, and when it is not subject to pressure it tends to become relatively thick. When we look at a distant object the muscle relaxes, and the capsule presses on the front of the lens and flattens it, thus adjusting for far sight. It should be noted that adjustment for near sight is brought about by muscular effort, hence is fatiguing; whereas adjustment for far sight is accomplished mechanically, without effort.



(2) Near-sighted Eye. (1) Normal Eye. (3) Far-sighted Eye.

Fig. 89. Defects in Eyesight.

Defects of Eyesight. — In old age the lens usually becomes less elastic, and cannot adjust for near sight. Since it is unable to grow more convex, artificial lenses (eye glasses) may be used to enable one to see near objects clearly. Most elderly people see fairly well at a distance, but use glasses for reading or any close work. In "near-sighted" eyes, the eyeball is often too long from front to back, so the rays meet in front of the retina. Concave glasses remedy this defect. The eye may also be too short (far-sighted) and need convex glasses. The refracting surfaces (cornea and lens) may be unequally curved, causing astigmatism. For most of these defects the oculist can supply suitable glasses.

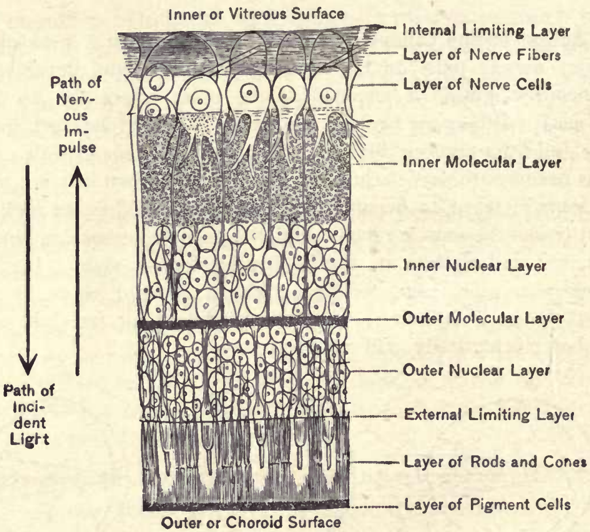


Fig. 90. Diagrammatic Section of the Human Retina. (Waller.)

The Structure of the Retina.—The retina is very complicated in its structure. No less than eight layers have been distinguished, as shown in Fig. 90. Of these layers the outermost, the layer of the rods and cones, is the one directly concerned in appreciating the differences in the vibrations of the light. The rays of light pass through the retina, and produce their effect on the rods and cones which constitute the outer (back) layer; and the nerve impulses aroused by the light must return through the thickness of the retina to be conveyed along the nerve fibers of the innermost layer of the retina to the optic nerve.

Importance of the Retina. — The chief structure in the eye is the retina. Without this all else is useless. If light of sufficient strength falls on the retina, it stimulates elements in the outer layer (rods and cones), and the nerve impulses, thus started, pass along the fibers of the optic nerve to the brain, and we have the sensation of sight. But in order to see anything distinctly, the light must fall on the retina in such a way as to form a distinct image of that object. If the lens be removed, or becomes opaque, as in "cataract," we fail to see distinctly, though we may discern light from darkness. The other parts of the eye exist to form images on the retina. The cornea, lens, and the aqueous and vitreous humors are the parts directly concerned in forming the images. Light from an object passes through the cornea, aqueous humor, lens, and vitreous humor, and the rays are so refracted as to form an inverted image. If this image falls on a good retina, we see well.

The Blind Spot. — The retina is much more complicated than any of the other nerve endings. Light must fall on these special structures to have any effect. Falling on the optic nerve itself has no effect in giving a sensation of light. And if the light falls on the spot where the optic nerve enters the eyeball we see nothing. Hence, this spot is called the blind spot.

Experiment illustrating the Blind Spot. — At the left (as looked at by the class) of a long blackboard make a bright circular spot, three inches in diameter, with white or yellow crayon. Beginning at the right of this write the figures 1, 2, 3, etc., along the whole length of the board, about eight inches apart. Let each pupil close the right eye and look at the bright spot. Then let each read the figures, passing slowly from one to another in order, at the same time noticing whether the bright spot can be seen To succeed in this the eye must not be allowed to waver. Have the pupils tell when the bright spot disappears, then read on, and note when the spot reappears.

Another Experiment. — In this experiment shut the right eye, and be careful not to let the left eye waver.

* Read this line slowly. Can you see the star all the time? If the star does not disappear before reaching the end of the line, let the eye travel on across the right-hand page, or hold the book nearer the face. In the human eye the optic nerve enters the eye not in the center, but nearer the nose, so that in turning the left eye toward the right at the proper angle, the image of the star falls upon the spot where the optic nerve enters. As this spot is insensitive to light, the star no longer appears.

The Optic Nerve not Sensitive. — The optic nerve, while capable of carrying nerve impulses that cause sensations of light, is not itself sensitive to light. If the optic nerve be cut, it does not give pain, but gives the sensation of a flash of light.

Sympathy between the Two Eyes. — While most of the fibers from each optic nerve cross to the other side of the brain, some fibers go to the same side of the brain. We can therefore better understand the close sympathy that we know exists between the two eyes.

Pain in the Eyes. — Pain, felt in the eyes, comes from impulses conveyed, not by the optic nerve, but by a branch of the fifth pair of nerves (the nerves of sensation for most of the face).

Color Sensations. — The difference in colors is due to the differences in the rapidity of the vibrations of the waves of light, as in sound differences in the rapidity of the vibrations of the sound waves cause the various degrees of pitch. Many interesting experiments may be made with color sensation, most of which are difficult of explanation. Fasten a bright red wafer or seal on a white card. Look intently at the center of the red spot till the eye is tired. Then quickly look at a point in the white surface. What color appears? This may be repeated with other colors.

Color Blindness. — It is found that some persons cannot distinguish certain colors. Blindness to red and green are most common. This is a matter of importance among railroad men and sailors where it is necessary to distinguish red and green signals.

Stereoscopic Vision. — In looking at an object with one eye more is seen to the side of that eye, while the other eye sees more of the other side, considerable of the object being seen with both eyes. The effects produced on the two eyes are united, and so we better see objects as solids. This is what is termed stereoscopic or binocular vision.

Duration of Impressions of Light. — Most boys have amused themselves around a bonfire by whirling a stick with a glowing coal on its end. The continuous circle of light thus produced indicates that the impression of light remains for a time, in this case until the stick completes the circle, giving a continuous line of light. Or when riding in a carriage the spokes of the wheels blur together because the impression of each lingers till another has taken its place.

After-Images. — But if we shut the eyes quickly, we may keep distinct the impression of the last positions, and so see them distinct from each other. Better still, shut the eyes while looking at the wheel, then open and shut them as quickly as possible.

Again, if one looks at a bright lamp and then closes the eyes, there may remain the same appearance as when we looked at the object itself. This is called the *Positive After-Image*. Or sometimes, especially after looking long at a bright light, we may, on closing the eyes or looking away, see a dark spot of the same shape as the bright one we looked at. This is called the *Negative After-Image*.

THE CARE OF THE EYES.

1. Objectionable Light. — In reading we wish light from the printed page. Hence we should avoid light entering the eye from any other source at this time. While reading, then, do not face a window, another light, a mirror, or white wall, if it can be avoided. White walls are likely to injure the eyes. Choose a dark color for a covering for a reading table. Sewing against the background of a white apron has worked serious harm. Direct sunshine very near the book or table is likely to do harm.

2. **Position in Reference to Light.** — Preferably have the light from behind and above. Many authors say "from the left," or "over the left shoulder." In writing with the usual slant of the letters this may be desirable. But vertical writing is now strongly advocated, as it enables one to sit erect, and have the light from above and equally for the two eyes. Sitting under and a little forward of a hanging lamp will thus give the light equally to the two eyes and send no light direct into the face. In reading by daylight avoid cross-lights so far as possible.

3. **Electric Light.** — The incandescent electric light has an advantage in being readily lighted, without matches, and in giving out little heat; but owing to its irregular illumination (due to the shadow cast by the wire or filament), it is not well suited for study or other near work. For this purpose an Argand gas or kerosene burner is much to be preferred, since it throws a soft, uniform, and agreeable light upon the work.

4. **Reading Outdoors.** — Reading out-of-doors is likely to injure the eyes, especially when lying down. To try to read while lying in a hammock is bad in many ways. Too much light directly enters the eye, and often too little falls upon the printed page.

5. **Reading Heavy Books.** — Do not hold the book or work nearer the eyes than is necessary. So far as possible avoid continuous reading in large or heavy books by arti-

ficial light. Such books being hard to hold, the elbows gradually settle down against the sides of the body, and thus the book is held too close to the eyes, or at a bad angle, or the body assumes a bad position.

6. **Resting the Eyes.** — Frequently rest the eyes by looking up and away from the work, especially at some distant object. One may rest the eyes while thinking over each page or paragraph, and thus really gain time instead of losing it.

7. **Strength of Light.** — Have light that is strong enough. Remember that the law of the intensity of light as affected by distance is that at twice the distance the light is only one fourth as strong. Reading just before sunset is not wise. One is often tempted to go on, not noticing the gradual diminution of light.

8. **Evening Reading.** — In all ways endeavor to favor the eyes by doing the most difficult reading by daylight, and saving the better print and the books that are easier to hold for work by artificial light. Writing is usually much more trying to the eyes than reading. By carefully planning his work the student may economize eyesight, and it is desirable that persons blessed with good eyes should be careful, as well as those who have a natural weakness in the eyes. It often results that those inheriting weak organs, by taking proper care, may outlast and do more and better work than those naturally stronger, but who, through carelessness, injure organs by improper use or wrong use (ab-use).

9. **Artificial Light in the Morning.** — Reading before breakfast by artificial light is usually bad.

10. **Reading during Convalescence.** — Many eyes are ruined during convalescence. At this time the whole system is often weak — including the eyes. Still, there is a strong temptation to read, perhaps to while away the time, perhaps to make up for lost time in school work. This is a time when a friend may show his friendship.

11. **Irritation of the Eyes.** — If one finds himself rubbing his eyes, it is a clear sign that they are irritated. It may be time to stop reading. At any rate, one should find the cause, and not proceed with the work unless the irritation ceases. If any foreign object, as a cinder, lodges in the eye, it is better not to rub the eye, but to draw the lid away from the eyeball and wink repeatedly; the increased flow of tears may dissolve and wash the matter out. To relieve the feeling that something must be done it may be well to rub the other eye, but of course this gives no positive relief to the affected eye. If it be a sharp cornered cinder, rubbing may merely serve to fix it more firmly in the conjunctiva. If it does not soon come out, the lid may be rolled up over a pencil, taking hold of the lashes or the edge of the lid. The point of a blunt lead pencil is a convenient and safe instrument with which to remove the particle. Sometimes being out in the wind (especially if unused to it), together with bright sunlight, may irritate the eyes. If after such exposure one finds lamplight irritating, he will do well to go to bed early, or remain in a dark room.

12. **Keep the Eyes Clean.** — Be careful to keep the eyes clean. Do not rub the eyes with the fingers. Aside from consideration of rules of etiquette, there is danger of introducing foreign matter that may be very harmful. It is very desirable that each person have his individual face

towel. By not observing this rule certain contagious diseases of the eyes often spread rapidly.

13. **Consult a Reliable Oculist.** — If there is any continuous trouble with the eyes, consult a reliable oculist. Many headaches are due to eye-strain, the real cause being unsuspected. If a child has frequent headaches, it is well to have the eyes examined. Many persons injure their eyes by not wearing suitable glasses. On the other hand, do not buy glasses of peddlers nor of any but *reliable specialists*. One may ruin the eyes by wearing glasses when they are not needed. *Sight is priceless.*

Effects of Alcohol and of Tobacco on Sight. — Impaired vision is a frequent result of the use of either tobacco or alcoholic drink, oftener of both combined. A peculiar disease known as the "cigarette eye" has been described as a dimness and film-like gathering over the eye, which appears and disappears at intervals. It can only be cured by long treatment and entire disuse of tobacco. The Belgian government once made an investigation into the cause of the prevailing color-blindness, and the testimony of experts was that the use of tobacco was one of the principal causes.

READING. — *Sight*, Le Conte.

Summary. — 1. Sight, like hearing, acts through space, outstripping the "contact senses" of touch, taste, and smell.

2. The eye is protected by its bony surroundings, lids, lashes, tears, sensitiveness of the conjunctiva, etc.

3. The eye is moved by muscles under nerve control.

4. The eye has three coats, — sclerotic, choroid, and retina.

5. The pupil is a hole in the iris, and varies in size to regulate the amount of light admitted.

6. The refracting media of the eye are the cornea, aqueous humor, lens, and vitreous humor.

7. These refracting media form an inverted image on the retina. The eye is a camera, darkened on the inside.

8. The ciliary muscle, acting on the elastic lens, adjusts the lens for seeing at different distances.

9. Suitable lenses overcome many of the defects in eyesight.

10. The retina is an expansion of the optic nerve, and is exceedingly complicated in its structure.

11. The blind spot is the place where the optic nerve enters the eye.

12. The optic nerve is insensitive to light, but injury to it causes sensations of light.

13. Most of the fibers of the optic nerve cross to the other half of the brain, but some do not cross.

14. Color is due to difference in the rapidity of vibration in the waves of light.

15. Eyes that do not distinguish these differences are color blind.

16. Pain in the eyes comes through the fifth pair of nerves, not through the optic nerves.

17. Binocular vision makes objects "stand out" more distinctly as solid bodies.

18. Impressions of light linger, making after-images.

19. Defects in eyesight are much more common among civilized men than with uncivilized men or animals.

20. The care of the eyes must be made a subject of study and careful thought by all reading people.

Questions. — 1. What is the position of the eyeballs during sleep?

2. What is "cataract"?

3. What is the cause of "double vision"?

4. Why does the well eye sympathize with the affected one?

5. Why does looking at a bright light often cause a person to sneeze?

6. Why is weeping associated with grief?

7. What is the condition of one who is "cross-eyed"?

8. Compare the pupils of a man, a cat, and a cow.

9. Does the color of the eye have any relation to the strength of eyesight?

10. Why is one going from a bright room into the dark unable to see at first, but gradually sees more distinctly?

11. Why can one not see well when the eye "waters"?

12. If each eye has a blind spot, why are there not blank spaces in the field of vision?

CHAPTER XXI.

TASTE, SMELL, AND HEARING.

Uses of the Sense of Taste. — The sense of taste helps us in judging of the fitness of anything that presents itself as a candidate for election as food. By reflex action the taste of agreeable substances aids in digestion by stimulating the glands, especially the salivary glands.

The Papillæ. — The surface of the tongue is covered with papillæ. These are of three kinds. Most numerous

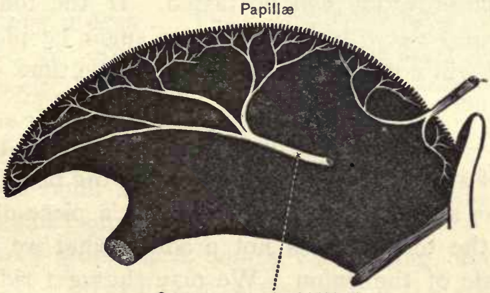


Fig. 91. Diagram of Tongue, showing Nerves and Papillæ.

are the filiform papillæ, slender, cylindrical projections. Like the papillæ of the skin, they seem to be organs of touch. Scattered among the filiform papillæ are small, bright red spots which, on examination, are found to be shaped somewhat like a mushroom, the fungiform papillæ. Near the base of the tongue are about a dozen larger papillæ, arranged like a letter V with its apex toward the base of the tongue. These are the circumvallate papillæ, each having around it a deep circular furrow.

The Nerve Supply of the Tongue. — On the sides of this furrow are small oval bodies, called "taste buds," connected with the ends of the nerves of taste. The nerves of taste are the glosso-pharyngeal, or ninth cranial nerves, distributed to the back part of the tongue, and a branch of the fifth pair of nerves, the gustatory, to the front part.

Although we ordinarily speak of an article of food as "palatable," or "unpalatable," the sense of taste in the palate is only feebly developed. The tip of the tongue seems to be most sensitive to sweets and salines, the back part to bitters, and the sides to acids.

Solution Necessary for Tasting. — Substances must be dissolved before they can be tasted. If the tongue be wiped dry, and a few grains of salt or sugar be placed on it, the taste will not be perceived for a little time. Insoluble substances give no taste.

Flavors. — What we call flavors affect us more through the sense of smell than through taste. If the nose be held shut, and we are careful about breathing, a piece of onion placed on the tongue does not produce what we usually call the taste of the onion. We may thus get rid of the disagreeable part of taking certain medicines. Let the student experiment with various substances as above indicated.

Effect of Temperature on Taste. — It is said that the temperature of about 40° F. is most favorable for tasting, and after rinsing the mouth with very hot or very cold water, such bitter substances as quinine will have only a trace of their usual taste.

The Sense of Smell. — "The sense of odor gives us information as to the quality of food and drink, and more especially as to the quality of the air we breathe. Hence we find the organ placed at the opening of the respiratory passages, and in close proximity to the organs devoted to taste. Taste is at the gateway of the alimentary canal, just as smell is the sentinel of the respiratory tract; and just as taste, when combined with smell to give the sensation we call flavor, influences the digestive process, and is influenced by it, so smell influences the respiratory process. The presence of odors influences both the amplitude and the number of the respiratory movements. Thus the smell of wintergreen notably increases the respiratory work, next comes ylang-ylang, and last rosemary. The breathing of a fine odor is therefore not only a pleasure, but it increases the amplitude of the respiratory movements. Just as taste and flavor influence nutrition by affecting the digestive process, and as the sight of agreeable or beautiful objects, and the hearing of melodious and harmonious sounds react on the body and help physiological well-being, so the odors of the country, or even those of the perfumer, play a beneficent *rôle* in the economy of life." — M'Kendrick and Snodgrass.

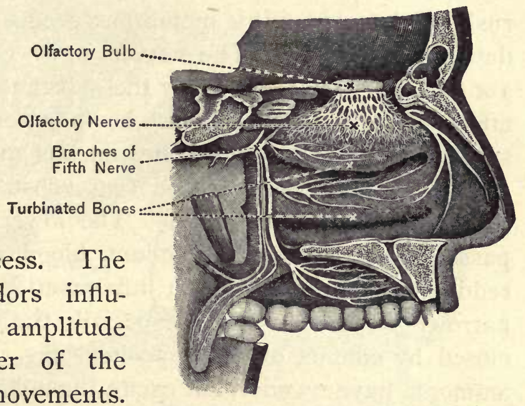


Fig. 92. Nerves of the Outer Wall of the Nasal Cavity.

Why we Sniff.—In quiet breathing the air passes along the lower air passages just above the hard palate. The true olfactory passages are higher, but still in communication with this lower passage. When we wish to test the quality of the air, we sniff, that is, make a sudden inspiration by jerking the diaphragm down, and air from the outside then rushes into these upper nasal passages, over the walls of which the nerves of smell, the olfactory nerves, are spread in the mucous membrane. The sudden rush of air against this membrane seems to aid greatly in detecting the odor. The nerves have peculiar endings, and it is not known just how the substances produce their effect. The substances must be in a very finely divided state, probably gaseous. The mucous membrane is supplied with mucus, and the odorous substance, probably, is first dissolved in the mucus. The lower, or respiratory, passages have a more abundant blood supply, and are redder than the upper. In inflammation, owing to their narrowness, the passages, especially the upper, are often closed by contact of the opposite sides. Substances like ammonia have no odor, but excite the tactile nerves. They are often spoken of as having a "pungent" odor, but are simply irritants.

The Sense of Hearing.—The ear passages are inclosed by the hard bones of the head. The ear is, in consequence, difficult to dissect. It is very desirable to have a model of the ear. The ear may be dissected in a cat or rabbit by following the accompanying description. It will take time and patience to trace all the parts.

The Parts of the Ear.—The ear is a much more complicated organ than would naturally be supposed. The parts of the ear are the external, the middle, and the internal ear.

The External Ear. — The external ear gathers the sound waves, and directs them into the opening of the ear, but the loss of the external ear does not seriously interfere with hearing. The passage leading inward from the ear extends about an inch, and is then completely shut off from the cavities beyond by a thin membranous partition, the tympanic membrane or drum skin. The skin of the

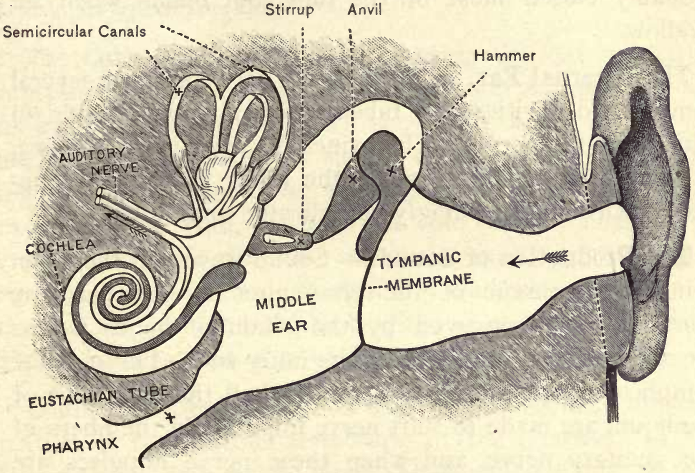


Fig. 93. Diagram of the Ear.

ear dips into and lines the external tube, and continues as a very thin layer over the membrane of the tympanum. The auditory meatus, as this passageway is called, is guarded by hairs, and is further protected by wax secreted by glands of the lining.

The Middle Ear. — Beyond the membrane of the tympanum is a cavity called the middle ear. Extending across the cavity of the middle ear is a chain of very small bones, the hammer, anvil, and stirrup, the hammer being attached to the inner surface of the membrane of the tympanum, and the stirrup being fastened by its base to the wall of the internal ear.

The Eustachian Tube. — The middle ear communicates with the pharnyx by means of a narrow tube called the eustachian tube. It admits air to equalize the pressure on the two sides of the tympanic membrane. This tube is probably closed most of the time, but opens when we swallow.

The Internal Ear. — The internal ear consists of several complicated cavities and tubes which contain a liquid in which rest the nerves. The principal cavity is the cochlea, or snail-shell cavity, in which the nerve endings are connected with an exceedingly complicated apparatus.

The Production of Sound. — Sound waves set the drum skin or membrane of the tympanum in vibration; the vibrations are conveyed by the chain of bones across the middle ear to the liquid of the inner ear. Through the complicated apparatus of the snail shell the vibrations of the liquid are made to start nerve impulses in the fibers of the auditory nerve, and when these nerve impulses are rightly received and interpreted by the brain, we have a sensation called sound.

The Equilibrium Sense. — Probably most of the senses contribute to the maintaining of the equilibrium of the body by giving information as to position, motion, etc., especially sight and the muscular sense.

Only that part of the auditory nerve which is distributed in the "snail shell" of the ear is now supposed to have to do with hearing. It is no longer believed that the semicircular canals are concerned with the process of hearing. There seems to be good evidence that the semicircular canals inform us as to changes of the position of the body, and they are regarded as the seat of an "equilibrium sense." The fact that one of these canals is horizontal, and that the two vertical canals are at right angles to each other, strengthens this belief. It is thought that each of these canals detects movements in its own plane. The experiment has been made of placing a man on a table that easily turned; with the eyes shut the subject could usually detect fairly well the changes of position from rotation of the table. What is known on the subject comes partly from observation in cases where these parts are diseased (which, in itself, does not cause loss of hearing), and by operating on lower animals; in both of these lines of observation injury to these parts appears to be followed by dizziness, loss of power to maintain equilibrium, etc.

The Care of the Ear. — In cleaning the ear no hard substance should be used; even the finger nail is likely to do harm. A moistened cloth should be used. If this is not sufficient, a physician should be consulted. In washing the ear it should be thoroughly dried before being exposed to a wind, especially a cold wind. The rapid evaporation may cool the parts so rapidly as to cause trouble. It is not well to stuff the ears with cotton. If there is any trouble with the hearing, of course a physician should be consulted without delay.

Colds and Deafness. — A cold often produces inflammation of the mucous membrane of the pharnyx. This inflammation may extend along the eustachian tube to the middle ear and affect the hearing.

The Use of the Ears. — The existence of an organ of hearing implies the existence of what? Why have we these organs of hearing? Is it merely a means of protection? Is it that we may enjoy the music of nature, such as the songs of birds? Is there not one sound that makes sweeter music than the most gifted of feathered songsters, surpassing all the instruments of man's device, even the violin, with its almost human flexibility and range of expression?

Experiments have been made upon the sense of hearing which show that alcohol in small quantities injures this sense as it does others.

What sound communicates to us the most of thought and sympathy?

What sound was it Robinson Crusoe, in his dreary solitude, most longed to hear?

READING. — *The Physiology of the Senses,* M'Kendrick and Snodgrass.

Summary. — 1. Taste enables us to judge of the quality of food, and it indirectly influences digestion.

2. The tongue has two nerves of taste, the fifth pair of cranial nerves supplying the front, and the ninth pair the base.

3. So-called flavors affect the sense of smell more than that of taste.

4. The sense of smell tests food and air.

5. Agreeable odors promote respiration.

6. The ear consists of the outer, middle, and inner ear. In the inner ear are the endings of the auditory nerve.

7. The semicircular canals have to do with a sense of equilibrium and not with hearing.

8. Colds and catarrh often seriously affect hearing.

Questions. — 1. How may the sense of taste be blunted?

2. What is the effect of inhaling menthol?

3. Does a person who is deaf in one ear hear "half as well" as before?

4. Which of the senses goes to sleep first when we go to bed?

5. In what order do the other senses go to sleep?

6. In what order do the senses waken in the morning?

CHAPTER XXII.

THE VOICE.

The Ear and the Voice. — The delicate mechanism and capabilities of the ear are fully matched by the fine adjustment and range of the voice. The organ of the voice is well worthy of study, if we look at it merely as a most ingenious contrivance, to say nothing of its importance to us as a means of expressing thought.

What we can learn from Our Own Throats. — We can learn a little from the observation of our own mouths and throats. The projection of the throat known as "Adam's Apple" is one angle of the Thyroid cartilage. A ridge may be felt running downward from the projecting angle. Above the Adam's apple a depression may be felt. Press the tip of the finger lightly into this depression and perform the act of swallowing. It will be noted that the Adam's apple is drawn upward and closer to the bone above the depression. This bone is the Hyoid bone; it is connected with the larynx below the base of the tongue. Below the thyroid cartilage another cartilage may be felt, the Cricoid cartilage. Below this is the windpipe with its rings of cartilage. The general form of the whole larynx may be felt in a person not overburdened with fat.

By depressing the tongue and looking into the mouth the tip of the epiglottis may possibly be seen at the base of the tongue. Beyond these points we cannot learn much without dissection. A small mirror set obliquely on a handle (like those used by dentists) may be inserted through the mouth so that the larynx can be seen from above. But the meaning of what would be thus seen would not be very clear without a careful dissection of the larynx.

The Vocal Cords. — The vocal cords are not very appropriately named. They are mere ridges projecting from the sides of the larynx. Under the covering of mucous membrane are ligaments and muscles that may be stretched to various degrees and placed in different positions, according to the sound that is to be produced.

The Position of the Vocal Cords. — While we are quietly breathing, the vocal cords, or bands, lie back, like low ridges, against the side of the larynx, and offer nearly the whole channel of the larynx for the free passage of air

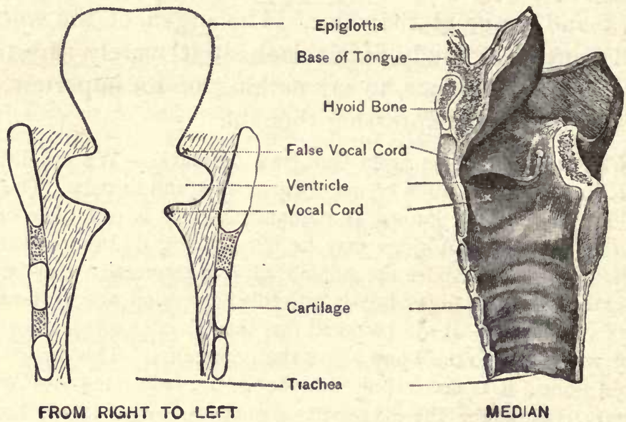


Fig. 94. Longitudinal Sections of the Larynx.

for breathing purposes. But when we wish to produce vocal sound, the vocal cords are made to stand out farther from the side walls, and interfere with the free passage of the air. In examining the larynx, it is seen that the vocal cords are attached close to each other in front, but that at the back of the larynx they diverge widely (in the position of rest), forming a letter V, with the angle of the V in front, just back of Adam's apple. "When changes in the voice or in breathing are being made, the white glistening vocal cords may be seen to come together or to go apart like the blades of a pair of scissors." In a high note the cords are close together and nearly parallel. As the air is forced past the approximated edges of the vocal cords, they are set in vibration, and produce the sound called the voice.

Illustration of the Vocal Cords. — The principle of the action of the vocal cords can be illustrated by the common toy known as the squeaking balloon, or "squawker." Here the air is driven out past a band of rubber stretched across the inner end of the tube. If instead

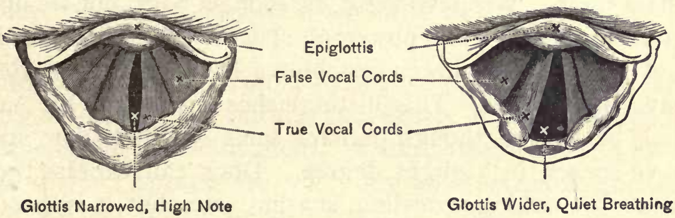


Fig. 95. The Larynx, as seen by Means of the Laryngoscope, in Different Conditions of the Glottis.

of one band with both edges free, we were to tie on the inner end of the tube two bands of rubber, each covering the outer edge of the tube, leaving the inner edge of the rubber free, and with the two bands touching at one end and considerably separated at the other end, we would have a pretty fair resemblance to the larynx.

Reënforcement of Vocal Sound. — As in many musical instruments, the vibrations of the membrane alone would be too feeble to have much effect. In the violin, piano, drum, etc., the vibrations are reënforced by the vibration of a body of air contained within. So here the vibrations of the cords are reënforced and modified by the air spaces above.

Loudness of Voice. — The loudness of the voice depends on the force with which the air is driven past the cords, together with the size and condition of the cords themselves.

Pitch of Voice. — Pitch depends on the rapidity of the vibrations, which is determined by the length of the cords and their tension. Other things being equal, the size of the larynx would determine the pitch.

Voice and Speech. — The larynx by itself produces vocal sound merely. In speech the sounds produced in the larynx are much modified by the lips, tongue, teeth, cheeks, etc. We have voice as soon as born, but we only gradually acquire the power of speech. Mammals, birds, and some of the lower vertebrates have voices, but they have not speech. This distinguishes man from the animals below him, though perhaps some of the higher apes have speech in a slight degree. Dogs can express their wants by barking, growling, snarling, etc., but it is mostly by their tone, with their attitudes, and a slight facial expression (as in snarling).

Vowels and Consonants. — By various positions of the tongue and organs of the throat we make the different vowel sounds. In the consonants we more or less shut off (for the time) the passage of air, and so stop, or modify, the sound. This is hardly the place to study and analyze the sounds of our spoken language, yet it may be found profitable to watch the different organs as each sound is produced; for when the structure and relation of the different parts concerned in the production of these sounds are better known, the definitions and statements of the books will be much more fully understood.

Differences between Voices. — Since no two throats are exactly alike, no two voices sound just the same. The size and shape of the pharynx, the shapes and positions of the teeth, lips, the condition of the mucous membrane of the passages generally, all affect the sound, and give it its "quality," by which we distinguish one voice from another, even if they are in the same pitch and have the same degree of loudness.

Change of Voice. — At about the age of fourteen a boy's larynx increases in size and the voice changes, becoming deeper and heavier. During the change the falsetto often breaks in upon the ordinary voice, the voice being said to "crack."

Hoarseness. — If the mucous membrane covering the vocal cords is inflamed, or covered with too much mucous, hoarseness is likely to result.

Whispering. — As in the animal we have voice without speech, so in whispering we have speech without voice; that is, there is no vocalization. The organs of speech so modify the aspiration as to produce speech. There is no true voice.

Culture of the Voice. — The voice and speech are very susceptible of culture, and nearly all voices may improve by proper cultivation. A cultivated voice and careful, distinct speech are very desirable accomplishments, and are not nearly so common as they ought to be. We delight in fine singing, and many strive to cultivate this art; but not so many try to learn to talk so that it is a pleasure to hear the spoken sound.

READING. — *The Throat and the Voice*, Cohen.

Summary. — 1. The larynx is very complicated. Various muscles move the cartilages and vary the length and tension of the vocal cords, and thus produce the varying degrees of pitch.

2. The vocal cords are not simple cords, but are band-like ridges on the sides of the larynx.

3. The higher animals have voice but not speech.

4. Whispering is speech without voice.

5. The larynx is affected by "colds" and catarrh.

Questions. — 1. Why does one become hoarse from hearing others shouting?

2. What is ventriloquism?

CHAPTER XXIII.

ACCIDENTS.—WHAT TO DO TILL THE DOCTOR COMES.

How to Stop Flow of Blood from Arteries.—In case of bleeding from an artery the blood comes in jets. Pressure should be applied between the cut and the heart. To know where to apply the pressure, study of the course of the main arteries should be made. By studying Fig. 16 it will be seen that the arteries to the arms pass down the inside of the upper arm. Here they come near the surface. At the elbow the artery is near the skin in the angle of the elbow. The artery which makes the pulse at the wrist is well known. By putting a baseball under the armpit and pressing the arm down firmly, the artery may be compressed.

Bleeding from the Upper Arm.—In case of a deep cut in the lower part of the arm, a handkerchief should have a knot tied in it, and the knot placed over the artery; that is, on the inside of the arm just below the armpit. Pass the handkerchief around the arm and tie it loosely. Then run a stick through it, and twist till the knot is drawn tightly against the artery. Instead of a knot, a potato, or anything else to make a firm lump, may be used. (See Figs. 16 and 35.)

Bleeding from the Neck.—In studying the pulse, we found the Carotid artery in the neck. If a deep cut has been made in the upper part of the neck, it might be possible to stop the flow by compressing the artery lower down the neck.

Wounds in the Thigh. — The femoral artery comes near the surface in the groin. Pressure may be applied here in the same way to stop bleeding from a cut farther down the thigh. In the angle back of the knee, pressure may compress the artery supplying the leg.

In case of severe wounds, pressure should be applied immediately to the wound. Sometimes it is well to make a plug of cloth and press upon the cut.

Bleeding from Veins. — In case of bleeding from veins, holding the part up may check the flow. If necessary to apply pressure, it should be beyond the cut, instead of between it and the heart, as in the case of the artery.

Hemorrhage of the Lungs or Stomach. — Blood from the lungs is bright, frothy, and salty; from the stomach is dark and sour. In case of bleeding from the lungs or stomach, let the person rest quietly on a lounge or easy-chair. Give him some bits of ice to swallow.

Bleeding from the Nose. — Nosebleed may sometimes be stopped by pressing firmly at the base of the nose. Do not lean forward, as this position aids the flow. Sit up, and hold up the head, and hold a cloth under the nose. Apply cold water or ice to the nose and to the back of the neck. If this does not stop it, inject cold water, with a little salt or soda in it, into the nose. Often the flow may stopped by pressing firmly on the upper lip at the sides of the nose. If these attempts fail, a long strip of cloth may be used to plug the nostril, pushing the cloth in a little at a time, and leaving the ends so it can be pulled out. This should not be removed till a long time after the flow is checked, as it may start the bleeding afresh. After an attack of this kind avoid blowing the nose, as this often starts bleeding again.

Treatment of Burns. — Plunge the burned part into cold water. As soon as possible apply a solution of cooking soda (a tablespoonful of bicarbonate of soda to a teacup of water); or lay a wet cloth on the burned part and put the soda on the cloth. Afterwards apply vaseline, and renew the vaseline till the wound is healed.

A mixture of equal parts of sweet oil and limewater makes a good liniment for dressing burns. Flour thickly applied gives relief, but is objectionable because it is hard to remove without taking the skin off with it.

Danger from Burning Clothing. — If the clothing takes fire, there is added to the danger of burning the body, the further risk of inhaling the flame and heated air. It is best to lie down and roll or wrap the body in any cloths at hand, — rugs, shawls, etc. Running serves to fan the flames. Hence, if a person whose clothing is on fire is seen to be thoroughly frightened, and to have lost presence of mind and be starting to run, the best thing to do usually is to grasp and try to throw him to the ground, putting a wrap of some kind around the body at the same time if possible. Rolling on the ground or floor in itself would very likely put out a small flame.

Treatment of Fainting. — Lay the body flat on the back. Keep the crowd away, and give plenty of fresh air. Loosen the clothing about the neck and waist. Sprinkle cold water on the face, but do not drench the body with a quantity of water. Apply smelling salts (ammonia) to the nostrils; rub the limbs toward the body. If these remedies do not soon restore consciousness, send for a physician. A faint is not usually a serious matter. Bad ventilation, disagreeable odors, or even the oversweet odors of such flowers as the tuberose, may cause fainting.

Broken Bones. — Keep the patient as quiet as possible till the physician arrives. There need be no anxiety if the physician is delayed, as ordinarily no harm comes from waiting. If there is inflammation, cold water may be applied. Cooling applications are desirable in case of severe bruises. If it is necessary to carry the patient, lay him on a board, or at least keep the injured part as quiet as possible; a cane or umbrella may be tied alongside a leg, and supported by a pillow or a coat. Sometimes the sharp ends of the bones may cut the flesh or even blood tubes.

Sunstroke. — Lay the patient in the shade and pour cold water over the head.

Fig. 96. Resuscitation from Drowning. (Lincoln, 3 Figures.)
(Position 1.)

TREATMENT OF THE DROWNED.

(Essentially the method recommended by the Michigan Board of Health.)

RULE I. *Remove all obstructions to breathing.* Instantly loosen or cut apart all neck and waist bands; turn the patient on his face, with the head down hill; stand astride the hips with your face toward his head, and, locking your fingers together under his belly, raise the body as high as you can without lifting the forehead off the ground (Fig. 96, Position 1), and give the body a smart jerk to remove mucus from the throat and water from the windpipe; hold the body suspended long enough to count slowly, one,

Fig. 97. Resuscitation from Drowning.
(Position 2.)

two, three, four, five, repeating the jerk more gently two or three times.

RULE 2. Place the patient on the ground face downward, and, maintaining all the while your position astride the body, grasp the points of the shoulders by the clothing, or, if the body is naked, thrust your fingers into the armpits, clasping your thumbs over the points of the shoulders, and raise the chest as high as you can (Fig. 97, Position 2) without lifting the head quite off the ground, and hold it long enough to count *slowly* one, two, three. Replace him on the ground, with his forehead on his flexed arm, the neck straightened out, and the mouth and nose free. Place your elbows against your knees, and your hands upon the sides of his chest (Fig. 98, Position 3) *over the lower ribs, and press downward and inward with increasing force* long

Fig. 98. Resuscitation from Drowning.
(Position 3.)

enough to count slowly one, two. Then suddenly let go, grasp the shoulders as before, and raise the chest (Position 2), then press upon the ribs, etc. (Position 3). These alternate movements should be repeated ten or fifteen times a minute for an hour at least, unless breathing is restored sooner. Use the same regularity as in natural breathing.

Rule 3. After breathing has commenced, restore the animal heat. Wrap him in warm blankets, apply bottles of hot water, hot bricks, or anything to restore heat. *Warm the head nearly as fast as the body lest convulsions come on.* Rubbing the body with warm cloths or the hand, and slapping the fleshy parts, may assist to restore warmth, and also the breathing. If the patient can *surely* swallow, give hot coffee, tea, milk, or five grains of carbonate of ammonia in a quarter of a tumbler of hot water. Place the patient in a warm bed, and give him plenty of fresh air; keep him quiet.

BEWARE!

Avoid Delay. A moment may turn the scale for life or death. Dry ground, shelter, warmth, hot drinks, etc., at this moment are nothing — artificial breathing is everything — is the one remedy — all others are secondary.

Do not stop to remove wet clothing. Precious time is wasted, and the patient may be fatally chilled by the exposure of the naked body, even in summer.

First restore Breathing. — Give all your attention and effort to restore breathing by forcing air into, and out of, the lungs. If the breathing has just ceased, a smart slap on the face or a vigorous twist of the hair will sometimes start it again, and may be tried incidentally.

Before natural breathing is fully restored, do not let the patient lie on his back unless some person holds his tongue forward. The tongue by falling backward may close the windpipe and cause fatal choking.

Prevent friends from crowding around the patient and excluding the fresh air; also from trying to give drinks before the patient can swallow. The first causes suffocation; the second, fatal choking.

Do not give up too soon: you are working for life. Any time within two hours you may be on the very threshold of success without there being any sign of it.

Learn to Swim. — Of course, persons who cannot swim well ought not to go out in a boat without taking along some sort of a float that may serve as a life-preserver. Some of the rubber cushions serve well for this.

Every father neglects his duty if he does not teach his children, girls as well as boys, to swim and to float. One cool, trained person may save the lives of a whole boat load.

When a Boat Upsets. — In case an ordinary rowboat is overturned, one should not attempt to climb into it or upon it. It takes very little to float a person in water, as the body is only a little heavier than water; in fact, if a person fills the lungs and lies back in the water his face and nose will keep above water, and a person (at any rate without clothing) can float in this way for some time if he breathes lightly. The trouble is that the person tries to lift the whole head out of the water. The dog and such animals, when swimming, have little out of the water but the tip of the nose and a little of the top of the head. If we could learn something from them it would be a good thing. The easiest way to float is on the back. Few persons have been taught these facts, and most of those who have learned them lose their presence of mind, and waste their breath and strength in wild and fruitless splashing. If a boat be overturned, those who can swim should help those who cannot to get hold of the edge of the boat, but not permit them to climb upon it. A small plank will float a person if he will not try to lift much of his body out of the water.

Suffocation in Wells. — Persons are sometimes suffocated by carbon dioxid in wells and cisterns. Before going down into a well, it is a safe precaution to lower a lighted candle. If this is extinguished, a warning is given. If a second person goes down after one who has become unconscious, great care must be taken that two lives are not lost. A rope should be firmly tied about the body, a hook, attached to another rope, taken to catch into the clothing of the first, and the rescuer should be lowered quickly and brought up immediately. A small rope or large cord might be carried, by pulling which the signal is given to pull up.

In resuscitating from carbon dioxid suffocation use the same method as after drowning, except the first part, which is to remove water from the windpipe, etc.

Poisons and their Antidotes. — Several of the common drugs and remedies kept about the house are more or less poisonous. The proper antidote for each should be known and kept at hand. In the first place, all such materials should be kept locked up so they will not be taken by children, or by mistake, as in the haste of getting medicine in the night. Again, all grown persons in the family should be instructed as to the effects of each poison, and taught its antidote. As soon as any new poisonous drug is bought, it should be made a point to read up about it, and procure an antidote. Every one should know that strychnin causes spasms, that opium brings on stupor, with contracted pupils, etc.

Objects of Treatment. — Treatment aims at three things, (1) to get rid of the poison, (2) to neutralize what remains and prevent further action, (3) to remedy the effects already produced.

1. **Mustard a Common Emetic.** — The most common emetic is mustard; a tablespoonful in a cup of warm water; give half of it, following with free drinking of warm water, then give the rest of the mustard. Do not wait for it to dissolve, but stir quickly and give at once. Provoke vomiting by tickling the throat with a feather or with the finger. If the mouth of the patient cannot readily be opened, insert the thumbs inside the cheeks and back of the teeth. If mustard is not at hand, a strong solution of table salt will serve. In a few cases, such as poisoning by ammonia, lye, etc., it is considered best not to administer an emetic, but to try to neutralize the effect.

2. **Neutralize the Poison.** — To neutralize a poison this general rule should be known: an alkali may be neutralized by an acid, and *vice versa*. For example, lye with vinegar, carbolic acid with whiting or magnesia, etc. Some acids and alkalis are always about a house.

3. **Give Something Soothing.** — After any irritant poison some mild and soothing substance should be given, — white-of-egg, milk, mucilage and water, flour and water, gruel, olive, or castor-oil. These materials are partly for neutralizing the poison, and are also soothing in their effect. If a patient is drowsy, some stimulant may be given, as strong coffee (after opium). Of course a physician should be sent for immediately, as the after-treatment is of great importance.

The tables of "Poisons, their Symptoms, Antidotes, and Treatment," in the appendix, are taken from the excellent *Text-Book of Nursing* by Clara Weeks-Shaw.

Wounds from Thorns, Rusty Nails. — Promote bleeding by rubbing and pressing the wound and bathing with warm water. Or suck the wound. This tends to remove any injurious matter. Apply poultices.

Bites of Cats, Dogs, etc. — If the animal is rabid (mad), suck the wound and cauterize quickly. A poker or nail heated red hot is best for cauterizing. If one cannot do this promptly, get lunar caustic with which to cauterize; strong acid or alkali, or a coal of fire, may be applied at once to the wound; the coal on a cigar may be used. Do not kill the animal if there is doubt. Keep it confined, and if it proves a false alarm much anxiety will be saved.

Snake Bites. — Apply ligatures around the part between it and the heart. Suck the wound (there is no danger in this if there are no sores or cracks in the skin of the mouth; venom is not a stomach poison, though, of course, it should not be swallowed). Then apply caustics, or a live coal. Wash the wound with vinegar or strong salt solution. If ammonia water is at hand, apply externally and take internally, five teaspoonfuls to each pint of water.

Ammonium carbonate, ten per cent solution, is also highly recommended. A teaspoonful dose should be given immediately, and repeated twice at intervals of ten minutes.

Bee Stings. — Apply soda, or dilute ammonia.

Poison Ivy. — The itching and discomfort may be relieved by bathing the part in a mixture of —

> Two teaspoons of carbolic acid (pure),
> Two tablespoons of glycerin,
> One half pint of water or rose-water.

The Sick-room. — Every boy and girl ought to learn something about the care of the sick, as any one is likely to be called on to do this kind of work. Good nursing is often "half the battle." In the first place, the nurse should faithfully follow the directions of the physician. This obedience should be complete as to admission of visitors, as well as in administering medicine, etc. The nurse often yields to the persuasion of some unwise friend, "It won't do any harm for him to see me."

Qualities of a Nurse. — The nurse should have a quick sympathy, and make the patient feel that all that can be done for his comfort will be done; yet this sympathy must not lead the nurse to do anything for, or give anything to the patient contrary to the orders of the physician. The nurse should always be cheerful, even when the patient is "impatient" and annoying in his demands. The patient is not "himself," and no attention should be paid to his unnatural irritability.

The Room should be Cheery. — The patient should have a cheerful room, but the bed should be so placed that the light will come not too strongly into his face. Evidence of illness, such as medicine bottles, etc., should be kept out of sight so far as possible.

Hope. — While it is not best to deceive the patient as to his condition, there should at all times be kept up an air of cheerfulness and hope. If the physician can inspire with confidence, and the nurse give unflagging good cheer, the chances of recovery are vastly improved. Nothing sustains like hope.

Pure Air in the Sick-room. — Keep the air of the room pure. Remove excreta and everything offensive just as soon as possible. Do not rely on *feeling* as to temperature, but keep a thermometer in the room.

Sympathy with the Patient. — One of the necessary characteristics of a good nurse is the power of imagination. "How would I feel, and what would I like to have done for me, if I were in his place?" This feeling will lead the nurse frequently to raise the patient's head and turn the pillow — the coolness of the other side of the pillow is refreshing; to give sips of cool water; to see that the patient does not suffer for want of a bath; in giving a bath, to do the work thoroughly, as a skillful barber carefully and thoroughly reaches every fold and crevice back of the ear, etc.

Bathing the Sick. — In bathing a weak person only a part of the body should be moistened at a time; after this part is thoroughly dried, another part may be washed; it is often necessary to do all this work under the bed clothing.

Changing the Bedding. — In changing the bed clothing move the patient to one side of the bed, push the clothing along close to his body, and place the clean bedding on the other side; then move the patient back, remove the soiled linen, and smooth out the clean. It is often necessary to warm the sheets first: they should be thoroughly dry.

Follow Physician's Directions Faithfully. — Have the physician's directions written out plainly, as they may be forgotten; and if there is a change of nurses during the night there is less chance of mistake. Never let yourself get drowsy when acting as nurse. Get up and walk about, get a breath of fresh air, and if inclined to be drowsy do not allow yourself to settle back in an easy-chair. If watching all night, take a good lunch in the middle of the night; coffee may help to keep you awake. It is not to be expected that one who has worked hard all day out-doors will be likely to keep awake all night.

There should be day and night watchers, and one would better not watch more than six hours at a time.

Sweeping the Sick-room. — Do not allow the room to be swept with the ordinary broom. The room should have rugs that can be removed and shaken, and the floor wiped with a moist cloth. If the room is carpeted, it may be swept with moist salt, tea-grounds or coffee-grounds, saw-dust, etc. Any dusting should be avoided; furniture may be wiped with a damp cloth.

Do not Whisper. — In the effort to be quiet many make a mistake; do not whisper, as it disturbs more than talking, and also has an air of secrecy that rouses suspicion in the patient.

Walk Flat-footed. — In walking on tiptoe often floors and stairs are made to creak when they would not in ordinary circumstances. It takes little reflection to see that in walking on tiptoe one brings more weight than usual on a smaller part of the floor, and is therefore more likely to spring a board in the floor; it is best to walk flat-footed. Wear an easy pair of shoes; an old pair are likely to be quiet.

Food for the Sick. — Raise the head with the hand, or bolster the patient up, when giving drink; or if the patient is very weak, use a rubber tube, so that he will not have to lift the head. The nurse should know how to prepare any food that may be needed during the night. An oil stove or gas stove is very desirable for cooking, or heating poultices, as an ordinary wood or coal fire is likely to die down, making it impossible for the nurse to do this work quickly, as is often necessary to take advantage of a favorable time, as when the patient wakens.

Care of Lamps. — Most lamps, when turned low, give off a disagreeable gas. It is better to have a very small lamp burning at full height than a large one turned low; sperm candles are recommended.

Bandaging, Preparing Food, etc. — It is well for every one to know something about bandaging, preparation of food for the sick, etc. Space here will not allow further treatment of these subjects, and the student is referred to treatises on the care of the sick, of which there are several good ones mentioned at the end of this chapter.

To Prevent Sneezing. — It is well known that a sneeze may be prevented by firmly pressing on the upper lip. This may enable a nurse to keep from waking a very sick patient when, at a critical point, sleep is almost a question of life or death. And it is a convenient fact for any one to know. To prevent coughing there are cough drops that will relieve the tickling in the throat.

For Disinfectants see Appendix.

In addition to the list of books on Accidents, Emergencies, etc., already given, read *Hand-Book of Nursing*, published under the direction of the Connecticut Training-School for Nurses, State Hospital, New Haven, Conn.; *Text-Book of Nursing*, Weeks-Shaw; *Nursing: Its Principles and Practice*, Hampton.

Summary. — 1. To stop flow of blood from an artery apply pressure to the wound, or between the wound and the heart.

2. To stop flow of blood from a vein apply pressure to the wound or beyond the heart.

3. Leaning forward promotes, instead of checking, nosebleed.

4. To burns apply cooking soda.

5. If the clothing takes fire lie down and roll, or wrap a rug or shawl about the body.

6. If a person with clothing on fire loses his presence of mind, seize, throw down, and wrap in any woolen clothing.

7. In case of fainting lay the body flat on the back, loosen clothing, give fresh air, and sprinkle lightly with cold water; if this does not revive, rub the limbs toward the body, hold to the nostrils smelling-salts (or ammonia) and, last, send for a physician.

8. Broken bones do not urgently need prompt attention. Keep patient quiet and send for a physician.

9. For resuscitation from drowning, use artificial respiration, promptly begun and long continued.

10. Before going down into a well, test the air by lowering a lighted candle.

11. Learn the antidotes of every poison in your house *as soon as it is bought*, and keep the antidote at hand.

12. Volunteer to help take care of sick friends, and learn to do this work well.

Questions. — 1. How does holding up the wounded part check bleeding?

2. What other methods of resuscitation from drowning are in use?

3. What are some of the poisonous substances commonly kept in the house?

CHAPTER XXIV.

THE SKELETON.

The Two Parts of a Skeleton. — Observe that the skeleton as a whole consists of two portions, the axial portion, consisting of a central axis, the spinal column, to which the head belongs; and the appendicular portion, the limbs and the bones belonging to them.

The Uses of the Bones. — In the skeleton as a whole observe: —

1. The skeleton shows the form of the body.
2. It supports the softer tissues.
3. It protects softer parts, as the brain in the skull, the spinal cord in the spinal column, the heart and lungs in the thorax, etc.
4. The bones serve as levers in producing motion and locomotion.

Study of a Vertebra. — Take a vertebra from the middle of the spinal column: —

1. Its most solid part is its body, or centrum.
2. On the dorsal side of this is the neural arch, forming with the body the neural ring, through which the spinal cord passed.
3. From this arch there extend projections, or processes. Hold the vertebra by the tip of its longest process, and place it beside the corresponding vertebra in the complete skeleton. Note that: —

(*a*) The body is flattened where it fitted against the vertebræ anterior and posterior to it;

(*b*) The holes in the vertebræ form a passage for the spinal cord;

(*c*) The middle process is the spinous process, and the series of spinous processes form the ridge of the backbone;

(*d*) The two lateral processes are the transverse processes.

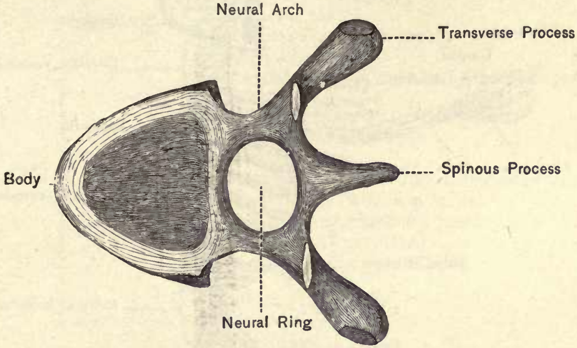


Fig. 99. Anterior View of Thoracic Vertebra.

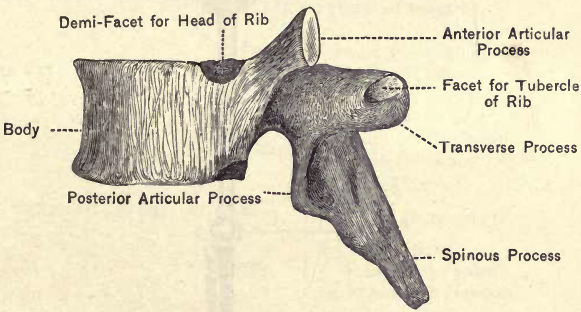


Fig. 100. Left Side View of Thoracic Vertebra.

Fit together two vertebræ in their proper order and observe that: —

(*e*) The openings at the sides, through which the spinal nerves passed, are formed by adjacent notches, or grooves, in the contiguous vertebræ.

(*f*) The two projections extending anteriorly from the ring of one vertebra fit against two corresponding processes extending posteriorly from the other vertebra. These are the anterior and posterior articulating processes.

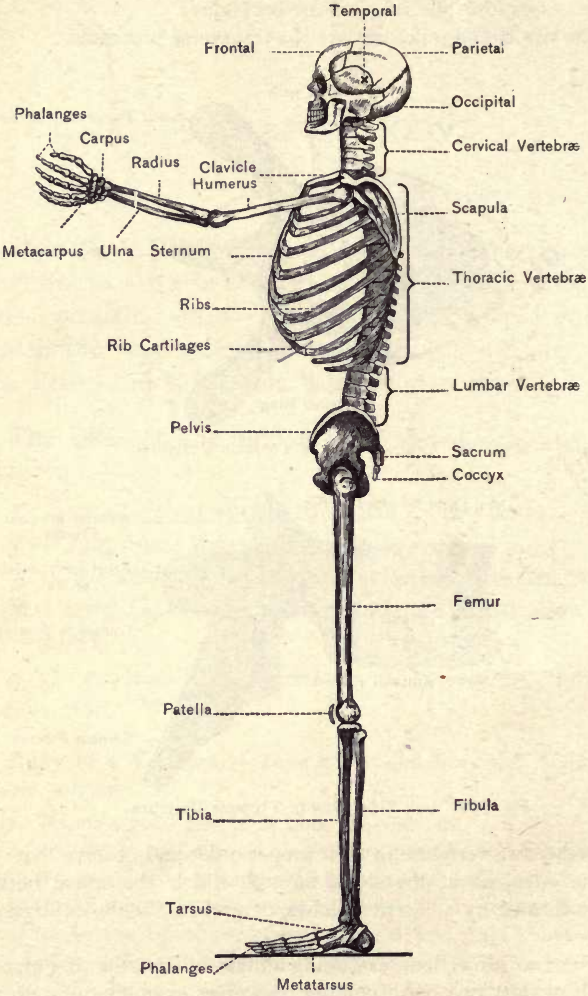


Fig. 101. Side View of the Human Skeleton.

TABLE OF THE BONES.

14
8
22

HEAD (28)	*Skull* (8)	Frontal (forehead).
		2 Temporal (temples).
		2 Parietal (side).
		Occipital (posterior base).
		Sphenoid (base).
		Ethmoid (base of nose and between eyes).
	Face (14)	2 Superior Maxillæ (upper jaw).
		2 Nasal (bridge of nose).
		2 Malar (cheek).
		2 Lacrymal (inner front corner of orbit).
		2 Turbinated (within nostrils).
		2 Palate (posterior hard palate).
		Vomer (nasal partition).
		Inferior Maxilla (lower jaw).
	Ears (6)	Malleus (hammer).
		Stapes (stirrup).
		Incus (anvil).
CERVICAL REGION (8)		7 Cervical Vertebræ (neck).
		Hyoid Bone (base of tongue).
THORAX (37		14 True, 6 False, 4 Floating Ribs.
		12 Thoracic Vertebræ (back).
		Sternum.
UPPER EXTREMITIES (64)	*Shoulder.*	Clavicle (collar-bone).
		Scapula (shoulder-blade).
	Arm.	Humerus (arm).
		Radius, Ulna (fore-arm).
	Hand.	8 Carpal (wrist).
		5 Metacarpal (palm).
		14 Phalanges (fingers).
LUMBAR REGION (5)		5 Lumbar Vertebræ (loins).
PELVIS (4)		2 Innominata.
		Sacrum.
		Coccyx.
LOWER EXTREMITIES (60)	*Thigh.*	Femur.
	Leg.	Patella (knee-pan).
		Tibia (large bone).
		Fibula (outer bone).
	Foot.	7 Tarsal (instep, heel).
		5 Metatarsal (arch).
		14 Phalanges (toes).

The Spinal Column. — The central part of the skeleton is the backbone, or spinal column. As a whole it is a column, widening toward the base, composed of a series of separate bones called vertebræ.

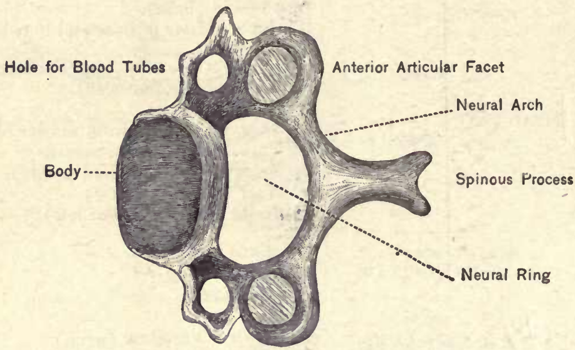


Fig. 102. Anterior View of Cervical Vertebra.

Fig. 103. Left Side View of Cervical Vertebra.

Each vertebra has seven processes, four articulating (two anterior and two posterior), two transverse, and one spinous.

Take a thoracic vertebra and in the presence of the class trim off the processes with a pair of bone-forceps. The vertebra will be seen to be essentially a ring, or padlock, consisting of the body and neural ring or arch.

Articulations of a Vertebra.—The smooth places where the articulating processes join are called facets. Observe on each side of the body of the vertebra a facet where the head of the rib articulated. There is also a facet on the transverse process where the tubercle of the rib articulated.

The Cervical Vertebræ. — The seven cervical vertebræ (neck) have holes through their sides, or transverse processes, for the passage of blood tubes.

Atlas and Axis. — The first vertebra, the atlas, has no body. The second vertebra is the axis. It has a peg, called the odontoid process, which represents the body of the atlas. In shaking the head, the atlas, with the head, turns on the axis. In nodding the head, the head simply rocks back and forth on the atlas.

The Thoracic Vertebræ. — The twelve rib-supporting vertebræ are the thoracic vertebræ.

The Lumbar Vertebræ. — The next five are the lumbar.

The Sacrum and Coccyx. — The sacrum is composed of five vertebræ grown together, and the remaining four are combined in the coccyx.

Review of the Spinal Column. — Let the eye slowly review the whole spinal column, noting what the vertebræ have in common. Note also their differences.

Flexibility of the Spinal Column. — In most articulated skeletons there are pads of felt between the vertebræ. These take the place of the inter-vertebral cartilages, which are a form of connective tissue, possessing the elasticity of cartilage and the toughness of fibrous connective tissue, such as ligament and tendon. These inter-vertebral cartilages serve both to keep the vertebræ apart and to hold them together. When we bend the shoulders to the right, the right edges of these cartilages are compressed,

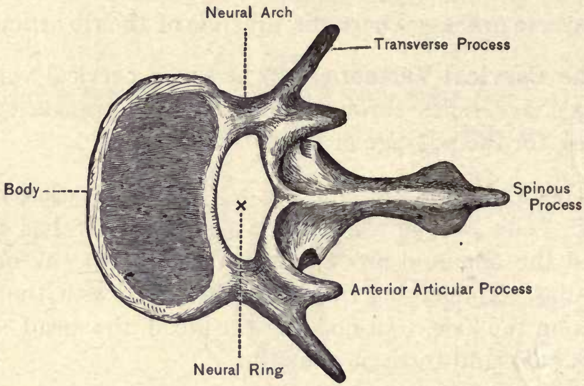


Fig. 104. Anterior View of Lumbar Vertebra.

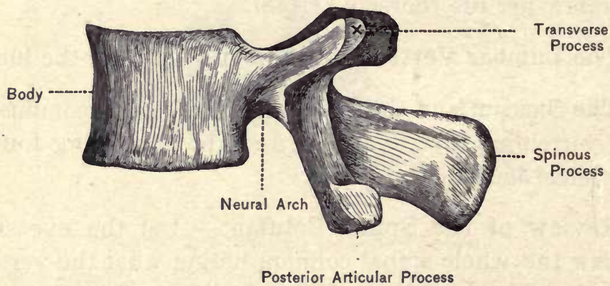


Fig. 105. Side View of Lumbar Vertebra.

and the left edges are stretched, as a piece of india rubber would be if it were glued between the ends of two spools, and the whole were slightly bent.

Curves of the Spinal Column.—View the spinal column from the side. Draw a line representing all its curves.

The Cavities of the Skeleton. — Examine the cavity of the skull. If the class has not a skull which has been sawed across, look into the skull cavity through the hole where the spinal cord joined the brain.

Observe the conical shape of the thorax. In the entire body the bones and muscles about the shoulders usually make a reversed cone of the upper part of the trunk.

Observe that the ribs are connected with the breastbone by cartilages.

The upper limbs are articulated with the body only where the inner ends of the collar bones join the breastbone.

Pronation and Supination. — Rest the forearm on the table with the palm up; keeping the elbow fixed, turn the hand over. Turning the palm up is called supination; turning it down is pronation. Perform this experiment with the articulated skeleton.

The Skeleton of a Cat or Rabbit. — Examine the skeleton of a cat or rabbit for the sake of comparison. Note especially the skull and spinal column, so that you will know better what to do when dissecting the brain and spinal cord in one of these animals.

The Weight of Bones. — The bones make about one sixth of the weight of the living body. When dried they may lose half of their weight.

Microscopic Structure of Bone. 1. Examine with a hand lens. — Hold a mounted cross-section of bone up to the light and examine with a hand lens. The solid part of the bone will be seen to be pierced by many small holes (or if the holes are filled they will appear as black spots). These are the cross-sections of the haversian canals, through which run the blood tubes, mainly lengthwise through the bone.

2. **Examine with the Low Power of a Compound Microscope.** — Examine the section under the microscope, using a half-inch objective. The bony matter will now be seen to be arranged in circles, lamellæ, around the haversian canals, somewhat like the rings seen on the end of a log.

Between the rings are circles of elongated dark dots. These are lacunæ, cavities in which lay the live-bone corpuscles which built up the bone. The bone was, at first, cartilage. Later, mineral matter was deposited, forming true bone.

3. **Examine with a High Power.** — Now examine the section under a one-fifth-inch objective. From the lacunæ there run out, in every direction, little crevices, appearing as fine black lines. These are the canaliculi. Through the haversian canals, lacunæ, and canaliculi, the nourishing materials of the blood reach all parts of the bone.

The Chemical Composition of Bone. — 1. Take a tall, narrow glass jar, called in the chemical laboratory a "graduate," or a lamp chimney corked at one end answers very well, and nearly fill with

Fig. 106. Cross-section of Bone. (Highly Magnified.)

water. Add one sixth as much hydrochloric acid. Put into this a slender, dry bone, such as a fibula or rib. In twenty-four hours take it out, rinse it thoroughly, and examine it. The acid will probably have dissolved out the mineral matter and left the animal matter.

2. Lay a piece of bone on a shovel, or piece of sheet iron, and place in the fire. The animal matter is burned out, leaving the brittle mineral matter.

Bone is composed of mineral matter, two thirds, and animal matter, one third; in childhood the animal matter is in larger proportion, while in old age the mineral matter is in excess.

The mineral matter is chiefly calcium phosphate, while the animal matter is largely gelatin.

Joints may be classified according to their structure as follows: —

Classification of Joints. — 1. Immovable, such as the sutures between the bones of the skull;

2. Mixed, such as the joints between the vertebræ;

3. Movable, which allow free motion between the parts;

(*a*) Ball and socket, as in the hip and shoulder;

(*b*) Hinge, as in the knee and elbow;

(*c*) Pivot, as in the forearm, and between the atlas and axis;

(*d*) Gliding, as between the short bones of the wrist, and of the ankle.

Study of Joints. — Examine these joints in the articulated skeleton, and so far as possible, in fresh specimens (of rabbits). Compare the ball and socket joints of the hip and shoulder. Also compare the hinge joints of the knee and elbow.

Hygiene of the Bones. — Sometimes the bones of children are deficient in mineral elements, and are unduly soft and flexible. This condition indicates a disease called *rickets*. Even if the bones are normal, children should not be encouraged to walk early, as bow-legs may result. Most bow-legged persons seem to be active, and probably their muscles developed faster than the bones. Constrained positions or excessive use of special groups of muscles may result in lateral curvature of the spine. The height of seats and desks should be carefully looked after.

Effects of Alcohol. — Alcoholic drinks are particularly injurious to the young. They interfere with proper nutrition and thus retard growth and development. In Europe a few years ago the examinations for military service revealed the fact that the stature of the young men was decreasing, and in order to secure the required number of recruits it was necessary to lower the standard. Official investigation was made to ascertain the cause, and experts reported that it was largely due to the use of alcohol.

Sprains and Dislocations. — Sprains and dislocations are injuries to the joints, and often bring more serious results than a broken bone. There should, usually, be complete rest until the part can be used without pain. Otherwise a stiffened joint may result. Hot water applied to a sprain or bruise promotes circulation and prevents discoloration. But if there is inflammation cold water should be applied. Bandages may be needed for support.

Summary. — 1. The skeleton consists of the axial and appendicular portions.

2. Each vertebra consists of a body, ring (around spinal cord) and processes.

3. Pads of cartilage connect the vertebræ.

4. Bone is traversed by tubes and crevices through which it receives its nourishment from the blood.

5. Bone consists of animal matter with limy matter embedded in it.

6. Sprains should be treated carefully to avoid stiffened joints.

Questions. — 1. Why do the bones of old people break so much more easily than those of children?

2. What is the use of the central marrow?

3. What is the work of the red marrow in the spongy ends of the bones?

4. What are "sesamoid" bones?

CHAPTER XXV.

THE MUSCLES.

The Number of Muscles. — There are over five hundred muscles in the human body. These vary in size from less than an inch in length, in the ear and in the larynx, to a foot and a half long in the thigh.

The Arrangement of Muscles. — The muscles of the two sides of the body are paired, and normally are about equal in size and strength. The muscles of the limbs are further paired into flexors, which bend, and the extensors, which straighten the limbs. The muscles are also arranged more or less in layers. There is generally a superficial layer and a more deep-seated layer.

Forms of Muscles. — Muscles are of various shapes. The prevailing form in the limbs is spindle-shaped, or fusiform. This is convenient, as the thicker middle portion of the muscle is opposite the more slender part of the bone, while the tendons at the ends of the muscles are opposite the enlarged ends of the bones at the joints. Some muscles are flat, some have their fibers arranged like the barbs of a feather, and are hence called penniform. Some muscles have a tendon in the middle which runs through a loop, as in the case of the muscle which depresses the lower jaw. As already stated, muscles which close openings are circular, and are called sphincter muscles.

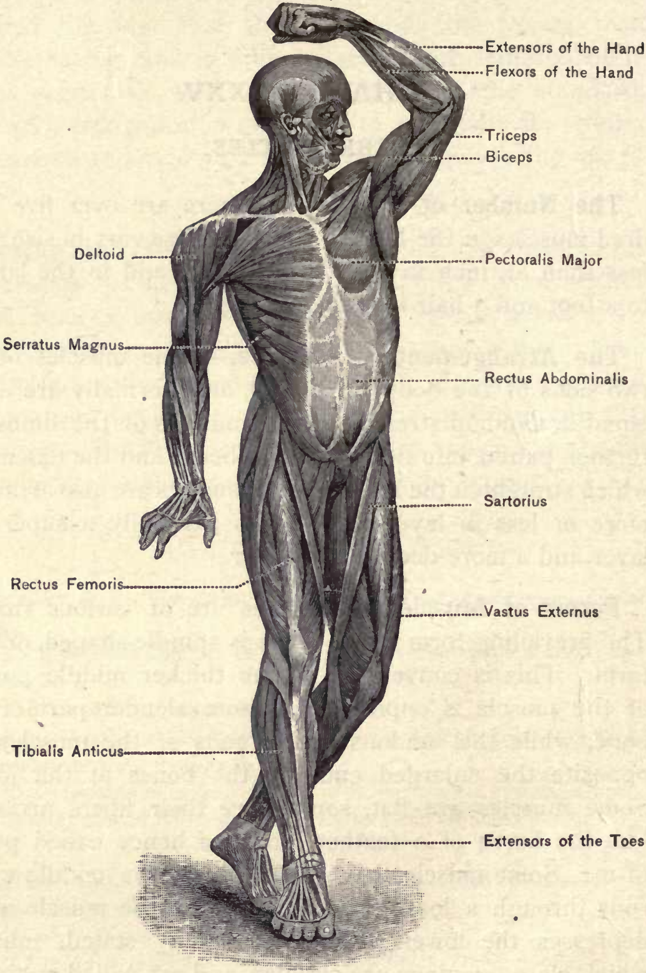


Fig. 107. Ventral View of the Superficial Muscles.

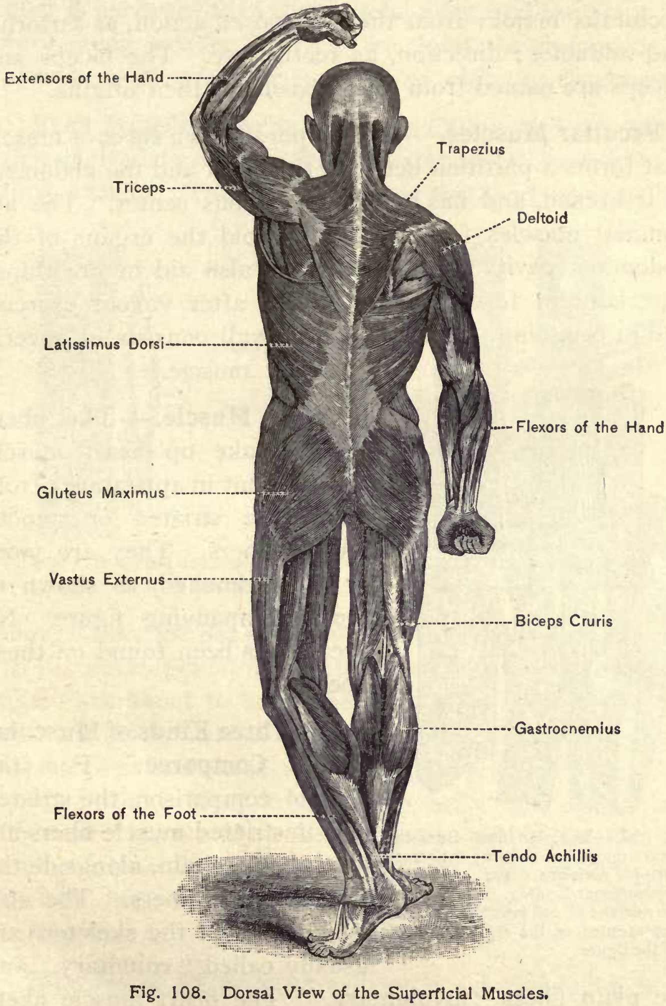


Fig. 108. Dorsal View of the Superficial Muscles.

Names of Muscles. — Some muscles are named from their shape, as the deltoid on the shoulder; from position, pectoralis major; from their supposed action, as sartorius and adductor; direction, as rectus, etc. The biceps and triceps are named from their division at their origins.

Peculiar Muscles. — The diaphragm is a sheet of muscle that forms a partition between the chest and the abdomen. It is arched, and has a clear tendinous center. The abdominal muscles form a wall to hold the organs of the abdominal cavity. These muscles also aid in breathing, especially in forced expiration, as after violent exercise and in coughing. The abdominal wall consists of several layers of muscle.

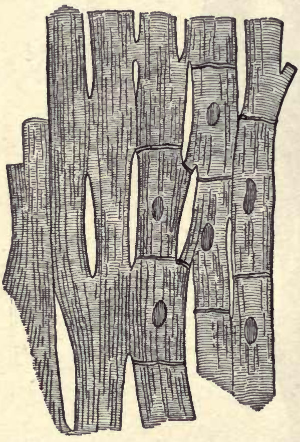


Fig. 109. — Muscular fibers from the heart, magnified, showing their cross striae, divisions, and junctions. (Schweigger-Seidel.)
The nuclei and cell-junctions are only represented on the right hand side of the figure.

Heart Muscle. — The fibers which make up heart muscle are different in appearance from either the striated or smooth muscle fibers. They are more or less branched, as shown in the accompanying figure. No sheath has been found on these fibers.

The Three Kinds of Muscular Fibers Compared. — For the sake of comparison, the striated and unstriated muscle fibers are here shown again, alongside the heart muscle fibers. The striated fibers (of the skeleton) are usually called "voluntary," and the plain fibers "involuntary." The heart muscle fibers are intermediate, being striated, but involuntary in their action. A striated muscle fiber may be $1\frac{1}{2}$ inches long and $\frac{1}{250}$ of an inch wide, though usually less. The heart muscle fiber is narrower than the skeletal fiber, and the plain fiber very much smaller than either. (But the figures do not attempt to give relative proportions with any exactness.)

Each Muscle Fiber is a Muscle Cell. — It is easily seen that each plain muscle fiber is a single cell, having its distinct nucleus. The same is true of the heart muscle fibers,

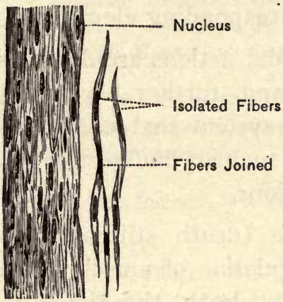


Fig. 110.—Plain (unstriated) muscular fibers from the bladder.

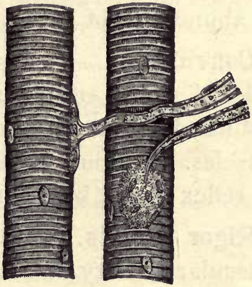


Fig. 111.—Two striated muscular fibers showing the terminations of the nerves.

though they are not so simple, being more or less branched. In the development of striated muscle, when the muscular fibers are about to be formed, the cells from which they develop (called muscle plates) become elongated so that each cell is converted into a long protoplasmic fiber, with many nuclei. Most investigators agree that the striated fibers are produced by the elongation of single cells with multiplication of their nuclei, though some have thought that the fiber is formed by the coalescence of several cells end to end.

Muscles of Expression. — The facial expression is due to the action of the muscles of the face, which in turn are under control of the cranial nerves. The habitual position becomes somewhat "fixed," so it is true that character is often shown by "the looks." Cultivation of happy thoughts therefore tends to make one better looking.

Muscles and Fat. — Fat fills in space between muscles, and, if abundant, forms a layer over the muscles. One notable instance is the hollow triangular space between the muscles of the cheek. If there is very little fat, a depression is seen, forming the "hollow cheeks." But an abundance of fat makes a corresponding elevation.

Convulsions. — These spasmodic actions are due to disordered action of the muscles, and, further back, to the disturbed action of the nervous system that controls the muscles. Various disturbances, such as indigestion, may by reflex action bring on convulsions.

Rigor Mortis. — Rigor mortis (death stiffening) is a muscular rigidity due to the coagulation of muscle plasma. It usually sets in not long after death, the time of its appearance and its duration being variable.

Some Prominent Muscles. — The deltoid on the shoulder is a noticeable muscle. The biceps and triceps have already been studied. The calf muscle is one of the thickest and strongest in the body. The great muscles of the rump are needed to raise and hold the body up. On each side of the front of the neck is a muscle easily observed in thin persons. It extends down to the top of the breast bone.

Sculpture and Anatomy. — The sculptor needs to be a thorough student of anatomy, so far as the bones and muscles are concerned. If he knows the muscles thoroughly, he can make them "stand out" naturally. Otherwise his work cannot be truly good.

APPENDIX A.

ANTISEPTICS AND DISINFECTANTS.

The following is chiefly from Sternberg's *Manual of Bacteriology*, and embodies part of the report of "The Committee on Disinfectants of the American Public Health Association."

Antiseptic Defined. — An antiseptic is a substance having the power to prevent or destroy putrefaction, or, what is the same thing, the bacteria upon which putrefaction depends.

Disinfectant Defined. — A disinfectant is a substance that can destroy disease germs.

Disinfection Defined. — Disinfection is the destroying of disease germs by means of heat, chemic substances, fumigation, or by fresh air.

"The injurious consequences which are likely to result from such misapprehension and misuse of the word 'disinfectant' will be appreciated when it is known that recent researches have demonstrated that many of the agents which have been found useful as deodorizers or as antiseptics are entirely without value for the destruction of disease germs."

An Antiseptic, but not a Disinfectant. — "This is true, for example, as regards the sulphate of iron, or copperas, a salt which has been extensively used with the idea that it is a valuable disinfectant. As a matter of fact, sulphate of iron in saturated solution does not destroy the vitality of disease germs, or the infecting power of material containing them. This salt is, nevertheless, a very valuable antiseptic, and its low price makes it one of the most valuable agents for the arrest of putrefactive decomposition."

Extracts from the Above-Mentioned Report.

Some Methods of Disinfecting. — "The most useful agents for the destruction of spore-containing infectious material are: —

1. Fire; complete destruction by burning.
2. Steam under pressure, 105 degrees C. (221 degrees F.), for ten minutes.
3. Boiling in water for half an hour.
4. Chlorid of lime; a four per cent solution.
5. Mercuric chlorid; a solution of 1 : 500.

For the destruction of material which owes its infecting power to the presence of microörganisms not containing spores, the committee recommends: —

1. Fire; complete destruction by burning.
2. Boiling in water for ten minutes.
3. Dry heat; 110 degrees C. (230 degrees F.) for two hours.
4. Chlorid of lime; a two per cent solution.
5. Solution of chlorinated soda; a ten per cent solution.
6. Mercuric chlorid; a solution of 1 : 2,000.
7. Carbolic acid; a five per cent solution.
8. Sulphate of copper; a five per cent solution.
9. Chlorid of zinc; a ten per cent solution.
10. Sulphur dioxid; exposure for at least twelve hours to an atmosphere containing at least four volumes per cent of this gas in the presence of moisture.

Methods of Disinfecting. — The committee would make the following recommendations with reference to the practical application of these agents for disinfecting purposes: —

For Excreta. — (*a*) In the sick room: —

1. Chlorid of lime, four per cent.

In the absence of spores: —

2. Carbolic acid in solution, five per cent.
3. Sulphate of copper in solution, five per cent.

(*b*) In privy vaults: —

1. Mercuric chlorid in solution, 1 : 500.
2. Carbolic acid in solution, five per cent.

(*c*) For the disinfection and deodorization of the surface of masses of organic material in privy vaults, etc.: —

Chlorid of lime in powder.

For Clothing, Bedding, etc. — (*a*) Soiled underclothing, bed linen, etc.

1. Destruction by fire, if of little value.
2. Boiling at least half an hour.

3. Immersion in a solution of mercuric chlorid of the strength of 1 : 2,000 for four hours.

4. Immersion in a two per cent solution of carbolic acid for four hours.

(*b*) Outer garments of wool or silk, and similar articles, which would be injured by immersion in boiling water or in a disinfecting solution: —

1. Exposure in a suitable apparatus to a current of steam for ten minutes.

2. Exposure to dry heat at a temperature of 110 degrees C. (230 degrees F.) for two hours.

(*c*) Mattresses and blankets soiled by the discharge of the sick: —

1. Destruction by fire.

2. Exposure to superheated steam, 105 degrees C. (221 degrees F.), for ten minutes. (Mattresses to have the cover removed or freely exposed.)

3. Immersion in boiling water for half an hour.

Furniture and Articles of Wood, Leather, and Porcelain. — Washing, several times repeated, with: —

1. Solution of carbolic acid, two per cent.

For the Person. — The hands and general surface of the body of attendants of the sick, and of convalescents, should be washed with: —

1. Solution of chlorinated soda diluted with nine parts of water, 1 : 10.
2. Carbolic acid; two per cent solution.
3. Mercuric chlorid, 1 : 1,000.

For the Dead. — Envelop the body in a sheet thoroughly saturated with: —

1. Chlorid of lime in solution, four per cent.
2. Mercuric chlorid in solution, 1 : 500.
3. Carbolic acid in solution, five per cent.

For the Sick Room. — (*a*) While occupied, wash all surfaces with: —

1. Mercuric chlorid in solution, 1 : 1,000.
2. Carbolic acid in solution, two per cent.

(*b*) When vacated, fumigate with sulphur dioxid for twelve hours, burning at least three pounds of sulphur for every thousand cubic feet of air space in the room; then wash all surfaces with one of the above-mentioned solutions, and afterward with soap and hot water; finally throw open doors and windows, and ventilate freely."

THE MORE COMMON POISONS, THEIR SYMPTOMS, ANTIDOTES, AND TREATMENT.

Poisons.	Symptoms.	Antidotes and Treatment.
Acids. Acetic. Citric. Muriatic. Nitric. Oxalic. Sulphuric. Tartaric.	All highly corrosive, excoriating the parts with which they come in contact, occasioning intense pain, followed by symptoms of shock. Nitric acid makes yellow stains; sulphuric blackens.	For nitric and oxalic acids, the carbonate of magnesia or lime; for sulphuric acid, strong soapsuds; for oxalic, lime water; for the others, any dilute alkali. Induce vomiting, give demulcent drinks, and treat the consequent inflammation and shock as if from any other injury.
Carbolic.	Caustic; whitening of the mucous membrane, with intense burning and numbness, nausea, weakness, stupor, and collapse.	Oil, milk. Secure rest, warmth of the body, and stimulation.
Prussic.	Gives an odor of peach kernels: nausea, giddiness, pain in the head, convulsions, and death.	Dilute ammonia. Cold affusion to the spine, emetics, and stimulants. A fatal dose leaves scarcely time for any treatment, death occurring in from three to five minutes.
Alkalies and Earths. Ammonia. Baryta. Lime. Potash. Soda.	Violent caustics, causing destruction of the mucous membrane, acute burning pain, vomiting and purging of bloody matter, and death by shock.	The vegetable acids — dilute vinegar, lemon-juice, etc. — neutralize them. The fixed oils — castor, linseed, olive, etc. — unite with them to form harmless soaps. Give these, and demulcent drinks; stimulants if necessary.

THE MORE COMMON POISONS, THEIR SYMPTOMS, ANTIDOTES, AND TREATMENT.

(*Continued.*)

POISONS.	SYMPTOMS.	ANTIDOTES AND TREATMENT.
METALLIC IRRITANTS.		
Antimony. *Tartar Emetic.*	Symptoms like those of cholera; violent cramps and purging, collapse; inflammation of whole alimentary canal, with metallic taste, suppression of urine, vomiting, cramps, delirium or stupor, death.	Induce vomiting, if the poison has not already done so, and give astringent infusions, as of strong tea or oak bark.
Arsenic. *Paris Green.* *Scheele's Green.* *Fowler's Solution.*	Intense pain, thirst, vomiting and purging, tenesmus, suppression of urine, clammy sweat, delirium or collapse, and death either in a few hours from shock, or after several days from inflammation.	The hydrated sesquioxide of iron — prepared by adding ammonia to the common muriated tincture, and washing the precipitate — is the antidote. Give *ad lib.* Or dialyzed iron and magnesia, half an ounce of each every ten minutes. After Fowler's solution, give lime-water freely, evacuate the stomach, and give demulcents.
Bismuth. Copper. *Blue Vitriol.* *Verdigris.*	Symptoms like other irritants.	Emetics, milk, albumin, and mucilaginous drinks.
Iodine. Iron. *Copperas.*		Starch unites with iodine, forming an insoluble compound, but not with the iodide of potassium.
Lead.	May occasion paralysis.	
Mercury. *Corrosive Sub.* *Vermilion.*		Albumin in some form, preferably the white of eggs, milk, flour gruel.

THE MORE COMMON POISONS, THEIR SYMPTOMS, ANTIDOTES, AND TREATMENT.

Poisons.	Symptoms.	Antidotes and Treatment.
Phosphorus.		Emetics, mucilage, and magnesia. No oil.
Silver, *Nitrate of.*		May be decomposed by common salt.
Tin. Zinc. *White Vitriol.*		Carbonate of soda in solution, milk and albumin.
VEGETABLE IRRITANTS. Colocynth. Croton Oil. Savin Oil.	Violent vomiting, diarrhœa, and pain, thirst, and constriction of the throat, difficult breathing, delirium, or stupor, death.	Evacuate the stomach and bowels as promptly as possible, and stimulate.
ANIMAL IRRITANTS. Cantharides.	Severe pain and burning all through the alimentary canal, bloody evacuations, strangury or retention of urine, convulsions, delirium, death.	Excite vomiting, give emollient drinks and enemata, but no oil. Rub the abdomen with camphor, or camphorated oil, to relieve the strangury.
Poisonous fish.	Indigestion, headache, vertigo, thirst, vomiting, and diarrhœa, collapse. Often an eruption on the skin.	Emetics, purgatives, and stimulants.
NARCOTICS and ACRO-NARCOTICS. Aconite. Alcohol. Belladonna (*Nightshade*). Camphor. Chloral. Colchicum. Conium (*Hemlock*). Digitalis (*Foxglove*).	These are nearly all vegetable poisons. They occasion nausea, numbness, stupor, delirium, or convulsions, overstimulation of the heart, followed by its failure, insensibility, coma, death. With the acro-narcotics, these symptoms are preceded by those of irritants, an acrid taste, dryness and constriction of the mouth and throat, fever, vomiting, and diarrhœa, with	Evacuate the stomach as thoroughly as possible, and give active purgatives ; give strong coffee, and keep the patient roused. The custom of walking the patient up and down, and slapping with wet towels, is objectionable ; it adds exhaustion to depression, and risks giving him pneumonia. Keep him in the recumbent position, and employ friction, and, if necessary, artificial respiration.

THE MORE COMMON POISONS, THEIR SYMPTOMS, ANTIDOTES, AND TREATMENT.

(*Continued.*)

Poisons.	Symptoms.	Antidotes and Treatment.
Dulcamara (*Bitter-sweet*). Ergot. Hellebore. Hyoscyamus. Laburnum. Lobelia. Nux Vomica.	intestinal pain. The pupils of the eyes are usually dilated, except under opiates, which contract them. Belladonna dilates them widely.	
Strychnine. Physostigma. Opium.	Strychnia excites violent convulsions, like those of tetanus.	The spasms may be quieted by inhalation of ether.
Morphine. Tobacco. Toadstools. Turpentine.		
Gases.		
Carbonic acid. Carbonic oxide. Nitrous oxide. Sulphuretted hydrogen. Chlorine. Chloroform.	Chlorine violently irritates the respiratory organs; the others act like narcotics. Each has a certain characteristic odor, by which it may be recognized.	Give plenty of fresh air, cautious inhalations of ammonia, stimulants, and artificial respiration if necessary.

Text Book of Nursing, Weeks; published and copyrighted by D. Appleton & Co.

Daily Excretions. — Sweat, from 1.5 lbs. to 4.5 lbs.; urea, about 1 oz.; organic matter exhaled, 3 grains; urine, 53 oz.

"Of the entire excreta, 32 per cent pass off by the breath; 17 per cent by the skin; 46.5 per cent by the kidneys; 4.5 per cent by the alimentary canal." — CUTTER.

Number of Sweat Glands. — The number of sweat glands may be as high as 3,500 in a square inch, and the average is estimated at 2,800 per square inch; as there are about 2,500 square inches of body surface, it is readily computed that there are several millions of sweat glands.

Number of Hairs on the Human Head. — The average number of hairs on the head is 120,000. They are set obliquely, and are controlled by muscles so that they may be made to stand erect, or nearly so, under the influence of certain emotions, as fear, anger, etc.

Huxley and others have classified the races of men according to the hair, into the Ulotrichi, or crisp or woolly haired division, including the negroes, bushmen, etc.; and Leiotrichi, or smooth-haired, subdivided into the Australioid, the Mongoloid, the Xanthochroic, and the Melanochroic.

In Europeans the hair is oval in cross-section; in the Japanese and Chinese it is circular.

Circulation. — Rate of blood flow: in the large arteries, from 12 to 16 inches a second; in the caval veins, about 4 inches a second; in the capillaries, from 1 inch to 1.5 inches a **minute.** A portion of the blood makes the complete circulation (in a horse) in less than half a minute. This is found by putting some readily detected chemical into one jugular vein, and noting how soon it appears in the other jugular vein. The time necessary for all the blood to pass through the heart is estimated as follows: Each ventricle pumps about six ounces of blood at each stroke. At this rate thirty strokes, 25 to 50 seconds (or less), would have pumped all the blood in the body. Still, some of the blood (from the shorter circuits) may have been pumped twice, and some (from the longer routes) may not yet have been around once. And since the total amount of blood has been only approximately determined, these figures are not very accurate.

Number of blood corpuscles to the cubic inch, about 83,000,000.

Dr. Tanner's Forty Days' Fast (Newspaper Account). No Food but Water Taken. — When Dr. Tanner came to New York from Minnesota he weighed 184 pounds. He was six weeks making arrangements for his fast; and when he began his experiment his weight was 157½ pounds. He weighed 121½ pounds on the day his fast ended. He had therefore lost 62½ pounds since he came to the city, and 36 pounds since he began his fast. Dr. Hammond, the well-known New York physician whose assertion that a forty days' fast was a physical impossibility led Dr. Tanner to make the attempt, came out in a card in the New York papers declaring that he believed the fast had been fairly conducted.

On each day of his fast Dr. Tanner weighed as follows: —

DAY.	POUNDS.	DAY.	POUNDS.
1st	157½	25th	131½
3d	153	26th	131½
5th	147½	27th	130½
7th	143½	28th	129¾
11th	139¾	29th	
13th	136¼	30th	130
14th	133	31st	128
16th	132	32d	127½
17th (8.30 P.M.)	133½	33d	126½
17th (11 A.M.)	135½	34th	126½
18th	136½	35th	
19th	136	36th	
20th (4 P.M.)	135½	37th	125½
20th (5 A.M.)	135	38th	
21st	135	39th	122½
22d	133½	40th	121½
26th	132½		

Cavities of the Body. — 1. Mucous cavities (open to the external air). Digestive tube, respiratory passages, genito-urinary passages, external and middle ear, etc.

2. Serous cavities (closed). They may all be said to be lymph cavities. They are the lymph spaces throughout the body, and the large spaces, called the pleural cavity around the lungs, the pericardial cavity around the heart, the peritoneal cavity in the abdomen, the arachnoid cavity around the brain, and a similar one along the spinal cord.

3. Synovial cavities in the joints.

4. Blood cavities, — the inside of the heart and blood tubes.

5. Secretion cavities, — the cavities and tubes from the glands; for example, the bile sac and its duct.

6. Bone cavities.

LOSSES OF THE TISSUES DURING STARVATION.

(FROM EXPERIMENT ON A CAT.)

Fat	loses 93 per cent.	Heart	loses 44 per cent.
Blood	" 75 "	Intestines	" 42 "
Spleen	" 71 "	Muscles of locomotion	" 42 "
Pancreas	" 64 "	Respiratory apparatus	" 22 "
Stomach	" 39 "	Bones	" 16 "
Pharynx, gullet	" 34 "	Eyes	" 10 "
Skin	" 33 "	Nervous system	" 2 "
Kidneys	" 31 "		
Liver	" 52 "		

QUANTITY OF WATER IN 1,000 PARTS.

Teeth	100	Bile	880
Bones	130	Milk	887
Cartilage	550	Pancreatic juice	900
Muscles	750	Urine	936
Ligament	768	Lymph	960
Brain	789	Gastric juice	975
Blood	795	Sweat	986
Synovia	805	Saliva	995

THE LOSS OF WATER FROM THE BODY.

From the Alimentary canal (feces)	4	per cent.
" " Lungs	20	"
" " Skin (perspiration)	30	"
" " Kidneys (urine)	46	"

ELEMENTS IN THE HUMAN BODY.

Oxygen	72.0	Chlorin	.085
Carbon	13.5	Fluorin	.08
Hydrogen	9.1	Potassium	.026
Nitrogen	2.5	Iron	.01
Calcium	1.3	Magnesium	.0012
Fosforus	1.15	Silicon	.0002
Sulfur	.147	Copper, lead, aluminum	(traces)
Sodium	.1		100.

DAILY RATION OF A U. S. SOLDIER DURING THE LATE WAR.

Bread or flour	22	oz.
Fresh or salt beef (or pork or bacon 12 oz.)	20	"
Potatoes (three times a week)	16	"

Rice	1.6	oz.
Coffee (or tea 0.24 oz.)	1.6	"
Sugar	2.4	"
Beans	.64	gill.
Vinegar	.32	"
Salt	.16	"

COMPOSITION OF FOODS.

	WATER.	PROTEIDS.	FATS.	CARBO-HYDRATES.	SALTS
Beef, lean	72	19.3	3.6	. . .	5.1
Beef, fat	51	14.8	29.8	. . .	4.4
Mutton, lean	72	18.3	4.9	. . .	4.8
Mutton, fat	53	12.4	31.1	. . .	3.5
Veal	63	16.5	15.3	. . .	4.7
Pork, fat	39	9.8	48.9	. . .	2.3
Poultry	74	21	3.8	. . .	1.2
Whitefish	78	18.1	2.9	. . .	1.0
Salmon	77	16.1	5.5	. . .	1.4
Eels (rich in fat)	75	9.9	13.8	. . .	2.7
Oysters	75.7	11.7	2.4	. . .	2.7
				SUGAR.	
Milk	86	4.1	3.9	5.2	.8
Buttermilk	88	4.1	.7	6.4	.8
Cream	66	2.7	26.7	2.8	4.9
Cheese, full	36	28.4	31.1	. . .	4.5
Cheese, skim	44	44.8	6.3	. . .	4.9
Eggs, white	78	20.4	. . .	. . .	1.6
Eggs, yelk	52	16	30.7	. . .	1.3
				STARCH.	
Bread	37	8.1	1.6	51	2.3
Flour	15	10.8	2	70.8	1.7

COMPOSITION OF THE BLOOD.

Water		784
Solids—		
Corpuscles	130	
Proteids (of serum)	70	
Fibrin (of clot)	2.2	
Fatty matters (of serum)	1.4	
Inorganic salts	6.0	
Gases, urea, kreatin, etc.	6.4	
		216
		1000

COMPOSITION OF GASTRIC JUICE.

Water		99.44
Solids —		
Pepsin	.319	
Salts	.218	
Hydrochloric acid	.02	
		.557
		100

Fluids of the Body (FORD). — 1. Circulating fluids, — chyle, lymph, blood.

2. Fluids for digestion, — saliva, gastric juice, pancreatic juice, bile, intestinal juice.

3. Fluids of closed cavities, — of the arachnoid, pleural, pericardial, and peritoneal sacs, of joints, of the eye and ear, and of cells.

4. Secretions for protection, — cerumen or wax, tears, fluid of mucous membranes, oily fluids on the surface of the body.

5. Fluids for discharge, — intestinal secretion, renal or kidney secretion, perspiration, vapor from the lungs, etc.

Acids and Alkalies of the Body. — Acids, — gastric juice, mucus, chyme, contents of large intestine.

Alkalies, — saliva (or neutral), pancreatic juice, intestinal juice, bile (or neutral), contents of small intestine, sweat.

Amount of Digestive Liquids. — The amount of saliva secreted daily is estimated at from 1 to 3 pints, of gastric juice from 10 to 20 pints, of bile from 2 to 3 pints. The amount of intestinal and other juices is difficult to estimate. But it is readily seen that a very large amount of liquid is daily separated from the blood to be used in the preparation of the food for absorption into the blood. This is to be looked upon as an investment. It is supposed to be reabsorbed with large returns in addition to the prepared food; and if anything interferes with the absorption of the food material, especially if the secretion goes on, it is plain that bankruptcy will follow as surely as in the business world whenever there is a continual expenditure without corresponding returns. The condition known as "diarrhea" illustrates this condition, perhaps, as well as any well-known condition of the body.

Specific Gravity of the Liquids of the Body. — As all the liquids of the body have dissolved and suspended in them various salts and other matters, they are all heavier than water.

Alcohol and Longevity. — Investigation by Baer has shown that the average expectation of life among users and dealers in alcoholic liquors is very much shortened. The following table gives a comparative view of the expectation of life in those who abstained from and those who used alcohol: —

EXPECTATION OF LIFE.

AGE.	ABSTAINERS.	ALCOHOL USERS.
At 25,	32.08 years,	26.23 years.
" 35,	25.92 "	20.01 "
" 45	19.92 "	15.19 "
" 55,	14.45 "	11.16 "
" 65,	9.62 "	8.04 "

TABLE SHOWING THE INFLUENCE OF ALCOHOL UPON THE MORTALITY FROM VARIOUS DISEASES.

	GENERAL MALE POPULATION.	ALCOHOL VENDERS
Brain disease,	11.77 per cent.	14.43 per cent.
Tuberculosis,	30.36 "	36.57 "
Pneumonia and pleuritis,	9.63 "	11.44 "
Heart disease,	1.46 "	3.29 "
Kidney disease,	1.40 "	2.11 "
Suicide,	2.99 "	4.02 "
Cancer,	2.49 "	3.70 "
Old age,	22.49 "	7.05 "

GLOSSARY.

Albumen (*al-bū′-men*). The white of an egg.

Albumin (*al-bū′-min*). A proteid substance, the chief constituent of the body. Its molecule is highly complex, and varies widely within certain limits in different organs and in different conditions.

Albuminuria (*al-bū′-mi-nū′-ri-a*). The presence of albumin in the urine, indicating changes in the blood or in the kidneys.

Amylopsin (*am-i-lop′-sin*). A ferment said to exist in pancreatin.

Anabolism (*an-ab′-o-lizm*). Synthetic or constructive metabolism. Activity and repair of function; opposed to katabolism.

Arbor Vitae (*ar′-bor vī′-tē*). A term applied to the branched appearance of a section of the cerebellum.

Argon (*ar′-gon*). A newly discovered element similar to nitrogen (found in the air).

Arytenoid (*ar-i-tē′-noid*). Resembling the mouth of a pitcher, as the arytenoid cartilages of the larynx.

Atlas (*at′-las*). The uppermost of the cervical vertebrae (from the mythical Atlas who supported the Earth).

Auricle (*aw′-ri-kl*). The auricles of the heart are the two cavities between the veins and the ventricles. Also, the pinna and external meatus of the ear.

Axis (*ak′-sis*). The second cervical vertebra, on which the head, with the atlas, turns.

Bacterium (*bak-tē′-ri-um*), pl. bacteria. A genus of microscopic fungi characterized by short, linear, inflexible, rod-like forms — without tendency to unite into chains or filaments.

Biceps (*bī′-seps*). Biceps brachii, the flexor of the arm.

Bicuspid (*bi-kus′-pid*). Having two points; the bicuspid or premolar teeth; the bicuspid valve, between the left auricle and the left ventricle.

Brachial (*brā′-ke-al* or *brak′-i-al*). Pertaining to the arm.

Bronchus (*brong′-kus*), pl. bronchi. The two tubes into which the trachea divides opposite the third thoracic vertebra, called respectively the right and left bronchus.

Caffein (*kaf′-ē-in*). An alkaloid that occurs in the leaves and beans of the coffee-tree, in Paraguay tea, etc.

Canaliculus (*kan-a-lik′-u-lus*), pl. canaliculi. The crevices extending from lacunae, through which nutrition is conveyed to all parts of the bone.

Canine (*ka-nīn′* or *kā′-nīn*). The conical teeth between the incisors and the premolars.

Capillary (*kap′-i-lā-ri* or *ka-pil′-a-ri*). A minute blood-tube connecting the smallest ramification of the arteries with those of the veins.

Capsule (*kap′-sūl*). A tunic or bag that incloses a part of the body or an organ.

Carbohydrate (*kar-bo-hī′-drāt*). An organic substance containing six carbon atoms or some multiple of six, and hydrogen and oxygen in the proportion in which they form water; that is, twice as many hydrogen as oxygen atoms. Starches, sugars, and gums are carbohydrates.

Cardiac (*kär′-di-ak*). Pertaining to the heart.

Carotid (*ka-rot′-id*). The principal right and left arteries of the neck.

Carpus (*kär′-pus*). Belonging to the wrist; as the carpal bones.

Cartilage (*kär′-ti-lāj*). Gristle of various kinds, articular, etc.

Casein (*kā′-se-in*). A derived albumin, the chief proteid of milk, precipitated by acids and by rennet at 40°C.

Cecum (*sē′-kum*). The large blind pouch or cul-de-sac, in which the large intestine begins.

Centrum (*sen′-trum*). The center or middle part; the body of a vertebra, exclusive of the bases of the neural arches.

Cerebellum (*ser-ē-bel′-um*). The inferior part of the brain, lying below the cerebrum.

Cerebrum (*ser′-ē-brum*). The chief portion of the brain, occupying the whole upper part of the cranium.

Cervical (*ser′-vī-kal*). Pertaining to the neck, as cervical vertebrae.

Chordae tendineae (*kor′-dē*). The tendinous cords connecting the fleshy columns of the heart with the auriculo-ventricular valves.

Choroid (*kō′-roid*). The second or vascular coat of the eye, continuous with the iris in front, and lying between the sclerotic and the retina.

Chyle (*kīl*). The milk-white fluid absorbed by the lacteals during digestion.

Chyme (*kīm*). Food that has undergone gastric digestion, and has not yet been acted upon by the biliary, pancreatic, and intestinal secretions.

Cilium (*sil′-i-um*), pl. ciliä. The eyelashes ; also the hair-like appendages of certain epithelial cells, whose function is to propel fluid or particles along the passages that they line.

Ciliary (*sil′-i-a-ri*). Pertaining to the eyelid or eyelash ; also by extension to the ciliary apparatus or the structure related to the mechanism of accommodation. Pertaining to the cilia.

Circumvallate (*sir-kum-val′-āt*). Surrounded by a wall or prominence, as the circumvallate papillae on the tongue.

Clavicle (*klav′-i-kl*). The collar-bone.

Coccyx (*kok′-siks*). The last bone of the spinal column, formed by the union of four rudimentary vertebrae.

Cochlea (*kok′-lē-a*). A cavity of the internal ear, resembling a snail-shell.

Conjunctiva (*kon-jungk-tī′-vä*). The mucous membrane covering the anterior portion of the globe of the eye, reflected on, and extending to, the free edge of the lids.

Corpus Arantii (*kor′-pus*). The tubercles, one in the center of each segment of the semilunar valves.

Corpuscle (*kor′-pus-l*). A name loosely applied to almost any small, rounded or oval body, as the blood corpuscles.

Cortex (*kor′-teks*). Bark. The outer layer of gray matter of the brain ; the outer layer, cortical substance, of the kidney.

Cricoid (*krī′-koid*). Ring-shaped, as the cricoid cartilage of the larynx.

Dentine (*den′-tin*). The ivory-like substance constituting the bulk of the tooth, lying under the enamel of the crown and the cement of the root.

Diabetes (*dī-a-bē′-tēz*). The name of two different affections, *diabetes mellitus*, or persistent glycosuria, and *diabetes insipidus*, or polyuria, both characterized, in ordinary cases, by an abnormally large discharge of urine. The former is distinguished by the presence of an excessive quantity of sugar in the urine.

Dialysis (*dī-al′-i-sis*). The operation of separating crystalline from colloid substances by means of a porous diaphragm, the former passing through the diaphragm into the pure water upon which the dialyzer rests.

Digastric (*di-gas′-trik*). Having two bellies, as the digastric muscle, enlarged near each end and with a tendon in the middle.

Duodenum (*dū-ō-dē′-num*). The first part of the small intestine, beginning with the pylorus.

Emulsion (*ē-mul′-shun*). Water or other liquid in which oil, in minute subdivision of its particles, is suspended.

Enamel (*en-am′-el*). The hard covering of the crown of a tooth.

Endothelium (*en-do-thē′-li-um*). The internal lining membrane of serous, synovial, and other internal surfaces, the homolog of epithelium.

Enzyme (*en′-zim*). Any chemic or hydrolytic ferment, as distinguished from organized ferments such as yeast; unorganized ferment.

Epiglottis (*ep-i-glot′-is*). A thin fibro-cartilaginous valve that aids in preventing food and drink from passing into the larynx.

Esophagus (*ē-sof′-a-gus*). The musculo-membranous tube extending from the pharynx to the stomach.

Eustachian (*u-stā′-ki-an*). Eustachian tube, the tube leading from the middle ear to the pharynx.

Facet (*fas′-et*). A small plane surface. The articulating surface of a bone.

Femur (*fē′-mer*). The thigh-bone.

Ferment (*fer′-ment*). Any micro-organism, proteid, or other chemic substance capable of producing fermentation, i.e., the oxidation and disorganization of the carbohydrates.

Fibrin (*fī′-brin*). A native albumen or proteid, a substance that, becoming solid in shed blood, plasma, and lymph, causes coagulation of these fluids.

Fibula (*fib′-u-lä*). The smaller or splint bone in the outer part of the leg, articulating above with the tibia. and below with the astragalus and tibia.

Filiform (*fil′-i-form*). Thread-like, as the filiform papillae.

Frontal (*fron′-tal*). Belonging to the front, as the frontal bone.

Fungiform (*fun′-ji-form*). Having the form of a mushroom, as fungiform papillae.

Ganglion (*gang′-gli-on*), pl. ganglions or gangliä. A separate and semi-independent nervous center, communicating with other ganglia or nerves, with the central nervous system, and peripheral organs.

Gastric (*gas'-trik*). Pertaining to the stomach.

Gelatin (*jel'-a-tin*). An albuminoid substance of jelly-like consistence, obtained by boiling skin, connective tissue, and bones of animals in water. The glue of commerce is an impure variety.

Glosso-pharyngeal (*glos'-o-fa-rin'-je-al*). Pertaining to the tongue and larynx.

Gluten (*glö'-ten*). A substance resembling albumin, and with which it is probably identified ; it occurs abundantly in the seeds of cereals.

Glycogen (*glī'-ko-jen*). A white amorphous powder, tasteless and odorless, forming an opalescent solution with water, and insoluble in alcohol. It is commonly known as animal starch. It occurs in the blood and in the liver, by which it is elaborated, and is changed by diastasic ferments into glucose.

Gustatory (*gus'-tā-to-ri*). Pertaining to the special sense of taste and its organs.

Hashish (*hash'-ēsh*). A preparation from Indian hemp, Cannabis indica. It is a powerful narcotic.

Haversian (*ha-ver'-zian*). Haversian canal, in bone, a central opening for blood-tubes, surrounded by a number of concentric rings, or lamellae, of bone.

Hemoglobin (*hem-ō-glō'-bin*). A substance existing in the corpuscles of the blood, and to which their red color is due.

Hepatic (*hē-pat'-ik*). Pertaining or belonging to the liver.

Hilum (*hī'-lum*). A small pit, scar, or opening in an organic structure ; the notch on the internal or concave border of the kidney.

Humerus (*hū'-me-rus*). The bone of the upper arm.

Humor (*hū'-mor*). Any liquid, or semi-liquid, part of the body.

Hyoid (*hī'-oid*). Having the form of the letter U. The hyoid bone situated between the root of the tongue and the larynx, supporting the tongue and giving attachment to its muscles.

Hypo-glossal (*hī-pō-glos'-al*). Under the tongue.

Iliac (*il'-i-ak*). Pertaining to the ilium, or region of the flanks, as iliac artery, vein, etc.

Incisor (*in-sī'-sor*). The chisel-shaped front teeth.

Inhibition (*in-hi-bish'-un*). The act of checking, restraining, or suppressing ; any influence that controls, retards, or restrains. Inhibitory nerves and centers are those intermediating a modification, stoppage, or suppression of a motor or secretory act already in progress.

Innominate (*i-nom′-i-nāte*). Nameless ; a term applied to several parts of the body to which no other definite name has been given, as the innominate bone, artery, vein, etc.

Invertin (*in′-ver-tin*). A ferment found in the intestinal juice, and also produced by several species of plants ; it converts cane-sugar in solution into invert sugar.

Jugular (*jö′-gū-lär*). Pertaining to the throat, as the jugular vein.

Katabolism (*ka-tab′-ö-lizm*). Analytic or destructive metabolism ; a physiologic disintegration ; opposed to anabolism.

Lacrymal (*lak′-ri-mal*). Having relation to the organs of the secretion, transfer, or excretion of tears.

Lacuna (*lā-kū′-nä*). A little hollow space ; especially the microscopic cavities in bone occupied by the bone corpuscles, and communicating with one another and with the haversian canals and the surfaces of the bone through the canaliculi.

Lamella (*lā-mel′-ä*), pl. lamellae. A thin lamina, scale, or plate ; of bone, the concentric rings surrounding the haversian canals.

Larynx (*lar′-ingks*). The upper part of the air passage between the trachea and the base of the tongue ; the voice-box.

Legumin (*lē-gū′-min*). A proteid compound in the seeds of many plants belonging to the natural order Leguminosae (peas, beans, lentils, etc.).

Lumbar (*lum′-bär*), pertaining to the loins, especially to the region about the loins.

Lymphatic (*lim-fat′-ik*). Pertaining to lymph.

Lymphatics (*lim-fat′-iks*). The tubes that convey lymph.

Lymphatic glands. The glands intercalated in the pathway of the lymphatic tubes, through which lymph is filtered.

Massage (*ma-säzh′*). A method of effecting changes in the local and general nutrition, action and other functions of the body, by rubbing, kneading, and other manipulation of the superficial parts of the body by the hand or an instrument.

Masseter (*mas′-e-ter*). A chewing-muscle felt on the angle of the jaw.

Medullary (*med′-u-lā-ri*). Pertaining to the medulla, or marrow ; resembling marrow. Also pertaining to the white substance of the brain contained within the cortical envelop of gray matter.

Mesenteric (*mez-en-ter′-ik*). Pertaining to the mesentery, as artery, vein, etc.

Mesentery (*mez′-en-ter-i*). A fold of the peritoneum that connects certain portions of the intestine with the dorsal abdominal wall.

Metabolism (*me-tab′-ō-lizm*). A change in the intimate condition of cells; (1) constructive or synthetic metabolism is called Anabolism; in anabolism, the substance is becoming more complex and is accumulating force; (2) destructive or analytic metabolism is called Katabolism; in katabolism there is disintegration, the material is becoming less complex, and there is loss or expenditure of force.

Metacarpus (*met-a-kär′-pus*). The bones of the palm of the hand.

Metatarsus (*met-a-tär′-sus*). The five bones of the arch of the foot, situated between the tarsus and the phalanges.

Mitral (*mī′-tral*). Resembling a miter; mitral valve, with two flaps, between the left auricle and the left ventricle.

Molar (*mō′-lär*). Mill; the grinding-teeth.

Mucous (*mū′-kus*). A term applied to those tissues that secrete mucus.

Mucus (*mū′-kus*). A viscid liquid secretion of mucous membranes, composed essentially of mucin, holding in suspension desquamated epithelial cells, etc.

Myosin (*mī′-o-sin*). A proteid of the globulin class, — the chief proteid of muscle. Its coagulation after death causes *rigor mortis*.

Narcosis (*när-kō′-sis*). The deadening of pain, or production of incomplete or complete anesthesia by the use of narcotic agents, such as anesthetics, opium, and other drugs.

Narcotic (*när-kot′-ic*). A drug that produces narcosis.

Neural (*nū′-ral*). Pertaining to the nerves.

Neuroglia (*nū-rog′-li-ä*). The reticulated framework or skeleton-work of the substance of the brain and spinal cord. The term is sometimes abbreviated to glia.

Nucleus (*nū′-klē-us*). The essential part of a typical cell, usually round in outline, and situated in the center.

Occipital (*ok-sip′-i-tal*). Pertaining to the occiput or back part of the head, as the occipital bone.

Odontoid (*o-don′-toid*). Resembling a tooth; the tooth-like process (axis) of the second cervical vertebra, on which the atlas turns.

Olfactory (*ol-fak′-tō-ri*). Pertaining to the sense of smell.

Osmosis (*os-mō′-sis*). That property by which liquids and crystalline substances in solution pass through porous septa; endosmosis and exosmosis.

Oxy-hemoglobin (*ok-si-hem-ō-glo′-bin*). Hemoglobin united, molecule for molecule, with oxygen. It is the characteristic constituent of the red corpuscles to which the scarlet color of arterial blood is due.

Pancreas (*pan′-krē-as*). A large racemose gland lying transversely across the dorsal wall of the abdomen. It secretes a clear liquid for the digestion of proteids, fats, and carbohydrates. The sweet-bread of animals, vulgarly called the "belly sweet-bread" in contra-distinction to the thymus, or true sweet-bread.

Pancreatin (*pan′-krē-a-tin*). The active element of the pancreatic juice.

Papilla (*pā-pil′-ä*), pl. **papillae**. Any soft, conical elevation, as papillae of the dermis, tongue, etc.

Papillary (*pap′-i-lā-ri*). Pertaining to a papilla; papillary muscles,—the conic muscular columns of the heart, to which the chordae tendineae are attached.

Parietal (*pā-rī′-e-tal*). Pertaining to the walls, as the parietal bone.

Parotid (*pa-rot′-id*). Near the ear, as the parotid salivary glands.

Patella (*pa-tel′-a*). The knee-pan.

Peptone (*pep′-tōn*). A proteid body produced by the action of peptic and pancreatic digestion.

Pericardium (*pėr-i-kär′-di-um*). The closed membranous sac or covering that envelops the heart.

Periosteum (*per-i-os′-tē-um*). A fibrous membrane that invests the surfaces of the bones, except at the points of tendinous and ligamentary attachments, and on the articular surfaces where cartilage is substituted.

Peristaltic (*per-i-stal′-tik*). The peculiar movement of the intestine and other tubular organs, consisting in a vermicular shortening and narrowing of the tube, thus propelling the contents onward. It is due to the successive contractions of the bundles of longitudinal and circular muscular fibers.

Peritoneal (*per-i-tō-nē′-al*). Pertaining to the peritoneum.

Peritoneum (*per-i-tō-ne′-um*). The serous membrane lining the interior of the abdominal cavity, and surrounding the contained viscera. The peritoneum forms a closed sac, but is rendered complex in its arrangement by numerous foldings produced by its reflection upon the viscera.

Phalanges (*fā-lan′-jēz*), plural of **phalanx** (*fā′-langks*). Any one of the bones of the fingers or toes.

Pharynx (*far'-ingks*). The cavity back of the soft palate. It communicates anteriorly with the posterior nares, laterally with the eustachian tubes, ventrally with the mouth, and posteriorly with the gullet and larynx.

Plasma (*plaz'-mä*). The original undifferentiated substance of nascent, living matter. The fluid part of the blood and lymph.

Pleura (*plö'-rä*). The serous membrane which envelops the lungs, and which, being reflected back, lines the inner surface of the thorax.

Plexus (*plek'-sus*). An aggregation of vessels or nerves forming an intricate net-work.

Pneumogastric (*nu-mō-gas'-trik*). Pertaining conjointly to the lungs and the stomach, or to the pneumogastric or vagus nerve.

Portal (*pōr'-tal*). Pertaining to the porta (gate) or hilum of an organ, especially of the liver, as the portal vein.

Postcaval (*pōst-kā'-val*). Pertaining to the postcava; the postcaval vein, formerly called the inferior vena cava, or vena cava ascendens.

Precaval (*prē-kā'-val*). Pertaining to the precava; the anterior caval vein, formerly called the superior vena cava, or vena cava descendens.

Pronation (*prō-nā'-shun*). The turning of the palm downward.

Protoplasm (*prō'-tō-plazm*). An albuminous substance, ordinarily resembling the white of an egg, consisting of carbon, oxygen, nitrogen, and hydrogen in extremely complex and unstable molecular combination, and capable, under proper conditions, of manifesting certain vital phenomena, such as spontaneous motion, sensation, assimilation, and reproduction, thus constituting the physical basis of life of all plants and animals.

Ptyalin (*tī'-a-lin*). An amylolytic or diastasic ferment found in saliva, having the property of converting starch into dextrin and sugar.

Pulmonary (*pul'-mō-na-ri*). Pertaining to the lungs.

Pylorus (*pī-lō'-rus*). The opening of the stomach into the duodenum.

Radius (*rā'-di-us*). The outer of the bones of the forearm.

Renal (*rē'-nal*). Pertaining to the kidneys.

Rennin (*ren'-in*). An enzyme, or ferment, to whose action is due the curdling or clotting of milk produced upon the addition of rennet.

Retina (*ret'-i-nä*). The chief and essential peripheral organ of vision; the third or internal coat or membrane of the eye, made up of the end organs or expansion of the optic nerve within the globe.

Sacrum (*sā'-krum*). A curved triangular bone, composed of five consolidated vertebrae, wedged between the two iliac (pelvic) bones, and forming the dorsal boundary of the pelvis.

Scapula (*skap'-ū-lä*). The shoulder-blade.

Sciatic (*sī-at'-ik*). Pertaining to the ischium; the sciatic nerve, the main nerve of the thigh.

Sclerotic (*sklē-rot'-ik*). Hard, indurated; pertaining to the outer coat of the eye.

Semilunar (*sem-i-lū'-när*). Resembling a half-moon in shape; semilunar valves, pocket-like valves at the beginning of the aorta and pulmonary artery.

Serous (*sē'-rus*). Pertaining to, characterized by, or having the nature of, serum.

Serum (*sē'-rum*). The yellowish fluid separating from the blood after the coagulation of the fibrin.

Solar plexus (*sō'-lär*). Solar, with radiations resembling the sun.

Sphincter (*sfingk'-ter*). A muscle surrounding and closing an orifice.

Splenic (*splen'-ik*). Pertaining to the spleen.

Steapsin (*stēp'-sin*). A diastasic ferment which causes fats to combine with an additional molecule of water and then split into glycerine and their corresponding acids.

Sternum (*ster'-num*). The breast-bone.

Subclavian (*sub-klā'-vi-an*). Situated under the collar-bone; subclavian artery and vein.

Sublingual (*sub-ling'-gwal*). Lying beneath the tongue, as sublingual gland.

Submaxillary (*sub-mak'-si-la-ri*). Lying beneath the lower maxilla, as submaxillary salivary gland.

Supination (*sū-pi-nā'-shun*). The turning of the palm upward.

Synovia (*sī-no'-vi-ä*). The lubricating liquid secreted by the synovial membranes in the joints.

Tarsus (*tär'-sus*). The instep, consisting of seven bones.

Temporal (*tem'-pō-ral*). Pertaining to the temples, as temporal artery, vein, muscle, etc.

Tetanus (*tet'-a-nus*). A spasmodic and continuous contraction of the muscles, causing rigidity of the parts to which they are attached.

Thein (*thē'-in*). An alkaloid found in tea.

Theobromin (*thē-ō-brō'-min*). A feeble alkaloid obtained from cacao-butter; the essential substance found in cocoa and chocolate.

Thyroid (*thī′-roid*). Shield-shaped, as the thyroid cartilage of the larynx.

Tibia (*tib′-i-ä*). The larger (inner) of the two bones of the leg, commonly called the shinbone.

Trachea (*trā-kē′-a* or *trā′-ke-a*). The windpipe.

Triceps (*trī′-seps*). Triceps of the arm, the extensor of the arm, lying along the back of the humerus.

Tricuspid (*trī-kus′-pid*). Having three cusps or points, as the tricuspid valve.

Trypsin (*trip′-sin*). The proteolytic ferment of pancreatic juice.

Ulna (*ul′-nä*). The larger (inner) of the two bones of the forearm.

Ureter (*ū-rē′-ter*). The tube conveying the urine from the pelvis of the kidney to the bladder.

Vaso-constrictor (*vas′-ō-kon-strik′-tor*). Causing a constriction of the blood-vessels.

Vaso-dilator (*vas′-ō-di-lā′-tor*). Pertaining to the positive dilating motility of the non-striated muscles of the vascular system.

Vaso-motor (*vas-ō-mo′-tor*). Serving to regulate the tension of the blood-vessels, as vaso-motor nerves; including vaso-dilator and vaso-constrictor mechanisms.

Ventricle (*ven′-tri-kl*). Applied to certain structures having a bellied appearance. The cavities of the heart from which the blood is forced out through the arteries.

Vesicle (*ves′-i-kl*). A small, membranous, bladder-like formation, as air vesicle.

Villus (*vil′-us*), pl. villi. One of the numerous minute vascular projections from the mucous membrane lining the small intestine, for absorbing digested food.

Vitreous (*vit′-re-us*). Glass-like, as the clear, jelly-like, vitreous humor of the eye.

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