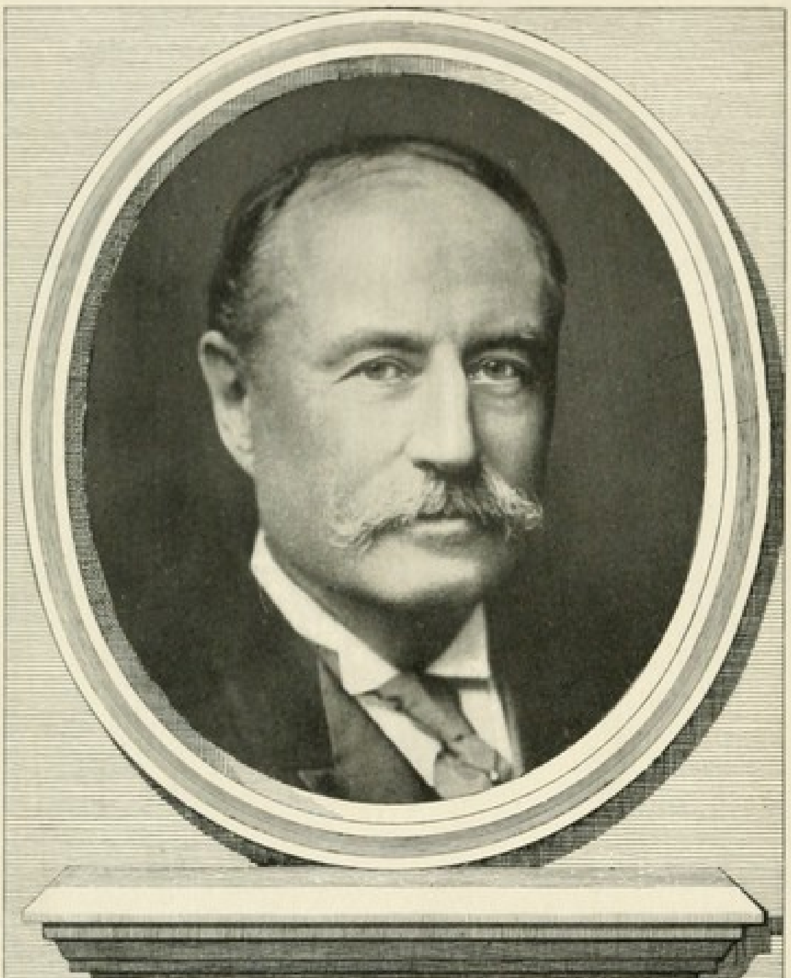
APPLETONS

SCIENTIFIC TEXT BOOK

ANATOMY
PHYSIOLOGY
AND HYGIENE



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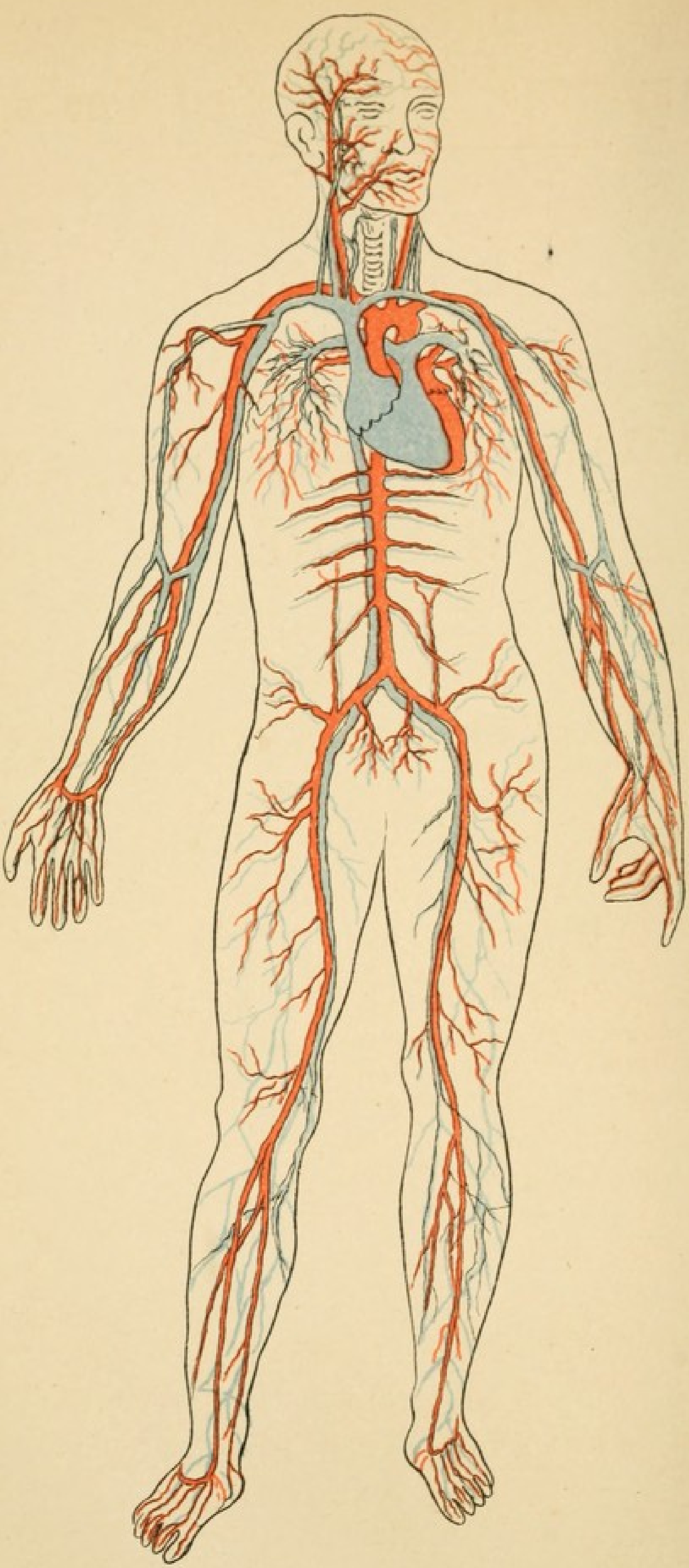

General Plan of the Circulation.

Appletons' Science Text-Books.

THE ESSENTIALS

OF

ANATOMY, PHYSIOLOGY, AND HYGIENE.

A TEXT-BOOK FOR SCHOOLS AND ACADEMIES.

BY

ROGER S. TRACY, M. D.,

SANITARY INSPECTOR OF THE NEW YORK CITY HEALTH DEPARTMENT;
AUTHOR OF "HAND-BOOK OF SANITARY INFORMATION
FOR HOUSEHOLDERS."

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1, 3, AND 5 BOND STREET.
1884.

PREFACE.

It has been my aim in preparing this volume to compress within the narrowest space such a clear and intelligible account of the structures, activities, and care of the human system as is essential for the purposes of general education. I have also sought to present the facts and principles of the subject in such a natural order as will best subserve the true ends of scientific education. Useful books of information upon physiology are already numerous, but they are too generally deficient in making the science valuable as a means of mental training. Of course, the great object of physiology is to teach how to preserve health, but this is not best done by merely memorizing rules. The rules must be supported by reasons, and if there is not some thorough understanding of the mechanism and powers of the human body, such as will task the efforts of the student, the real fruits of knowledge will not be gained. I have accordingly given prominence to the anatomical and physiological facts which are necessary preliminaries to instruction in hygiene, and in the reasonings upon these facts I have aimed to attract and interest the pupil, to teach him something of the scientific methods of approaching the subject, and to connect new acquisitions logically with those already gained, so that the knowledge of the subject may become, as it were, organized into faculty in the minds of the students. So important has it seemed to me to impress deeply upon the pupil's mind the laws of connection and dependence among the various parts of the living system that I have thought it best to present this view, in outline, at the very outset. I have, therefore, prefixed to the volume a General Analysis, which, while it serves as a table of contents, is interspersed with running comments explaining the general relations of the different organs and processes, and I recommend that this analysis be carefully read by the pupil, so that he may become familiar with its argument before proceeding to the detailed study of the text.

One of the greatest modern reforms in scientific study is undoubtedly that which makes it more and more objective, so that the student shall constantly confirm the knowledge he gets from the book by reference, as far as possible, to the objects themselves, making his acquaintance with them direct, and his information real. The various sciences lend themselves to this mode of study in different degrees; chemistry and physics favoring experiment, and botany offering systematic observation more than any other scientific subjects. Physiology is less favorable to the objective method. For the purpose of ordinary education, it must be chiefly taught from the book, with such accompaniments of lectures and illustrations by charts as the circumstances will allow. But even here much may be done to give the pupil more correct ideas of the elements of the subject than can be obtained from the book alone. A good manikin is an invaluable help to the popular study of anatomy and physiology. Human dissection being out of the question, the manikin, which can be taken to pieces so as to show all the organs in their situations, connections, and relative dimensions, will afford the pupil a vivid and exact conception of the dependent parts of the living body, and make his physiological knowledge truthful and actual. A manikin for school purposes costs about $250, and may be imported from Paris,* where they are made, free of duty for educational institutions.

A great deal is also to be learned from such rough dissections of organic tissue and structures as may be made anywhere. Every butcher's shop is full of specimens of all parts of animals, that can be cheaply obtained for examination, and parents and teachers should encourage pupils to make such rude dissections as are practicable, and will help to give correct ideas of the relations and functions of the different organs.

The study of the minuter parts of organized beings with the microscope, histology as it is called, has come into great prominence in modern times, and may be said to have revolutionized the science of life. No class in physiology should be without a microscope for the direct study of cell-structures and the finer tissues of both plants and animals. A suitable instrument, with a magnifying power of three hundred and fifty diameters, will show the circulation in the web of a frog's foot, and open a new world of fascinating and wonderful observation,

* Auzoux is the principal manufacturer of these models.

while it may be bought for sixteen dollars. Microscopic preparations of blood-corpuscles, muscular and nervous tissues, and sections of organs may be got for about twenty cents apiece, but it is desirable that the pupil should not rely upon these, but should learn the method of preparing and mounting objects himself. The microscope is not to be recommended as a mere toy to amuse idle curiosity; there is work connected with it which is in a high degree educational. It cultivates critical observation and careful manipulation, and is invaluable as a means of self-education. The little hand-book of Phin * will be found useful in guiding beginners with this instrument.

The illustrations are largely copied from Gray's "Anatomy," though I am also indebted to Dalton's "Physiology," to Flint's "Physiology," to Ranney's "Applied Anatomy of the Nervous System," to Rüdinger's "Topographisch-Chirurgische Anatomie," and to Neumann's "Hand-Book of Skin Diseases." Many of the figures I have altered to suit my purpose, and the necessary descriptions are so inscribed upon or near them as to do away with the inconvenience of lettered references. A few of the cuts are original.

For the use of material other than the illustrations, I have to acknowledge my indebtedness to Flint, Beaumont, Stricker, Neumann, Rüdinger, Paget, Maudsley, Reynolds, Aitken, Huxley, Soelberg Wells, Uhle and Wagner, Foster, and especially to Dalton.

R. S. T.

March 1, 1884.

* "A Book for Beginners with the Microscope," 30 cents.

GENERAL ANALYSIS.

Part I.—Introduction.

Gives certain necessary definitions, and describes the cell and its properties as being the real basis of all more fully developed living organisms.

Part II.—Organs of Motion.

A large body entirely composed of cells would be a soft, jelly-like mass, incapable of locomotion or of self-protection. But to obtain food it must be able to move from place to place, and also to move its different parts with reference to one another. For these purposes there must be points of resistance and points of support. These points are furnished by the bones, which act as levers, the joints being the fulcra.

But levers alone are of no use. The bones form a strong framework for the body, but they can not move themselves. To produce motion, organs are required, which can become longer or shorter, under varying circumstances. Such organs are the muscles.

Part III.—Organs of Repair.

Energy is never lost or created. If the body loses energy in one way, it must gain it in another, or it will soon be worn out. Every muscular contraction wastes a certain amount of material, and an equal amount must be again supplied. This is done in the form of food.

But food, as it exists outside of the body, can not be appropriated by the wasting tissues. It must first be prepared. The process of preparation is called digestion.

After the food has been so far prepared, it must in some way be carried through the body to all its different parts, that each may take what it requires for its sustenance. This is accomplished by means of a fluid which passes continually and rapidly through all parts of the body, carrying the nutritious material. This fluid is the blood.

But the blood, besides carrying nutriment, must also remove the waste and used-up matters, which injure the health if they remain in the body. There is also a gas, called oxygen, which is found to be necessary to the processes of nutrition. This gas exists in the air, and is taken from the air into the blood. The process, by which the blood gets rid of impurities and takes in oxygen, is called respiration.

The blood can not visit the different parts of the body of its own accord. It is a fluid, and must be propelled. There are organs for this purpose, which keep up what is called the circulation of the blood.

PART IV.—ORGANS OF CO-ORDINATION.

The motions of the body, the continual waste and supply, and the processes of digestion and circulation, form a very complicated series of phenomena. Certain parts of the body require more blood at certain times than at others. Processes taking place at the same time in different parts of the body might conflict and interfere with each other. We find, therefore, a system of organs whose function it is to harmonize or co-ordinate all these processes, to produce a sympathy between them, and make them all work together for the common interest. This is the nervous system.

PART V.—ORGANS OF PROTECTION.

All the organs previously described form a very delicate structure, which is continually exposed to external injurious influences. It is exposed to heat and cold, to blows and scratches, and all manner of violence, and so we find it enwrapped in a strong covering, which protects it from these influences, partly by its own strength and toughness, and partly by certain organs which are imbedded in it, and form a part of it. This organ is the skin, with the various glands and other structures found therein.

PART VI.—ORGANS OF PERCEPTION.

The body being now complete, so far as its movements, nutrition, co-ordination of parts, and protection are concerned, we see that, as its food must come from outside, there must be organs to bring it into relation with the external world, to aid it in its search for food, and to protect it during the search. These organs are the organs of the senses, which bring us into relation with what is outside of us, and in this way are the sources of our ideas. The elementary one of these senses is touch, the others being only modifications of it.

The body being now practically complete, we find still another organ, whose function it is to enable us to communicate our ideas to others. This organ is the larynx, the organ of speech, that wonderful faculty which has had so much to do with creating the tremendous gap that exists between man and the lower animals.

PART I.

INTRODUCTION.

CHAPTER I.

DEFINITIONS.

1. **Definitions.**—The science which tells us about the different parts of the body, what they are, where they are, and how they look, is called *anatomy*.

The science which tells us about the purpose of these parts, what they do and how they do it, is called *physiology*.

The science which tells us what will interfere with the working of these parts, what will injure and what will help them, and how to avoid what is hurtful, is called *hygiene*.

A part of the body, which is so small that when it has been separated from other parts it can not be further subdivided without the destruction of its organization, is called an *anatomical element*, as a cell or a fiber.

Two or more anatomical elements, united or interwoven so as to form one substance, make what is called *tissue;* e. g., fatty tissue, connective tissue, etc.

A part of the body, which is made up of anatomical elements and tissues, together forming one whole, which can be separated from the rest of the body as an entire mass, and which performs a particular function, is called an *organ;* as, the liver, the heart, a bone, or a muscle.

A number of organs, similar in structure, but differing in size and shape, and spread throughout the body, are called a *system;* as, the nervous system, the arterial system, etc.

Several organs, which differ in structure but are so connected as to work together for a particular end, are called an *apparatus;* thus, the stomach, liver, etc., constitute together the digestive apparatus.

The work that is done by a healthy organ in the body is called its *function;* e. g., the secretion of bile is a function of the liver.

CHAPTER II.

MINUTE STRUCTURE OF THE BODY.

2. Minute Structure of the Body.—The body, when its parts are examined with the microscope, is found to be made up mainly of *cells*, *fibers*, and *fluids*. The cell is considered to be the original element out of which every other element in the body is formed; fibers, fluids, etc., being derived from or generated by previously existing cells.

The different consistency of different organs is due to the varying proportions of these elements. If the fibers are in the largest proportion, the tissue or organ will be hard, tough, and elastic; if the cells form the greatest part, it will be soft, inelastic, and yielding.

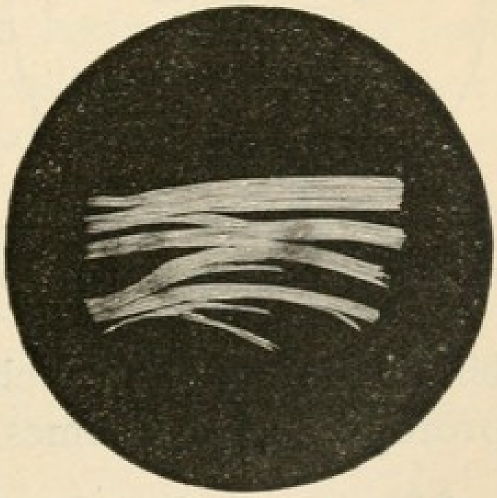

Fig. 1.—Fibrous tissue.

3. The Fiber. — The *fiber* proper (Fig. 1) is a slender thread, composed of a hard whitish or yellowish substance, sometimes elastic and sometimes not, but very tough and strong. Fibers are found in almost all parts of the body, binding the parts of organs together, and constituting almost the entire mass of some parts, as the tendons or sinews, for instance. The word "fiber" is also used of certain portions of muscular and nervous tissue, in a different sense from the one given above. These differences will be explained hereafter.

4. **The Cell.**—The cell is the most important structure in the living body, whether animal or vegetable. Life resides in the cell; and every plant or animal may really be looked upon as a mass composed of billions of cells, each of which is alive, and each of which has its own part to play in the nourishment of itself and the rest of the body.

A single cell* (Figs. 2 and 3) is a portion of al-

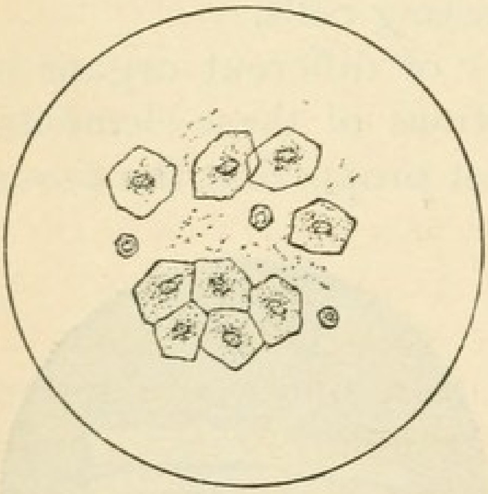

FIG. 2.—Epithelium from the mouth.

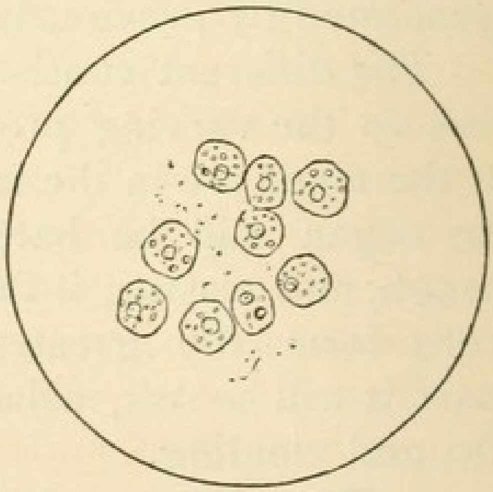

FIG. 3.—Liver-cells.

buminous matter, which has by some been called protoplasm,† sometimes surrounded by a thin mem-

* Scrape gently the surface of the tongue, and put the fluid thus obtained under the microscope. Plenty of cells will then be seen, similar in appearance to those shown in Fig. 2.

† *Prō'toplasm*, from two Greek words, signifying the first (or primitive) formed matter, because, so far as we know at present, it is the

brane and sometimes not, and usually having in its interior what looks like a smaller cell. This small body is called the *nu'cleus* of the larger one. Inside of the nucleus is often found another exceedingly minute body, or sometimes a mere shining point, called the *nucle'olus* (see Fig. 52).

5. **Protoplasm.** — The protoplasm, or matter which forms the mass of a cell, is of a semi-fluid consistency, somewhat like jelly, and can not be distinguished by chemical tests from albumen. Hence it is said to be albuminous in its nature, resembling to some extent the white of a raw egg, which is almost pure albumen. All cells are so exceedingly small, being rarely more than $\frac{1}{1000}$ of an inch in diameter, that we really know very little of their minute structure, on account of the difficulty of investigating them with such imperfect instruments as we have.

6. **Granular Matter.**—The points just mentioned are the most characteristic of the cell. Besides the cells, fibers, and fluids, there is a great deal of matter in different parts of the body, which has been formed or deposited by the cells at different periods of their growth. This matter, under the microscope, sometimes appears granular, or as if made up of very minute specks, and sometimes almost transparent. Some of it is found to be fat in a finely-divided state, but some of it is albuminous, and some of it contains mineral matter in considerable amount.

7. **Difference between Living and Dead Cells.**— A living and a dead cell look precisely alike, except-

simplest form of living matter, and makes up the only part of all animal and vegetable bodies which shows signs of life.

ing that the dead one is motionless. A living cell, minute as it is, frequently possesses the power of independent motion, or at least is able to change its form (Fig. 4). It also can take up nourishment into its mass, and can propagate itself. The movements of the cell can be beautifully seen in the white cells of the blood, which will be described hereafter.

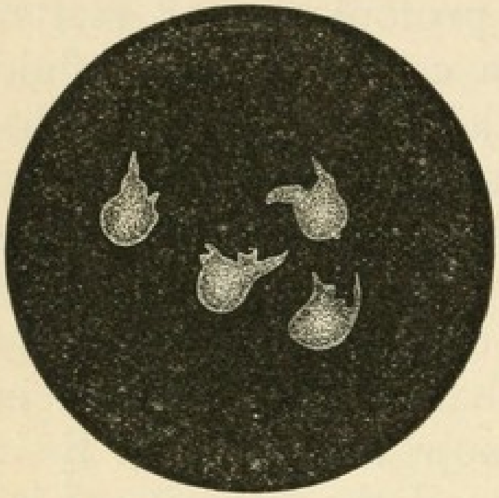

FIG. 4.—White cells in motion.

8. Growth of Cells.—A cell propagates itself in several ways; one of the most common is by dividing into two parts. This operation has been often watched under the microscope by skilled observers. The change is seen to begin in the nucleus, and, as that divides by a line through its center, the protoplasm of the cell arranges itself in halves around each part of the nucleus, its surface dipping in toward the center, until finally the approaching surfaces meet and the

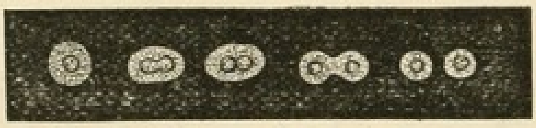

FIG. 5.—Cell dividing and forming two new cells.

cell is divided into two new cells, each with its nucleus, and in every way complete (Fig. 5). This division goes on with great rapidity. The secretion from the throat and nose in nasal catarrh is composed mainly of cells, which are thrown off by millions during an inflammation.

9. Other Properties of Cells.—Cells also possess other powers which enable them to perform their important offices in the body. They are able to select certain substances out of a general mixture, and reject others. This is done by the liver-cells, for example, which secrete the bile, and by the cells of those glands which secrete the saliva. The cells of the brain act, in some unexplained way, as the instruments of thought. The cells in the kidneys separate matters from the blood which are very poisonous, and have to be expelled from the system.

The power of division and of numerical increase of cells is not unlimited. If a portion of the body is wounded, it is healed again by the active efforts of the uninjured cells in the borders of the wound. The action of these cells ceases, however (if the part is healthy), to reproduce substance, when the part made vacant by the injury has been filled up. Why does this action of the cells, once started, not continue until the body dies? Why does the replacement of tissue cease as soon as the former surface is reached? This question can not at present be answered.*

Thus we see that the cell, minute as it is and simple as it is, performs its office in the body with

* When the cells in the borders of a wound or sore are not in a healthy condition, they sometimes increase in number very rapidly, but the new cells, instead of being like the older ones, are larger, chiefly owing to the greater amount of fluid in their interior. This makes them soft and spongy, and seems to interfere with their functions. They do not nourish themselves properly, and they increase and grow beyond the limit where they should stop, and where, if they were healthy, they would stop. This unhealthy growth is what is known as *proud flesh*, and it has to be repressed by proper surgical treatment.

care and evidence of forethought and intention. It does what is necessary and no more. It does not act blindly. It does all it does with a purpose. Where and what is the intelligence that directs the active living cell to repair so far and no farther, to eat this and reject that, to multiply up to a certain point and then stop, and, most wonderful of all, to take upon itself the duties of other cells when they are sick and unable to act,* and stop performing these extra duties, when the other cells recover?

* When the kidneys, for instance, are diseased, so that the excretion of urine is interfered with, it is found that some of the poisonous matters which usually pass out through them are ejected from the body through the lungs and skin. In such cases, physicians try to assist this process by inducing active perspiration, so as to relieve the kidneys from work as much as possible, and allow them to rest until they get well.

PART II.

ORGANS OF MOTION.

CHAPTER I.

BONES.—GENERAL STRUCTURE.

10. **Uses of the Bones.**—If the body were composed merely of cells, such as have been described, with fibers and fluids, it would be a shapeless, jelly-like mass, incapable of locomotion, and of self-protection. There is a necessity, in such a large mass, of points of support and resistance, and the organs or tissues which furnish such points must be tough, hard, and elastic. Such organs are the bones, which form the framework of the body and determine its shape and size. Their most important offices are two in number, viz., to act as levers and points of support and action for the muscular parts, and to protect the soft and delicate organs from external injury.

11. **Living and Dead Bone.** — A bone, as we usually see it outside the body, is as different from a living bone as the skin of a corpse is from the living skin. We usually see it deprived of blood, while in the living body it is full of it, and is of a pinkish-white color externally, and deep red within.

12. **Composition of Bone.**—To accomplish the

two purposes above mentioned, bones must be hard and tough, in order to maintain their stiffness when the muscles pull upon them, and also to be able to resist external blows. They must also be in some degree elastic, or they would be too brittle for use, and would snap in two under great pressure. Accordingly, we find all bones composed of two kinds of material, so thoroughly mingled and united that, when either kind is removed, the bone still retains its peculiar shape and size, although of course it does not weigh as much as before. About two thirds of the weight of every bone in the adult consists of earthy substances, mostly lime phosphate and lime carbonate, and the remaining third of animal matter, part of which can be separated from the rest of the bone by long boiling, and is known as gelatine.

If a bone be burned in a hot fire, all of the animal matter will be destroyed, and the earthy matters left. These will still retain the shape of the bone, but will be white in color, and will easily break and crumble in the fingers. If a bone, on the other hand, be soaked for a time in dilute hydrochloric acid, all the earthy matter will be dissolved out, and the animal portion left. This, as in the other case, will retain the shape of the bone, but will be flexible and tough, and may even be tied in a knot.

By the combination of these two kinds of matter, then, the bone is made hard, tough, and elastic, and admirably adapted to its uses in the body.

13. The Composition of Bone varies with Age.—In infants and children, the amount of animal matter in the bones is proportionately greater than in the adult, and so the bones of very young people will often bend when injured, instead of breaking. Surgeons call this the "green-stick" fracture, because the bone is bent like a green twig, only a small portion of it on the outside of the bend being broken or torn apart. As a person grows older, the amount of earthy matter increases, until in old people the bones become very brittle, and break with very slight blows.

14. Varieties of Bone and their Structure.—Bones are divided, according to their shape, into *long* bones, *short* bones, *flat* bones, and a fourth kind, called *irregular*, which combine qualities belonging to the other classes. The *long* bones are found only in the limbs, and are the most important to the surgeon, as it is in them that most fractures and other injuries occur. They are divided into a *shaft* and *extremities*. The *shaft* of every long bone consists of hard, compact, closely-grained tissue, somewhat like ivory. This is the only part used in the manufacture of ornaments, buttons, knife-handles, etc. The *extremities* of these bones form the *joints*, and, in order to give greater security and a greater purchase to the muscles as well as a greater surface for their attachment, the ends are much larger than the shaft. The tissue of which they are composed is also not so hard and close in texture, as, if it were so, the bone would be too heavy. There is no finer example of economy of material and the combination of strength with lightness than the structure of the long bones (Fig. 6). The ends are made of fine threads of bone interlaced and crossing and supporting each other, so as to make a sort of *spongy* tissue, full of little cavities, and yet very strong and tough. And even the shaft of the bone is not solid, but, as every one knows, is hollow in the middle. This hollow space and the little cavities of the ends of the bone are filled with what is called *marrow*, a substance composed chiefly of blood-vessels and fat, which has important duties to perform in the growth and nourishment of the bone. The other varieties of bone are composed entirely of the *spongy* (or cancellous) tissue, with a thin layer of hard, compact tissue on the surface.

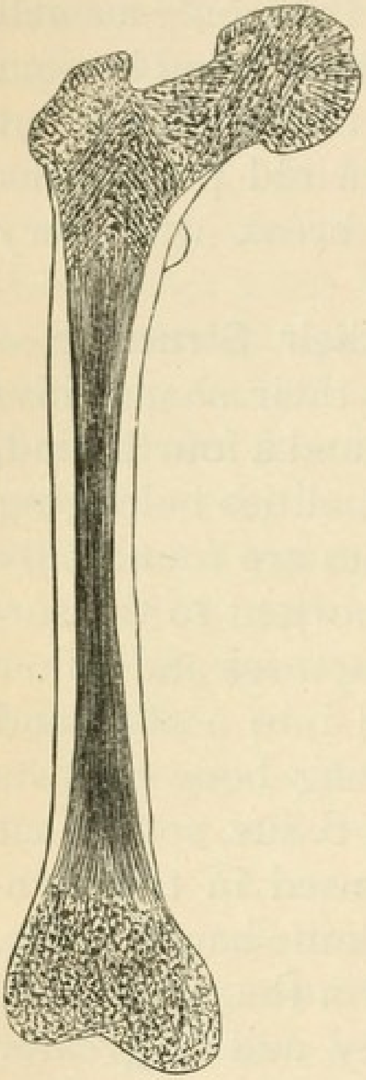

FIG. 6.—The right femur, or thigh-bone, sawn in two lengthwise. Notice the arrangement of the bony fibers at the upper end, its peculiarity being somewhat exaggerated so as to make it more plain.

15. The Periosteum and the Minute Structure of Bone.—All the bones are covered with a very tough, strong, fibrous membrane, called the *perios'teum*, excepting at the parts which enter into the formation of the joints, where they are covered with cartilage. This membrane adheres so closely to the bone as to require considerable force for its separation. It seems to form a part of the bone. Now, the periosteum and the marrow of the bones are necessary to their growth and nourishment. The blood-vessels and nerves spread and divide in these tissues before entering the actual substance of the bone. The bone itself is full of minute channels and tubes varying in size from $\frac{1}{200}$ to the $\frac{1}{20000}$ of an inch in diameter, through which the blood circulates, and the smallest of these tubes are connected at one end with exceedingly minute cavities in the bone, in each of which lies a little cell, which does the work of nourishing, repairing, and enlarging the bone (Fig. 7). Thus we see that, even in so hard and firm a tissue as bone, what has been said about cells holds true. They are the real life of the bone; they separate from the blood the necessary material and deposit it around themselves, somewhat as a crab renews his shell every year after getting rid of the old one.

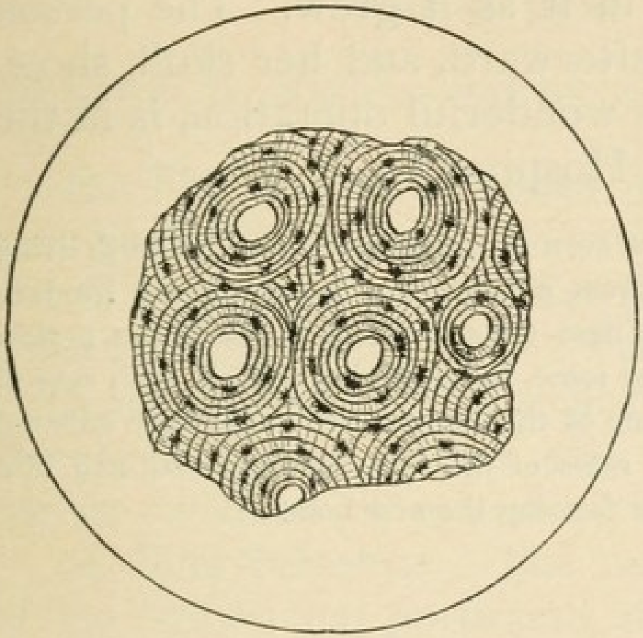

FIG. 7.—Cross-section of bone, magnified. The small black spots are the cavities in which the bone-cells live. The fine lines are canals through which the plasma (section 122) of the blood passes. The large holes are for blood-vessels.

16. Uses of the Periosteum.—It has long been known that, when the periosteum is severely bruised and separated from the bone by violence, the portion of bone deprived of the periosteum dies and has to be removed from the body. It is also found that a portion of bone, or even an entire bone, may be removed from the body, and if it be carefully done, so as to leave the periosteum in its place, the bone will grow again. A remarkable example of this was a case operated upon by the late Dr. James R. Wood, of New York. In a young woman, whose lower jawbone had become dead and caused her great suffering, this distinguished surgeon removed the whole jaw, leaving the periosteum and even the teeth, held in their places by an apparatus made for the purpose. The entire bone grew again, and the teeth became fixed in it as it grew. The person died several years afterward, and her skull, showing the result of this wonderful operation, is in the museum at Bellevue Hospital.*

* Other experiments have even shown that, if a piece of fresh living periosteum be transplanted from a bone to a muscle, it will produce bone in its new situation. These remarkable qualities of the periosteum have been explained by some, by supposing that, in each case of operation or experiment, some of the minute bone-cells have adhered to the periosteum when the mass of the bone was removed, and that they were the chief agents in forming the new bone.

CHAPTER II.

NUMBER OF BONES.—PARTICULAR BONES.—JOINTS.

17. **The number of bones** in the human body is two hundred (Fig. 8). At one period of life they are all cartilaginous, but the cartilage gradually becomes changed into bone. This process of change, *ossification*, as it is called, is not complete before the twenty-fifth year of life, and therefore no person can be called really grown up until that time.

18. **The Vertebræ.**—The foundation, so to speak, of the body—that portion of the skeleton to which the remainder is attached, and from which it is built up—is the *spine*, or backbone (Fig. 9). This is composed of many small bones, all of the same general pattern, called *ver'tebræ*. The principal part of the *vertebra* (Fig. 10), called the *body*, is shaped very much like a wooden pill-box slightly hollowed out on the top and bottom. The bodies of the vertebræ form the front of the spinal column. From the rear of each of these bodies are offshoots of bone, which unite in such a way as to leave a hole about half an inch in diameter running up and down. These vertebræ are placed one above another, with elastic *pads of cartilage* between their bodies. These pads are so thick that, taken all together, they make up about one fourth of the whole

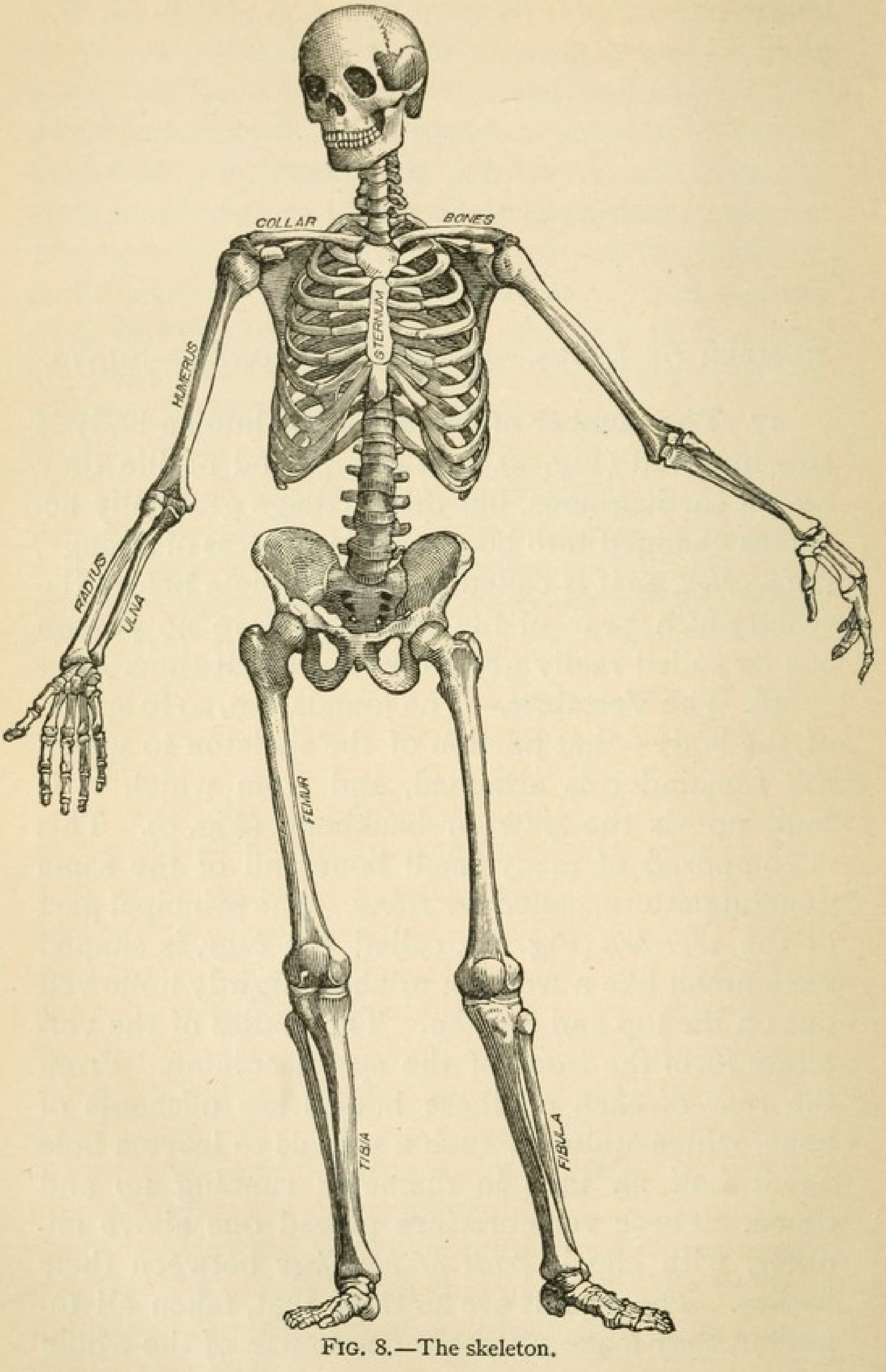

FIG. 8.—The skeleton.

length of the backbone. The vertebræ being applied to each other in this way, it is evident that the holes just mentioned, which are surrounded by bone, will form a continuous canal (the spinal canal) running from the skull down the back. This canal contains the *spinal cord*, which, next to the brain, is the most important part of the nervous system. At the sides of the spine, throughout its whole length, are holes, out of which pass nerves supplying the muscles and other organs of the body, and into which pass the blood-vessels that nourish the spinal cord.

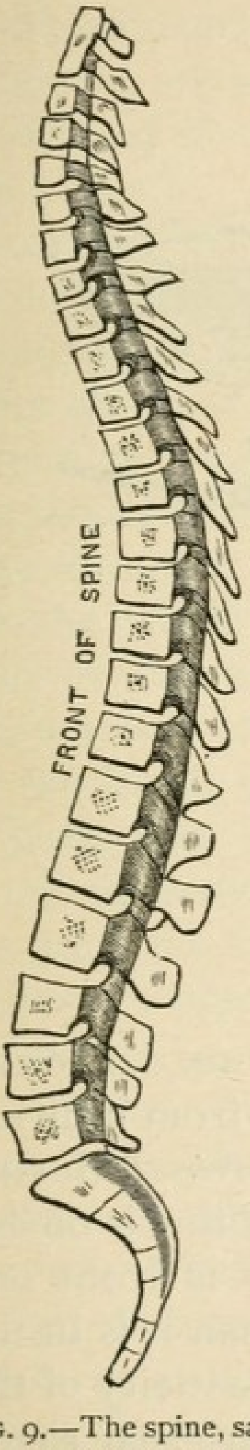

FIG. 9.—The spine, sawn in two lengthwise, showing the spinal canal and the holes between the vertebræ, where nerves and blood-vessels pass out.

19. The Spine. — The backbone, being composed of so many pieces, is very movable. The power of motion varies, however, in different parts. It is greatest in the neck, and least in that portion of the back to which the ribs are attached. In the human being, the neck is not so flexible as in many animals. Birds, in particular, can look directly backward.

Notwithstanding the great power of motion in the spine, the different bones are very strongly united and protected by powerful ligaments and muscles, which render it difficult for a vertebra to slip out of place, and such an accident is one of the rarest which a surgeon is ever called upon to treat.

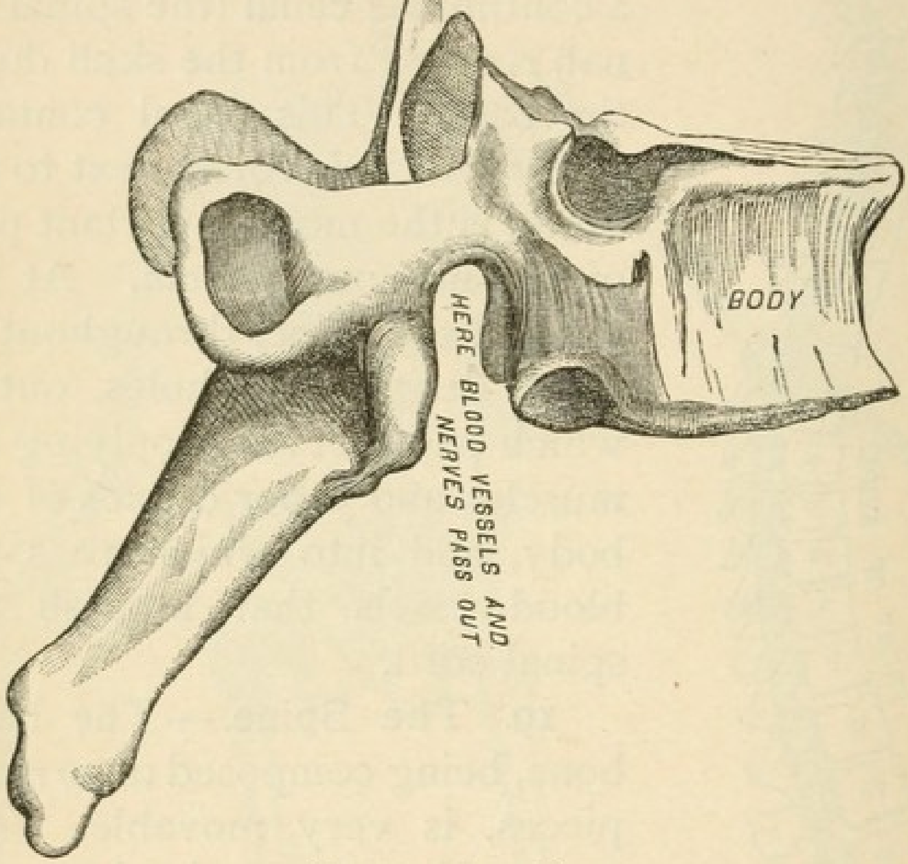

FIG. 10.—A vertebra.

The elastic pads between the vertebræ deaden all shocks of the body and prevent them from injuring the brain. These pads become compressed during the day, especially when a person is much on his feet, so that at night-time the body is from one quarter to one half an inch shorter than it is in the morning. During sleep or rest the elasticity of the pads causes them to resume their original shape and thickness.

20. The Skull.—The *skull* is the only portion of the skeleton whose principal office is the protection of soft parts within it. Accordingly, we find that its bones are differently composed and differently put together from the other bones in the body. Those forming the outside of the skull, immediately surrounding the brain, and most exposed to blows, are composed of three layers. The outside layer is the thickest, and is tough and somewhat elastic. The innermost layer is very thin, but hard and brittle, so that it is called the *vit'reous* (glassy) table of the skull. Between these layers is spongy tissue, like what has been before described. This deadens every blow upon the head, and the safety of the brain is still further provided for by the arched shape of the skull, which tends to diffuse the force of a blow. The protection afforded by the shape and structure of the outside portion of the skull is very great, and it is a well-known fact in surgery that a blow upon the top of the head, without breaking the bone on which it falls, may break the bones at the base of the skull, immediately opposite the spot of the blow, by the mere force of the shock, although the latter bones are much thicker and more massive than the others.

There is only one movable bone in the skull and that is the *lower jaw*. If the upper jaw be made to move in eating or speaking, it is only by moving the whole head where it joins the neck.

21. Sutures of the Skull.—The bones of the skull are joined together by what are called *sutures* —i. e., their edges are jagged and irregular, and fit together like dovetailed boards (Fig. 11). This renders the arch of the skull more compact, and, as far as resistance to pressure is concerned, the bones might be considered as one piece, while the interruptions at the sutures tend to deaden the shock of a blow.

22. The Frontal Sinuses.—In the front of the skull there are two cavities in the substance of the bone itself. These are situated just above the eye-brows, and are called the *frontal si′nuses* (Fig. 12). The layer of bone which forms their front wall causes the prominences just over the eyebrows, and, as the cavities increase in size with age, this portion of the forehead becomes more prominent. The cavities are lined with mucous membrane, and are connected with the inside of the nose by a canal or small passage, so that, when a person has a severe cold in the head, the inflammation sometimes runs up this passage into the frontal sinuses. When this is the case, the person has a dull, stuffy headache in that locality, due to the swelling of the mucous membrane.

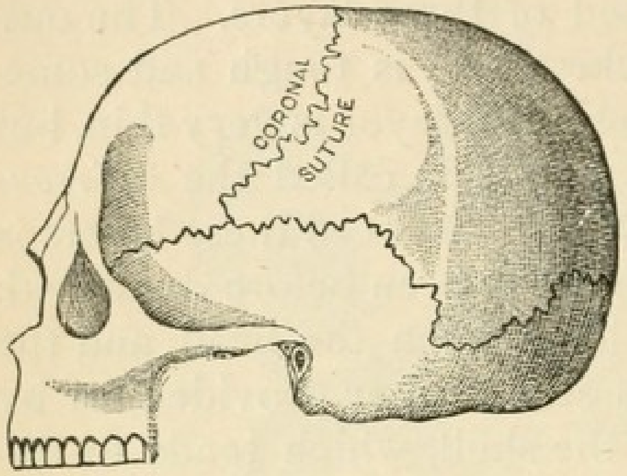

FIG. 11.—General outlines of the skull, showing the sutures.

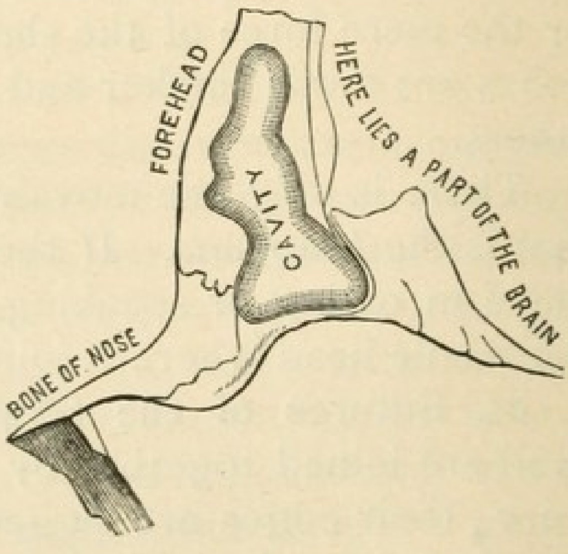

FIG. 12.—Frontal sinus.

23. The Ribs.—The bony part of the walls of the chest is made up of *twenty-four ribs* and the *breast-bone*, together with part of the spine behind. There are twelve ribs on each side, the first, nearest the neck, being usually the shortest. They increase in length from the first to the seventh, and then diminish, so that the twelfth is also quite short. They are flat and narrow, and are attached at one end to the spine, in such a manner that they move easily up and down, while the other end is attached to the breastbone, or sternum, by means of a piece of cartilage, varying in length with the length of the rib. The eleventh and twelfth ribs are not attached to anything at their forward end, and hence are called floating ribs.

The ribs are attached to the spine in such a way that all of them move together up and down. In front, the stiff but elastic cartilage allows motion in every direction. Now the shape of the ribs is so peculiar, being a sort of double curve, that when they are raised at the sides, the ends which join the breastbone are pushed forward, and of course carry the breastbone with them. So it is evident that at every inspiration the diameter of the chest increases from front to rear as well as from side to side.

24. Natural Shape of the Chest.—In young people the *cartilages* are soft, but they grow harder as age advances, and become partially turned into bone. In youth they yield to pressure to such an extent that by tight lacing the shape of the chest is sometimes made exactly the reverse of what it ought to be (Fig. 13). The ribs naturally form a cone, with the smaller end uppermost, but it is not uncommon to see the smaller end at the waist. Nature will endure a great deal of meddling, but it is not always safe to trifle with her, and all persons who carry tight lacing too far will inevitably suffer.

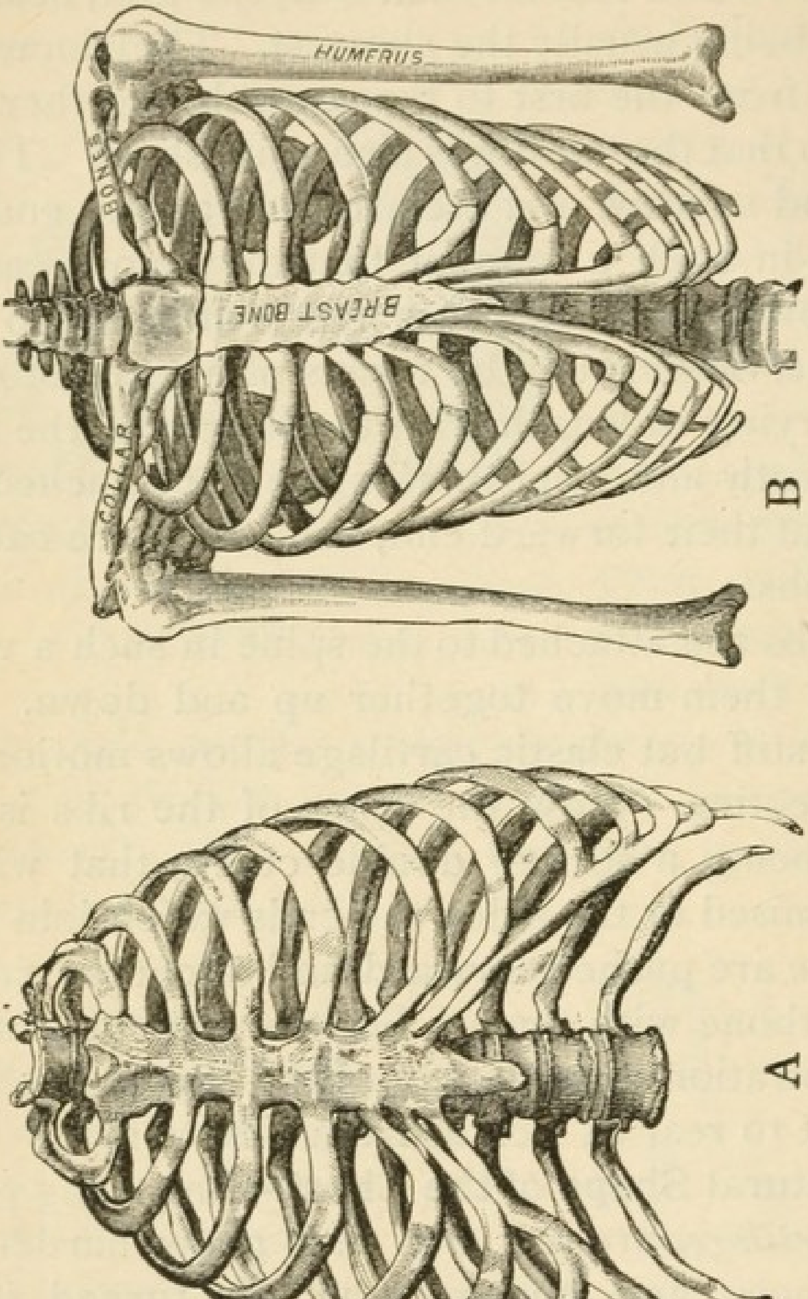

FIG. 13.—A represents the normal appearance of the ribs. B represents part of a photograph of the skeleton of a young woman of twenty-three years, showing the distortion of the ribs produced by tight lacing in an actual case.

25. The Limbs.—More than one half of the bones in the body are found in the *limbs*. Out of two hundred bones, they contain one hundred and twenty-six, and these are so constructed and so arranged as to afford a great variety of movement. The upper and lower limbs are what is called *homol'ogous* in their parts—i. e., each bone in the arm has its counterpart in the leg, with only slight apparent exceptions. Thus, the shoulder-blade corresponds to the body of the hip-bone, the collar-bone to the front of the hip, the arms to the thigh, the two bones of the fore-arm to the two of the leg, the wrist to the ankle, and the hand and fingers to the foot and toes. The similarity and correspondence of these parts are quite clear in the skeleton.

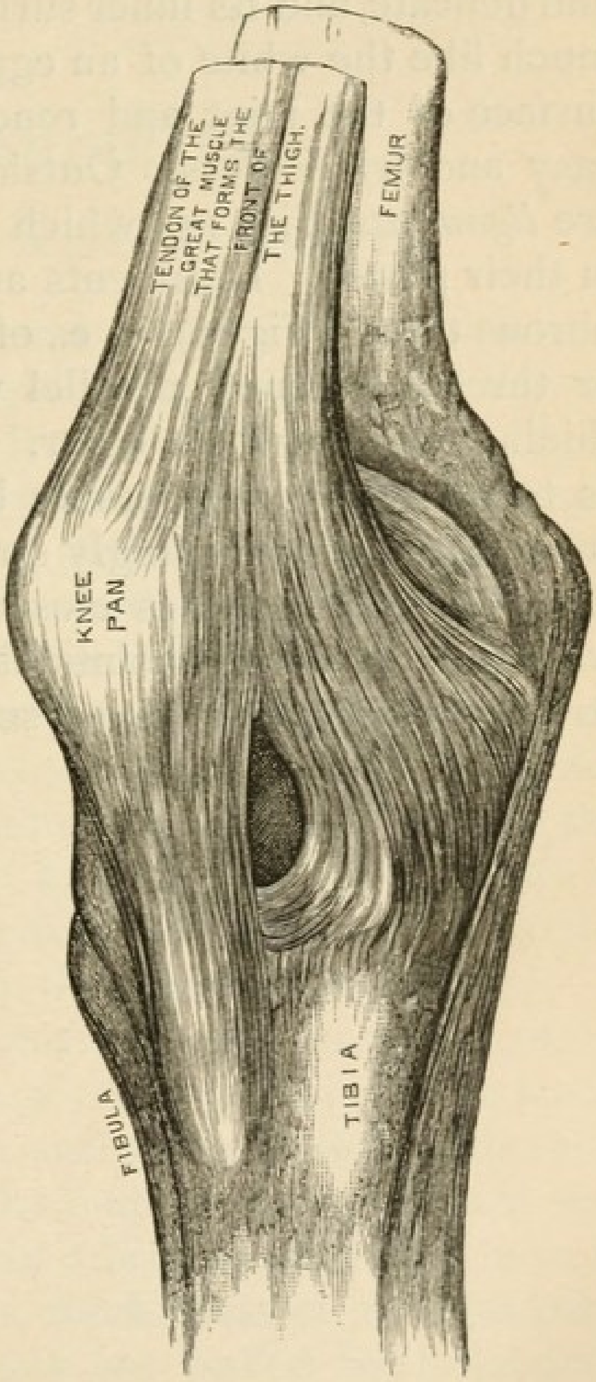

FIG. 14.—The right knee-joint, showing how strongly it is bound about by ligaments.

26. The Joints.—To render movements possible, the skeleton is broken up in its whole extent by numerous *joints*. The surfaces of the joint are not covered by periosteum, but by a firm, bluish-white, smooth, and very elastic substance called *cartilage*. The two cartilage-covered surfaces in every joint are in contact with each other. The joint is closed entirely by the *syno'vial membrane*, which passes over from one bone to the other, all round the outside. This membrane is exceedingly smooth and delicate, and its inner surface exudes a fluid very much like the white of an egg, which moistens the surface of the joint and renders every movement easy and frictionless. Outside of these structures are *ligaments* (Fig. 14), which hold the bones firmly in their places. Ligaments are composed of white, fibrous tissue (Fig. 1)—i. e., of tough, inelastic fibers or threads running parallel with each other, of a shining, silvery-white color. They are flexible, so as to allow of considerable lateral movement, but are tough and exceedingly strong, so that they hold the ends of the bones close together. Thus, the construction of the joints is such that they are strong, flexible, elastic, and supple.

CHAPTER III.

INJURIES OF BONES AND JOINTS.

27. Injuries in General.—The injuries to which the bones are most liable are *fractures* and *dislocations.* If the bone be fractured, the jagged ends of the broken bone irritate the parts about them, and the muscles contracting pull the broken ends out of their proper relation to each other (Fig. 15). In the dislocation, the end of the bone is out of its proper place. But the limb is movable at the point of fracture, while it is always stiff and fixed at the point of dislocation. In a fracture, also, the ends of the bone, if gently moved against each other, produce a peculiar grating feeling, which always tells the surgeon with certainty that the limb is broken.

28. Fractures.—Bones are rarely broken straight across, excepting in very young persons. The fracture is usually oblique, and so the broken ends slide past each other, and the limb is shorter than it was before the accident. In a broken thigh, the bone is surrounded by such a thick mass of muscles that, even if the broken ends are pulled by force into their proper places, it is impossible to keep them there. They will always slide past each other to a slight extent, and a person never recovers from such an accident, without having the injured limb from half an inch to an inch shorter than the sound one. This has been shown and proved by thousands of careful measurements, and should always be borne in mind when there is a temptation to blame a surgeon for fancied neglect.

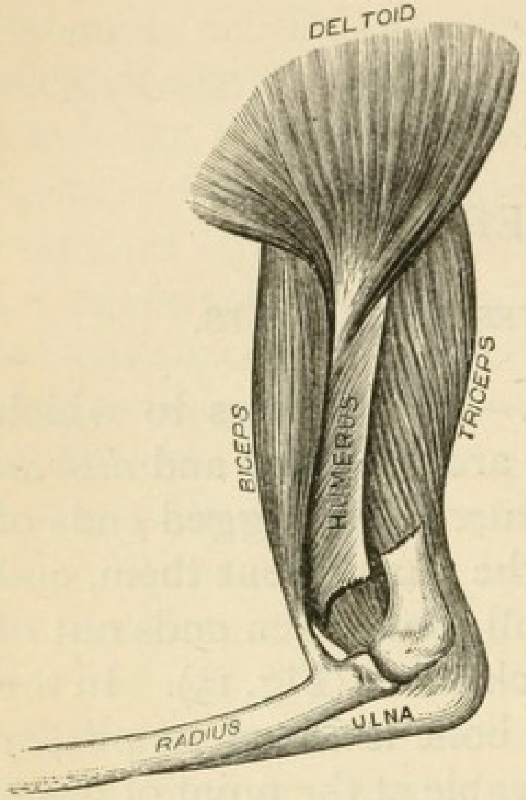

FIG. 15.—Fractured humerus, showing how the muscles pull the ends of the broken bone out of place.

When a fracture occurs near a joint it is a much more serious accident, for the inflammation which follows the injury involves the parts about the joint, and sometimes the joint itself, which may be left stiff and almost useless for a long time afterward. This is particularly the case with fractures near the wrist, for the slow recovery of which the surgeon is so often blamed.

29. Dislocations. — When a bone is dislocated there is always a certain amount of injury to the parts about the joint. The ends of the bone are so carefully and strongly guarded and fastened by ligaments and muscles, that these must necessarily be considerably torn and bruised, in order to let the bone out of its place. Thus it happens that a dislocation often gives rise to more pain and suffering immediately after the accident than a fracture.*

* Sometimes the violence resulting from a fall is not sufficient either to break or dislocate a bone, and yet the parts about a joint are so se-

The vast majority of dislocations occur in the shoulder and hip joints, and are usually caused by a blow on the end of the bone when the limb is firmly extended, as when a person is falling and tries to save himself by stretching out his hand. The lower jaw is sometimes dislocated, and then the mouth remains wide open until the dislocation is reduced, rendering the sufferer a somewhat ludicrous as well as pitiable sight. This accident has been known to occur during a prolonged yawn.

30. **Healing of Injured Bones.**—A fractured bone takes from three to six weeks, and sometimes longer, to become healed. A dislocated bone, after it is reduced, requires to be kept quiet until all pain and swelling have subsided. In either case, there always remains more or less stiffness, which sometimes does not disappear for months after the accident.

31. **Care of Injured Persons.**—It frequently happens that a bone is broken when the person is at a distance from his home, or from any place where he can be attended by a surgeon. In fractures of the lower limbs, he must be carried often for a long distance, and every one should know how to make him comfortable during transit. It must be remembered that the only object of any person who is not a surgeon, should be to keep the broken limb in such a position that there will be no motion of the fractured ends, so that the patient may suffer as little as possible, and the surgeon may find him as nearly as may be in the condition in which the in-

verely strained that some of the ligaments are torn apart. Very often only a few fibers are ruptured, but such injuries always cause great suffering, and recovery is very slow. This form of injury is called a *sprain*, and is most likely to occur in the wrist, ankle, or knee.

jury left him.* Therefore, he should be carried on a litter, the broken limb being packed about with soft materials in such a way as to keep it from rolling or jarring. The weight of the foot will often make the lower part of the leg swing from side to side, and in the case of a fractured thigh, the leg should be protected on each side from the hip down. Dislocations require the same care, excepting that a splint is not necessary.

* It is a very good plan to bind the lower limbs together in such a case, above and below the injured part, so that the sound leg may serve as a splint to the broken one. A broken arm may be bound to an improvised splint (a cane, a stick of wood, a shingle), a folded handkerchief or other padding being used to fill up the hollows between the splint and the skin, and the broken limb being supported by a sling around the neck.

CHAPTER IV.

MUSCLES.

32. The Muscles.—The bony framework of the body is set in motion by a system of organs called *muscles*, which cover the skeleton almost entirely (Fig. A), and cause the different bones to move upon each other by means of their peculiar property of contractility, or the power of becoming longer or shorter under varying circumstances.

There are two kinds of muscles in the body, called *voluntary* and *involuntary*, which differ very much in their structure and functions. The voluntary muscles, as the name implies, are under the control of the will; while the involuntary muscles are not only beyond our control, but act as a rule without our knowledge or consciousness.

33. The Voluntary Muscles.—A *voluntary* muscle is a mass of reddish fibers, somewhat loosely joined together by connective tissue, and easily separated lengthwise.* The flesh of animals is composed of muscular tissue. Every voluntary muscle is united

* If the fibers of a piece of lean meat are carefully separated and closely scrutinized, it will be seen that they are connected with each other by a delicate tissue of fine white threads, interwoven like the fibers of a cobweb or of the most delicate lace-work. This is called *connective tissue*, and is found in almost all parts of the body, uniting the different elements that make up the various organs.

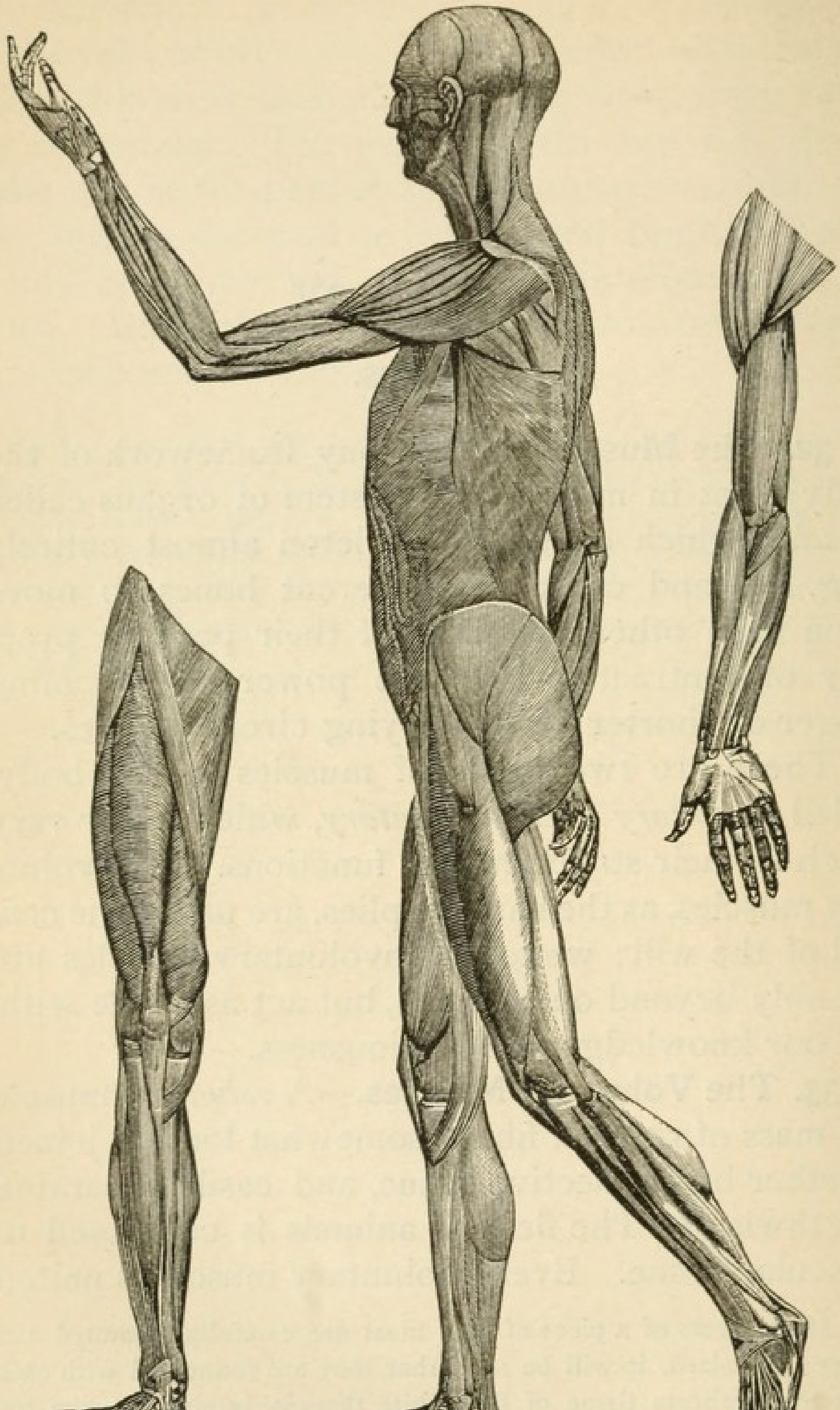

FIG. A.—The muscular system.

at each end to some fixed point in the body, and there is always a joint or point of flexure between its points of attachment. When the muscle contracts, therefore, the two ends are brought nearer together, and motion is produced in the organ or limb to which it is attached.

Every voluntary muscle can be divided into small fibers, lying side by side, and these again into fibrils still more minute. Each fibril under the microscope presents an appearance of delicate lines running at right angles to its length (Fig. 16).

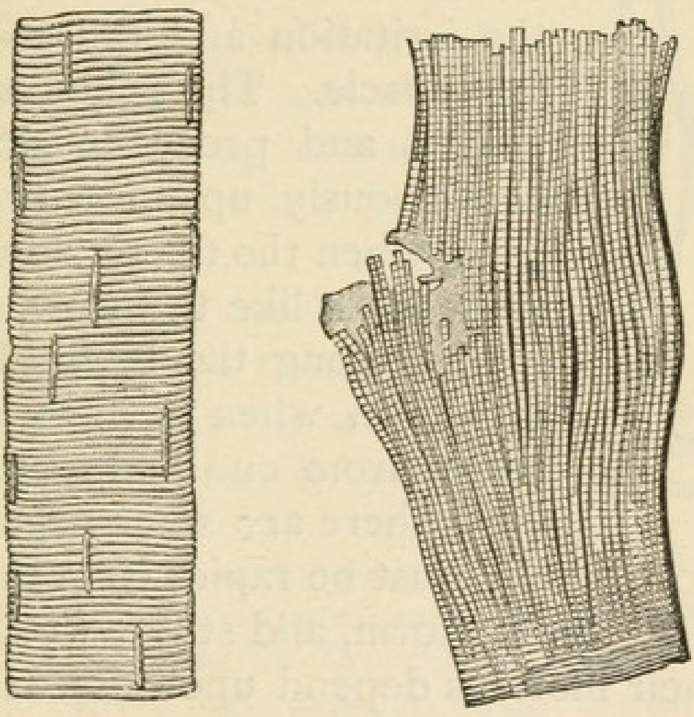

FIG. 16.—Voluntary muscular tissue.

These lines are called *striæ*, and the appearance is called *striation*.

34. **The Involuntary Muscles.**—*Involuntary* muscles are made up of flattish bands of long, narrow fibers, tapering at each end, somewhat of the shape of an oat, but more slender. Each fiber has a nucleus in its middle, and they are all connected

together lengthwise, as the voluntary muscular fibers are (Fig. 17).

35. Differences between the Voluntary and Involuntary Muscles.—The *voluntary* muscles are all composed of the striated muscular fiber which allows of very rapid contraction, while the involuntary muscular fibers contract in a very peculiar manner. They do not begin to contract immediately, as soon as they are stimulated, but there is a short interval between the irritation and the response of the muscle. Then the contraction begins, and proceeds slowly and continuously up to a certain degree, when the fibers slowly relax, very much like the slow, crawling motion along the body of a worm or snake, when a wave seems to travel from one end to the other. Now there are some organs in the body, whose action must be rapid, from the nature of the office they perform, and still it would not do to have their motions depend upon the will. Such an organ is the heart. It must contract often and quickly in order to supply sufficient blood to the body, and yet, if its action depended upon our will, it would require all of our attention, to the exclusion of everything else. Accordingly, we find it composed of muscular fibers that are intermediate in structure between the voluntary and involuntary kinds. The involuntary muscular fiber is found, among other places, in the stomach and intestines,

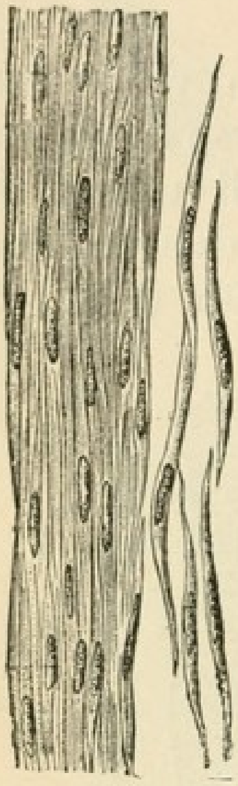

FIG. 17.—Involuntary muscular tissue.

in the iris of the eye, and in the walls of the arteries.

36. Difference in Size of Muscles.—The largest muscle of the back, the *latissimus dorsi*, weighs several pounds; and one of the muscles of the leg, the *sartorius*, is two feet long; while the *stapedius*, one of the little muscles inside the ear, is only the sixth of an inch long, and weighs about a grain.* Between these extremes are many variations in size and shape.

37. The Tendons.—Muscles are connected with the bones by means of tendons. A *tendon* is made up of fibrous tissue, and is a white, glistening cord, of exceeding strength and toughness. At the ends, they gradually change their appearance, becoming muscle at one extremity and bone or periosteum at the other. There is no sharp line, where the muscle or bone can be distinguished from the tendon. Wherever the tendons would be likely to rise and form a line like the string of a bow during the contraction of a muscle, as at the wrist and the

* *Latis'simus dorsi*—i. e., the *broadest of the back*. This muscle is attached to the spine in the lumbar region and also to the lower ribs. The fibers come together so that the muscle has a triangular shape, and its small end is attached to the humerus. It is the chief muscle that comes in play when the body is raised from the ground by means of the arms.

The *sarto'rius* means the *tailor's muscle*. It is a long, ribbon-like muscle, which begins on the outside of the hip-bone and ends on the inside of the knee, crossing the thigh on the inner side. When it contracts, it raises the lower part of the leg, and turns it inward, thus crossing the legs, tailor-fashion—hence its name. It comes in play when one foot is placed on the opposite knee.

Stape'dius means the *stirrup-muscle*, so-called because it is attached to a small bone in the ear, which is shaped like a stirrup, and hence called *sta'pes* (Latin for stirrup).

ankle, for example, they are bound down by stout ligaments, through or under which they slide to and fro, the channels in which they move being lined with synovial membrane like the joints.

38. Force of Muscular Contraction. — When a muscle contracts (whether voluntary or involuntary), it becomes not only shorter and thicker, but harder, than before, and the *force* with which it contracts is enormous. To attain the compactness which we see in the body, the muscles of the limbs, for example, have to lie parallel with the length of the limb. Besides this, many of them are attached between the fulcrum and the weight, and very near the fulcrum. The biceps, for instance, which (with the brachialis anticus) bends the forearm upon the arm, is attached at one extremity to the shoulder-blade, and at the other to the forearm, just below the elbow, where its tendon can be felt. Thus there are two disadvantages under which it acts. In the first place, its point of action is only about one eighth as far from the joint or fulcrum as the hand is, and in the second place, when it begins to contract, it acts at a very acute angle—in fact, almost parallel with the bone (Fig. 18). As the arm becomes flexed,

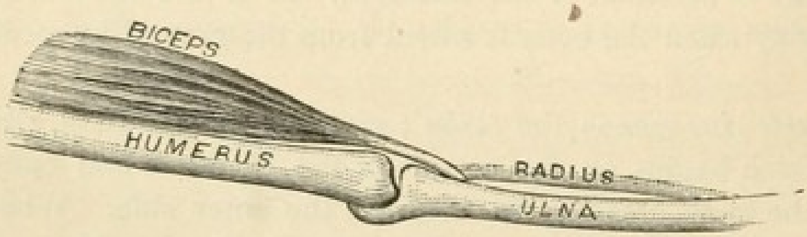

FIG. 18.—Disadvantageous action of the biceps muscle, illustrated.

the angle of action approaches more and more to a right angle, and the necessary effort becomes less and less. And yet we not only flex the arm easily enough at the elbow, but we do it with a considerable weight in the hand. It has been estimated that the muscles of the arm, in flexing it at the elbow, with a ten-pound weight in the hand, contract with a force of at least two hundred pounds. And yet this is a feat which a delicate woman or a child can perform, and the force required is not to be compared with the power of an athlete.

39. Muscular Irritability. — Muscular tissue will contract under any kind of irritation. In the living body, the stimulus always comes from the nerves, but the muscle itself has a form of *irritability*, which lasts for a considerable time after death. When an ox is killed, and has been prepared for the market, the muscles may often be seen twitching and quivering in the beef for half an hour, and the muscles of an amputated arm may also be seen to contract for some minutes merely under the irritation of the cold air. In cold-blooded animals, this irritability persists for a long time. If the heart of a frog be entirely removed from the body, it will continue to beat for several minutes, and, when it has finally ceased, it will start again on being pricked with a needle. This experiment may be repeated several times before the muscular irritability finally vanishes.*

40. The Muscular Sense.—When a muscle contracts, the degree of contraction is perceived or felt

* There are reasons for believing that the continued beating of the heart of a cold-blooded animal for hours after it has been removed from the body may be due to the presence of microscopic nervous ganglia in the substance of the muscle. This supposition, however, does not affect the usefulness of the frog's heart as an illustration of the fact that parts of animals continue to live after separation from the main body.

by the brain. For example, any one is conscious whether his thumb is bent inward toward the hand, or outward toward the wrist, entirely apart from the use of the sight. The precise manner in which this sensation is conveyed to the brain is still a subject of conjecture. Although apparently so simple, it brings up questions of great intricacy and difficulty, which can not be considered here. But this sense, whatever its manner of operation, is called the *muscular sense*. It is one of the chief means we have of determining the weight or the hardness and softness of bodies, as we judge of these qualities mainly by the resistance our muscles meet with when handling the bodies. But, more than all, the muscular sense is necessary in keeping the body upright. The size of the feet is so small, compared with the height of the body, that early in life it is a matter of extreme difficulty for us to keep our balance. To stand and walk is one of the first and one of the hardest things we have to learn. It requires a constant contraction of the muscles, now one set and now another, in order to keep from falling.

41. Use of the Muscular Sense in Standing.— Ordinarily we are assisted in standing upright by our sight. This fact, together with the muscular effort required to stand still, may both be made very evident in the following manner: if a person stands with the feet close together, he will perhaps feel a slight swaying of the body, which has to be counteracted by muscular contraction. Perhaps no such swaying will be perceptible to him. But now, still keeping the feet close together, let him shut the eyes, when the swaying of the body will become much greater than before, and the constant muscular contractions, now here, now there, will be so plainly felt as to be disagreeable. In certain diseases, this muscular sense in the legs is lost, and then the person can stand with the eyes open, but if the eyes be closed he instantly totters and falls, for he then has nothing to guide him as to his vertical position.

42. **Waste during Muscular Contraction.**—The cause of muscular contraction is an unsolved problem. There is nothing in the chemical composition or the physical structure of the muscle which would lead us to expect to see it contract when irritated, if we knew nothing more about it. All we can say is, that it depends upon the composition of the muscular substance, and we know, also, that every contraction is accompanied by a loss of or change of material. In this way, our muscles are being continually used up, and if they were not constantly supplied with fresh nourishment by the blood, they would soon wear out and die. But the minute muscular fibers (or the cells composing them) not only perform their special function of contraction, but are able to choose and take up out of the blood their own proper food and appropriate it.

43. **Muscular Overwork.**—If a muscle is hard pressed and exercised too much, so that the waste of material is greater than the supply, and it wears away faster than it is repaired, it falls into the condition which we call *fatigue*, and it is only with great effort that we can make it work. If it be still further imposed on, without opportunity to recuperate, it soon gives out entirely, and can not be made to contract with vigor under any stimulus our brain can send to it. Such extreme fatigue is dangerous, because there is always the chance that the

muscular fibers may become so completely wasted that even their power of nourishing themselves may be impaired, and the recovery of their natural condition may be very slow and imperfect, or, in rare cases, impossible.

44. **Muscular Inactivity.**—On the other hand, if a muscle is not exercised at all, its power of nourishing itself is interfered with almost as much as if it is exercised too much. It is found that unused muscles gradually waste away, growing smaller and smaller, and becoming soft and flabby, and finally, if they are not used for a very long time, it can be seen by the microscope that the muscular fibers disappear altogether, or are filled with little particles of fat, which take the place of some of the muscular substance, and so make it very weak and useless. Such inactivity of the muscles may occur in cases of paralysis, and the physician is then careful to stimulate them with electricity, in order to keep them, as nearly as possible, in a sound condition. The electrical current, in such cases, takes the place of the nervous stimulus, which naturally causes muscular contraction. The muscles of a broken limb, also, which have necessarily been idle while the bone was mending, are always very feeble for some time after the limb comes in use again.*

*Curvature of the spine, which is more frequent among girls than among boys, is often directly attributable to lack of exercise. The muscles of the back become weak, and, as some exercise of the muscles of the right side can not be avoided, so long as the girl performs any duties whatever, the difference in strength between the muscles of the right side and those of the left side becomes greater than is natural. The result of this is that the stronger muscles overpower the others and pull the spine over toward the right side, greatly distorting the figure. In left-handed persons the curvature is toward the left side.

45. Exercise.—It is necessary, therefore, that the muscles should be sufficiently exercised, and not too much. The kind of exercise is not of so much importance. No better form of exercise can be devised than the various out-door sports that boys are so fond of. It is much better that exercise should be a pleasure than a duty. For this reason, the ordinary exercises of the gymnasium do not compare in value, as health-giving ones, with rowing, skating, running, riding, wrestling, swimming, and the various out-door games.* It is really of no advantage, in our ordinary modern life, that the upper arm should, by judiciously and ingeniously planned exercise, grow to be an inch larger than it was a year before, and to the ordinary youth the duties of a gymnasium are irksome to the last degree.† There is no evidence that athletes, whose bodies are knobbed with unsightly bunches of muscle, are any healthier or any happier, or live any longer, or do any more good in the world, than the less muscular

* These remarks apply to girls as well as to boys. Out-door exercise of an agreeable kind is as necessary for the health of one as of the other. The hot-house plant is never strong, and the tom-boy grows to be the most healthy and vigorous woman, both mentally and physically.

† It is not to be understood that the gymnasium is here altogether condemned. It is of great use in its proper sphere. But the boy's idea of a gymnasium is that it is a place to get strong, rather than healthy. The surroundings and examples are such as to encourage straining for effect, lifting heavy weights in emulation, and the like acts, which may injure a boy permanently. When gymnastic exercises are performed under a competent instructor, with proper ends in view, and an intelligent use of means to those ends, the matter is altogether different. But, as mentioned in the text, gymnastic exercises, excepting for the purpose of remedying particular defects, training special muscles for a particular purpose, or treating actual disease, can not be compared in efficiency with out-door sports.

person who confines himself to simple food, who insists upon pure air, and exercises moderately and for his own pleasure in the way that suits him best.*

46. Danger of Exhaustion.—But, while muscular exercise is necessary to continued good health, it should never be carried to the point of exhaustion. This is dangerous, not only, as previously indicated, because the nutrition of the muscle may thus be interfered with, but because, when the point of simple fatigue is passed, and exhaustion supervenes, the nervous system has become implicated and is getting worn out. This danger will be better understood when that part of our bodies is described hereafter. It is enough, for the present, to remember that a person is not harmed by being tired, but that it *always harms one to be exhausted.*

47. Rest.—When a muscle is fatigued, it recovers very fast if allowed to rest. For this reason it is much less fatiguing to walk an hour than to

* The muscular strength which is developed by gymnastic training vanishes when the training ceases. It is often noticed by those who practice much in gymnasiums that constant practice is necessary to retain what increase of muscular power they have acquired. There seems to be a normal condition of the muscular system in each individual, to which he reverts when special training is abandoned. The strong men are not made so by training; they are born with a tendency to a preponderance of the muscular organs. Marvelous stories are told of men of this class. It is said of Frederick Augustus of Saxony, King of Poland (1670–1733), commonly called Augustus the Strong, that on one occasion, wishing to present a bouquet to a lady, and seeing nothing to wrap it in, he took a silver plate from the table and folded it around the stems with the greatest ease. In Dresden is exhibited a horseshoe, or the halves of it, which he is said to have broken with one hand. Similar stories are told of Baron Trenck (1711–1747); and of Milo, of Crotona, a famous athlete (520 B. C.), it is said that he once carried a live ox on his shoulders around the stadium, then killed it with a blow of his fist, and afterward ate the whole of it in a single day.

stand still an hour. In the former case the muscles constantly have short intervals of rest, while in the latter they are not able to rest at all, but are continually in a state of contraction. If we are obliged to stand for a long time, therefore, we almost instinctively change our position frequently, stand on one leg and then on the other, or find some place to lean against, in order to give the muscles the rest they need.

Out-door sports, then, are more healthful than gymnastic exercises.

Exercise may be pushed to the point of fatigue without injury, but never to the point of exhaustion.

PART III.

ORGANS OF REPAIR.

CHAPTER I.

FOOD.

48. Necessity of Food.—We all know that, as long as we are living beings, we tend constantly to lose weight. In our excretions, our breath, the perspiration, the tears, the saliva, we lose altogether several pounds a day. All of this matter is so much gone, and if it be not replaced the body dies. It can not be too clearly impressed upon the mind that this waste or loss of material is continuous and inevitable. The processes of muscular contraction, of secretion, even of thought, produce substances which are taken up by the blood to be put out of the body. These substances are, many of them, very poisonous, and if they can not be expelled from the body they kill it.* They are not the result of disease; they are the constant product of living processes in a healthy body. So we see

* Thus a substance called *urea* is excreted from the body through the kidneys. This substance is very poisonous, and, when the kidneys are diseased and are no longer able to discharge all of it from the body, it accumulates in the blood and finally causes death. So it is with the bile and with certain matters which pass away in the breath at every respiration.

that there must be a continuous expulsion of such matters, and, of course, what each part of the body has lost by such a process must be replaced with fresh material.

49. **Living without Food impossible.**—If this fact be clearly understood, it will be easy to see that the numerous stories about persons who live without eating are false. If such persons live, their hearts must beat, their brains must think, their lungs must move in breathing, and all of these things cause inevitably a waste of material. How absurd, then, to gravely talk of a person who has not taken any food or drink for six months, and still has not lost weight, but remains plump and healthy! It is just as absurd as it would be to say that such or such a person had a limb amputated day after day, and yet after each operation weighed as much as before. These cases are all cheats, for if there is waste going on, which is not made good, the body must decrease in weight. If there is no waste, there is no life, no thought, no heart-beats, no respiration, no movement of any kind. These facts of the generation of force by food and of constant loss and gain are the chief foundation-stones of all correct knowledge of physiology, and can not be too firmly fixed in the mind.

50. **Classification of Food.**—In order to supply the waste in our bodies we need a great variety of food; and, indeed, the procuring and preparing of food occupy a large portion of the lives of most people. The food we use is usually classified as *nitrogenous* and *non-nitrogenous*, or *carbonaceous*. But, besides these two great divisions, which include all our animal and vegetable food, there are some substances

which are neither animal nor vegetable, and yet are quite as necessary to our health as any other portion of what we eat. The most important of these are water and salt.

51. Water.—*Water* is present in a greater or less quantity in every part of the body, and, as it is rapidly expelled, it has to be frequently supplied. It constitutes between three fourths and two thirds of the entire weight of the body, and the amount required for an adult man daily is about three pints, in addition to that which forms a part of the solid food. The quantity used varies enormously, according to the waste. In a hot day in summer we need much more than in cold weather, and in damp days much less than on dry ones.

52. Salt.—*Salt*, also, is not only an agreeable condiment, but has important offices to perform in the body. It has been shown by experiments on animals that, if they are entirely deprived of salt, they decline very much in vigor, and every farmer knows how necessary it is to the health of his cattle and sheep.*

53. Other Inorganic Matters.—There are other

* Boussingault, a French chemist (born in 1802), reported in 1854 some experiments he had made in regard to the importance of salt to cattle. He took six bullocks, of about the same age and vigor, and fed them alike, excepting that to three of them he gave 500 grains of salt every day and to the others none. At the end of six months the hides of those that had had no salt were rough and dull in color, while those of the others were shining and smooth. At the end of a year the salt-fed bullocks were in perfect health, while the others were dull and stupid, and the hair upon their hides was rough and tangled, with bare patches here and there.

Wild animals, especially of the grazing kind, like deer and cattle, will travel long distances in search of salt, and seem to be as fond of it as children are of sugar.

inorganic matters which are essential to the growth and nutrition of the body, but which are naturally found in articles of food and are not taken separately. Such are the salts of *lime*, *soda*, *potash*, and *magnesia*, all of which form a part of our common fruits and vegetables. The most important of these is probably the *lime phosphate* which forms so great a part of the bones. The husk of grain contains a certain proportion of this salt, and in growing children, in whom the cartilaginous portions of the bones are becoming ossified, wheaten grits or Graham bread is a very welcome and advantageous article of diet. It has been affirmed that the large size of the inhabitants of Kentucky is due to the fact that they live in a limestone region, and the water they use is strongly impregnated with lime. So large a proportion of lime taken into the body, at a time when the bones are forming and growing and hardening, is said to make them longer and stronger than they would be otherwise.

54. **Non-nitrogenous Foods.** — The *non-nitrogenous*, or, as they are sometimes called, the *carbonaceous* foods, are *sugar*, *starch*, and *fat*. These substances are all composed of carbon, hydrogen, and oxygen, in varying proportions, the sugar and starch taken in our food being mostly of vegetable origin, while the fat may be either animal or vegetable.

55. **Starch.**—*Starch* forms a part of all grains and most vegetables, sago, tapioca, arrowroot, etc., being almost pure starch, which has been extracted from the plants in which it is found. Rice contains about 85 per cent of starch, wheat about 70 per cent, and the potato about 15 per cent. This latter amount seems very small, but most of the remainder

of the 100 parts of the potato consist of water, and starch really forms the bulk of the solid matter.

It is a peculiarity of starch that it is very easily converted into sugar. This is actually accomplished in the human body, during the processes of mastication and digestion, as will be shown hereafter.

56. **Sugar.**—*Sugar* is taken in our food in various forms, for it has not always the same chemical composition. It is always sweet, and is always easy to recognize as sugar, but varies in its proportions of carbon, hydrogen, and oxygen. Thus we find that cane-sugar, milk-sugar, and grape- or honey-sugar (often called glucose*), all differ from each other. Sugar is taken partly as an addition to the food for the sake of improving its flavor, and partly as a natural constituent of vegetables and particularly of fruits, some of which contain an enormous proportion of it. Figs, for example, are more than half sugar, and hardly any fruit contains less than 10 per cent.

57. **Fat.**—*Fat* is found in almost all parts of the body, and particularly just underneath the skin, where it serves to give rounded outlines to the form, and also undoubtedly acts as an elastic cushion to protect the parts beneath from injury. During life, owing to the warmth of the body, the fat is fluid and transparent; † but after death, as the body cools, it

* Glucose is now produced artificially in enormous quantities by the use of sulphuric acid and corn. When anything containing starch is boiled with this acid, the starch is converted into glucose, which is the kind of sugar found in fruits. Cane-sugar can be changed into glucose in the same way, and as a matter of fact it is changed into glucose in the act of digestion, so that glucose must be looked upon as that form of sugar that it is natural for us to take in our food.

† If the fingers be held close together in front of a bright light, the

becomes solid. The fat which is found in the body is not all taken in with the food, but a certain amount of it is formed in the body itself, in a manner which is not yet understood. Certain articles of diet tend to increase the amount of fat in the body. This is notably the case with starch and sugar. In sugar-growing countries, as the Southern States, it is a matter of common observation that the negroes grow fat and sleek during the sugar-season, and lose their superabundant flesh when the season is over. Articles of food which contain much starch also increase the amount of fat. The famous Banting system of treating corpulence is based on this fact, and consists mainly in depriving the patient of starchy vegetables, grains, and sugar.*

58. **Nitrogenous Foods.**—The *nitrogenous* portion of our food is also both animal and vegetable, but chiefly animal. The principal substances of this class are *fi'brin*, *albu'men*, and *ca'seïn*. They all contain a considerable amount of nitrogen, in addition to carbon, hydrogen, and oxygen, and are generally called by physiologists *pro'teïd* substances, or the *proteids*.

Casein is found in large proportion in milk, from which it is extracted to form cheese, and the two

rosy tinge of their borders shows that they are to a certain extent translucent. The fingers of a corpse, under similar conditions, are opaque.

* Mr. Banting, the court undertaker, was put under treatment for corpulence by Mr. William Harvey, a London surgeon. He was allowed to eat any meat except pork, any kind of fish except salmon or eels, any vegetables except potatoes or rice, any kind of poultry or game, dry toast, fresh fruit, tea without milk or sugar, and to drink claret, sherry, or madeira wine, or gin, whisky, or brandy without sugar. When he began this diet in August, 1862, he weighed two hundred and two pounds, and a year after, he had lost forty-six pounds, and reduced his girth twelve and a quarter inches.

others are found mostly in the animal fluids, and in muscular fiber.

There are also substances very much like the animal albumen and casein which are found in vegetables, but they present slight chemical differences, although they probably answer nearly the same purpose in nutrition. Peas and beans contain a considerable quantity of the vegetable casein.

59. **Necessity of Variety of Food.**—It is necessary, for the preservation of health, that our food should contain a sufficient amount of these different kinds of matter. We must have water; we must have salt and the lime compounds mentioned above; we must have starchy substances (much the same to the body as sugar) and fats,* and we must have a certain amount of nitrogenous food. If one of these be lacking, the body soon feels it, and, although the person may not know precisely why he feels bad, he will often recover from his temporary disorder by a mere change of diet. The lack of any particular ingredient in our food is often indicated to us by a longing for it. We feel a strong desire to eat particular things and no others, and such a desire may generally be taken as a safe indication that the body needs them.

60. **Paramount Necessity of Water.**—Of all articles used for food or drink, water, in some form or other, is the most indispensable. Men can live much longer on water without food than on food without water. The celebrated French physiologist, Magendie, found that dogs lived eight or ten

* This is said of a healthy person. Excessive production of fat, as in Mr. Banting's case, is to be regarded as a diseased condition, and so requires special diet.

days longer, when supplied with water alone, than when they were deprived of both food and water. The pangs of thirst have been felt in a slight degree by almost every one, and it is the experience of those who have suffered from deprivation of food and water, in deserts and shipwrecks, that the tortures of thirst are much harder to bear than those of hunger.

61. **Daily Amount of Food.**—It has been found by Dr. Dalton, by experiments upon himself, that an adult requires food in about the following proportions:

Meat	16 ounces.
Bread	19 "
Butter, or fat	3½ "
Water	52 "

or about two pounds and a half of solid food and about three pints of liquid food daily. This is about the least amount which will keep him in good health.

62. **Cooking.**—Man does not take his food in the natural state, like other animals, but prepares it by *cooking*. This process is of advantage in two ways: it softens the hard parts of the food, such as beans, potatoes, and the various grains, and the fibrous tissue of meat; and it also develops a pleasant flavor by the action of heat, which excites the flow of the fluids of the mouth and stomach, and thus aids digestion.

CHAPTER II.

MASTICATION.—SWALLOWING.

63. The Digestive Apparatus.—The food we eat is mostly insoluble, and in an unfit condition to be used for the nourishment of the body. Even so nutritious a substance as albumen can not be used without undergoing some change, and if pure fluid albumen be injected directly into the blood, it will be thrown out of the body by the kidneys unaltered. To prepare the various foods for use in the body, we are provided with a complicated series of organs, called the *digestive apparatus*, in which the food is ground fine and mingled with various juices until it is reduced to a fluid mass, which can be taken up by the blood and carried to all parts of the body in a condition fit for their nutrition.

64. Processes to which Food is subjected in the Body.—The process of preparing food for our nourishment may be conveniently divided into five stages. The *first* of these is *mastication*, which takes place in the mouth, and is a voluntary act. The *second* is *swallowing*, or the act of passing food on from the mouth to the stomach, the beginning of this act being voluntary, and the greater part of it involuntary. The *third* is *stomach digestion*, which is involuntary; the *fourth*, *intestinal digestion*, which

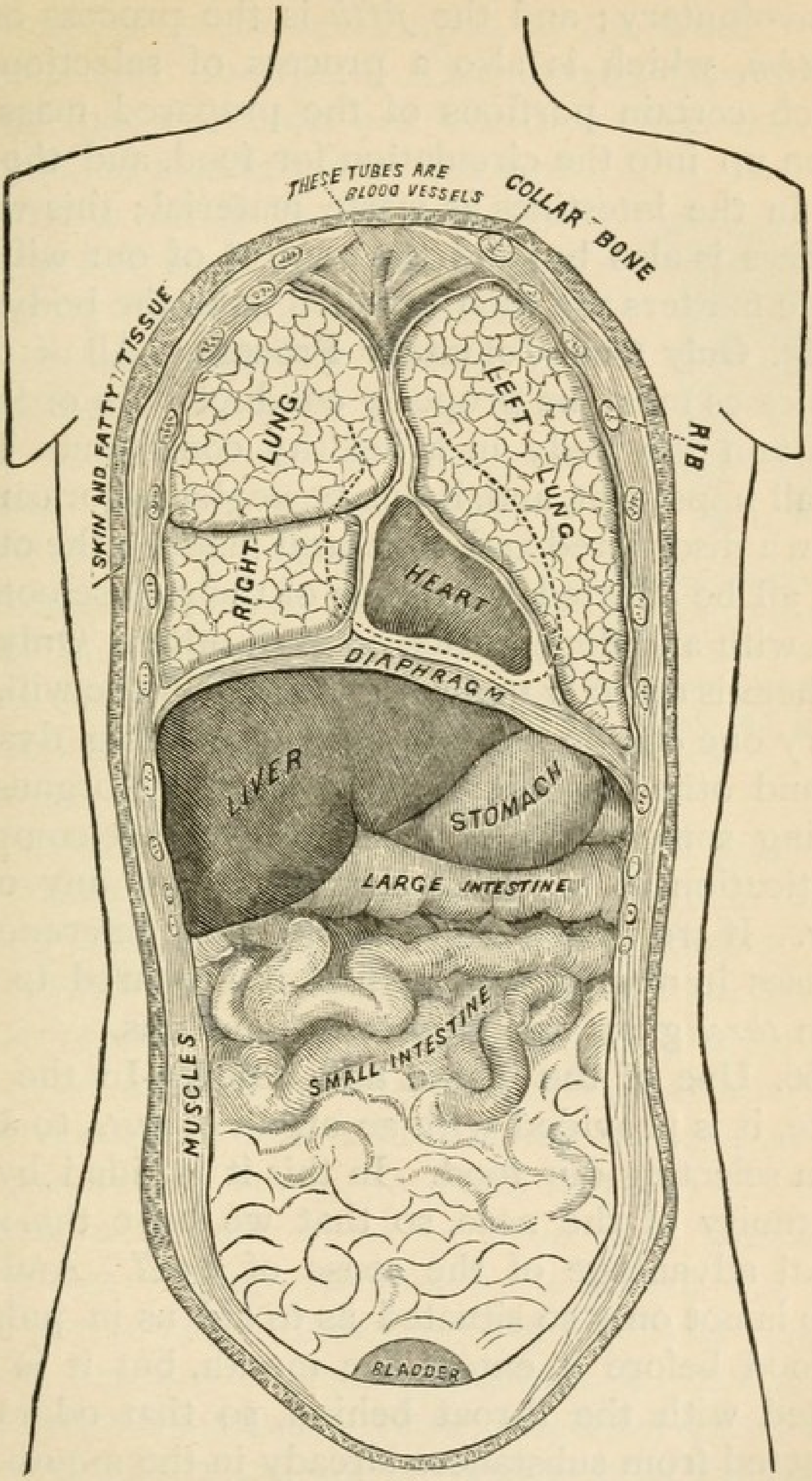

FIG. 19.—Front view of the organs in their natural relations. The heart is partly covered by the lungs, but its true outline is indicated by a dotted line. Only ten ribs are shown on each side, the eleventh and twelfth (the floating ribs) being too short to be included in the section.

is involuntary; and the *fifth* is the process of *absorption*, which is also a process of selection, by which certain portions of the prepared mass are taken up into the circulation for food, and the rest left in the intestines as waste material; this whole process is also beyond the control of our will; all waste matters are then expelled from the body.

65. Only One Voluntary Process.—All of these processes must be properly conducted, in order to maintain the body in a healthy condition. They are all important, and, if one be neglected or carried on in a disordered and unnatural manner, the others will all be affected, by reason of their close connection with and dependence on each other. Only one of them is directly under the control of the will, and every one can do more toward preventing dyspepsia and other disorders of the digestive organs, by paying some attention to the proper and complete mastication of his food than in almost any other way. If we examine the *mouth*, with reference to its uses in mastication, we find it prepared to perform *three* great and important functions.

66. Use of the Taste and Smell.—In the *first* place, it is provided with an organ of *taste*, to assist us in selecting our food. In this it is aided by the proximity of the nose, so that we have the additional advantage of the sense of *smell*. And the nose is not only so situated as to aid us in judging of food before it enters the mouth, but it is connected with the throat behind, so that odors are detected from substances already in the mouth.

67. The Teeth.—In the *second* place, the mouth is provided with organs for grinding and crushing the hard parts of the food, and reducing them to a soft mass, fit to be acted upon by the fluids in the stomach and intestines. The organs directly of use in this operation are the *teeth* (Fig. 20), but essential aid is afforded by the muscles of the *cheeks* and the *tongue*. The rows of teeth are narrow, and, except for the action of these muscles, the food could not be kept between them. Indeed, it has been found that in cases of paralysis, when the muscles of the cheek are unable to contract, while the tongue still retains its power, the food gets pushed out between the cheek and the teeth, and accumulates there. The lower jaw is moved by some of the most powerfully acting muscles in the body. The chief one of all is the *mas'-seter*, which is attached above to the ridge of bone running backward from the lower border of the eye toward the ear, and below to the horizontal portion of the jaw. The muscle is nearly square in shape, and, as is easily seen, acts at a great mechanical advantage. As a matter of interest connected with this muscle, it may be stated that it is the muscle generally referred to for proof that muscular contraction is accompanied by a sound. If the lower jaw be firmly closed, and the teeth powerfully pressed together so that the muscles of mastication are strongly contracted, a low, rumbling sound will be heard, which can not be explained in any other way than as caused by the muscular contraction.

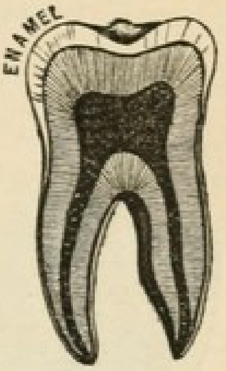

FIG. 20.—Section of a tooth. The black portion is the cavity occupied by the nerve and blood-vessels.

68. The Saliva.—In the *third* place, the food, while undergoing mastication, is mixed with certain fluids, called collectively the *saliva*. They are the product of *three* sets of glands, each of which is double—i. e., there are three glands on each side of the mouth (Fig. 21), and the secretion of each

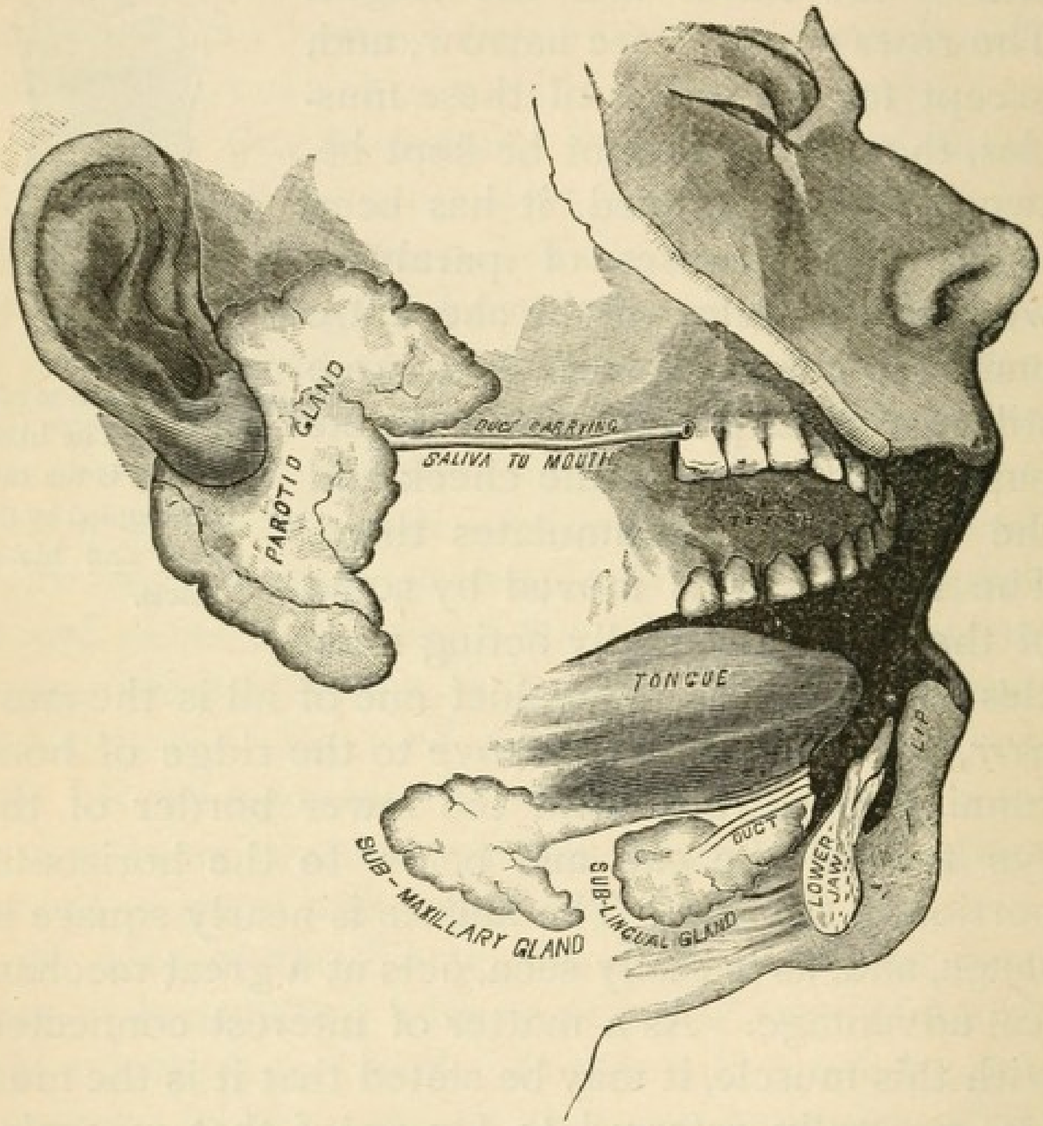

FIG. 21.—The salivary glands of the right side.

pair is peculiar to itself. The largest of these are the *parot'id glands*, which are situated just in front of the lower border of the ears, and are the glands which become swollen and cause the distortion of the face in the disease known as the mumps. The fluid secreted by these glands is very thin and watery, and constitutes the greater part of the saliva. The other glands are situated just inside the lower border of the jaw and beneath the tongue. Their secretion is much thicker and more glutinous than that of the parotid glands. Besides these fluids, there is a small amount secreted by the mucous membrane lining the mouth, and all these mingled fluids constitute the saliva.

The saliva is secreted to some extent at all times, and keeps the lining membrane of the mouth moist and soft, but it is a familiar fact that its amount is greatly increased at certain times. Thus, we say, at the sight, or even sometimes at the suggestion, of an appetizing meal, the "mouth waters." * The fact of its excessive secretion at such times shows that it has a part to perform in the process of mastication and digestion.

69. Properties and Use of the Saliva.—Experiments have shown that saliva possesses the property of converting starch into sugar; but, as this is also done by the digestive fluids, it is not considered to be a very important function, and the chief use of the saliva undoubtedly is, to make the processes of mastication and swallowing of food easier. If food were taken dry, and there were no means at hand of moistening it, mastication would be very difficult and tiresome, and swallowing almost impossible. Bernard † found, by experiments upon a horse, that

* In physiological lectures before medical students, it is not uncommon to illustrate this fact in a curious way. A slender tube is introduced into the opening by which the parotid saliva is discharged into the mouth, and, according to the condition of the person operated on, there will either be no flow of saliva or it will come out drop by drop. But now let food be brought in, and the moment it is seen the saliva begins to run from the tube in a plentiful stream.

† Claude Bernard, a famous French physiologist (1813–1878). He

when an operation had been performed, which prevented the parotid saliva from entering the mouth, the animal could masticate and swallow (the latter process being accomplished with great difficulty) only three quarters as much oats in twenty-five minutes as he had previously eaten in nine. It is probable that the parotid saliva, which is almost like water, assists mainly in the mastication of the food; while the other secretions, which are thicker and more slippery, coat the outside of the mass, and render it easier to swallow.

The total amount of saliva secreted by a healthy adult in twenty-four hours has been calculated, after numerous experiments, to be nearly *three pounds*.

NOTE.—It is important for the health of the individual that the teeth should be kept in good condition, in order that mastication may be thorough and complete. Particles of food which stick between the teeth, if they are allowed to remain, putrefy and impart an offensive odor to the breath. The acids which are developed during the putrefaction of such matters are also injurious to the teeth and tend to hasten their decay. There are also certain substances deposited from the saliva around the necks of the teeth, called "tartar." If this is not removed, the gums are bruised against it, and finally recede from the teeth, leaving a part of the fang bare, and thus exposing to all sorts of injurious influences a part of the tooth which was never intended to be so exposed.

The teeth should therefore be frequently cleaned, at least twice a day, with water and a *soft* brush (a stiff brush injures the gums), toothpicks being used when necessary. Avoid fancy tooth-powders and washes, for they often contain injurious acids or gritty substances. To polish the teeth, use powdered orris-root and chalk, which can be bought of any druggist. Never crack nuts with the teeth, and, on the slightest appearance of decay, consult a good dentist.

was Professor of Physiology in the College of France from 1855 until his death. Especially distinguished for his discovery of the formation of sugar in the liver, and for his researches on the functions of the sympathetic nervous system. (See later.)

CHAPTER III.

STOMACH-DIGESTION.

70. The Alimentary Canal.—The food, which is now ready to be operated upon by the digestive fluids, passes beyond the control of the person who swallows, and begins its travels in the long tube, called the *aliment'ary canal* (Fig. 22). This canal begins at the mouth and ends with the large intestine, and is nearly thirty feet in length. It does not properly assume the form of a tube until the beginning of the *œsoph'agus*, or gullet, and at one point, namely, at the lower extremity of the œsophagus, there is a considerable enlargement, which has the appearance of a bag or pouch, and is called the *stomach.* To understand the working of the alimentary canal, it is necessary to know something of its anatomy.

The two most important tissues in its structure are the mucous membrane which lines it throughout, and the muscles which surround it, and are imbedded in its walls.

71. Mucous Membrane.—*Mucous membrane* (Fig. 23) is the skin which lines the interior canals of the body. While the outside of the body is covered by a smooth, white, tough skin, we see that, at the openings leading to its interior, such as the mouth, nose, etc., the character of this covering suddenly changes, and it becomes a reddish or pinkish mem-

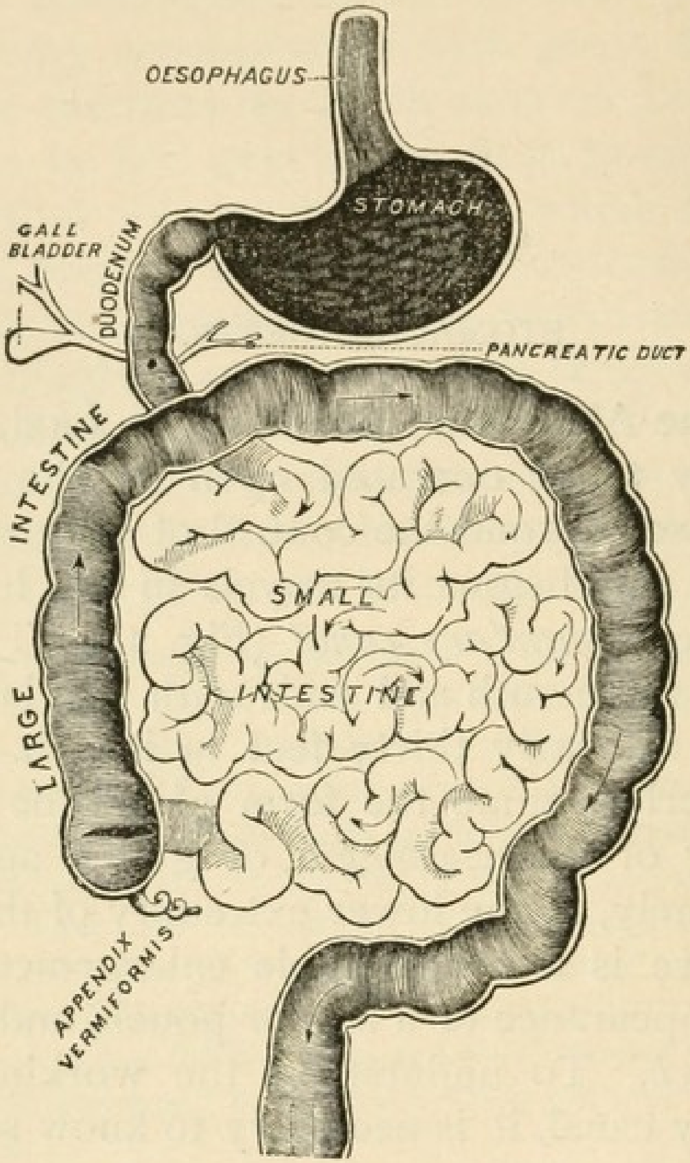

FIG. 22.—The alimentary canal.

brane very soft and delicate in texture, and continually moistened by its secretions. This is called mucous membrane, and in one form or another it lines all those internal parts of the body, which communicate with the external air.

It is made up mainly of *fibrous tissue*, consisting of fine threads, interlacing with each other in every direction and densely woven. Its surface is covered with minute cells, called *epithe'lial cells.** At various points on the membrane are minute tubes or cavities, less than $\frac{1}{100}$ of an inch in diameter, of different shapes in different places, and in some situations so numerous that they lie almost in contact with each other. These minute tubes are closed at the bottom, but open on the surface of the membrane. Small as they are, they are lined from top to bottom with epithelial cells, which really carry on the work of secretion. All around, among, and underneath these tubes are small blood-vessels, which nourish the membrane, and from which the little epithelial cells separate the materials which form the mucus.

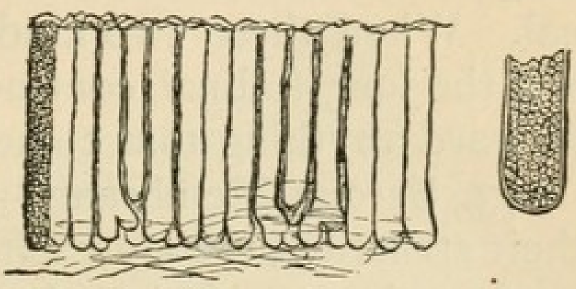

FIG. 23.—Structure of mucous membrane illustrated. At one side is a detached portion of a tube, or follicle, enlarged so as to show the epithelium more clearly.

72. **Muscles of the Alimentary Canal.**—The muscles which form a considerable part of the walls of the alimentary canal are of the involuntary or non-striated kind. The fibers run in various directions, some of them surrounding the œsophagus and the

* All free surfaces of the body, whether inside or outside, are covered with cells. In the interior of the body, the alimentary canal, the lungs etc., these cells are soft, and, so to speak, plump, and are called *epithelial cells*, or a mass of them taken together is called *epithelium*. On the external surface of the body they are dry, flat, hard, and horny, and are called *epider'mal cells*, or, in a mass, the *epidermis*. In both situations they are being constantly shed and renewed. The fresh ones are continually forming underneath, and, as they grow, take the place of the old ones on the surface, which are being constantly rubbed off in one way or another. All the secretions of mucous membranes contain these epithelial cells, and the slightest scraping of the skin dislodges epidermal cells.

intestines in a circle, so that when they contract they make the canal smaller; while others run lengthwise, and their contraction shortens the canal. When these two kinds of fibers, the circular and the longitudinal, contract together, they propel forward anything that comes within their grasp.

73. **Serous Membrane.**—Besides these parts of their structure, the stomach and intestines are covered on the outside by what is called a *serous membrane*, which is found lining all cavities inside the body that do not communicate with the air, excepting the joints. This kind of membrane is transparent, exceedingly fine and soft, and smooth like satin, and is constantly moistened with a slight amount of fluid. The use of serous membrane is to allow organs to move freely upon each other without friction. If it were not for some provision of this sort, the movements of the stomach and intestines during digestion would be painful, or at least disagreeable, while, as things now are, we are entirely unconscious of any movement at all.

74. **Swallowing.**—After mastication is completed the tongue passes the mass of food backward into the *phar'ynx* (or throat), whence it goes on into the œsophagus. The *œsophagus* (Fig. 24) is about nine inches long, and extends from the throat to the stomach, not just behind the breastbone, as many suppose, but just in front of the spine. The muscles of the upper portion are of the striated variety, but, nevertheless, their contraction is not voluntary. When anything has once passed to the back of the throat, it will be swallowed and sent into the stomach, in spite of our will.

75. **The Stomach.**—The *stomach* varies in size

in different persons, but on the average will contain about *three pints* of fluid in the adult. Its

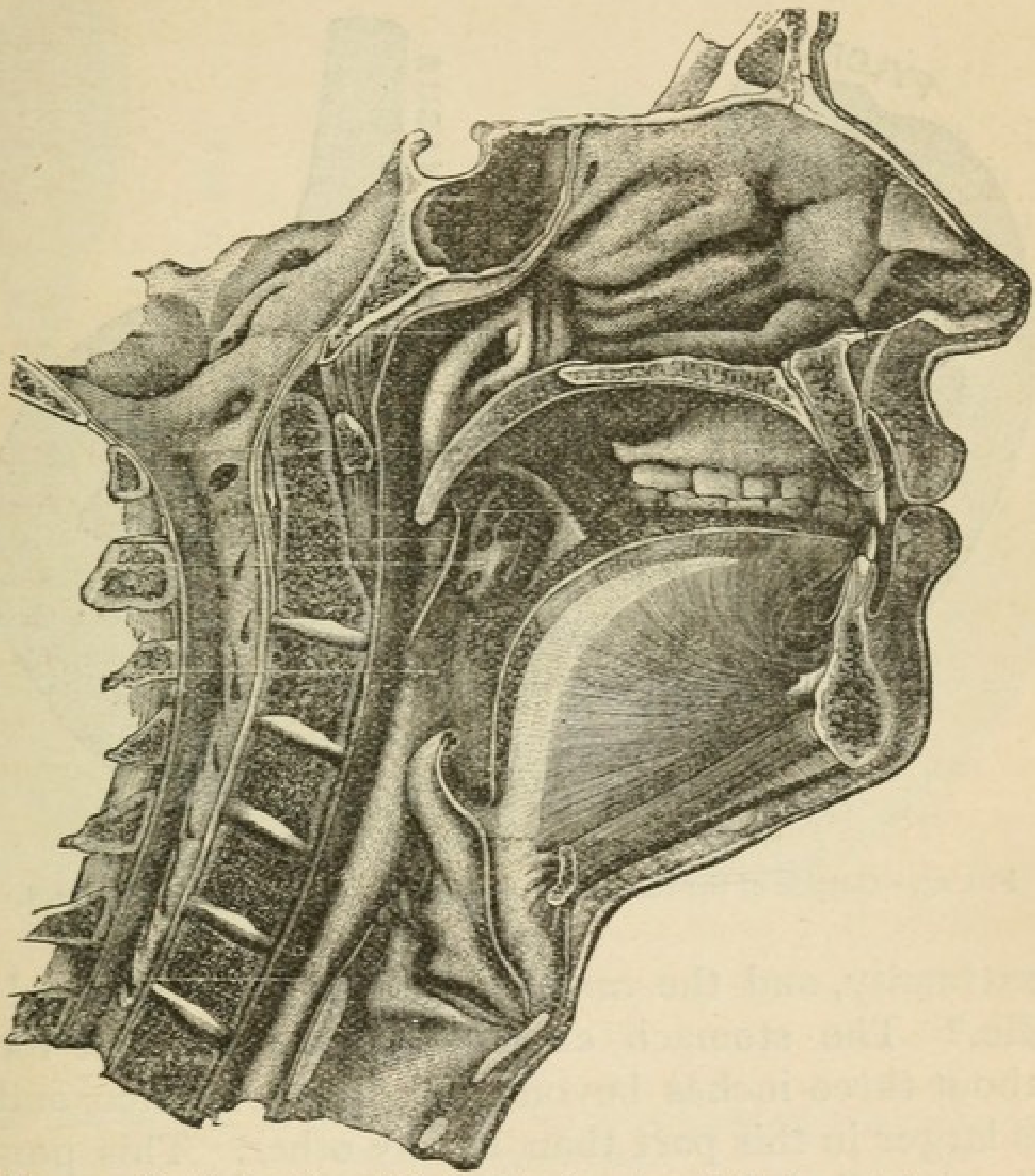

FIG. 24.—Vertical section of the head and neck. At the base of the tongue is seen the epiglottis, and below this the larynx. Between the larynx and the bodies of the vertebræ lies the œsophagus.

shape has often been compared to that of the air-bag of a bag-pipe, which it much resembles (Fig. 25). It has two openings, one at the lower extremity of the œsophagus, where food enters, and the other at the point where food passes out and the small intestine begins. These openings are both in the upper border of the organ, and only a short distance apart, the *pylo'rus*, or exit, being at the right

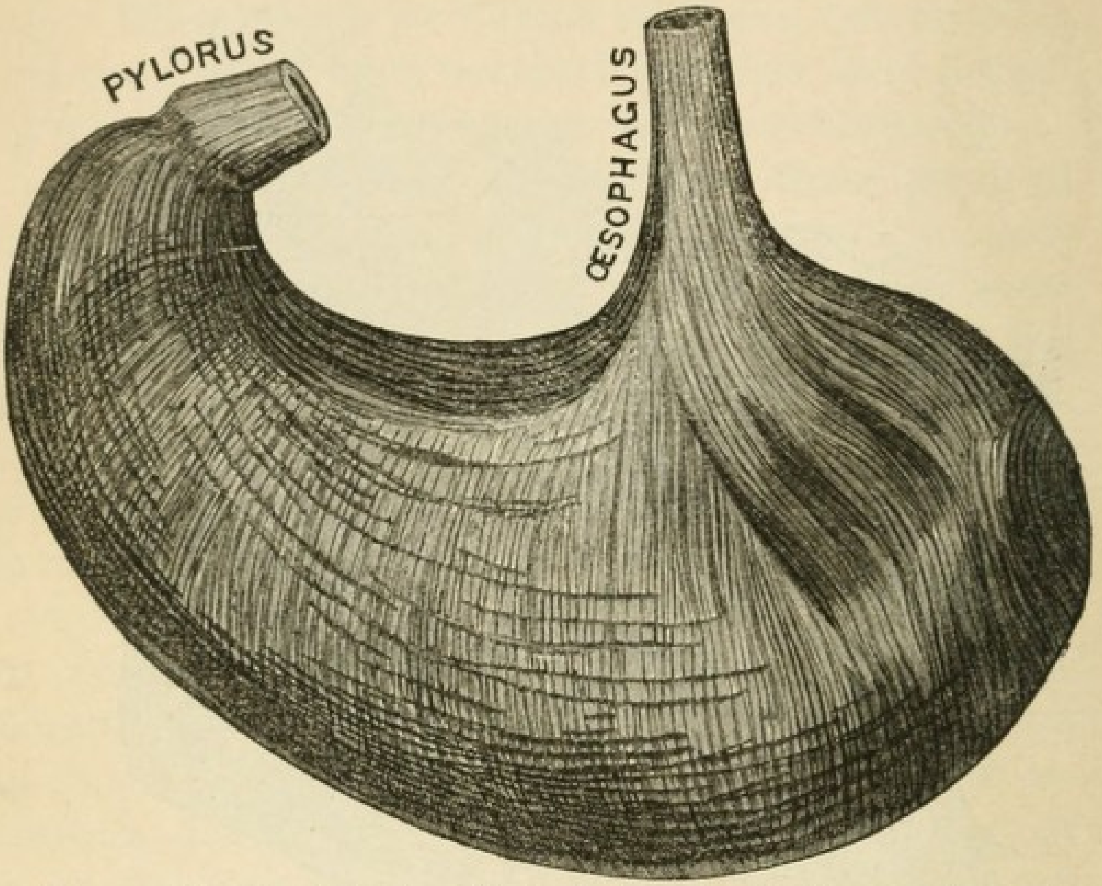

FIG. 25.—Outside of the stomach, front view, showing the muscular coat.

extremity, and the *car'diac* opening near the middle.* The stomach extends toward the left for about three inches beyond the cardiac orifice, and is larger in this part than in any other. This portion is called the *great pouch* of the organ (Fig. 26).

Each orifice is guarded by a powerful muscle, surrounding it in a circular form, which can contract so tightly as to prevent the passage even of a fluid. As a rule, these muscles prevent the passage of any substance backward through them, in opposition to the natural course of the food.

* *Pylorus*, a Greek word meaning the gate-keeper; *cardiac*, from a Greek word meaning the heart, because it is very near that organ.

76. Stomach-Digestion. — It was formerly supposed that the whole process of digestion was

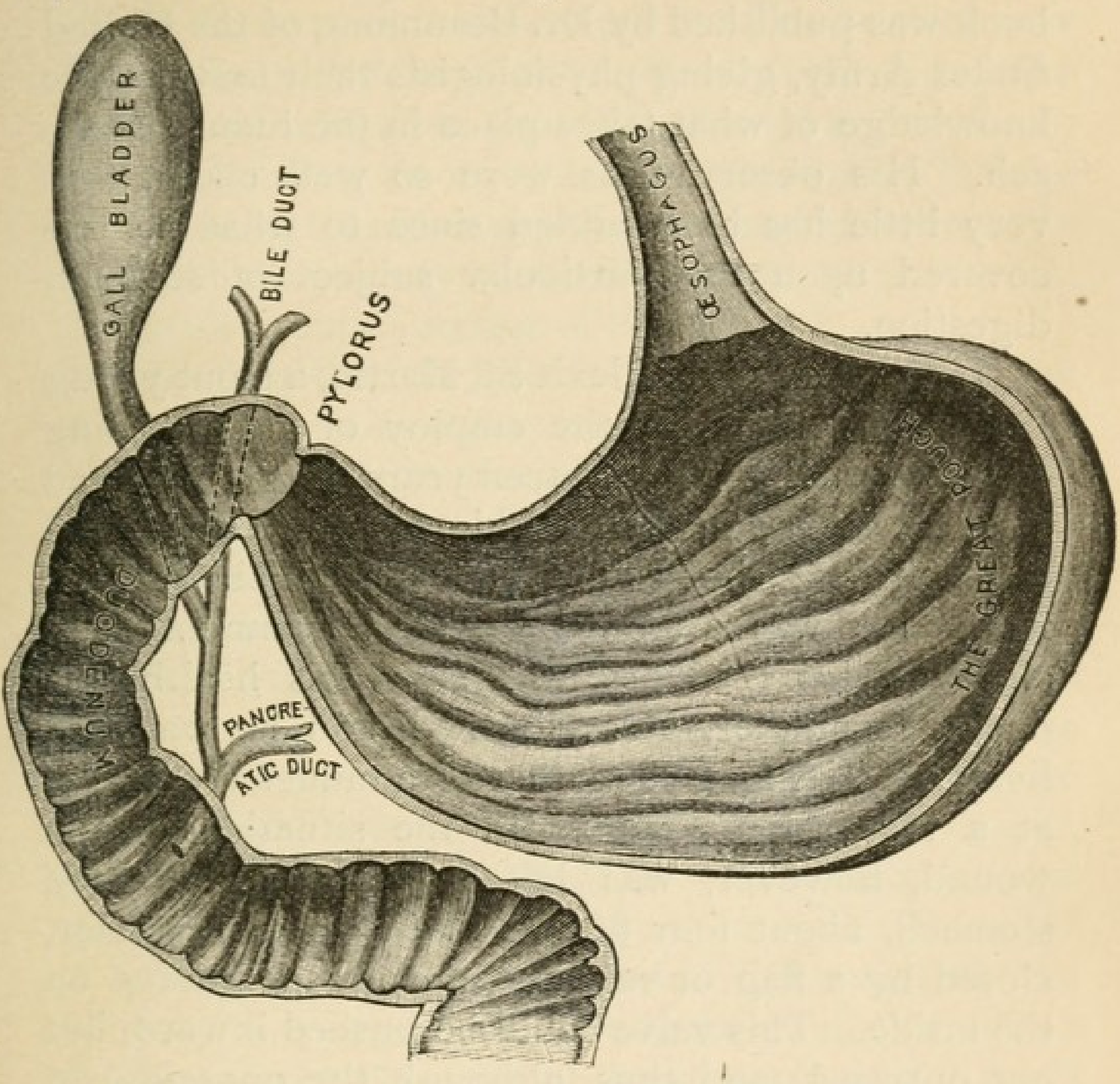

FIG. 26.—Inside of the stomach, front view, showing the folds (or rugae) of the mucous membrane.

performed in the stomach, but this is now known not to be the case. The nitrogenous portions of the food are the only ones that are digested in the stomach. The *oily* and *fatty*, as well as the *starchy*, portions are digested in the small intestines. Fluids are very rapidly absorbed by the stomach.

77. Dr. Beaumont and St. Martin.—There are so many difficulties connected with the investigation of the subject of digestion, that very little was really known about it until the year 1833, when a small book was published by Dr. Beaumont, of the United States Army, giving physiologists their first precise knowledge of what takes place in the human stomach. His observations were so well taken, that very little has been added since to what he discovered upon the particular subject of stomach digestion.

In the year 1822, Alexis St. Martin, a stout young French Canadian, in the employ of a fur-trading company, and about eighteen years of age, received a severe wound in the left side from the accidental discharge of a shot-gun at a distance of about three feet. He was attended by Dr. Beaumont, and, although his recovery was slow, his health was finally completely re-established, and he was still living in Vermont, the father of a numerous family, at a very recent date. In the situation of the wound, however, was left an opening into the stomach, about four fifths of an inch in diameter, closed by a flap or valve of mucous membrane on the inside. This valve could be pushed inward, but not outward; and thus, although the operation of digestion was not at all interfered with, the interior of the stomach could be thoroughly examined, and experiments performed with the greatest facility and accuracy. Dr. Beaumont kept the young man in his employ for several years, and made hundreds of observations upon him. These were published in his little book, and made both him and St. Martin immediately famous.

As Dr. Beaumont was the first, and for many years the only, person who ever saw the interior of the stomach in a living man, much of the following description will be taken from his volume.

78. **Interior of the Stomach.**—"The interior coat of the stomach," he says, "in its natural and healthy state, is of a light or pale-pink color, varying in its hues according to its full or empty state. It is of a soft or velvet-like appearance, and is constantly covered with a very thin, transparent, viscid mucus, lining the whole interior of the organ."

79. **The Gastric Juice.**—The changes which the food undergoes in the stomach are due to the action of the *gastric juice*, the appearance of which, with the manner of its secretion, is thus described:

"By applying aliments or other irritants to the internal coat of the stomach, and observing the effect through a magnifying-glass, innumerable minute lucid points can be seen arising from the mucous membrane, and protruding through the mucous coat; from which distils a pure, limpid, colorless, slightly viscid fluid. This fluid is invariably distinctly acid."

"The fluid so discharged is absorbed by the aliment in contact, or collects in small drops and trickles down the sides of the stomach to the more depending parts, and there mingles with the food or whatever else may be contained in the gastric cavity."

"The gastric juice never appears to be accumulated in the cavity of the stomach while fasting. When aliment is received, the juice is given out in exact proportion to its requirements for solution, *except when more food has been taken than is necessary for the wants of the system.*"

80. **Composition and Amount of Gastric Juice.**—

The *gastric juice* contains two important constituents, viz., hydrochloric acid and pepsin. If it be deprived of these, it will no longer exhibit its peculiar properties; while, if it retains them, as Dr. Beaumont first showed, it will digest food in a glass tube, outside the body, provided the tube and its contents be kept at a temperature of 100° Fahr., which is about the ordinary temperature inside the stomach.

The average amount of gastric juice secreted daily by an adult human being has been estimated at a little less than *fourteen pounds*, or about a *gallon and a half*.

81. Movements of the Stomach. — But, besides the action of the gastric juice in stomach-digestion, a very important office is performed by the muscles which form a large part of the walls of the organ. During digestion, these muscles are continually contracting in a slow, regular order, producing movements of the contents of the stomach in a very peculiar manner, which, in health, never varies. Dr. Beaumont says that the ordinary course and direction of the revolutions of the food are first, after passing out of the œsophagus into the stomach, from right to left, thence down along the great curvature, from left to right, to the pylorus, whence it returns again along the upper border of the organ to the left extremity of it. Each of these journeys of the food around the organ occupies from one to three minutes, and they serve to mingle the gastric juice more thoroughly with the food. As soon as the process of digestion is gone so far as to bring portions of the food into a condition for absorption, it is found that every time the contents of the stomach pass the pylorus the mass becomes diminished in amount, showing that a portion has been squeezed or pressed through the opening into the intestine.

"These peculiar motions and contractions continue until the stomach is perfectly empty, and not a particle of food remains. Then all becomes quiet again."

Thus that part of the digestion of food which is carried on in the stomach is accomplished by the action of the gastric juice, and the changes produced by it are assisted, and the prepared food is passed out of the stomach, by the constant contractions and churning motions of the organ just described.

This, then, is the ordinary healthy process of stomach-digestion, when not in any way hindered or interfered with. Let us see what changes take place in the appearance of the stomach and in its functions when it is injuriously affected.

82. Appearance of the Stomach during Indigestion. — "In a feverish condition, from whatever cause—obstructed perspiration, undue excitement by stimulating liquors, overloading the stomach with food—fear, anger, or whatever depresses or disturbs the nervous system," the lining of the stomach "becomes somewhat red and dry, at other times pale and moist, and loses its smooth and healthy appearance; the secretions become vitiated, greatly diminished, or entirely suppressed."

"There are sometimes found, on the internal coat of the stomach, eruptions or deep-red pimples. These are at first sharp-pointed and red, but frequently become filled with white purulent matter;

at other times, red patches, from half an inch to an inch and a half in circumference, are found on the internal coat. These appear to be the result of congestion in the minute blood-vessels of the stomach."

"These diseased appearances, when very slight, do not always affect essentially the gastric apparatus. When considerable, and particularly when there are corresponding symptoms of disease, as dryness of the mouth, thirst, furred tongue, etc., no gastric juice can be extracted. Drinks received are immediately absorbed or otherwise disposed of; none remaining in the stomach ten minutes after being swallowed. *Food, taken in this condition of the stomach, remains undigested for twenty-four or forty-eight hours or more.*"

"Whenever this morbid condition of the stomach occurs, with the usual accompanying symptoms of disease, there is generally a corresponding appearance of the tongue. When a healthy state of the stomach is restored, the tongue invariably becomes clean."

These are the observations of one who saw what he describes, and took careful notes of what he saw.

83. Time required for Stomach-Digestion.—The *time* required for digestion in the stomach varies very much according to the character of the food. Dr. Beaumont found that the time of stomach-digestion in St. Martin varied from one hour to about five and a half. Among meats, the soonest digested was boiled pig's feet, which took an hour, and the longest time was taken for roast pork, viz., five hours and a quarter; among vegetables, rice is digested in an hour, while boiled cabbage requires four. The average time required for an ordinary meal is probably about *three hours*.

84. Advantage of Thorough Mastication.—Dr. Beaumont found that, when a piece of meat or other food is attacked by the gastric juice, it is slowly dissolved from the outside. The juice is not soaked up and does not penetrate the interior of the mass, but gradually softens the exterior of it; and, as the outside portion becomes friable and dissolves, the piece grows smaller and smaller, the gastric juice in this way advancing little by little, until the whole mass is liquefied. From this it is evident that it will take longer to digest a large piece of meat than to digest the same amount after it has been divided into small pieces; for this reason it is important to *masticate the food thoroughly before sending it into the stomach.*

85. Eating too little.—It is evident that it will not do to take too little food. Enough must be eaten to supply the needs of the system, and it must be of such a quality that it can be readily digested and appropriated.

86. Eating too much.—But, on the other hand, we *must not take too much food.* There seems to be some subtile relation between the amount of food required by the system and the amount of gastric juice furnished by the stomach. What is likely to be the result, then, if more food is taken into the stomach than can be acted on by the gastric juice? Let us consider. The temperature of the interior of the stomach is about 100° Fahr. This is just about the temperature at which fermentation and putrefaction (which is a sort of fermentation) are most active. Heat and moisture favor these processes. Both of these conditions exist in the stomach, but, under ordinary circumstances, the gastric juice prevents any other changes than those due to its own action. But, if more food is introduced than the gastric juice can dissolve, fermentation occurs, and offensive gases and irritating acids are produced. Then the symptoms of indigestion come on, there is constant belching of wind from the mouth, an uneasy sensation in the stomach, and, as soon as the undigested and fermenting mass passes out into the intestine, rumblings and colic set in, followed probably by a diarrhœa, which continues until the offending matters have been ejected from the body.

87. **Eating between Meals.**—Similar symptoms may be produced by *eating between meals.* When a sufficient meal has already been eaten, we should wait until it has been digested and the stomach has had a short period of rest before we give it any more work to do. This organ can not work incessantly any more than other parts of the body, and when it is ready for more food the sensation of hunger apprises us of the fact. If we load it with fresh food before the previous supply has been disposed of, there may not be enough gastric juice secreted to digest it. Then it ferments, or putrefies, and causes a fit of indigestion, as just described.

88. **Hunger.**—It is sometimes said that a person should rise from the table, after every meal, still hungry. This is not correct, and the reason is plain. Hunger is the natural indication that the body is beginning to be worn out, and needs fresh material to repair its losses. And although the appropriation of the food is finally made by the

cells that compose the body, and so must be after it has been already digested and carried to them, nevertheless the sympathy of the different parts of the body with each other is such that hunger is satisfied by the mere act of supplying food to the stomach. Not only that, but the digestibility of the food has a great deal to do with it. Certain kinds of food, which we call rich, generally containing a great deal of fat and sugar, satisfy the hunger and produce a sense of satiety, when we have not really eaten enough to supply the bodily needs. This is because such food is digested very slowly, being so permeated with fat that the gastric juice, which does not digest fat, penetrates to the albuminous portions of the food with great difficulty. In such cases also fermentation frequently occurs, and persons who eat much so-called rich food may satisfy their hunger with it day after day, and still suffer from indigestion, and not get enough nourishment to repair the waste of the body. For these reasons, *plain food* is the best, especially for the young.

89. **How much to eat.**—The true way, therefore, is not to rise hungry from the table, but to stop eating when the hunger has been satisfied, and before any feeling of repletion comes on. It should be borne in mind that the process of digestion ought to go on without our consciousness. After a proper meal, the only sensation caused by the food we have taken should be that of complete satisfaction and contentment. If the stomach feels stuffed and full, we have eaten too much. It may be properly disposed of if the eater is in vigorous health, and able to rest for a time until the uneasy feeling of repletion wears away. But the whole

process ought to go on without causing us a moment's thought. If we are healthy, and if we treat our digestive organs properly, we ought never to feel that we have a stomach, or liver, or bowels. They will never trouble us, if we do not trouble them.

Our meals, therefore, should be sufficiently far apart to allow an hour or two at least to intervene between the digestion of one meal and the beginning of another. As digestion in the human being ordinarily occupies from three to four hours, our meals should be at least five hours apart, and this is about the time usually allowed.

90. **What to eat.**—The matter of what to eat, amid the great variety of foods, may safely be left, in a healthy person, to the appetite. It is a familiar proverb that "one man's meat is another man's poison." Each individual must learn for himself what food is the best for him. If any article is found to disagree, it should thereafter be let alone; no attempt should be made to overcome a natural repugnance, and acquire an appetite for what is distasteful. This is to fly in the face of Nature; it is much the same as saying that one is competent to direct the secret processes of nutrition and to regulate the functions of organs, about which he knows almost nothing, and which he can not control. Such action is intermeddling, not judicious care.

91. **Condiments.** — Something should here be said, however, about the use of certain substances which are not foods, and yet are in common use throughout the world, to make food more acceptable to the palate. Such substances are pepper and

mustard. These condiments have two qualities that have caused them to be used in the preparation of food, viz., a peculiar flavor, which makes articles of food to which they have been added more savory, and a quality called pungency—i. e., they irritate any part of the body with which they are brought in contact. When either is placed upon the tongue, smarting is produced, sometimes to a painful degree, and tears start in the eyes. The effect can therefore be imagined when these substances are rubbed over the delicate mucous lining of the stomach during the movements of digestion. They can not but be extremely irritating, and therefore injurious. As a matter of fact, the excessive use of such things, whether alone or in highly-seasoned sauces (Worcestershire, etc.), results in extreme debility of the digestive apparatus and confirmed dyspepsia. The golden rule in the treatment of the stomach is, to put nothing into it that can be felt after entrance. As before stated, the operations of the stomach ought to go on without our consciousness of them. If enough spice is taken to produce a feeling of warmth in that organ, it is too much, and the mucous membrane has been irritated. We are all, or nearly all, born into the world with sound digestive organs, which need no spurring to make them do their duty. If they get out of order, it is our own fault, and rest will do more than anything else to set them right. If you whip a good horse, when he is doing his best, you will spoil him.

92. **The Natural Drink.**—The natural drink of all animals is water, for milk is to be looked upon as a food. Many people, however, are not satisfied

with water alone, but prefer it flavored with something else, and a great variety of drinks have been invented, of which we shall only consider tea, coffee, and those which contain alcohol, as malt and spirituous liquors and wines.

93. **Effects of Alcohol ; Intoxication.**—Alcohol is a poison, and the proof of this assertion is clear when the ordinary effects of liquors containing it are considered. When a person takes so much of an alcoholic drink that he feels the effects of it, he is somewhat exhilarated, the pulse is quicker and stronger, the face is flushed, his ideas seem to flow more freely, he is more cheerful and happy, and he seems brighter than before. And yet, even in this very first stage of intoxication, a close observer can see that a poisonous effect has been produced upon his nervous system. His judgment is weakened, his control over his thoughts is slightly lessened, and things, which when strictly sober he conceals, often come to the light in his conversation. In brief, he is beginning to lose the mastery of himself. If more alcohol is taken, the brain becomes more and more oppressed, he loses control of his muscular movements, he mumbles in his speech, talks nonsense, and finally becomes unconscious. The poison, however, if enough has not been taken to kill, is gradually ejected from the body, through the lungs, skin, and kidneys, and the paralyzed organs begin to recover. When consciousness returns, the person is dreadfully sick with a throbbing headache and nauseated stomach, which only recover their normal condition after a more or less prolonged period of rest. Surely such effects are not those of a food, but of a rank poison.

94. Narcotic Poisons. — But the more remote effects of alcohol are even more striking and of greater importance. It is not only a poison but a *narcotic* poison. It belongs to the same class with opium, chloroform, ether, hydrate of chloral, etc.; the great peculiarity of which is, that they never leave the body, through which they have once passed, in quite the same condition in which they found it. The person who has once taken them is apt to feel a desire to take them again. And this desire is not like the ordinary appetite for food: it is not that their taste or smell is agreeable, for as a rule the reverse is the case. It is the after-effect that is sought. The oftener this desire is gratified, the stronger it becomes, until finally the man is no longer master of himself, neglects his daily affairs, and takes no interest in anybody or anything but plans for obtaining a fresh supply of the poison.

95. First Symptoms of Narcotism.—This evil effect of the narcotic poisons does not follow unless enough has been taken to produce the first symptoms of narcotism, which is really the only agreeable stage, and is characterized by a curious sort of tingling all over the body, somewhat as if the running of the blood could be felt in the blood-vessels. Indeed, it is probably caused by the contact of the alcohol with the millions of cells that compose the body, and is the symptom of commencing paralysis.* When this sensation is felt, too much alcohol has already been taken, and poisoning has begun.

96. Effect of Alcohol on Growing Persons.—Be-

* The flushing of the face and the more rapid action of the heart are due to the paralyzing effect of the alcohol on the vaso-motor nerves, which will be described hereafter.

sides this danger connected with the use of alcoholic drinks, which is common to them with other narcotic poisons, alcohol retards the growth of young cells and prevents their proper development. Now, the bodies of all animals are made up largely of cells, as heretofore shown, and, the cells being the living part of the animal, it is especially important that they should not be injured or badly nourished while they are growing. So that alcohol, in all forms, is particularly injurious to young persons, as it retards their growth, and stunts both body and mind.

97. Effect of Habitual Excess in the Use of Alcohol.—When alcohol is used habitually in quantities sufficient to produce symptoms of poisoning, it causes serious changes in many parts of the body, especially in the stomach, liver, kidneys, and blood-vessels. The habitual drinker is therefore never in good health, and never lives to be old.*

98. Alcohol diminishes the Power of Endurance.—It has been amply shown by Arctic explorations and by military campaigns in India and Africa, that those who use no alcohol endure privation, fatiguing labor, and extremes of temperature much better than those who take daily rations of grog. The common opinion that alcoholic liquors ward off the cold and temper the heat arises from the fact that the bodily sensations are dulled by the narcotic;

* It is not to be inferred, from what has been said, that every person who uses alcoholic stimulants will become a drunkard, but it can not be denied that every such person runs a risk of becoming one. Not every one who goes into battle is killed or even wounded, but every one incurs danger. Alcoholic drinks are not necessary to healthy persons, and the habitual use of them is like playing with fire near a keg of gunpowder. No harm may result, but it is a foolish thing to do.

the drinker, in other words, is partially anæsthetized, so that, although he feels cold and heat in a less degree, he is really less able to resist them.

It is found, also, that even moderate drinkers are more likely to be attacked by epidemic diseases, that they do not bear surgical operations so well, that they suffer more from exposure of any kind, and that they are apt to succumb to diseases from which the abstinent generally recover.

99. **Tea and Coffee.**—Tea and coffee are found to stimulate the nervous system, producing slight exhilaration and relieving exhaustion without the subsequent depression that follows the use of alcohol. In excess, however, they produce nervous disorders, and, although the moderate use of them is not harmful to adults, their influence upon the nerves, the most impressionable part of a growing person, renders them unsuitable articles of diet for the young.*

100. **Confectionery.**—Confectionery is not injurious, when pure, unless taken in excess. Unfortunately, it is frequently adulterated, and, instead of containing simply sugar, flour, gum-arabic, and such harmless substances, is mixed with *terra alba* (gypsum), because it is heavy and cheap. Poison-

* Of tobacco, it may be said that, although it is a poisonous weed, and, when first used, produces alarming symptoms of nervous prostration, it is soon tolerated by the system, and becomes a source of great comfort and satisfaction to those who use it habitually. The excessive secretion of saliva, however, in those who chew it, produces extreme thirst, and may thus lead to the habitual use of alcoholic stimulants; while tobacco-smoke, constantly irritating the mucous membrane of the throat and nose, produces chronic catarrh of those parts. It is said that no habitual smoker has a healthy throat. It has been abundantly shown that the habitual use of tobacco stunts the growth, and it should therefore be shunned by the young.

ous coloring-matters are also used. All candy that has a gritty feeling in the mouth should be rejected, and bright-yellow, orange, and green candies are to be looked on with suspicion, for they are almost always colored with chromate of lead.

101. Danger of Parasites in Food.—A word of caution is necessary about the eating of pork. This meat occasionally contains millions of minute parasitic worms, called the *trichi'na spira'lis*, and, if such meat is eaten without killing these worms, they are set free in the alimentary canal, bore their way into the blood-vessels, and are carried by the current of blood all over the body. When they come to vessels so small that they can not pass, they are stuck, dam up the blood-current, interfere with the circulation, and produce serious and often fatal disease. These parasites are killed by a temperature of 160° Fahr., and pork, therefore (including ham, of course), should never be eaten unless it is thoroughly cooked.*

Briefly, then, to keep the stomach healthy, *masticate the food thoroughly, eat when you are hungry, avoid overeating and eating between meals, eat plain food, do not spur the stomach with condiments or appetizers, and use alcoholic drinks and tea and coffee, if at all, with the greatest moderation and caution.*

* The flesh of the pig occasionally contains another parasite, called the *cysticer'cus cellulo'sæ*, which, if taken alive into the stomach, develops into the *tape-worm*. This parasite, like the *trichina*, is killed by thorough cooking.

CHAPTER IV.

INTESTINAL DIGESTION.

102. The Chyme.—After the partially digested food has passed out of the stomach into the intestine, it undergoes still further changes, and the difficulties of investigation in this part of the body are so enormous that very little progress has been made toward a clear explanation of what takes place there. Enough has been learned, however, to give us a general idea of how the process of digestion is completed.

We have seen that the *fats* and the *starches* are not digested in the stomach. The gastric juice does not act upon them at all, and they pass into the intestine in very much the same condition in which they enter the stomach. The fibers and tissues which hold the fats and starches together, being nitrogenous in their nature, are acted upon in the stomach and dissolved, so that the fat is set free and floats in globules like those upon the surface of a kettle of soup. The food thus prepared to pass into the intestine forms a thick, turbid, grayish fluid, called the *chyme*.

103. The Intestines.—The *small intestine*, into which the food passes from the stomach, is a tube about twenty feet in length, and an inch in diameter. It is composed, like the stomach, of three layers, the innermost one being mucous membrane, the middle one muscular fibers, some of which are circular and some longitudinal, and the outer layer serous membrane.*

The small intestine is connected with the large one by a valve-like opening situated in the vicinity of the right groin. The *large intestine* passes from this point upward to the liver, thence across to the left side, and then downward, constituting the last five feet of the alimentary canal.†

104. Muscular Fibers of Intestine.—The *muscular fibers* of the intestine contract with a worm-like motion, which always begins near the stomach, and extends slowly along the whole length of the intestine, gradually emptying it of its contents. In this

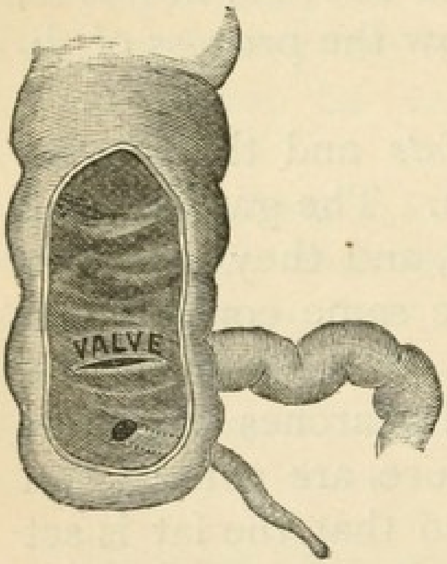

FIG. 27.—Junction of the small and large intestines, and the appendix vermiformis. The large intestine (here called the *cæcum*) is cut away so as to show the internal openings.

* The outer membrane of the intestine of animals, when separated from the rest, is used for sausage-casings, and, when properly prepared, also makes what is called gold-beater's skin.

† The beginning of the large intestine is situated in the right groin, and forms a sort of bag or pouch, called the *cæcum*. From one side of this pouch there projects a slender tube resembling the intestine in structure, and about six inches long. This is called the *appendix vermiformis*, i. e., the worm-like appendage (Fig. 27). In man it seems to be entirely useless, and is in fact a constant source of danger; for occasionally small objects, like cherry-pits and grape-seeds, which are swallowed with the food and not digested, become lodged in it, and gradually produce an irritation which results in an abscess, and destroys life. Such cases are not uncommon in medical practice.

slow passage of the food from the stomach through the small intestine to the large one, it is mingled with various fluids which complete the process of digestion, and the nutritious portions of the mass are absorbed and carried away by the blood and other vessels.

105. **The Duodenum.** — The first eight or ten inches of the small intestine are somewhat larger than the remainder, and are called the *duode'num*, because its length is about twelve fingers' breadth. Into this duodenum empty small canals from two very important organs, viz., the *pan'creas* and the *liver*.

106. **The Pancreas.** — The *pancreas* (Fig. 28),

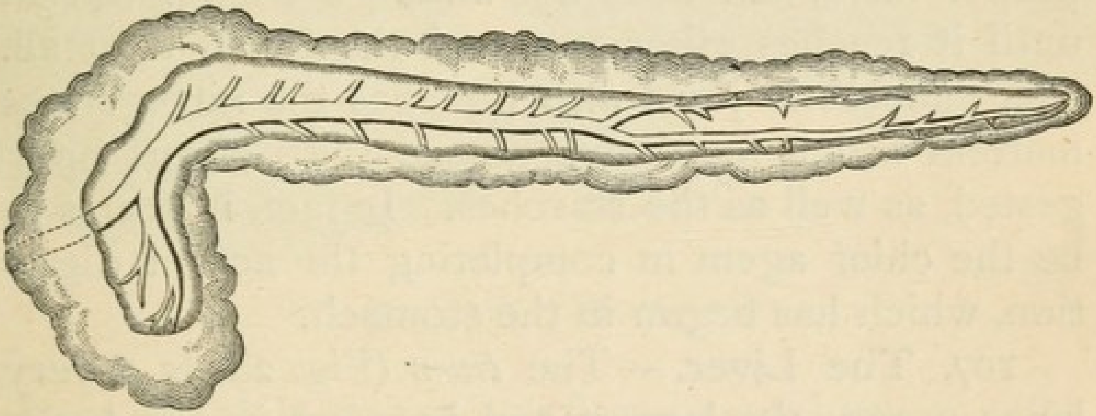

FIG. 28.—The pancreas, partly cut away, so as to show the duct, which collects the pancreatic juice, and empties it into the duodenum.

which we call the *sweet-bread* when we cook it for food,* is about six inches long, is shaped somewhat

* There are three kinds of sweat-breads, viz.: the thyroid-gland, or throat sweet-bread, which is tough, almost like India-rubber; the pancreas, or belly sweet-bread, which is more tender, and is quite commonly used; and the thymus-gland, or breast sweet-bread, which exists only in young animals, wasting away as they grow up. This gland is situated just behind the upper portion of the breastbone, attains its greatest size in human beings at the age of two years, and disappears before the sixteenth year. Its use is not known. This

like a pistol, and is situated behind the stomach, with the large end, or the breech of the pistol, toward the right. It secretes a fluid, called the *pancreat'ic juice*, which has been shown to be the chief agent in the digestion of the *fatty* portions of the food. If a quantity of oil be shaken up with pancreatic juice, a white, opaque, creamy fluid is formed, in which the drops of oil or fat are not visible any more than they are in ordinary milk or cream. Microscopic examination, however, shows that the oil is not in any way decomposed, but is divided into very minute particles, in which condition it can be absorbed by the proper channels. In this way fat is taken up into the circulating fluids in its own proper form, and does not undergo decomposition until it reaches other parts of the body, if at all. The pancreatic juice also liquefies the nitrogenous matters which may have passed the pylorus undigested, as well as the starches. In fact, it seems to be the chief agent in completing the act of digestion, which has begun in the stomach.

107. The Liver. — The *liver* (Fig. 29) is a very large organ, the largest and heaviest in the body, weighing in a healthy adult from three to four pounds, and situated on the right side, protected by the lower four or five ribs. It secretes the *bile*, and from its size, and the amount of its secretion, is evidently one of the most important organs in the body, and yet its precise use is still a matter of dispute and doubt.

108. Liver-Sugar.—It was long supposed that the only function of the liver was to secrete the bile; but

gland, taken from calves and lambs, is the most tender and palatable sweet-bread of all.

it has been found, in recent years, that it also forms a kind of *sugar* in large amount. The blood which enters the liver is found to contain a small amount

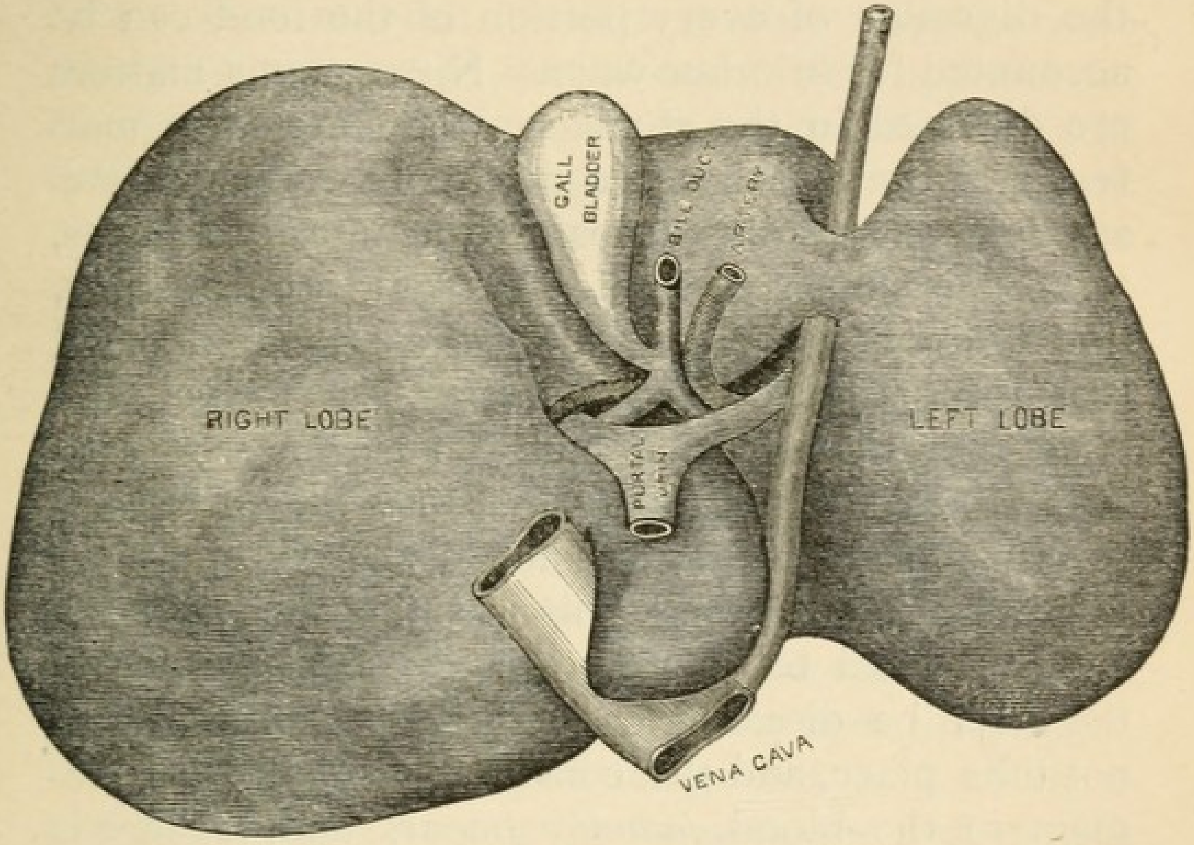

FIG. 29.—Under surface of the liver.

of sugar, while that which flows away from it, after having circulated through it, always contains sugar in considerable quantity. Even this fact, well established as it seems to be, is still a subject of dispute among experimental physiologists.

109. The Bile.—The *bile* is a somewhat glutinous fluid, of a rich, golden-red color,* which is discharged into the duodenum through the same open-

* When vomiting takes place and lasts for a time, the intestines reverse their action, and bile is carried backward through the pylorus into the stomach. It is here out of place, and produces extreme nausea. Its color is changed by the gastric juice to a greenish yellow.

ing with the pancreatic juice.* It must, therefore, become mingled with the food long before digestion is completed. The natural inference from this is that it has something to do with the process; but the digestion of every portion of the food can be accounted for in other ways. Nitrogenous matters are digested in the stomach, while the fatty matters and the starches are digested by the pancreatic juice, assisted, perhaps, by the intestinal juices, to be hereafter spoken of. It would appear, then, that there is nothing left for the bile to do, and that it must be an *excrementitious fluid*— i. e., that it consists of matters which have been separated from the blood by the liver because they are hurtful to the organism, and must, therefore, be expelled from the body. This was the ancient view, and it seemed to be supported by the fact that, if the liver be diseased so that this separation can not take place, and the constituents of the bile remain in the blood, *jaundice* occurs, and, if there is no relief, the person dies with all the symptoms of poisoning. So far, it seems plain enough that the bile has no office to perform in the body, but is only secreted to be expelled. But operations have been performed on animals in such a way that the action of the liver should not be interfered with, and yet the bile should not enter the intestine, but should be discharged outside the body through an artificial opening. Under such circumstances, if

* As soon as the partially digested food, containing a certain amount of gastric juice, passes the opening of the bile-duct, there is a great gush of bile into the intestine. It is found that any acid, applied to this opening, will produce the same effect. The bile, being alkaline, neutralizes the gastric juice, which is therefore of no further use, and so the digestive process has to be completed by other means.

the bile be simply an excrementitious fluid, its discharge from the body by one channel rather than by another ought not to make any difference in the health of the animal. But it is found, on the contrary, that animals treated in this way die with every appearance of starvation. Their appetite remains good, their digestion is not interfered with; but, nevertheless, although they eat ravenously, and are plentifully supplied with food, they become rapidly emaciated and die in about a month. These facts show conclusively that the bile has some important part to play in the nutrition of the body.

It is found, moreover, by actual chemical examination of the excretions, that the bile, although it is discharged into the intestine, does not all leave the body. It must, then, be reabsorbed into the circulation. But, if this be so, why does it not give rise to symptoms of poisoning, just as if it were prevented from leaving the blood in the first place? The only possible answer to this is, that it is somehow changed in the intestine, so that when it is reabsorbed it is harmless.

110. The Intestinal Juices.—Besides the bile and pancreatic juice, the food meets in the small intestine with the *intestinal juices* proper. Of these very little is known with certainty, owing to the great difficulty of obtaining them from the living animal unmixed with other fluids. The small intestine is lined, however, with a mucous membrane containing millions of small tubules and glands, which secrete certain colorless alkaline fluids. Of these fluids it is both affirmed and denied that they possess the property of turning starch into sugar with great rapidity; but, so far as is known, their part in the process of digestion is not important.

111. **Absorption of Food.**—If animals are killed at different times after the eating of food, and different portions of the intestine are examined, it is found that, while the upper portion of the small intestine contains a large amount of partially-digested food, the lower portion contains the shriveled remnants of muscular tissue, the husks of grains, the woody, indigestible fibers of vegetables, etc.; in short, the unappropriated residue of the food which has been taken. The great mass of what has been eaten has disappeared, and after a certain time the whole intestine will be found empty. There are two systems of vessels by which this absorption of food is accomplished—they are the *blood-vessels* and the *lacteals*.*

112. **The Peritonæum.**—To understand the arrangement of these vessels, it is necessary to know something of the *peritonæ'um*. The serous membrane, which has been spoken of as covering the outside of the stomach and intestines, covers to a greater or less extent all of the organs contained in the abdomen, and also lines the abdominal walls. This smooth, satiny membrane is called the peritonæum, and it renders the movements of the abdominal organs possible without discomfort to the rest of the organism. Now, the intestine being, as has been shown, a long, narrow circular tube, or canal, and the peritonæum passing entirely around it, there is a line running the whole length of the

* *Lacteals*, from a Latin word meaning milk, because when they are filled with the products of digestion they look as if they were filled with milk.

intestine, where the membrane becomes double, and this double fold is brought together like the gathers of a dress, and attached to the spinal column. So the intestine is loose in the abdomen, and still has an attachment to the spinal column. Between these two folds, or, in other words, within the double fold, between the two layers of membrane, the blood-vessels and lacteal vessels pass to the intestine (Fig. 30).

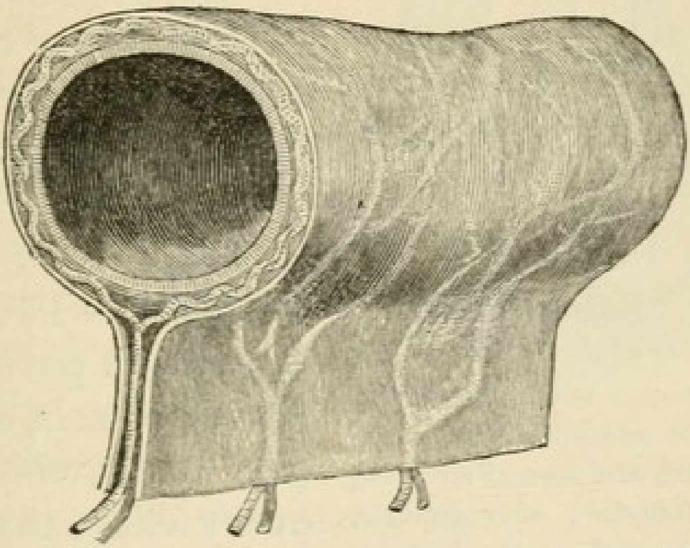

FIG. 30.—Diagram representing a cross section of the small intestine, showing the three layers, and the way in which the blood-vessels pass between the two folds of serous membrane (the peritonæum).

These vessels grow smaller and smaller and more and more numerous as they approach the intestine, and, when they at length enter its walls and penetrate to the mucous membrane, they divide into vessels so exceedingly minute as to be invisible to the naked eye, and fill the interior of the little projections of the mucous membrane, which are called *villi*.

113. The Intestinal Villi.—The *villi* are small projections on the surface of the mucous membrane, about a thirtieth of an inch long, and thickly covering the whole interior of the intestine, there being about ten thousand of them to the square inch, and about four million altogether (Fig. 31). Each villus is covered with epithelium, and in its interior is a complicated mass of blood-vessels, twisted and knotted like a bunch of earthworms (Fig. 32). In the very center of the whole is an open space, which is the commencement of a *lacteal.*

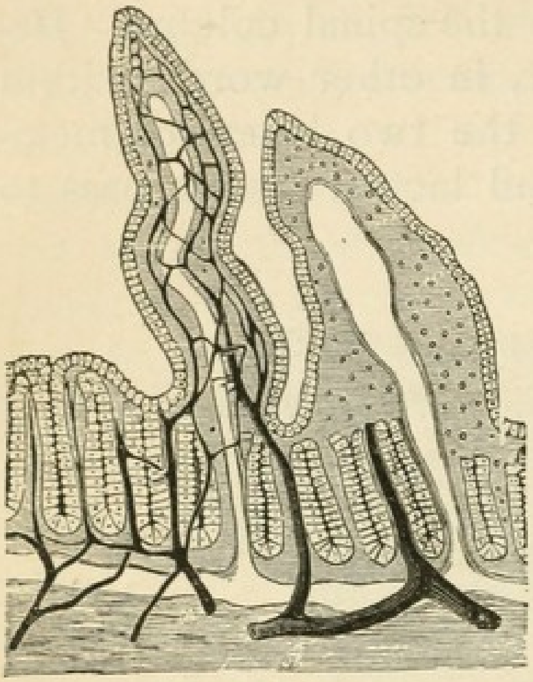

FIG. 31.—Section of the mucous membrane of the small intestine, showing two villi, and several secreting tubes or follicles; also lacteals, blood-vessels, and, at the bottom, the muscular layer.

114. The Lacteal Vessels. — The *lacteals* are only a part of a system of vessels, called the *lymphat'ics,* which extend everywhere throughout the body. The lymphatics all begin in a way that is not clearly understood, and gradually unite to form larger and larger vessels, until their contents are finally discharged into the veins and mingled with the blood. The fluid found in the lymphatics, called *lymph,* is yellowish, transparent, and saltish, and is presumed to be derived in some way from the change constantly taking place in the tissues. At certain intervals in their course, the lymphatic vessels are interrupted by small bodies called *glands,** varying in size from a hemp-seed to

* The lymphatic glands are the bodies that sometimes undergo

an almond, into which the vessels enter, and from which they emerge. Whether they actually pass through the gland, or whether one vessel ends in it and another begins, is still a subject of discussion. But the lymphatic vessels all over the body have great absorbing power, taking up indiscriminately foods, poisons, or the waste of used-up tissues.

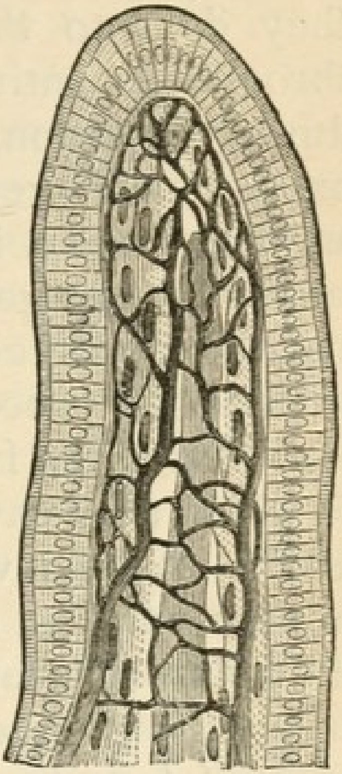

FIG. 32.—Intestinal villus, showing the epithelial cells outside, the blood-vessels, and the beginning of a lacteal vessel.

The *lacteals,* then, are that portion of the lymphatic system which is connected with the small intestine, and all the lacteals from the villi gradually unite to form a vessel called the *thorac'ic duct*, about as large as a goose-quill, which passes up close to the spine, and empties into a large vein very near the heart.*

115. The Portal Vein.—The blood-vessels which absorb the food from the intestines are veins, and they unite with the veins from the stomach, pancreas, and spleen, to form one large vein, called the *portal vein*, which enters the liver, so that all the blood from the digestive apparatus

slow inflammation in persons of a scrofulous tendency, forming hard lumps or abscesses in the neck.

* Many years ago, a man named Calvin Edson became extremely emaciated without any known cause. He was exhibited for a long time as "the living skeleton." After his death it was found that his thoracic duct was completely obstructed, so that none of the contents of the lacteals could pass into the blood. He died, therefore, of fat-starvation—i. e., a complete or almost complete deprivation of fat.

passes through the liver before it enters the general circulation.

116. The Chyle.—The villi, then, projecting as they do into the interior of the small intestine through its entire length, are continually bathed, during digestion, in the nutritious fluid which other organs have prepared for absorption. They float and sway about in this fluid, and suck it up as the roots of a tree get their sustenance from the soil,* and the blood-vessels probably have quite as much to do in the process as the lacteals. The latter absorb mostly the fatty matters in the cream-like form to which they have been reduced by the pancreatic juice. As the walls of the vessels are thin and transparent, the creamy contents, called the *chyle*, show through, and hence arises the white appearance during digestion which has given them the name of *lacteals*.

117. Changes in the Blood during Digestion.—

* The latest researches seem to show that the lacteal begins in the interior of the villus as a sort of hollow space, without any special wall of its own, and that around this space there are small fibers of involuntary muscular tissue. It is believed that, during the process of absorption, these muscular fibers contract at regular intervals. The effect of the contraction would be to pull down the top of the villus toward the base, and thus diminish the size of the hollow space above referred to, and empty its contents into the lacteal vessel. When the fibers relax, and the hollow space expands to its original dimensions, the fluid which has been forced into the lacteal is prevented from being sucked back again by the valves, with which all lacteal vessels are provided. The space is therefore filled again by the fluids which surround the end of the villus in the intestinal canal. In this way, by the alternate and regular contraction and relaxation of these minute muscular fibers, the villus acts like a suction-pump, and the intestine may be looked upon as lined with millions of microscopic suction-pumps, which work away during digestion, pumping the contents of the intestine into the lacteals, by which they are discharged into the blood.

As absorption goes on, the blood becomes more and more loaded with fatty matters, which can easily be recognized in it in the form of minute oily drops, but all of this blood passes through the lungs before it goes to the rest of the body. In its passage through the lungs, the fatty matters disappear in some way, not exactly understood, and the blood which comes away from the lungs contains none. After a time, however, as digestion progresses, the blood is so heavily charged with these oily matters that they can not all be decomposed, and a portion remains and is sent in the general circulation all over the body. If blood be drawn from a man or other animal at this time and allowed to stand, there will be a yellowish, creamy layer on its top.

Presently, however, the fat begins to disappear, as digestion approaches its close; the amount in the blood gradually diminishes, until it is entirely gone, the lymph in the lacteals becomes once more a transparent fluid, and digestion is complete.

118. The Spleen.—At the left extremity of the stomach, just under the ninth, tenth, and eleventh ribs, is an organ which is to this day a great puzzle to physiologists. It is called the *spleen*, and is about five inches long, four wide, and an inch thick. It is reddish in color, soft and pulpy in texture, with a very tough and strong fibrous covering. It receives its blood from a very large artery, and its vein, which carries away the blood from the organ, joins the portal vein, so that the blood from the spleen, like that from the other organs of digestion, passes through the liver, before it reaches the heart. The spleen is large in well-fed animals, and very small and shrunken in starved ones, while in some cases of disease, such as fever and ague, it reaches the enormous weight of twenty pounds, and forms an immense hard tumor in the left side.

The facts just stated would seem to imply that the spleen has some important office to perform in digestion, but what that office is no one has been able to discover.* It is a singular fact that the spleen may be entirely removed from animals without permanent injury to their health. This operation has often been done to dogs, and the animal recovers from the wound very rapidly. He shows, however, an enormous increase of appetite, usually gains considerable flesh, and acquires an unnatural ferocity of disposition. These things, however, do not seem to indicate that any particular function has been lost to the body, and the uses of the spleen are still a subject of earnest investigation.

* The most reasonable theory about the spleen at present seems to be that it has something to do with the destruction of old and worn-out blood-corpuscles and the formation of new ones.

CHAPTER V.

THE BLOOD.

119. The Blood.—After the nutritious portions of the food have been taken into the blood, they pass through the lungs before they go into the general circulation. Before we consider the respiration, however, it is necessary to know something of the circulating fluid.

The *blood* is a thick, opaque fluid, varying in color in different parts of the body from a bright scarlet to a dark purple or even almost black. It has a somewhat viscid feel, a faint odor peculiar to itself, and a saltish taste.

120. The Red Blood-Corpuscles.—If a drop of blood be placed under the microscope,* immense numbers of small bodies will be seen, which are called the *blood-corpuscles* (Figs. 33 and 34). They are very minute, averaging only $\frac{1}{3500}$ of an inch in diameter, and are flattened in their shape. They may be described as looking like a cylindrical ring, the center of which has been filled up, but not quite to the level of the border, so that there is a slight depression on each flattened side. Taken singly,

* Prick the end of the finger with a pin. The most minute drop of blood is sufficient. Put it on a glass slide under a thin glass cover, and place it under a microscope.

these bodies, called the *red blood-corpuscles*, are of a light amber color, but in a large mass they give the characteristic red color to the blood. They vary somewhat in size in different animals, those of the monkey approaching most nearly to those of the human being. In birds, reptiles, and fish, they are very much larger, and instead of being circular are oval (Fig. 35).* They also have a distinct nucleus.

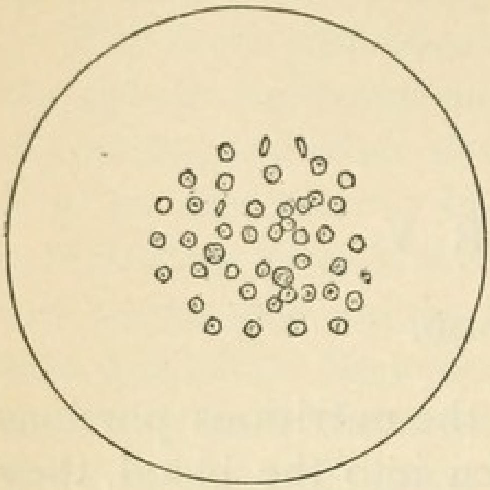

FIG. 33.—Human blood-corpuscles, including two white ones.

It is mainly by these microscopical differences that the blood of different animals can be distinguished

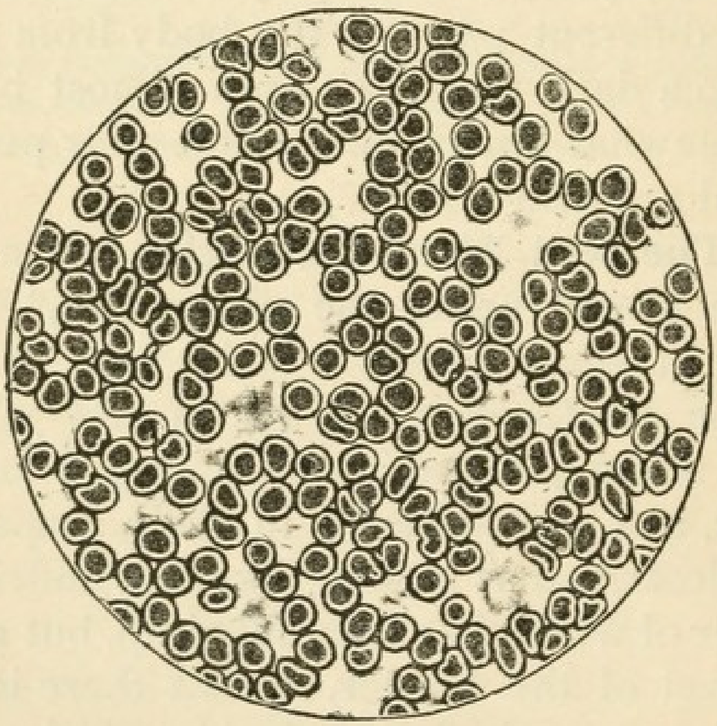

FIG. 34.—Human blood-corpuscles (highly magnified). From a photograph.

* The blood-corpuscles of the camel tribe are also oval, but smaller than those of birds.

from that of man, as is sometimes necessary in trials for murder.

121. **The White Blood-Corpuscles.**—The blood also contains *white* corpuscles in the proportion of one white corpuscle to three hundred red ones. They are larger than the red, are perfectly colorless, and globular in their form. The white corpuscles, under proper conditions, are seen to be continually changing their form, almost like living animals. There have been many speculations as to their office in the body, but nothing definite has been ascertained. In certain diseases, however, they are found to increase enormously in number, and some of these diseases are among the most dangerous and difficult to treat of any the physician meets with.

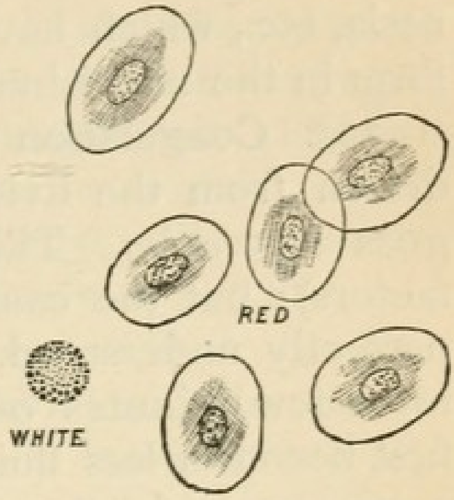

FIG. 35.—Blood-corpuscles of the frog.

Although the blood-corpuscles are so very minute, they exist in such enormous numbers that they are estimated to compose half the mass of the blood.

122. **The Plasma.** — The fluid portion of the blood, in which these small bodies float, is called the *plasma*. It is almost colorless, quite transparent, and is nine tenths water. Its two most important ingredients are *albumen* and *fibrin*.* The

* It is now believed that fibrin does not exist, as such, in fluid blood, but that there are certain substances (known as *fibrino-plastin* or *paraglobulin, fibrinogen, and fibrin-ferment*) which, by their inter-

former of these is chiefly concerned in nutrition, and the latter brings about the remarkable phenomenon known as *coagulation*. The plasma also contains various compounds of lime, soda, magnesia, etc., which have their own functions to perform in the nourishment of the body.

123. Coagulation of the Blood.—If blood be drawn from the living body, it very soon undergoes *coagulation*. This is due to its fibrin (or fibrin-factors); but the cause of the change is very imperfectly understood. After the blood has stood for a few minutes outside the blood-vessels, it at first becomes less fluid and assumes somewhat the appearance of jelly. Shortly the fibrin begins to contract and occupy a smaller space, gradually squeezing out the portion of the blood which still remains fluid. This mass which separates from the rest of the blood is called the *clot*, and the remainder, or still fluid portion, is called the *serum*. The contraction of the clot continues for several hours, until it forms quite a firm mass of a deep-red color, the remaining fluid being transparent and nearly colorless.

The red color of the clot is due to the fact that the red corpuscles become entangled in the coagulated fibrin, and, being semi-solid in consistency, they remain there and are not pressed out with the serum. It will be noticed that the *serum* is not the same as the *plasma*. The *latter* includes the *fibrin* (or fibrin-factors), while the *former* is *without it*.

124. Coagulation under Varying Conditions.—It is found that the blood coagulates more rapidly in

action, produce fibrin, and so cause coagulation. The evidence for this view is of too abstruse a nature to be given here.

thin layers than in a large mass; in a vessel or on a surface which is rough than in one which is smooth. For this reason the blood flows longer from a smooth cut in the body than from a wound with torn and ragged edges. In the latter case the blood coagulates very rapidly and stops the hemorrhage.

But the coagulation of the blood takes place not only outside the body, but, under similar circumstances, inside, though not always with equal rapidity. If a vessel bursts inside the body, and blood escapes into the tissues around it, coagulation takes place after a short time; and this occurs even inside the blood-vessels, if there be any obstruction to the circulation. If an artery or vein be compressed by a string or wire or finger, the blood will soon coagulate in the vicinity of the pressure. These facts have suggested the means used by surgeons to stop the flow from a bleeding wound, and will be referred to again.

125. Total Amount of Blood.—The *total amount of blood* in the human body is believed to be about *one twelfth* of the *whole weight* of the individual. Thus, in a man who weighs one hundred and fifty pounds there will be about thirteen pounds of blood, or somewhat more than a gallon and a half.

126. Oxygen in the Blood.—This rich, nutritious fluid is forced to all parts of the body in a way hereafter to be described, carrying food to exhausted tissues and removing the used-up matters. A large part of the material necessary for the growth and nourishment of the body is taken in through the digestive organs; but there is a gas absorbed by the blood, in its passage through the lungs, which is even more necessary to life than food. This gas is *oxygen,* which constitutes about one fifth of the atmosphere, and is essential to the life of all animals, probably without exception. We can live for days without food, but we can not live ten minutes without oxygen. Even water-animals are not exempt from this law; for fish extract the air, which is in solution in the water, by passing it through their gills. If a dish of water containing a fish be placed under the receiver of an air-pump, and the air be exhausted from it, the fish will be as surely drowned as a man would be if held under water. This is the reason why fish which are kept as pets in aquaria need fresh water continually. If a jet of water be kept falling into the vessel in which they live, so as to drag down bubbles of air, the water need never be changed, except for cleanliness.

127. **Varying Color of the Blood.**—The blood which enters the lungs is very dark, and sometimes almost black. When it has passed through the lungs, and flows away, it is of a bright scarlet. It has lost certain substances and gained others during this passage, and this beautiful and surprising alteration is produced by what is called the process of *respiration.*

CHAPTER VI.

RESPIRATION.

128. Respiration a Complicated Process. — At first sight, the process of respiration is a very simple one, consisting merely in the inspiration and expiration of air. In reality, however, it is complicated—certain very essential parts of it going on without our consciousness, like so many of the phenomena of digestion. The organs mainly concerned in the acts of respiration are the lungs; but there are certain additional organs, whose functions, if not absolutely necessary, are certainly important.

129. The Nasal Passages. — The air, before reaching the lungs, goes through several passages, lined throughout with mucous membrane. The human being can breathe through either the nose or the mouth; but in some animals (the horse, for instance) respiration only takes place through the nose, and, if this be closed, suffocation follows. The external openings of the nose are guarded by short, stiff hairs, which grow just inside the nostrils, and which serve to purify the air somewhat, as it passes through them, by catching and retaining particles of dust. The interior of the nose is so formed that it is not a large, open, free passage, but has a number of projecting bones, running lengthwise along its walls, which are covered with moist membrane and present an extensive mucous surface to attract particles from the air. If we breathe through the mouth, on the other hand, the air goes directly to the throat, and the cavity of the mouth is so large that the purifying effect of the moist membrane is hardly perceived. This shows how much better it is to breathe always through the nose; for the air, undoubtedly, in this way, is rid of many impurities; and physicians habitually, and almost unconsciously to themselves, keep their mouths shut as much as possible when they are exposed to a contagious disease.

From the nose the air arrives at the throat, and thence it passes into the windpipe, or trachea, through a small opening called the glottis.

130. The Trachea.—The *tra'chea* (Fig. 36) is a tube about four and a half inches long and an inch wide, which divides at its lower extremity into two smaller tubes called *bronchi*, one of which goes to each lung. It is mainly fibrous in its structure, and it is kept open to its full extent by a number of rings of cartilage, placed at a short distance apart through its whole length. The trachea is situated in the neck just in front of the œsophagus, and as these stiff rings might press backward on the œsophagus, and thus interfere with the process of swallowing, they do not pass completely around the trachea, but are lacking in the part next the œsophagus, comprising about one third of the whole circumference of the tube. At the upper extremity of the trachea is the *lar'ynx*, or the organ of voice, which is essentially a triangular-shaped box of cartilage, the lower end opening freely into the trachea, and the upper being closed by muscles and membranous tissues, with the exception of the opening of the glottis.

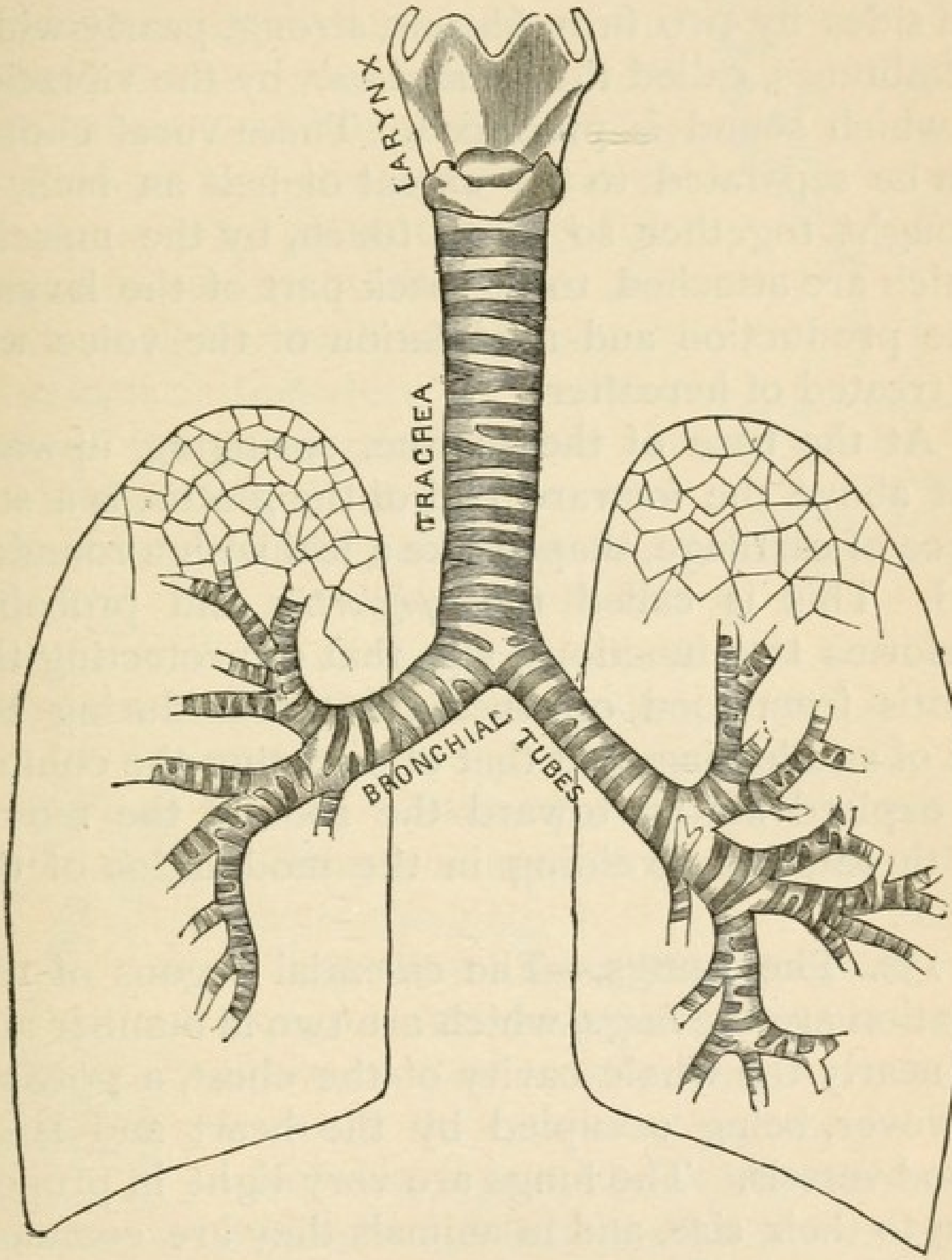

FIG. 36.—Larynx, trachea, and bronchi, showing the manner of division, and the rings of cartilage.

131. The Glottis.—The *glottis* is a slit-shaped opening, a little less than an inch long, extending from before backward and from above downward, not being, in other words, either perpendicular or horizontal in the throat, but shelving toward the rear. The front extremity is at the base and back of the tongue, and the opening itself is bounded at the sides by two firm, fibrous, strong, pearly-white membranes, called the *vocal chords*, by the vibration of which sound is produced. These vocal chords can be separated to the extent of half an inch, or brought together so as to touch, by the muscles which are attached to the back part of the larynx. The production and modulation of the voice will be treated of hereafter.

At the base of the tongue, springing upward just above the forward end of the glottis, is a stiff piece of cartilage, shaped like a leaf with a rounded end. This is called the *epiglottis*, and probably performs two functions, viz., that of protecting the glottis from food or other substances during the act of swallowing, and that of directing the column of expired air up toward the roof of the mouth or throat, and so aiding in the modulation of the voice.

132. The Lungs.—The essential organs of respiration are the *lungs*, which are two in number and fill nearly the whole cavity of the chest, a portion, however, being occupied by the heart and large blood-vessels. The lungs are very light in proportion to their size, and in animals they are commonly called "the lights." They weigh together only about two pounds and a half, and easily float in water. In small children they are of a beautiful pinkish color, but in older persons they become slate-colored, and have black spots scattered here and there over their surface.

133. Minute Divisions of the Lungs.—After the trachea divides into two bronchial tubes, one of which goes to each lung, these bronchial tubes continue to subdivide into smaller and smaller tubes, all the branches diverging widely from each other, until their diameter is diminished to about $\frac{1}{20}$ of an inch. At about this point the cartilage rings disappear, but the tubes still divide until the smallest are only $\frac{1}{50}$ of an inch in diameter. At the very ends of the smallest tubes, there is an enlargement about $\frac{1}{12}$ of an inch in diameter, called a *pulmonary lobule* (Fig. 37). It constitutes a small cavity, into which dip little partitions, that do not meet each other, but create minute hollow spaces around the sides of the lobule, called *pulmonary vesicles.* These are about $\frac{1}{75}$ of an inch in diameter, and are the smallest divisions of the lung.

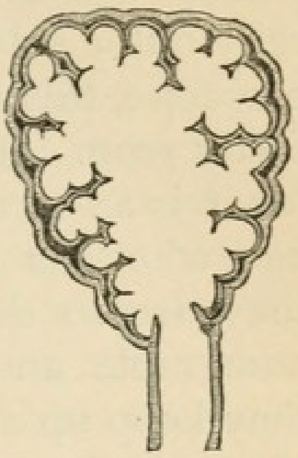

FIG. 37.—Section of a pulmonary lobule, showing its division into pulmonary vesicles.

134. The Lining Membrane of the Lungs.—All these tubes and passages, down to the most minute, are lined with a delicate mucous membrane, which has this remarkable peculiarity. The little epithelial cells with which all mucous membranes are covered, have in this situation what are called *cilia* at their ends (Fig. 38). That is to say, each cell has at its tip a fine, hair-like lash, which keeps in constant motion, as long as the person lives, and for some time

FIG. 38.—Ciliated epithelium from a small bronchial tube. The small round cells at the bottom are young ones.

after he is dead. If a piece of the mucous membrane from a frog's throat be snipped off with a pair of scissors, and then doubled with the naturally outer side outward, and placed under the microscope, this incessant motion of the cilia may be easily seen. It is an experiment well worth trying, for it is an astonishing and beautiful sight even to one who has often seen it. The cilia, although they are so delicate in their structure, are so innumerable and act in such perfect concert, that they keep up a constant current toward the outside of the body. They probably aid in the expulsion of the foul gases which the blood leaves in the lungs.

135. **Asthma.** — The smaller bronchial tubes, which have no rings of cartilage, are nevertheless surrounded by involuntary muscular fibers. When, in consequence of disease, these fibers contract strongly, they diminish the caliber of the tubes, and render it very difficult sometimes for the sufferer to get air through them in either direction. This condition gives rise to great distress and a sense of suffocation, and is called *asthma*.

136. **The Blood-Vessels of the Lungs.**—Between the pulmonary vesicles run the small blood-vessels immediately under the delicate mucous membrane, so that the blood comes almost in contact with the air that we breathe. They surround the vesicles completely, and it is in this part of the lung that the great changes take place in the blood during respiration.

137. **The Outer Covering of the Lungs.**—The outside of the lung is covered by serous membrane, and so is the inside of the chest-wall. This renders

the movements of the lung painless and easy. This membrane is called the *pleura*, and when it becomes inflamed, in the disease known as *pleurisy*, respiration becomes excessively painful.

138. Inspiration.—As the cavity of the chest is enlarged, the air already in the lungs is rarefied, and the external atmospheric pressure forces air in to fill the organs. We have already stated that the ribs are so shaped, and so connected with the spine behind and the sternum in front, that when they are raised up toward the shoulders the sides move outward, and the sternum moves forward. This motion of the ribs is caused partly by powerful muscles attached to their external surface all the way down the chest, and partly by short muscles which pass between the ribs from the lower edge of each one to the upper edge of the one just below it.

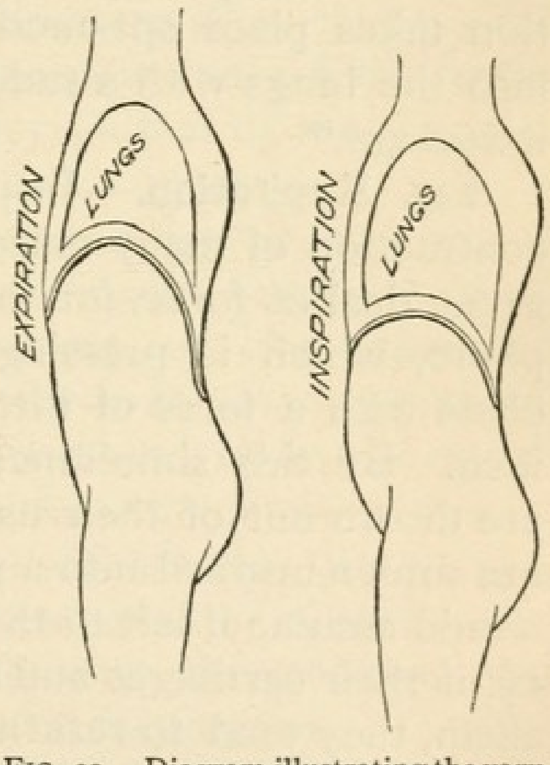

FIG. 39.—Diagram illustrating the varying position of the diaphragm during respiration.

But, in addition to its expansion toward the front and sides, the cavity of the chest is enlarged in a downward direction by the contraction of the *diaphragm* (Fig. 39). This muscle has a strong, flat, tendinous center, from every side of which strong muscular fibers pass to the walls of the chest. It separates the chest from the abdomen, and while the muscular portion of it is attached to the lower ribs, the spine and the very end of the breastbone, the center rises much higher in the chest, so that it has the shape of a vaulted roof, on top of which are the lungs and heart, and underneath the stomach and liver. Of course there are passages through it for the blood-vessels and nerves, but these openings are so guarded that the diaphragm forms a tight partition. Now, as the center of the diaphram rises so much higher than the sides, it is very evident that a contraction of the muscular fibers will pull the center downward, and so increase the capacity of the chest. And this is what actually occurs at every inspiration. When this contraction takes place spasmodically, the air is drawn into the lungs with a sudden impulse, and we call it *hiccough*.*

139. **Expiration.**—Inspiration then involves a contraction of many muscles, and they act with a great deal of force, for they have to lift the atmosphere, which is pressing on the outside of the chest with a force of fifteen pounds to the square inch. By this simultaneous contraction, the ribs are drawn out of their natural position—i. e., they are drawn upward into a position which they never would assume if left to themselves. By the elasticity of their cartilages and other tissues attached to them, they tend to return to their former position as soon as the force which has drawn them out of

* *Hiccough*, being due to a spasmodic action of the diaphragm, may be stopped by any means that tends to control the spasm. The easiest method is to put the diaphragm on the stretch, as follows: prolong the act of expiration as much as possible, and at the end make a forcible expiration; then inspire slowly and take as full an inspiration as possible. It is rare that a second trial will be necessary.

it ceases. The diaphragm, also, when contraction stops, tends to recover its former arched shape. The lungs also contain, in addition to the elements already mentioned, a large amount of elastic fibers, interlaced with the other tissues in every direction. These, too, as soon as the pressure which has stretched them ceases, tend to return to their former condition. This elasticity of the different organs concerned in the act of respiration, then, brings the chest and lungs back to the condition in which they were before inspiration began. This is the ordinary act of *expiration*.

140. Relative Force of Inspiration and Expiration.—As we usually breathe, then, the act of inspiration is an active one, requiring effort and powerful muscular contraction, while the act of expiration is passive, and is accomplished by the elasticity of the tissues.*

Under other conditions, however, the act of expiration may be more powerful than that of inspiration. There are strong muscles connected with the chest in such a way as to act in opposition to the muscles of inspiration, and make the cavity of the chest smaller than it ordinarily is. It is by the active contraction of these muscles that we produce what is called a forced expiration, which has been estimated by careful observers to be one third more powerful than a forced inspiration.

141. Amount of Air respired with Each Breath.

* The outer surface of the lungs is kept in contact with the chest-walls by atmospheric pressure. If the chest-wall be punctured, so that the air-pressure is the same both outside and inside of the lung, the elasticity of the organ is such that it immediately collapses, driving out all the air from its interior.

—The *amount* of *air* taken into the lungs with each inspiration is about *twenty cubic inches*. Now, the entire capacity of the lungs varies in different persons from one hundred and fifty to two hundred and fifty cubic inches or even more. So that with each breath, a very small amount, generally not one tenth, of the air in the lungs is changed. It is even estimated that after the most forcible expiration possible, at least one hundred cubic inches of air will remain in the chest of a man of medium size, which can not be expelled. In ordinary breathing, therefore, only the air in the larger bronchial tubes can pass in and out of the lungs. But the changes in the blood must be produced at the extreme end of the finest tubes in the pulmonary vesicles. So the question arises, How does the air get to the vesicles?

142. How the Air in the Lungs is changed.—In the *first* place, the law of the *diffusion of gases* comes in play. When two gases come together, they tend to mingle with each other until they finally occupy equally the whole of the vessel or other confined space in which they may be. After the mixture, each gas will be found in the same proportion in every part of the vessel. Now, the air in the pulmonary vesicles and smallest bronchial tubes is heavily loaded with carbon dioxide (carbonic acid), while that which is drawn in with inspiration is rich in oxygen. These two gases, then, carbon dioxide and oxygen, are constantly being diffused throughout the whole of the lungs. In the *second* place, the cilia, which have already been described, being in constant motion, keep up a current of the foul air from the pulmonary vesicles along toward the larger bronchi and trachea, and fresher air keeps constantly pressing in to fill the place of what has been in this way removed. Thus, in the smallest bronchial tubes, there are always two currents of air passing each other in opposite directions: one, immediately next the mucous membrane, being a thin layer moving outward; and the other, in the center of the tube, moving inward (Fig. 40). So that the air in the larger bronchi and trachea is changed periodically by the acts of inspiration and expiration, while the circulation of the air in the small bronchial tubes and pulmonary vesicles is continuous.

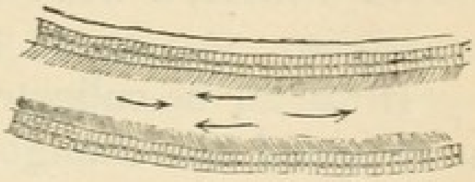

FIG. 40.—Imaginary section of a small bronchial tube, showing the influence of the cilia in producing an outward current of air.

143. Amount of Air respired daily.—The amount of air taken in with every inspiration is about twenty cubic inches. The average number of respirations per minute is eighteen. This is a matter which varies very much with the individual. Children and women breathe somewhat more rapidly than men; but taking eighteen as the average, the quantity of air breathed per minute is three hundred and sixty cubic inches, or about one fifth of a cubic foot. In an hour, then, we use about twelve cubic feet of air, and in a day nearly three hundred cubic feet. This amount is increased by every muscular exertion, and also by the curious fact that the ordinary respiration does not seem to be altogether sufficient for the needs of the body, and every now and then we draw a deeper breath than the average. This occurs usually about once in every five or six acts of respiration. Considering the increase in the amount of air respired at each long breath, and the increase of rapidity of respiration due to slight causes during the day, it is estimated that an adult really respires about three hundred and fifty cubic feet of air per day.

144. Changes produced in the Air by Respiration.—When the air enters the lungs it contains nearly 21 per cent of *oxygen* and 79 per cent of *nitrogen*, with about one twentieth of one per cent of *carbon dioxide*, a little *watery vapor*, and a trace of *ammonia*.

If the air be collected at expiration, after having undergone the changes in the lungs, we find the following:

1. *It has lost oxygen.*
2. *It has gained carbon dioxide.*
3. *It contains more watery vapor.*

The watery vapor in the expired air is not ordinarily visible, but in cold weather, when it becomes condensed, it can be very plainly seen. The whole amount of water passed away daily in the breath of a man has been carefully estimated, and found to average about one and one sixth pound avoirdupois.

145. Former Theory about the Formation of Carbon Dioxide.—Out of the four cubic inches of oxygen taken into the lungs with each inspiration, one cubic inch disappears. The *carbon dioxide* which is exhaled from the lungs consists of carbon and oxygen united in certain proportions, and it used to be supposed that the carbon in the blood united with the oxygen of the air in the lungs themselves, forming carbon dioxide, and that in this way the carbon, released by the wear and tear of the body, was got rid of. Now, the process of *combustion* in a flame of any kind consists in this same change, viz., the union of the carbon and hydrogen of the oil or other inflammable substance with the oxygen of the surrounding air, forming carbon dioxide and water, and giving out heat during the process. So it was for a long time thought that the lungs were a sort of furnace in the body, where the carbon and hydrogen of the blood were burned, so to speak, and the products of combustion exhaled, while the heat occasioned by the process kept up the warmth of the body. This was a beautiful theory, but it is found not to be warranted by the facts.

There is *more oxygen absorbed* in the lungs, with every respiration, *than is exhaled* in the carbon dioxide and watery vapor taken together. This fact of itself disproves the above theory, for it shows that a portion of the oxygen disappears in the lungs, or is carried away by the blood.

146. Organic Matter in the Breath. — Besides the carbon dioxide given off in the expired air, there is a certain amount of organic matter, containing nitrogen, which gives the breath a slight but peculiar odor. Where many persons are breathing in a badly ventilated room, this organic matter accumulates, and imparts to the atmosphere that odor which we all recognize as peculiarly oppressive and close.

147. Changes in the Blood during Respiration. —The blood undergoes changes in its passage through the lungs which correspond to the changes in the air. In the first place, it is altered in its color. As it enters the lungs, it is of a deep bluish purple, almost black; as it emerges, it is of a beautiful and most brilliant scarlet. On chemical examination, to determine the cause of this remarkable change, it is found that the blood which comes away from the lungs contains more oxygen and less carbon dioxide than that which enters them. Additional proofs that the formation of carbon dioxide does not take place by direct combination in the lungs are the facts that the venous blood, before it enters the lungs, is deeply charged with carbon dioxide already formed, and that the blood which comes away from the lungs contains oxygen in free solution.

The brilliant color, which is the result of this change in the blood, has not yet been satisfactorily accounted for. It has been proved that the oxygen and carbon dioxide are carried by the blood-corpuscles, and not by the plasma, and the change of color in the blood is entirely due to the change in those minute bodies. They have been said to change their shape and become more globular in one case than in the other, but the attempts to explain the difference of color have not yet been entirely successful.*

148. Where the Carbon Dioxide is formed.—If the carbon dioxide is not formed in the lungs, then where does it come from? Experiments of the most ingenious kind have been performed to determine this question, and they are too long to

* The coloring-matter of the red corpuscles is called *hæmoglobin.* It is found that this substance, when united with an excess of oxygen, forming oxyhæmoglobin, has a bright scarlet color, and, when the amount of oxygen is greatly reduced, is of a dark purple. But this does not explain much.

mention in detail. But it has been conclusively shown that most of the carbon dioxide is formed in the tissues in all parts of the body, during the processes of nutrition. And even here it is not produced by a direct combination of the oxygen with the carbon, for the exhalation of carbon dioxide will continue for a considerable time in an atmosphere of hydrogen, where of course there is no oxygen furnished to the tissues. The carbon dioxide, then, is formed by decomposition of the tissues, and the oxygen is used by them to build themselves up again.* The amount of carbon dioxide given off in the breath has been found to be somewhat less than one cubic inch, or about fourteen cubic feet per day, weighing about a pound and a half, and representing waste of the organism to about this amount.

149. Composition of Air.—Air being so essential to life, it is evidently important to have it as pure as possible. It must contain enough oxygen, so that with each respiration the temporary needs of the body may be satisfied, and should contain no substances which are injurious to life or health. Now, the air normally contains about four parts of nitrogen to one of oxygen. It always contains a small amount of carbon dioxide, and a variable quantity of watery vapor.† It is also never found

* It will be understood that the place of the carbon which is lost to the body in the carbon dioxide which passes off by the lungs, is supplied by the fresh material taken in with the food.

† This watery vapor is a very necessary constituent of the air. Out-of-doors the amount of it is regulated in ways beyond our control; but in-doors, unless special care is taken, the air may be so dried by artificial heat, that when respired it will absorb more than the ordinary amount of moisture from the mucous lining of the lungs. Then the

entirely free from impurities, such as other gases than those named, in small quantity, and minute floating particles of matter, which we group together under the common name of dust.

It has been shown, however, that the breathing of animals is continually removing oxygen from the air and increasing the amount of carbon dioxide. Now, carbon dioxide is a poison to animals, and if inhaled in large amount produces almost immediate unconsciousness and death. It is for this reason that it is being constantly rejected from the body. If this process of removing oxygen from the air and adding carbon dioxide to it were to go on indefinitely, it is evident that after a time the one would be so much reduced in amount, and the other so much increased, that animals would die of carbon-dioxide poisoning—i. e., of asphyxia.

150. Respiration of Plants. — This danger is guarded against in the outer atmosphere by the constant absorption of carbon dioxide by plants. All plants, through their leaves, decompose carbon dioxide into its original parts, carbon and oxygen. The carbon they appropriate for their own nourishment, and the oxygen they return to the atmosphere. Thus the respiration of plants is exactly the reverse of that of animals. The latter absorb oxygen and give out carbon dioxide, and the former absorb carbon dioxide and give out oxygen.

mucous membrane becomes dry, there is an increased flow of blood to the part, and, if the dryness of the air is not remedied, inflammation may result—i. e., a catarrh. For this reason a vessel of water should always be kept on the top of a heated stove or furnace, that its evaporation may insure sufficient moisture in the air to prevent injury to the lungs and throat.

By this never-ending interchange the proportions of oxygen and carbon dioxide in the atmosphere are kept about the same.

151. Contamination of the Air in Houses.—Indoors, however, there is no opportunity for this self-purification. Even if a few plants are kept in the house, the amount of carbon dioxide they consume is very little, and the effect they are able to produce toward purifying the room can not be compared with that of the immense stretches of forest and plain out-of-doors. Moreover, the amount of carbon dioxide in houses is increased by combustion. A five-foot gas-burner throws out as much carbon dioxide as five men. The unhealthiness of a closed room is also increased by the organic matter of the breath, which is very poisonous.* The odor of this matter is perceptible in a room long before the accumulation of carbon dioxide reaches a point when it is likely to be injurious. It is, therefore, to be looked upon as by far the most dangerous impurity in the atmosphere of an occupied room.

152. Ventilation.—In order to forestall any evil result from such impurities, the air of a room should be changed frequently enough to prevent the odor of this organic matter from being perceptible. This usually requires some special attention, and is called *ventilation*. In warm weather, all that is necessary is to open the doors and windows and allow the air to circulate freely through the house. But in cold

* The composition of this organic matter is not known. It is given off in such small quantity that the chemists have never been able to analyze it. It putrefies rapidly after it has left the body, and then becomes very offensive.

weather more care is required. A fireplace, with an open fire, is an excellent means of drawing out the foul air—sending it up the chimney, and so out of the house. The fresh air, to supply the place of what has been thus removed, may come in through cracks in the windows and doors. But the fresh air admitted in this way in cold weather, being heavier than warm air, falls and sweeps along the floor. This is very dangerous, for few people can endure a cold draught on the feet and ankles, while the rest of the body is warm, without taking cold. Moreover, the smallness of the apertures through which the air comes increases the rapidity of the current. It is better, therefore, to let in the fresh air through a special opening, so arranged that the cold air shall not immediately fall to the floor. This can be done cheaply and effectively by raising the lower sash of the window about four inches, and putting underneath it a board, fitted to close the opening tightly between the sash and the sill. There will then be a long, narrow opening between the upper and lower sash, through which air will enter in a current directed upward toward the ceiling, and, before it descends, its momentum will be so much diminished that it will not create a draught. In very cold places, where double windows are used, the same result may be obtained by raising the lower outer sash a little, and lowering the upper inner one. The best way, however, is to warm the fresh air before it enters the room; but this is too large a subject for discussion here.

This foul organic matter from the lungs of animals, when it gets out into the open air, is immensely diluted, and, being acted upon by the oxygen of the atmosphere, is changed into other and less harmful substances, which, in their turn, are washed down by the rain and become a part of the soil.

153. **Contagious Diseases.** — The air is not only polluted by these products of the respiration of healthy animals, but it is made unfit for breathing, in a way involving still more danger to life, by the matters given off from the lungs and bodies of sick persons. There are certain diseases which are called *contagious* or infectious, because they can be communicated from one person to another. Such diseases are small-pox, measles, scarlet fever, typhus fever, diphtheria, and perhaps consumption.* It is known that the matters contained in the air expired from the lungs, or, in some cases, specks of matter cast off from the skins, of persons sick with these diseases, will produce similar diseases in persons who inhale them. Exactly what it is that reproduces the disease is not known, but there is believed to be a *microscopic organism*, peculiar to each disease, which, like a kind of seed, will always produce that disease by its own growth and multiplication whenever it meets with proper conditions. Whether these little organisms ever grow and multiply outside of the body we do not know, but that they do so in the blood we have abundant evidence.†

* Whooping-cough, mumps, and chicken-pox, are propagated in a similar manner, but are less dangerous.

† It is thought by some that malarial fevers (fever-and-ague, etc.) are produced by microscopic organisms of this kind, but this is uncertain. It is well for those who live in districts where such diseases are prevalent to remember that the poison, whatever it may be, is most active in the spring and fall, at night, and near the surface of the ground. In such a region, and at such a season, therefore, people should not go

There are other diseases which are believed to be produced by similar organisms growing and multiplying in the discharges from the stomach and bowels. Such organisms are believed to grow outside the body as well as inside, and are supposed to be the cause of Asiatic cholera, typhoid fever, and yellow fever.*

154. Precautions against such Diseases. — It is probable that all of these microscopic organisms (called bacteria, bacilli, micrococci, etc.) which float about in the atmosphere, if they do not find a favorable place in some animal body, where they can grow and propagate their kind, finally die. If it were not so, the human race would be exterminated by them. But men have two ways of dealing with them so as to prevent their spreading. One is to separate the sick person from well ones, as far as possible, and the other is to kill these little organisms as fast as they leave the body and before they can get out of the room. This is accomplished by the use of powerful drugs, called *disinfectants*.

Nurses and doctors adopt special means of warding off infection, or are willing to expose themselves

out after sundown, should keep their bedroom-windows closed, and should sleep above the first story.

* The discharges from the bowels and kidneys of healthy persons, even, are believed to become dangerous when they decompose, and to cause serious diseases. Microscopic organisms multiply in them with great rapidity, and are disseminated in the surrounding atmosphere. For this reason, it is desirable that such matters should be removed from the vicinity of dwellings as quickly as possible. When they are discharged into sewers, their decomposition produces various gases—some of them very offensive—which are popularly known as sewer-gas, but should more properly be called, collectively, sewer-air. The most dangerous thing about sewer-air, however, is not the offensive gases, but the little organisms that float out with it into the streets or houses.

to the risk necessary for the proper care of the sick. If it becomes the duty of any other person to enter a sick-room, he should have in mind the following points: that the nose, on account of its narrow passages and extensive moist surface of mucous membrane, acts as a sort of filter, so that many impurities of the air are detained there and never reach the lungs, whereas, through the mouth, there is a straight and almost unimpeded course to those organs; that the body is less able to resist injurious influences of every kind when it is fatigued or in want of a fresh supply of food; and that matters escaping from the bodies of the sick and floating in the air are likely to settle on articles standing in the room. Hence we deduce the following rules:

Never enter a sick-room when you are hungry or tired.

Always keep your mouth shut, except when talking.

Never eat or drink anything that has been standing in the sick-room.

CHAPTER VII.

ASPHYXIA.

155. Asphyxia.—When the blood is deprived of its constant fresh supply of oxygen, the carbon dioxide produced in the tissues accumulates very rapidly, and in a short time the blood is brought into a condition in which it can not circulate, producing *asphyxia* or *suffocation*. The blood throughout the whole body then becomes venous. The arteries* as well as the veins are filled with black, sluggishly-moving blood. This black blood shows through the skin, particularly where it is very thin, as in the lips; and parts of the body which are usually of a healthy red or pink color become blue and livid. This blueness of the lips and of the flesh under the finger-nails is, therefore, a sure indication that the person is suffering from a lack of oxygen, and the only thing to do to save life, under such circumstances, is to supply fresh air. In drowning, strangling, poisoning by coal-gas or illuminating gas, this is always the great thing to be aimed at, and, as long as the heart beats, life exists, and consciousness can usually be restored.

* The arteries are those blood-vessels that carry the bright scarlet blood, which has received a fresh supply of oxygen, and the veins convey the dark blood, called venous, which is loaded with carbon dioxide and other waste matters, as hereafter explained.

156. Drowning. — The length of time during which a human being may remain under water and still recover, under proper treatment, is not yet actually determined. Young persons, it is known, live longer when submerged than older ones. As a rule, however, a person who has been entirely submerged for five minutes is dead beyond the possibility of resuscitation. And yet, even in such cases, attempts should be made, for any case may be an exceptional one.*

157. Resuscitation of the Drowned.—What, then, are the indications for the treatment of a person who is almost dead from drowning?

In the *first* place, he has been for some time deprived of oxygen. It is this which has made him unconscious.

In the *second* place, he has, probably, in his frantic efforts to breathe, taken water into his lungs, where it stops up the bronchi and air-vesicles, and must be cleared out before any air can enter.

In the *third* place, he is cold, and warmth, of itself, will do much toward bringing about his recovery.

In the *fourth* place, his circulation is at a very low ebb. The blood is so charged with carbon dioxide that it is sluggish, and, possibly, has almost ceased to flow.

We must *first*, then, *turn the person on his face*, and raise the lower part of the body somewhat, so as to let what water there may be in the lungs run

* Unconsciousness sometimes persists for a long time after a person has been removed into fresh air, when no special attempts at resuscitation have been made. It is said that persons have been restored by artificial respiration after they have lain unconscious and apparently dead for *five* hours.

out by the force of gravity. This action need occupy only an instant, for, if there be any water there, it will immediately run out.

The person should then be laid *flat upon the back*, without having the head raised, for we want the first fresh blood to run to the brain, and the heart is acting so feebly that it will be unable to send it there if it has to propel it up-hill. The shoulders should be raised a little by a pillow, a folded coat, or other padding. All the *clothing should be loosened* about the neck, chest, and waist, so as not to interfere at all with the movements of respiration.

The *wet, clinging clothing, if convenient, should be removed entirely*, as it tends to keep up the chilliness of the body. In any event, some one should attend to the duty of *warming the body*, by rubbing it with warm flannels, by bottles of hot water to the feet, etc., etc.

In addition to these things, and chief of all, *artificial respiration* should be kept up until the patient breathes naturally, or until absolutely all hope is lost.

158. Artificial Respiration.—As the person lies upon the back, the arms are to be grasped above the elbows and brought upward above the head, so as to touch, or nearly so. The large muscles of the shoulder are attached to the walls of the chest in such a manner that this movement of the arms raises the ribs, and expands the cavity of the chest in very much the same way that ordinary respiration does. The chest being thus expanded, of course air rushes in, and inspiration is effected. The arms should now be returned to the sides of the body and pressed against the ribs, when the chest-walls will recover their former position by virtue of their elasticity, and expel all the air which had been taken in. This, it will be observed, is exactly the process of *natural expiration*. The rapidity of these movements should approach as nearly as possible to the rapidity of natural respiration—i. e., about *sixteen* or *eighteen movements to the minute*, and the drawing up of the arms above the head should occupy the usual time of inspiration. This process should be continued for hours, if necessary, and the first sign of recovery will usually be a slight change in the color of the lips and finger-nails to red or pink, indicating that the circulation and oxygenation of the blood have begun to be more active.

159. **Additional Precautions.**—During the whole process of resuscitation of a drowned person, care should be taken to keep the *mouth and throat clear of mucus and froth* by means of a finger covered with a towel. *The tongue must also be watched.* In persons who are almost dead and have lost their muscular power, this organ often slips backward into the throat, and covers the glottis so that no air can pass in or out. It is necessary, in such cases, for some person to take hold of the tip of the tongue with a towel to prevent its slipping from the grasp, and draw it forward so as to leave the passage to the lungs clear.*

As soon as the person begins to breathe he can swallow, and a tablespoonful of brandy should be given him in a quarter of a tumblerful of water,

* In all cases of asphyxia, pure air is of the utmost importance. The sufferer should therefore be in a well-aired room, and whether indoors or out should never be surrounded by a crowd of people, whose respiration will pollute the air before it reaches the one who needs it most.

dry clothing should be placed upon him, and he should be put in a warm bed until his recovery is complete.

The above directions apply to all cases of suffocation, where there is no other injury to complicate the results of the mere deprivation of air.

CHAPTER VIII.

THE HEART.

160. General Plan of the Circulation.—The *circulation* of the blood is brought about by a compli-

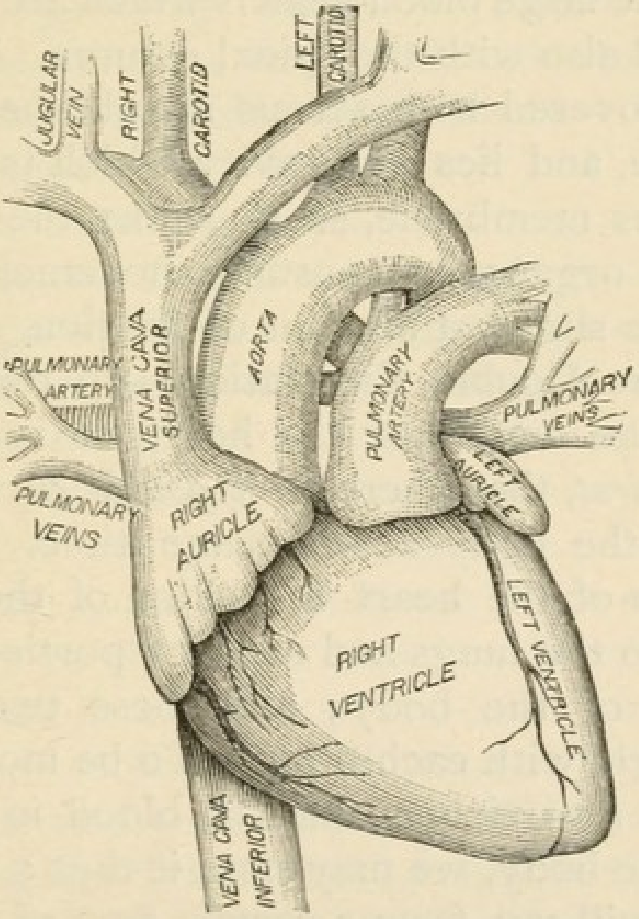

FIG. 41.—The heart and the large blood-vessels connected with it. The greater part of the left ventricle is hidden by the right ventricle.

cated series of tubes and channels, extending through every portion of the body, and all communicating with each other and with a powerful muscular central organ called the *heart*. The tubes are called, according to their structure, size, and function, *arteries*, *veins*, or *capillaries*.*

161. The Heart.—The *heart* (Fig. 41) is a strong, hollow, muscular organ, lying behind the breastbone, with its greater portion to the left of it. It is shaped somewhat like a cone, with both ends rounded, and the larger end directed upward and toward the right. The lower end, or apex, is free to move in any direction, not being attached to anything, while the upper and larger end is held in place by the large blood-vessels which are connected with it and also with the spinal column. The whole organ is covered with serous membrane called the *pericardium*, and lies in a cavity which is also lined with serous membrane, so that, like the lungs and abdominal organs, its constant movements can go on with the slightest amount of friction.

162. The Double Circulation.—In order to understand the action of the heart, it is necessary to know, *first*, that there is a *double circulation* going on in the body at the same time. At every contraction of the heart a portion of the blood is thrown into the lungs and another portion into the remainder of the body; and these two portions never mingle with each other. To be more precise, and follow a particular mass of blood in its course through the body, we may state it thus: The blood starts, we will say, from a certain part of the heart; it goes directly to the lungs; thence it returns to the heart, but to a different part of the organ; then it goes out of the heart in the arteries to what is

* See Frontispiece.

called the general circulation—i. e., to all parts of the body, excepting the lungs; thence it is collected by the veins, and returns to the heart; at the next contraction it goes to the lungs again, and begins the same process; so that in this way all the blood passes through the lungs, and all of the blood visits all parts of the body; but in doing this it visits and passes through the heart twice. In short, it flows—1. *From the heart to the lungs;* 2. *Back to the heart;* 3. *To the rest of the body;* 4. *Back to the heart.* Thus, there are two systems of circulation: one, called *the pulmonary circulation,* from the heart to the lungs and back again; the other, *the general circulation,* from the heart to the body and back again.

163. **The Two Sides of the Heart.**—This double and simultaneous circulation can not be brought about by a heart containing but one cavity. And, accordingly, we find that the heart is divided by a muscular partition, running lengthwise of the organ from front to rear, into two parts of nearly equal size, called the right and left sides of the heart. The *right side* carries on the *pulmonary circulation,* and the *left* the *general circulation.* So that the course of the blood is as follows: *From the right side of the heart to the lungs; thence to the left side of the heart; thence to all parts of the body; thence back to the right side of the heart.* If this order of the circulation be carefully observed, it will be seen that the *right side* of the heart never contains anything but dark or *venous blood,* and the *left side* always contains bright or *arterial blood.*

164. **The Auricles and Ventricles.**—Each side of the heart is divided into two cavities, making four in the whole organ. These cavities are called the

auricles and *ventricles*. The *ventricles* constitute the greater part of the heart, and it is in their walls that the greatest muscular power is located. The *auricles* are smaller cavities, situated at the upper extremity of the organ, and their walls are much thinner and weaker than the walls of the ventricles. The blood passes from the veins into the auricles, from the auricles into the ventricles, and from the ventricles it is forced out into the body. The course of the blood, then, is from the body in general *through the veins to the right auricle; from the right auricle to the right ventricle; from the right ventricle to the lungs; from the lungs to the left auricle; from the left auricle to the left ventricle; from the left ventricle out to the body in general*, whence it is collected by the veins and brought back to the right auricle, to begin the same course again (Fig. 42).

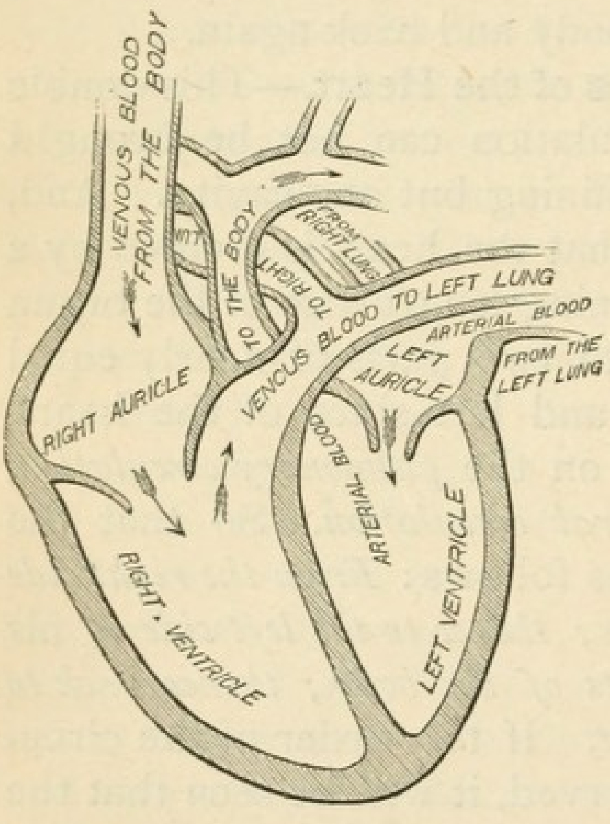

FIG. 42.—Diagram illustrating the course of the blood through the heart.

165. The Valves of the Heart. — At the mouths of the veins, where they empty into the auricles, there are no valves, and they are not really needed at this point, for the auricles do not contract with much force, and as there is always a current in the veins running toward the heart, and as the ventricles lie below the auricles, the blood naturally flows into the ventricles, where it meets with no resistance, rather than backward, where it would meet with considerable, having to oppose the force of gravity and also the current in the veins. In this manner the ventricles become filled with blood, and, when they begin to contract, the case is very different. Here there is an enormous pressure to overcome. The right ventricle must contract with force sufficient to send its contents into the lungs, pushing before it the column of blood already in the vessels. The left ventricle has to contract with a force sufficient to send its contents to the remotest parts of the body, also pushing along the blood which is already in the vessels. On the other hand, the resistance backward toward the veins is not nearly as great. The current of blood in the veins is not strong, and, even supposing that the resistance were equal in both directions, it is plain that the circulation would soon come to an end. The ventricle in contracting would force blood backward into the auricles and veins, and forward into the arteries, and then, when the heart relaxed, the blood would flow back again into the ventricles from both directions. This danger is averted by the introduction of *four sets of valves*, one between each auricle and ventricle, and one at the opening from the ventricle into the artery, through which the blood passes during contraction. The valves of the heart are double folds of the serous membrane which lines all the cavities of the organ, and are stiffened somewhat by a few fibers which run between the folds. All of these valves have three flaps, excepting the one which separates the left auricle from the left ventricle, and this has only two.

The valves are all so constituted as to allow the blood to pass only in one direction. The valves between the auricles and ventricles will allow blood to pass from the auricles into the ventricles, but not from the ventricles back into the auricles; and the valves at the mouths of the arteries will allow blood to pass from the ventricles into the arteries, but not from the arteries back into the ventricles.

166. The Blood-Vessels connected with the Heart.—The large veins, by which all the blood from the general circulation is poured into the right auricle, are called the *venæ cavæ* (i. e., the hollow veins); the large artery, by which the blood passes from the right ventricle to the lungs, is the *pulmonary artery;* the large veins, by which the blood returns from the lungs and enters the left auricle, are the *pulmonary veins;* and the large artery, by which the blood goes out from the left ventricle to all parts of the body, is called the *aorta.*

167. The Circulation of the Blood.—The blood, then, coming from all parts of the body in the veins, enters through the venæ cavæ into the right auricle; when the auricle is filled, it contracts and sends the blood downward into the right ventricle; when the ventricle is filled, its walls contract, and the blood passes into the pulmonary artery, its return into the auricle being prevented by the closure of the valves between the auricle and ventricle; the blood then goes through the lungs, and becomes changed into arterial blood; it returns to the heart, to the left auricle, and passes from there into the left ventricle; the contraction of the ventricle then forces it into the aorta, its return into the auricle being prevented by the valves; from the aorta it goes to all parts of the body, to be returned by the veins to the right side of the heart. The valves at the mouth of the pulmonary artery and the aorta prevent the blood which has entered them during the heart's contraction from flowing back into the cavity of the ventricle when it becomes relaxed.

168. Peculiar Valves in the Heart.—There is one peculiarity connected with the working of certain valves in the heart which is one of the most beautiful examples of adaptation in the whole body. It has been shown that there are no valves at the points where the veins enter the auricles, and still, when the auricles contract, the blood is not forced backward in the veins to any great extent, but passes downward into the ventricles. Some of the reasons for this have already been mentioned, but there is the additional fact that the opening between the auricle and ventricle on each side is very large, almost as wide as the auricle itself. There is, therefore, very little resistance, hardly any in fact, to the stream of blood passing from either auricle to the ventricle. But this large size of the opening might give rise to imperfect closure of the valves. The valves are made of thin sheets of membrane, stiffened a little by fibrous threads, but still very flexible. In the pulmonary artery and the aorta, the openings from the ventricles are so small that the valves are stiff enough to resist the backward pressure of the blood and keep the openings closed. The openings from the auricles to the ventricles, however, are so large that, if there were no special provision to prevent it, the valves would not only be pressed backward toward the auricle when the ventricle contracted, so as to meet at their edges and close the opening, but, on account of their flexibility, their borders would be bent still farther back, so as to open into the auricle, and allow a reflux of blood into that cavity.

This difficulty is obviated in the following manner: There are numerous fine but strong fibrous threads or cords attached to the edges of the valves, and from that point running downward to the walls of the ventricle. These cords are just long enough to allow the valves to close perfectly, but not pass any farther back toward the auricle. But here another difficulty arises. If the cords are long enough to allow the valves to close at the beginning of the contraction of the ventricle when the cavity is at its full size, then they will be too long when the contraction is toward its end and the cavity is diminished in size, and allow the valves to be pressed

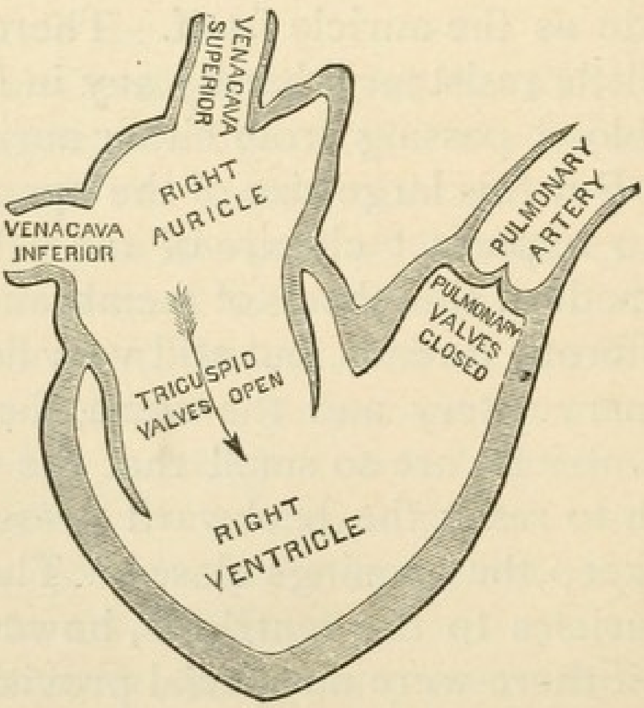

FIG. 43.—Illustrating the action of the valves in the right side of the heart.

too far back. In other words, to fulfill their object, these cords must be able to become longer or short-

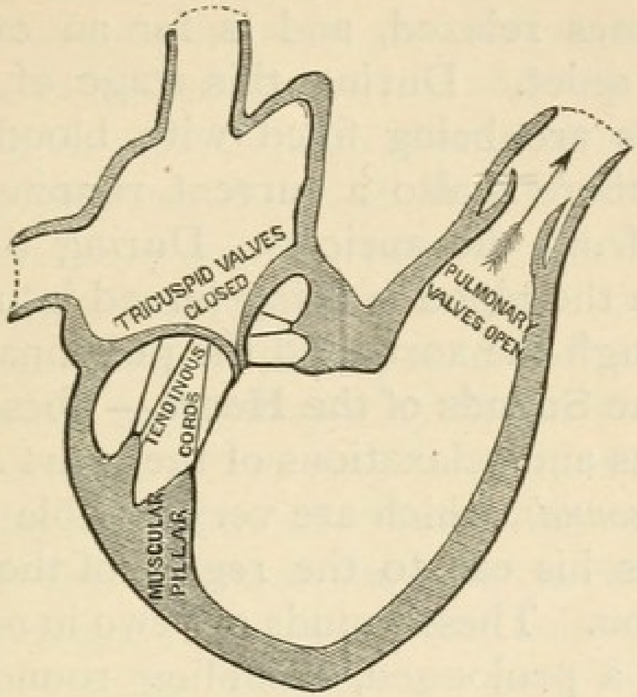

FIG. 44.—Illustrating the action of the valves in the right side of the heart.

er according to circumstances. This is effected by small muscular projections or pillars, which extend from the walls of each ventricle into its interior, and to which the cords are attached. When the heart contracts, these little pillars contract at the same time, and make the cords attached to the valves shorter and shorter as the contraction proceeds, just in proportion as the cavity of the ventricle grows smaller and smaller. In this way the reflux of blood through these large valves is prevented (Figs. 43, 44).

169. The Contraction of the Heart.—The contraction of the heart does not run successively from one auricle to the corresponding ventricle, and then from the other auricle to the other ventricle, but the contraction of both sides of the heart is simultaneous. It begins at the auricles and extends downward until the ventricles are both firm and hard and reduced to their smallest possible size. The organ then becomes relaxed, and is for an exceedingly short time quiet. During this stage of relaxation the auricles are being filled with blood from the veins, and there is also a current running into the ventricles from the auricles. During the stage of contraction the blood is being forced into the circulation through the aorta and the pulmonary artery.

170. The Sounds of the Heart.—These alternate contractions and relaxations of the heart are accompanied by *sounds*, which are very audible to any one who applies his ear to the region of the heart in a living person. These sounds are two in number, the first being a prolonged, rumbling sound, and the second short and sharp. The *first* sound is made during the time when the heart is contracting, and the *second* just at the end of the contraction, or beginning of relaxation. The *first* sound is supposed to be produced partly by the closing of the large valves between the auricles and ventricles, which occurs just at the moment when this sound begins, and partly by the contraction of the muscular fibers of the heart. The *second* sound is positively known to be produced by the closing of the pulmonary and aortic valves. It is by the variation in distinctness and quality of these sounds, and the addition of other sounds to them, that physicians are enabled to determine with wonderful accuracy the condition of the valves of the heart.

171. Rapidity of Pulsation in Health.—The *contractions* of the heart take place with regularity, and average in the adult about *seventy per minute*. The rate is higher in children and women than in men, and this fact is probably connected with their greater impressionability. The heart-pulsations appear to be slower in proportion as the individual is cool and deliberate in his judgments. The pulse of Napoleon Bonaparte is said to have averaged only forty-four to the minute, and is one of the slowest on record. Sudden emotions may increase its rapidity and force, so that a process, of which we are usually unconscious, becomes very perceptible and unpleasant, or, on the other hand, they may cause it to stop for a moment altogether, to skip a beat, as it were, producing the sensation of "fluttering" at the heart. Although the action of the heart is thus influenced by our feelings, it is beyond our control. Its pulsations are ceaseless and regular, until interrupted by disease or death. But, notwithstanding this general fact, there are some instances on record of persons who have been able to affect the action of the heart by an effort of the will. The most remarkable one of these, perhaps, was a Colonel Townsend, of Dublin. This person, on several occasions, in the presence of medical men, lay down and caused the contractions of his heart to become so faint as to be imperceptible. During the experiment the circulation was so far interfered with that he became pallid and unconscious. After a half-hour or so, he would gradually return to his natural condition. As might have been expected, he performed the experiment once too often. He stopped the action of the heart for the last time in the same way as he had done before, and it never resumed its work.

CHAPTER IX.

THE BLOOD-VESSELS.

172. **The Blood-Vessels.**—The heart, although a very powerful organ, would not be able to force the blood through the whole body, and back to itself again, without assistance, and this assistance is furnished by the structure of the blood-vessels themselves. The blood leaves the heart by the arteries and comes back to it through the veins, and these two systems of vessels differ very much in their structure.

173. **Structure of the Arteries.**—The *arteries* are tubes, with strong walls, described by anatomists as having *three layers*. The *innermost* is a delicate, smooth membrane; the *middle* one is composed of elastic fibers and also fibers of the non-striated or involuntary muscular tissue; the *outer* one is made up of strong connective tissue. Thus the walls of the arteries are very elastic, and, if the tube is distended, it returns to its former size as soon as the internal pressure is removed.

174. **The Pulse.**—When the heart contracts, its contents are driven with great force into the arteries, and, as the blood already contained there resists somewhat the advance of the fresh supply, the walls of the arteries are stretched to accommo-

date the mass of blood which is thrown into them. When the heart relaxes, and the pressure from that direction is removed, the elastic walls of the arteries react upon their contents, and, if it were not for the valves, would drive the blood, or a portion of it, back into the heart. At the slightest backward pressure, however, the valves close, and the elasticity of the arteries thus gives the blood another impulse forward toward the surface of the body. The impulse given by the heart's contraction, together with that caused by the recovery of their natural position by the walls of the arteries, gives rise to the *pulse*, which can be felt at any point in the body where an artery runs near enough to the surface. The common place of feeling for it is in the wrist, merely because that is the most convenient and accessible; but it may also be felt in the ankle, in the neck, in the temple, or in the upper arm.

175. **The Capillary Blood-Vessels; their Structure.**—The large vessels, by which the blood leaves the heart, viz., the pulmonary artery and the aorta, divide and subdivide continually, the branches growing smaller and smaller as they approach their termination, their walls at the same time undergoing a change in structure. The elastic tissue, which is so abundant in the larger arteries, gradually disappears as the vessels diminish in size, and the muscular tissue becomes more prominent, until even this finally vanishes, and the smallest blood-vessels, called the capillaries, are composed of a thin membrane, not divisible into layers. Thus the largest arteries are very strong and very elastic, while the smaller ones lose in elasticity, but, from

the amount of muscular tissue they contain, are very contractile.

176. **Size of the Capillaries.**—The *capillaries*, in which the arteries finally end, are only about the $\frac{1}{3000}$ of an inch in diameter—just large enough to allow the blood-corpuscles to pass through them, so to speak, in single file. Their number is beyond computation. They are so thickly strewed in the body that the point of a fine cambric needle can not anywhere be inserted between them. As every one knows, it is impossible to find an instrument with a point so fine as not to wound a blood-vessel if introduced through the skin. These vessels are entirely indistinguishable to the naked eye, and, before the discovery of the microscope, it was a great problem for anatomists to explain how the blood got from the arteries into the veins, as they could find no direct communication.

177. **The Veins.**—After passing through the capillaries, the blood enters the *veins*. These vessels contain in their walls much less muscular and elastic tissue than the arteries, and more connective tissue. The consequence of this is, that the walls of the veins are flaccid and yielding, and, if they are cut across, the sides fall together and tend to close the opening. If an artery, on the other hand, be cut, the tube remains open and in a sense rigid, although, as will soon be shown, its caliber is somewhat diminished. The veins, very minute at first, gradually unite and become larger and larger, until finally all the veins of the general circulation form two large vessels, called the *venæ cavæ*, which discharge their contents into the right side of the heart—one vena cava receiving all the blood from

the head and upper extremities, and the other that from the rest of the body.

178. Circulation of Blood in the Veins; Influence of Respiration.—The *circulation* of the *blood* in the *veins* is brought about in *three ways:* In the *first* place, the act of respiration has its influence. When the chest is expanded by muscular action, every fluid which is outside of it tends to rush in and fill the enlarged cavity. The chief space is filled by the air, as that is more perfectly fluid and meets with the least resistance from friction. But the blood is also drawn in through the veins, and the real extent and power of this suction can be very easily seen whenever the entrance of air is impeded. In such cases the veins in the neck can be plainly seen to become swollen and full during expiration, and emptied again during inspiration.

179. Influence of Muscular Contraction.—In the *second* place, the contraction of the voluntary muscles aids in the return of the blood to the heart. While the arteries, as a rule, run deep in the body, out of the reach of injury, the veins are largely near the surface, and the whole exterior of the body is more or less streaked by the blue lines which indicate their course. Now, during the contraction of a muscle, it not only shortens but becomes broader and thicker, and, of course, compresses to a greater or less degree everything near it. Thus the veins are continually being pressed upon here and there, in various parts of the body, during the whole of our waking hours, and even to some extent during sleep.

180. The Valves of the Veins.—But merely pressing the blood out of a certain portion of a vein might send it in either direction; it would be almost as likely to send it away from the heart as toward it. This reflux of blood in the veins is prevented by *valves* (Fig. 45), which allow the blood to pass through them readily toward the heart, but not away from it.* These valves are particularly

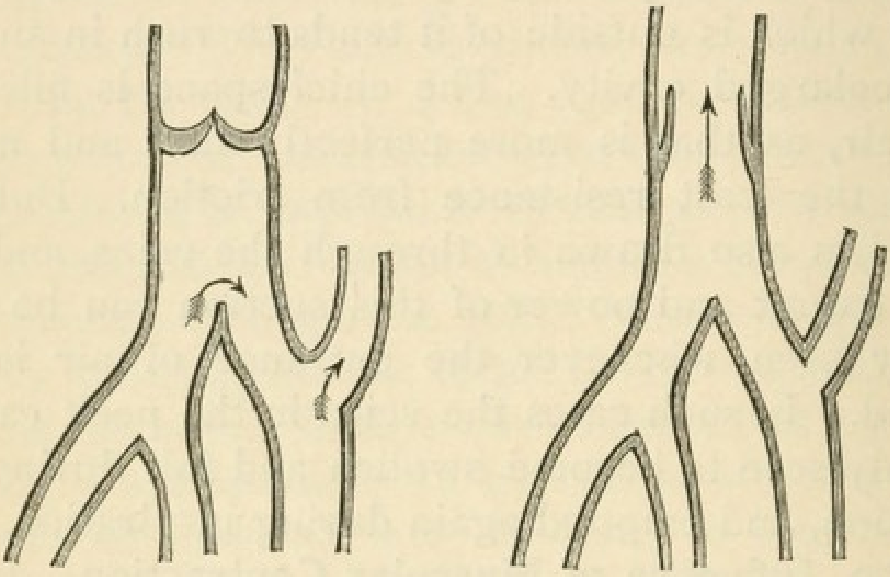

FIG. 45.—Diagrams illustrating the action of the valves in the veins.

numerous in the lower extremities, for here the force of gravity acts in opposition to the current of blood, and would seriously interfere with the circulation if there were no special provision with reference to it.

Thus, when blood has been forced out of a portion of a vein by pressure, it can not go backward on account of the valves, but must go forward in every case. This fact and the action of the valves may be beautifully seen in the arm of any person, where the veins are not obscured by too much fat beneath the skin. If a place be chosen where a vein

* It is said that the discovery of the proper working of these valves first suggested to William Harvey the true theory of the circulation of the blood.

is visible, with no branches for an inch or so, and one finger be placed upon it so as to stop the flow of blood, the portion of the vein on the farther side from the heart will be seen to fill with blood, and at some point will probably look swollen. This slight swelling marks the situation of a valve. If a finger be passed along a vein toward the heart, pressing upon it all the time, the vein will be seen to fill behind the finger; while if the finger be passed in the opposite direction, away from the heart, the vein will be empty and collapsed behind the finger, and perhaps hardly noticeable. This clearly indicates the direction of the current of blood.

181. **Influence of the Pressure in the Capillaries.**—But the *third* cause of the venous circulation, and the most important of all, is the blood which is constantly accumulating in the capillaries and exercising pressure on the column of blood already in the veins. This pressure is unceasing and powerful.

These three causes, acting together, keep up a free and steady flow of blood in the veins toward the heart.

182. **Communicating Blood-Vessels.**—In both arteries and veins, there are numerous communicating branches, so that, when a blood-vessel is obstructed, the blood passes out into other vessels and around the point of stoppage, and, excepting in extraordinary cases, the nutrition of the part is not interfered with.

183. **Recapitulation: Rapidity of the Blood-Current in the Vessels.**—The arteries, then, carry the bright scarlet, highly oxygenated blood from the heart out to all parts of the body for its nutrition.

It is sent to the remotest capillaries, partly by the contraction of the heart, and partly by the elasticity of the arteries; from the arteries it enters the capillaries, where the essential but very obscure processes of nutrition are carried on. It has been found that the current of blood rushes through the arteries with an average velocity of twelve inches per second, but, in consequence of the smallness of the capillaries and their distance from the heart, as well as the magnitude of their combined areas as compared with that of the aorta, the blood moves through them very slowly, not faster, it is thought, than one thirtieth of an inch per second. When the capillary circulation is looked at through a microscope, as it may be in the web of a frog's foot,* it is seen that the red corpuscles pass along through the minute vessels, sometimes two together, but oftener in single file, and without much trouble; but the white corpuscles are more affected by friction, and drag along, sticking fast here and there until they are started again by the current. This slowness of the current of blood in the capillaries gives time for the cells of the tissues to take up what they want from the vital fluid, and deposit their waste to be removed, and so we find that, when the blood emerges from the capillaries into the veins, it has become of a dark-purple color, and unfit for further use in the body until refreshed. So the process which takes place in the capillaries is in some degree the reverse of that which takes place

* The foot of a live frog may easily be fastened by strings and pins so that it can be placed under the microscope. The thin membrane is transparent, and the circulation of the blood, as seen in this way, is perhaps the most surprising and instructive sight that can be witnessed.

in the lungs. The blood enters the lungs of a black or deep-purple color and comes out bright red. It enters the capillaries bright red and comes out dark purple. It then passes back to the heart through the veins, the steady flow being maintained partly by the suction caused in the act of respiration, partly by muscular contraction and consequent pressure on the veins, and mainly by the pressure from the capillaries, which constantly forces the blood onward.

184. Peculiarity of Pulmonary Artery and Veins.—There is one exception to the rule that the arteries carry scarlet blood, and one to the rule that the veins carry purple blood. The *pulmonary artery* carries *venous blood* from the right side of the heart to the lungs, and the *pulmonary veins* bring back *scarlet* or *arterial blood* from the lungs to the left side of the heart.

185. Rapidity of Venous Circulation.—The rapidity of the current in the veins is estimated at about two thirds of that in the arteries, or about eight inches per second. As all the blood which goes out through the arteries must return through the veins, it might be inferred that the velocity of the flow in both systems of vessels would be the same. If the capacity of the vessels were the same, it would necessarily be so, but there are generally, with rare and unimportant exceptions, two veins returning the blood sent out by one artery, so that the capacity of the venous system is as a whole about twice that of the arterial, and the velocity would be half as great; but, if we take into account the difference in the distension and fullness of the two systems, the estimate given above is probably nearly correct.

186. Rapidity of the General Circulation.—An interesting question arises with regard to the *rapidity* of the *general circulation.* Experiments have been made which show that this is somewhat greater than would have been expected. A substance, which remains unaltered in the blood, and which can easily be detected by chemical means, was introduced into a large vein on the right side of a horse's neck. It was plainly detected in the blood drawn from the vein of the left side, in from twenty to twenty-five seconds. In this short time, the blood in which the substance was introduced must have gone down to the right side of the heart, from there to the lungs, thence to the left side of the heart, and thence through arteries to the head, before it entered the vein in which it was detected on its way back to the heart.

The time required for all of the blood in the body to pass through the heart can not be accurately determined, but only estimated. It probably varies very much with the vigor of the heart's action, the amount of exercise taken, the frequency of the respiration, etc. In the dead body, however, each ventricle is found to contain about two ounces of fluid. Now, one ventricle is to be estimated in the calculation, because, in order to complete the entire round of the body, all the blood must pass through the left ventricle. If two ounces enter and leave the ventricle at every contraction of the heart, and there are seventy pulsations in a minute, one hundred and forty ounces, or eight and three quarter pounds, will pass through the organ in this short time. Estimating, then, thirteen pounds of blood as the average amount in an adult, two minutes at the most would suffice for the completion of the circulation, and this is probably pretty near the truth.

187. **The Supply of Blood in any Part varies.**—The amount of blood in any portion of the body at any particular time depends upon certain relations which exist between the blood-vessels and the nervous system. The walls of the arteries are plentifully supplied with involuntary muscular fibers. The contraction of these fibers diminishes the caliber of the artery. They are most abundant in the small arteries, and their contraction or relaxation is controlled by certain nerves called *vaso-motor nerves*, because they control or cause motion in the vessels to which they are distributed. If the nervous stimulus be such as to cause a contraction of the arteries supplying any particular part of the body, the supply of blood to that part will be diminished, and will be diminished in exact proportion to the amount of contraction in the blood-vessels. If, on the other hand, the nervous control be altogether withdrawn, and the arterial walls completely relaxed, the amount of blood in the part affected will be increased to a corresponding extent.

188. **The Aorta.**—The blood destined for the general circulation all leaves the heart through the *aorta*. This is a large vessel, about five eighths of an inch in diameter, with thick, strong walls, as it has to bear an enormous pressure. It begins at the upper end of the left ventricle and on its right side, and, after leaving the heart, springs upward toward the right, near the breastbone, to the second rib; then arches backward, and passes between the lungs to the back; here it curves again, and runs down along the spine, through the diaphragm, to the

lower portion of the abdomen—all the way lying in front of the vertebræ. When it reaches the pelvis it divides into two branches, one of which goes to each lower extremity.

189. The Femoral Arteries.—These branches run the same course in either limb. They emerge from the abdomen on the front of the limb, in the groin, not far beneath the skin, and pass in as straight a line as possible on the inside of the thigh to a point behind the knee-joint, at about the middle of the hollow space which is found there between the tendons on each side. In its course along the thigh the vessel is called the *femoral* artery (Fig. 46). At the knee it again divides into two branches, one of which runs down in front of the leg, and the other behind to the foot, where they further subdivide, to supply each of the toes with a small artery on each side. All through this course, however, arteries of different sizes are given off as branches to supply the different organs in the chest and abdomen, as well as the muscles and skin, the course of the main arteries only being here indicated.

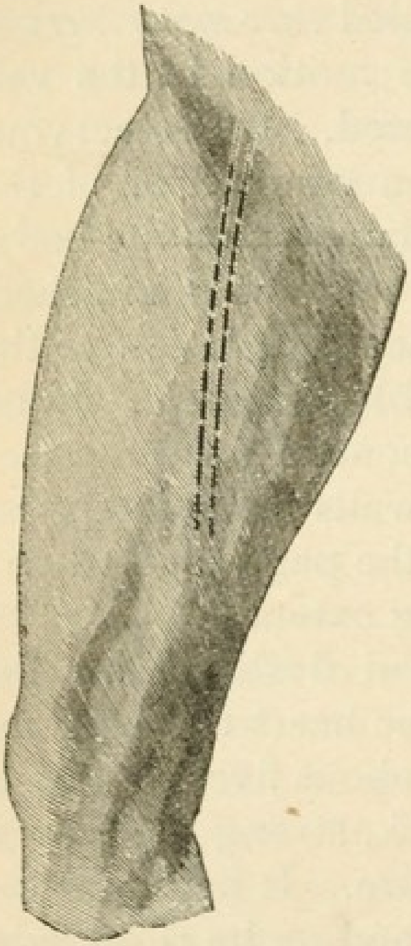

FIG. 46.—The right thigh. The dotted line represents the course of the main artery (the femoral).

190. The Brachial Arteries.—From the arch of the aorta spring upward the vessels which supply the neck and head and upper extremities. Two large vessels go to the arms, one to each. They pass upward and outward between the collar-bone and the first rib, and dip down from the neck, passing to the arm through the arm-pit. As soon as the artery enters the arm it is called the *brachial*, and it continues its course down the inside of the limb to the elbow, where it comes in front (Fig. 47). Here it divides in two, the *radial* and *ulnar*, which pass down, one on each side of the arm, to the hand, where their subdivision furnishes a small artery for each side of each finger and the thumb. These vessels also, throughout their course, give off branches to the muscles and other parts. The *radial* artery is the one ordinarily felt in order to judge of the pulse, and is easily found on the radial or thumb side of the arm, about an inch above the fold where the hand bends upon the arm.

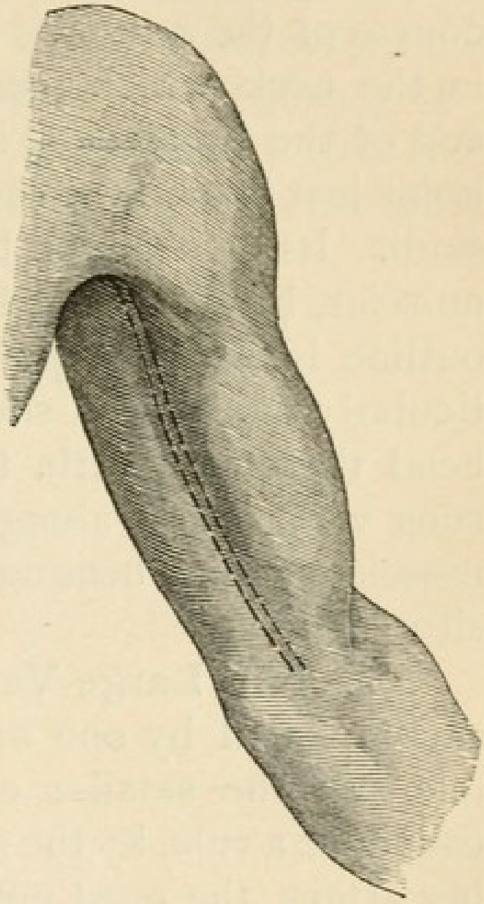

FIG. 47.—The left upper arm. The dotted line represents the course of the main artery (the brachial).

191. The Carotid and Vertebral Arteries.—Four arteries supply the head and face. These are the two *carotid* arteries in front and the two *vertebral* behind. The two *carotids* pass up on each side of the neck, and, when they approach the skull, divide into two main branches, one of which supplies the face, while the other enters the skull and supplies the brain. The *vertebrals* supply the brain, and pass up to it almost the entire distance inside the bones of the spinal column. It is important to know the course of the *carotid.* There is a powerful muscle in the neck, which passes upward from the upper end of the breastbone and parts in its vicinity to a point just behind the ear, where it is attached to the skull. Its contraction turns the head, or, with other muscles, bends it over to one side or the other. Its outline is distinctly perceptible under the skin, particularly when it is somewhat contracted, and the head thereby a little twisted. The *carotid* artery runs very nearly along the anterior border of this muscle, and its beating may be readily felt in this situation.

192. **The Large Veins.**—Each artery is usually accompanied by one or two veins—the largest by one, and the smaller ones by two. The veins are called, as a rule, by the same name as the corresponding artery, the most notable exception to this being the *jugular* veins, which are the companions of the *carotid* arteries, and run close by their side. All the blood from the lower part of the body is finally collected in a large vein, called the *vena cava inferior*, which runs up the spine beside the *aorta*, while that from the head, neck, and upper extremities is collected in the *vena cava superior*, and both these large veins discharge their contents into the right auricle of the heart. The veins which take the blood from the digestive organs unite to form the *portal vein*, which enters the liver, and the large vein which emerges from the liver joins the *vena cava inferior*, so that all the blood from the digestive organs must go

through the liver before it enters the general circulation.

The *pulmonary artery*, soon after it leaves the right ventricle, divides into two branches, one of which passes under the arch of the *aorta*, before described, to the right lung, and the other goes to the left lung. The corresponding *pulmonary veins* are two from each lung, and they empty their contents into the left auricle.

CHAPTER X.

DISORDERS OF CIRCULATION.—HÆMORRHAGE.

193. Obstruction of the Circulation.—If a cord be tightly bound about a finger, that part of the member which is farthest from the heart will soon become livid and begin to swell. This effect is due to the difference in structure and position of the arteries and veins. The arteries are tubes with stiff, elastic walls, and do not usually lie very near the surface, whereas the veins have thin, inelastic walls, and many of them are very superficial. The consequence is that it is a somewhat difficult matter to compress an artery so as to entirely prevent the flow of blood through it, while the veins are very easily compressed. In binding a cord around the finger, then, unless great force be applied, the veins are compressed and the current of blood in them checked, while that in the arteries is not at all or only slightly interfered with, so that blood is being continually carried into the finger, and can not flow out. The accumulation of blood in the part accounts for the swelling, and the dark color is that of venous blood. If, now, the cord be removed, the swelling does not immediately disappear, because wherever there is a damming of the current of blood so that its flow in the veins is interfered with, after the vessels become distended to a certain point, the pressure on their walls is relieved by the loss of a portion of their contents. The serum of the blood begins to pass through the walls of the veins into the tissues outside of them, producing the condition called *dropsy*.* When the circulation of the part is restored, all this serum which has left the vessels has to be reabsorbed, partly by the blood-vessels and partly by the lymphatics, and this occupies an appreciable time.

Now, let us suppose that this obstruction, instead of being applied to the veins on the surface of the body, is situated in some of the interior organs. It is plain that a similar effect will be produced if the supply of blood to any part remains the same, while the return of it is prevented. Such obstructions are most common in the heart and lungs, as a result of disease in those parts.

194. **Disease of the Heart.**—Let us suppose that the valves between the left auricle and left ventricle have been inflamed, and have become so altered in their shape and size that, when the heart contracts to force the blood from the left ventricle into the aorta, they do not completely close the opening. It is plain that a portion of the blood will be forced backward into the auricle. This regurgitation, as physicians call it, takes place at every beat of the heart, and as the auricle is in this way kept filled with blood, and a sort of conflict continually takes place between the current coming into it from the

* When fluid passes in this way from the interior of the blood-vessels through their walls into the tissues outside of them, the fibrin does not form a part of it. In other words, it is not the *plasma* that is effused, but the *serum*.

lungs and that coming back to it from the ventricle, the current in the pulmonary veins is materially interfered with. In short, the blood is dammed backward into the lungs. Here, then, is an actual obstruction to the circulation, as much as there is when we tie a string around the finger. The result can be easily ascertained by following backward the course of the circulation. The obstruction to the exit of blood from the lungs causes the blood to accumulate in that organ—in other words, produces a congestion there. The blood, not being changed frequently enough, does not get enough oxygen, and the person is obliged to breathe faster in order to supply more. This we call *shortness of breath.* The accumulation of blood in the lungs, in a measure, obstructs the current of blood which comes to them through the pulmonary artery. The blood in the pulmonary artery being hindered in its course, the right ventricle is not able to empty itself perfectly, becomes dilated, and its walls become thinned. The obstruction at this point prevents the right auricle from emptying itself properly, and this interferes with the free return-current in the large veins which are connected with it. Thus the flow of blood is hindered in the veins from all parts of the body by the disease of one set of valves. The obstruction of the venous flow brings about the same results that we have observed in the constricted finger. The face becomes more or less livid, the lips and finger-nails bluish, and the serum of the blood passes out into the tissues around the veins, causing *general dropsy.* This is the most common form of *heart-disease,* and it has been somewhat minutely described, in order to show how purely mechanical are some of the diseases to which we are subject. There are other forms of disease of the valves, whose effects may be traced by those curious in such things. The aortic valves, for example, may be affected so as to close incompletely, and allow a part of the contents of the aorta to be forced back into the ventricle by the elasticity of the artery every time the heart relaxes. On the other hand, these same valves may be made so rigid by disease that, although they close tightly enough to keep the current of blood from setting back through them, they do not open sufficiently wide to allow a free flow through them during the heart's contraction. This latter form of disease is one of the most common, and gives rise to symptoms very much like those of the disease which has been more fully described above. Sometimes, as a result of inflammation of a peculiar kind, the edges of the valves have small, wart-like masses attached to them. These little masses sometimes prevent the valves from closing properly, and sometimes not, but they always offer more or less obstruction to the circulation. Occasionally one of these bodies becomes detached from the valve by the force of the blood-current, and is whirled away through the body. As the current of blood in the arteries is continually in the same direction, and they grow smaller and smaller, such a little body at length reaches a spot where the caliber of the artery is too small to let it through. It plugs up the artery. This gives rise to different consequences, according to circumstances. Sometimes the circulation is carried on, in spite of the obstruction, by other arteries which pass around the point of plugging; and sometimes the part which receives its supply of blood from the affected artery, being thus suddenly deprived of it, dies, falling into the condition known as *gangrene*.

195. How Heart-Disease is detected. — All of these affections of the valves of the heart, interfering as they do with the free flow of the blood, give rise to *sounds* of greater or less intensity, the varieties of which are familiar to practicing physicians, and indicate to them quite accurately the character and extent of the disease.

196. Effect of the Coagulation of the Blood.— Whenever the surface of the body is wounded, blood-vessels are necessarily severed, and, if there were no means of stopping the consequent escape of blood, it would not take very long for the whole body to be drained. The fibrin of the blood, however, by its property of coagulation, serves to arrest bleeding. All of the methods used by surgeons to stop hæmorrhage in any part of the body have for their object the coagulation of the blood.

197. Conditions of Coagulation.—Blood coagulates much more rapidly on a rough, ragged surface than on a smooth one, and in a wound that is much bruised or lacerated there is often very little bleeding, even from large arteries. Instances have been known in which the arm has been violently torn from the body by machinery, and the brachial artery divided, with comparatively little bleeding; although, if the arm were cut off, without controlling the main artery, the person would die of hæmorrhage in a few minutes. In a clean-cut wound the hæmorrhage is often very severe from small blood-vessels, and almost always needs some artificial control.

198. Arterial and Venous Hæmorrhage.—When an artery has been severed, it is not difficult for one who understands the circulation to detect it. In the *first* place, the arterial blood is of a bright scarlet color, and, in the *second* place, it comes from the vessel in jets or spurts. The blood in the veins is dark purple, and, as the veins do not pulsate like the arteries, it flows from the wound in a steady, uniform stream. The force with which the blood issues from a cut artery is surprising. A jet from one of the little arteries of a finger will spurt at least a foot in a stream no bigger than a knitting-needle. A vein never bleeds in spurts. In a wound, however, both veins and arteries may be severed and the blood mixed, although usually either the arterial or venous color predominates. If the blood from the wound be soaked up by a sponge or soft cloth, an arterial spurt can be seen before the cut fills up again with blood.

199. Natural Arrest of Hæmorrhage.—If a wound be left to itself, the following are the means provided by Nature to arrest bleeding: When an artery is cut, its walls always contract somewhat, so that its caliber is diminished. The elasticity of the artery also draws it backward to some extent into the flesh. In the smallest arteries, these acts are often sufficient to stop the bleeding entirely. In every case they resist the current, make it move more slowly, and so favor coagulation. When a vein is cut, the walls, being thin and inelastic, collapse, the opposite sides coming in contact and tending to obstruct the flow of blood. In these ways the current of blood from all cut vessels is diminished in force. The blood begins to coagulate almost immediately, and this offers still further resistance to the out-coming current. If the bleeding continues, and the blood-vessels are so drained that the brain feels the lack of blood, the person faints, the nervous force of the heart is diminished, and in this way also the force of the flow is lessened. This is Nature's last resort, and, if the vessels injured are so large that these means are not sufficient to stop the flow, the person will bleed to death.

200. Artificial Arrest of Hæmorrhage; Cold.—The artificial means which we have at our command for arresting hæmorrhage merely aim to assist these attempts of Nature.

The application of cold to any part of the body produces pallor, caused by a diminution in the supply of blood to the part. This is owing to the fact that the stimulus of cold causes contraction of the smaller blood-vessels, and so lessens the amount of blood in them.* When a cut surface is exposed to the air, if the vessels which have been severed are small, the coldness of the air is sometimes sufficient to stop the bleeding by causing a contraction of the vessels. This effect can be increased by bathing the wound in cold water. If this be done, however, the cut surface should not be wiped or rubbed with the sponge or towel, for fear that the already coagulated blood, which begins to form an obstruction to the flow, may be washed away.

201. Styptics.—We also have artificial means of bringing on coagulation of the blood. The sub-

* The diminution in the caliber of arteries in such cases is caused by the contraction of the involuntary muscular fibers which surround them, as previously explained.

stances used for this purpose are called *styptics*. The *persulphate of iron* is an exceedingly powerful one. The *muriated tincture of iron* is another. *Alum*, or *tannic acid*, or any other astringent, produces the same effect. The great objection to all of these substances is, that they so alter the tissues with which they come in contact that the wound is often hindered from healing as rapidly as it otherwise would. They are mostly used when it is impossible to apply actual pressure upon the bleeding vessels.

202. **Compression.**—*Compression* is the most perfect and unobjectionable method of arresting hæmorrhage. This brings no outside injurious matter in contact with the wounded surface, and acts merely by stopping the flow temporarily until Nature has time to stop it permanently.

If the wound be small, and can be covered by the finger, it will generally be enough to put the finger or thumb immediately on the cut and press toward a bone until the bleeding stops. If the wound be too large for this, pressure must be made at a point outside of the wound, where the vessels which are supposed to be cut are known to run.* If the bleeding be venous, of course the current is running toward the heart, and the pressure must be made on the side farthest from that organ. If the hæmorrhage be arterial, the pressure must be made between the wound and the heart. In the

* Or some soft, porous material, such as a towel, handkerchief, sponges, or cotton cloth or batting, may be crowded into the wound and held there by the hand or a bandage. This is often the easiest way to apply pressure directly to the mouths of the bleeding vessels. Woolen material is too rough and stiff for this purpose.

case of venous hæmorrhage, a comparatively slight pressure will generally be sufficient, as the walls of the veins possess little resisting power, and are readily forced into contact. On the arteries, however, greater force is necessary, and it is sometimes surprisingly difficult to fix the vessel and compress it. It is to be remembered that in the limbs the course of the arteries is, in the main, nearly straight and lengthwise of the limb, so that all that it is necessary to do in case of severe arterial hæmorrhage is to feel along the outer edge of the wound, an inch or so from it, pressing the finger down deeply until the artery is felt pulsating, and then compress it against the nearest bone.

203. Permanent Arrest of Hæmorrhage.—When the hæmorrhage has thus been temporarily arrested, the pressure must in some way be kept up until there is no danger of a fresh burst on its removal. Nature's method of permanently arresting bleeding is this: It has been before stated that blood will coagulate not only outside the vessels, but inside them, if its free motion is interfered with. Now, if from the contraction of the vessels, or coagulation of the blood which has flowed from them, or in consequence of pressure artificially applied, or for any other reason, the current of blood in the artery is stopped at the severed end, the fibrin of the blood begins very soon to coagulate inside the vessel, and this coagulation extends from the cut end backward toward the heart to a point where the circulation becomes free and unobstructed, that is, to the point at which some branch artery is given off from the wounded one (Fig. 48). Thus the coagulum (or clot) formed will vary, according to circumstances, from an eighth of an inch or less to an inch in length. If the compression or other obstruction continues long enough to allow of it, this coagulum becomes firmly attached to the inside of the vessel, and forms a plug which effectually and permanently closes it, and, as the wound heals, this plug and the walls of the now useless artery become gradually absorbed until a mere thread remains, and even this may disappear so as to leave no trace of the vessel which formerly existed. But it is to be considered that during the formation of this plug, and its attachment to the walls of the vessel, it has to receive the impulse of the blood continually driven against it seventy times a minute by the heart; and in large vessels this blow is a very strong one; so that, if the pressure be removed from an artery too soon, even after this coagulum is formed, the impulse of the current of blood may be sufficient to drive out the plug, and bleeding will begin again. This danger is absent in venous hæmorrhage, and it is a general rule that if such hæmorrhage is once stopped it will not recur. But in arteries this is a peril that must always be guarded against, and surgeons accomplish what they want by tying the end of the bleeding artery with a string. Ligatures, made expressly for this purpose, are used, and although they are finally discharged from the wound with the secretions, showing that they have cut through the walls of the vessel around which they were tied, they re-

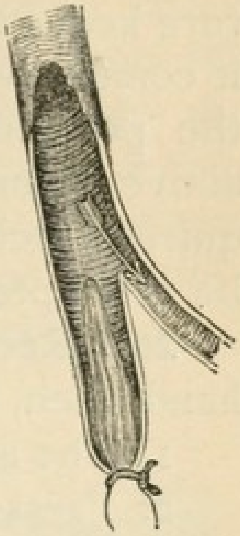

FIG. 48.—Clot in an artery that has been tied.

main long enough to accomplish the purpose.* A person's finger soon becomes exhausted by continual exertion in maintaining pressure, but a ligature keeps the artery closed for several days before it comes away, and thus ample time is afforded for the permanent closing of the vessel in the way above described. The application of a ligature requires special knowledge and skill, and should only be attempted by a surgeon.

204. Recapitulation.—The means at everybody's hand, then, for arresting hæmorrhage are these:

1. The application of cold by water, ice, or air.

2. Pressure by the finger, thumb, bandage, or in any way that suggests itself.

(*a.*) If the wound be small, pressure on the wound itself.

(*b.*) If the wound be large, and the bleeding from the veins, pressure on the side farthest from the heart, or by plugging the wound full of some soft material. If the blood comes from an artery, pressure on the side nearest the heart.

(*c.*) Pressure to be kept up until the bleeding stops, or until some means can be applied to make the pressure permanent.

3. Styptics or astringents. These are to be used chiefly where pressure can not be applied, and after the application of cold has proved insufficient.

205. Wounds of the Extremities.—Wounds of the *extremities* often bleed profusely. Usually, direct pressure on the spot of the wound will suffice

* Surgeons are now in the habit of using ligatures made of some animal material, such as catgut or chamois-leather, which does not irritate the wounded parts, and is gradually absorbed, so that the wound can be completely closed when first dressed.

to check it. If, however, the wounded vessel is so large that it bleeds in spite of this, the main artery must be compressed above the wound. It has been already shown that the artery is a single trunk only in the upper part of each limb—i. e., from the shoulder to the elbow in the arm, and from the groin to the space behind the knee in the lower extremity. Somewhere in this course, then, the vessel must be compressed against the bone beneath; for below the elbow and knee the artery divides, and the branches are so situated that they can not be compressed. The brachial and femoral arteries—that is, the arteries of the upper arm and thigh—are so large and strong, and receive such a strong impulse from the heart, besides being in a measure protected by the surrounding tissues, that they can not be compressed by the fingers to any advantage. The best method yet devised is the use of a *knotted handkerchief* or other bandage, a rope or cord being so small as to cut the flesh, and therefore unsuitable (Fig. 49). A handkerchief should be tied loosely around the limb, with a hard knot over the artery. Immediately underneath the knot should be placed another handkerchief, folded so as to form a pad about two inches

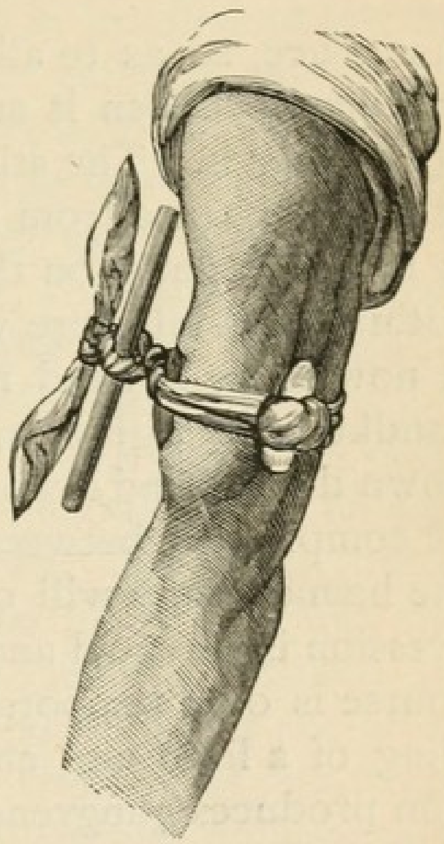

FIG. 49.—Manner of compressing an artery with a handkerchief and stick.

wide and three long, to keep the knot from bruising the flesh when the handkerchief is tightened (Fig. 50). The handkerchief should be loosely tied in the

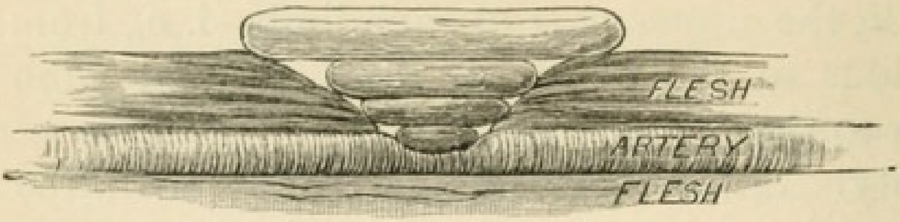

FIG. 50.—Direct compression of a wound by means of what surgeons call a graduated compress, made of pads of cloth, folded in different sizes, with the largest one on top.

first place, so as to allow a stick or rod to be introduced between it and the skin for the purpose of twisting it. The stick or lever should be placed at some distance from the compressing knot, and it is better to put it on the outside of the limb, where nothing will interfere with the twisting. The stick is now to be twisted round and round, making the handkerchief tighter and tighter and the knot press down deeper and deeper, until finally the artery will be compressed between the knot and the bone, and the hæmorrhage will cease. This method of compression is effectual and easy of application, but of course is only temporary, for such complete encircling of a limb and entire stoppage of the circulation produces gangrene if too long continued.

206. Fainting.—When, for any reason, the supply of blood to the brain is insufficient for its nutrition, the person *faints*. In our ordinary erect position, the blood has to be driven upward by the heart for a foot or more, in opposition to the force of gravity. In a fainting person there is not power enough to do this, and we must relieve the heart of a certain amount of its burden. We accomplish this end by laying the person flat on his back, without raising the head by a pillow or rest of any kind. In this position the blood readily reaches the brain, and that organ rapidly recovers its functions.

207. Shortness of Breath.—Shortness of breath always indicates that the blood contains too little oxygen. When we are short of breath from exercise, it is due to the fact that our bodies have made more waste material than usual, which the blood has been unable to get rid of, and also that the oxygen taken in from the lungs is insufficient for the needs of the wasting tissues. In other words, we are wearing out. Then we begin to breathe faster, and thus try to get rid of more waste and take in more fresh material. But, if the exercise which produces the excess of waste be continued, the time comes when we can not breathe rapidly enough to dispose of it, the body becomes limp, and we are forced to rest and recover. After we have completely ceased our exertions the rapidity of breathing continues for a time, making the supply much greater than the waste, and gradually expelling the latter from the body until the balance between the two has become even again and the parts are all in their natural condition. In diseases of the lungs which render parts of these organs useless, such as pneumonia, consumption, etc., the same effect is produced. When we have only half as much lung to breathe with, we have to breathe much faster to make up the deficiency.

PART IV.

ORGANS OF CO-ORDINATION.

CHAPTER I.

NERVE-SUBSTANCE.

208. Difficulty of Investigation.—The *nervous system* is less thoroughly understood than almost any other portion of the body. The difficulties of investigation are enormous, and its functions are so intimately connected with the phenomena of conscious life that, with the exception of a few facts on which all observers are agreed, the truth is buried under a mass of conflicting theories, which the earnest and tireless efforts of patient workers all over the world are not yet able to remove. We shall occupy ourselves mainly with what are accepted facts.

209. The Two Divisions of the Nervous System.—We have seen, in previous chapters, that certain operations constantly go on in our bodies, not only without our willing them, but without our consciousness. Such are the processes of digestion, circulation, etc. Our voluntary acts, those which are the result of and accompanied by consciousness, constitute, in fact, the smallest part of what goes on within us. Now, the organs which are un-

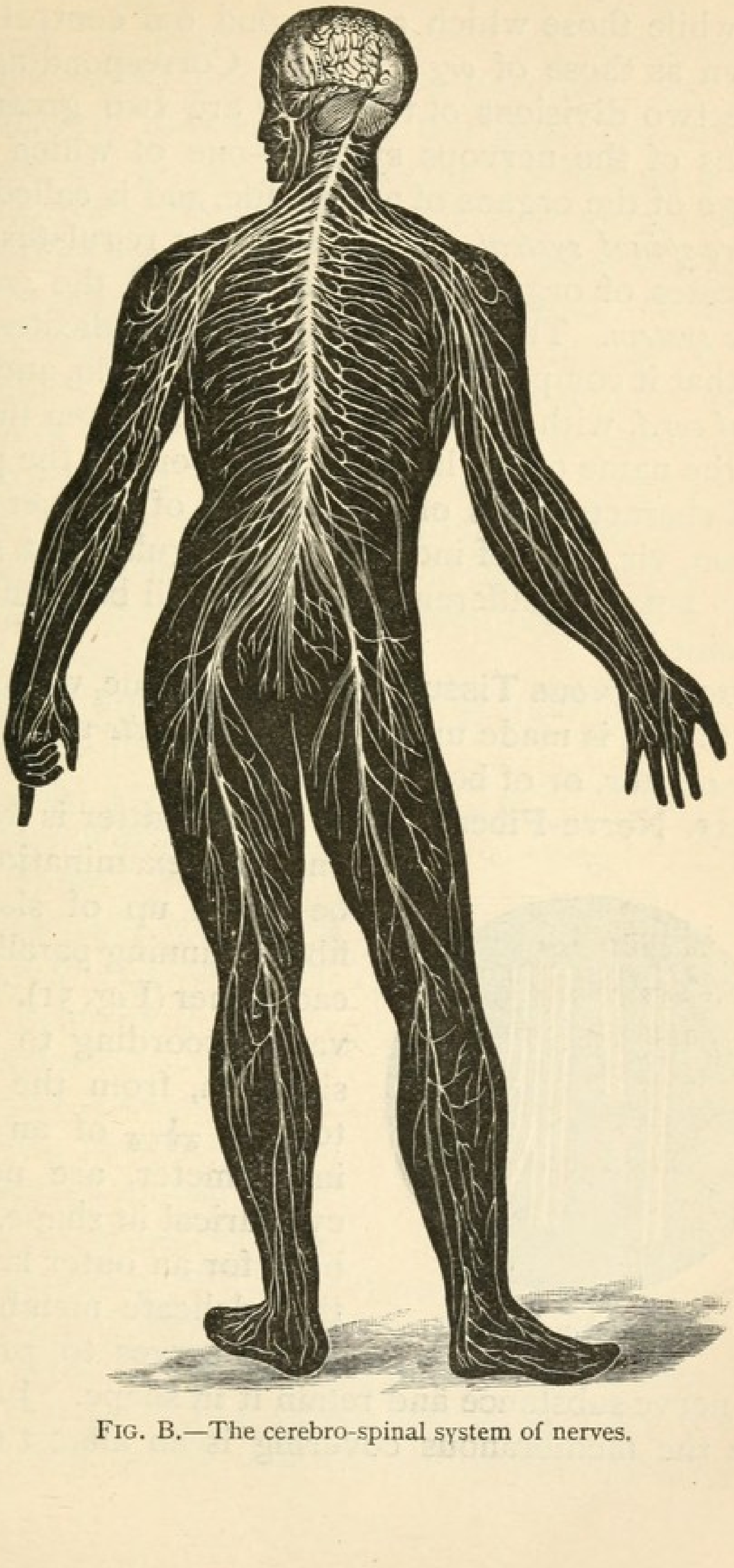

FIG. B.—The cerebro-spinal system of nerves.

der voluntary control are called the *organs of animal life*, while those which are beyond our control are known as those of *organic life*. Corresponding to these two divisions of the body are two great divisions of the nervous system—one of which has charge of the organs of animal life, and is called the *cerebro-spinal system*, while the other regulates the processes of organic life, and is called the *sympathetic system*. The name of the former indicates the fact that it comprises the *cer'ebrum*, or brain, and the *spinal cord*, with the nerves proceeding from them; and the name of the latter suggests one of the principal characteristics of that portion of the nervous system, viz., that of inducing and regulating a sympathy between different organs, as will be hereafter explained.

210. Nervous Tissue.—Nervous tissue, wherever it is found, is made up of so-called *white* matter, or *gray* matter, or of both combined.

211. Nerve-Fibers.—The *white* matter is found, on close examination, to be made up of slender fibers, running parallel to each other (Fig. 51). They vary, according to their situation, from the $\frac{1}{2000}$ to the $\frac{1}{4000}$ of an inch in diameter, are nearly cylindrical in shape, and have for an outer layer a thin, delicate membrane, which serves to protect the nerve-substance and retain it in shape. Just inside the membranous covering is an almost trans-

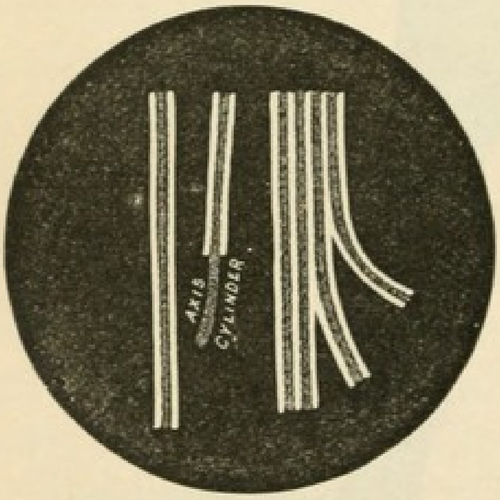

FIG. 51.—Nerve-fibers.

parent material, which, after death, appears to coagulate and becomes whitish and slightly granular. This is called the *my'elin*, or, by others, the *white substance of Schwann*, from the man who first described it. In the center of the whole runs a slender thread of transparent, very finely granular matter, called the *axis-cylinder*. This latter substance, in all probability, serves for the actual conduction of the nervous influence, whatever it may be, and the white substance of Schwann, or myelin, probably acts as an insulator. These distinctions between the different portions of a nerve-fiber are not visible in the living body, but are the result of changes which take place after the nerve has been separated from its connections, probably from a sort of coagulation.

212. Nerve-Cells. — The *gray* matter does not consist of fibers, but of cells (Fig. 52) imbedded in a mass of granular matter. These *cells* vary in size from $\frac{1}{200}$ to $\frac{1}{2000}$ of an inch in diameter, and each contains a *nucleus* and *nucleolus*, usually very distinctly marked. Each cell also has prolongations which extend from its circumference in various directions, and are supposed in every instance to connect either with a nerve-fiber or with some other cell. These prolongations vary in number from one up to five or six, and, as they are traced along their course with the aid of the microscope,

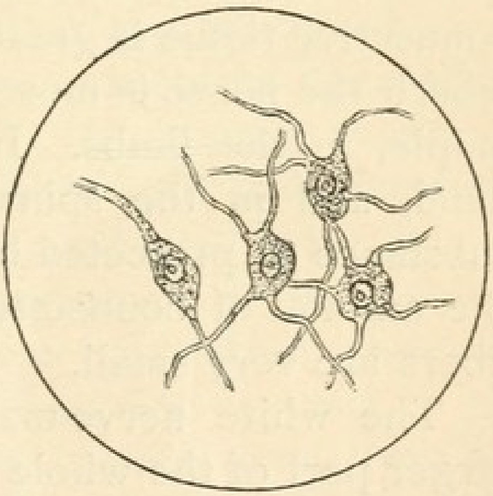

FIG. 52.—Nerve-cells.

they are seen to divide and subdivide until they become too small to follow. It is supposed that every nerve-fiber is connected with such a cell.

The *nerve-fibers*, above described, constituting the white nerve-matter, are mere *conductors of the nerve-force.* They constitute the means of communication between the outside of the body and the nerve-centers. The *nerve-centers*, on the other hand, are made up of gray matter, and are the *originators of nerve-force.* So we see that the nervous system, like the rest of the body, is made up of cells and fibers, and that the essential part of the whole is the cell, the fiber playing a very subordinate *rôle.*

213. Structure of the Nerves.—A nerve which is large enough to be seen by the naked eye is composed of a great number of the fibers above described, lying side by side and bound together by a considerable amount of connective tissue. The connective tissue is greatest in amount in situations where the nerve is most exposed to injury—for example, in the limbs. In the brain, on the other hand, and in the spinal cord, where the nerve-substance is protected by a strong bony covering, the amount of connective tissue is scanty and the fibers are very small.

The white nerve-matter constitutes much the larger part of the whole nervous system. It forms the great nerve-trunks which go to the limbs and to the exterior of the body in every direction, and also forms the greater part of the brain and spinal cord.

214. Ganglia.—The gray matter, however, forms an important part of the brain and spinal cord, and also of various small nerve-centers, called *ganglia*, which are scattered throughout the body. In fact, every collection of gray matter, which is separated from other masses of gray matter by intervening white matter, is called a *ganglion*, and so even the different parts of the brain are included under this name.

215. Function of Nerve-Fibers.—The function of the nerve-fibers, as has been stated, is to convey impressions from one end to the other. Each nerve-fiber, even in the largest bundle, is completely isolated from all others, and runs an uninterrupted course from the cell, where it takes its origin, to the point of its termination. At its termination, it receives an impression, and this impression acts as a stimulus, which produces some molecular change through the whole length of the nerve, and eventually in the cell from which it comes. How this communication is accomplished is not yet known. Some change is produced in the nerve, which is not to be detected in any way excepting by its effect at the farther extremity.* In a similar manner, a change originating in a nerve-cell is transmitted along the fiber or fibers connected with it, and manifests itself at the termination of the fiber in some peculiar manner. Some nerve-fibers thus convey impressions from the outside inward to the nerve-centers, while others convey them from the nerve-centers outward to the exterior of the body. An intelligible illustration of this is to be seen in

* It has been found by the use of delicate instruments (galvanometers) that there is a constant electrical current in all nerves in a state of rest, supposed to be due to the nutritive changes taking place in the nerves. When the nerve is stimulated, however, so that the natural nerve-current is conveyed along the nerve, the electrical current is diminished in force.

the phenomena of ordinary sensation and muscular contraction. The prick of a pin stimulates the extremity of a nerve-fiber, or perhaps of several. The current originated by this stimulus travels along the course of the nerve to the nerve-center, and produces what we call *sensation*. Then the nerve-center, acted upon by this stimulus, sends out a certain amount of nerve-force along another nerve-fiber. This impulse follows the course of the nerve down to the muscular fiber in which it terminates, and there produces contraction of the muscle, and removal of the part which has been pricked, out of harm's way. This process, so simple to describe, so plain in its gross outline, is probably a very complex one, and it is not at all understood. When it takes place, as it often does, without any consciousness on the part of the person, it is called *reflex action*, because the result of the first stimulus, which produced the sensation, is reflected, as it were, along the second nerve to the muscle.

216. Rapidity of Nerve-Current.—It seems, at first thought, as if the reaction to a nervous stimulus were instantaneous. If the finger be hurt, it is jerked away so quickly that there seems to be no interval between the injury and the action. And yet it is evident that, if the received theory be true, viz., that a current must go from the finger to the brain in order to be felt, and from the brain back to the muscle in order to produce muscular contraction, there must be a lapse of time. Most people would probably say, however, that the nerve-force must travel as rapidly as electricity, and hence the time required for such a circuit would be inappreciably short. It has been shown, however, by ingenious and beautiful experiments, that the nerve-force does not travel over one hundred and ten feet (thirty-three metres) per second, and hence to go from the foot to the brain would require at least one twentieth of a second, and the same to return. Thus an injury to the foot would not be followed by voluntary muscular contraction until at least one tenth of a second had elapsed. Electricity, on the other hand, travels with almost inconceivable rapidity.

217. Exhaustion of Nerves.—The transmission of an impulse along a nerve-fiber not only requires time, but exhausts the nerve. We have previously shown that continued muscular contraction exhausts the muscular fiber, and that every muscle must have rest and nourishment, in order to maintain itself in health and vigor. It is the same with the nerves, but they recover, when exhausted, much more slowly than the muscles, and require a longer period of rest.

218. Nerve-Fibers as Conductors of Force.—The fact that nerve-fibers are mere conductors of nerve-force, and do not originate it, is shown by cutting them in two. All sensation and motion then cease in the portion of the body supplied by the nerve which has been cut. After some time, however, such injuries become healed, the cut extremities of the nerve unite, and the powers of sensation and motion return.

219. Gray Matter originates Force.—It has been already stated that the gray matter originates force. This is indicated by the fact that all the nerve-fibers end in collections of gray matter, and that in the natural condition no nerve-fiber conducts an impulse in either direction, inward or outward, unless it be directly connected with gray matter. What the force may be which resides in the nerve-cells, and what changes accompany their action, we do not know, and possibly never shall know. It has been often compared to electricity, and was once supposed to be identical with it, but it has been plainly demonstrated to be different. The diminution of the electrical current during the passage of the natural nerve-current shows this, and, if a nerve be tightly bound, the transmission of the nervous impulse is prevented, while the electrical current will pass through the constricted nerve without appearing to meet with resistance.

220. Difference between Cerebro-spinal and Sympathetic Nerves.—The cerebro-spinal nervous system and the sympathetic nervous system bear a close relation to the voluntary and involuntary muscular tissues respectively. The *voluntary* muscles are supplied by nerves from the *cerebro-spinal* system, and the *involuntary* muscles by the *sympathetic*, and the same differences, that we have observed between the two kinds of muscular tissue in their manner of contraction, are also found in the two systems of nerves. A stimulus applied to any portion of the cerebro-spinal system produces an immediate response, while irritation of any portion of the sympathetic system only produces an effect after the lapse of an appreciable time.

The only portion of the nervous system over which we have any control whatever, and which stands in any relation to our consciousness, is the cerebro-spinal system (Fig. 53). This system, constituting by far the greater bulk of our nervous apparatus, comprises the brain and the spinal cord, together with all the nerves which take their origin

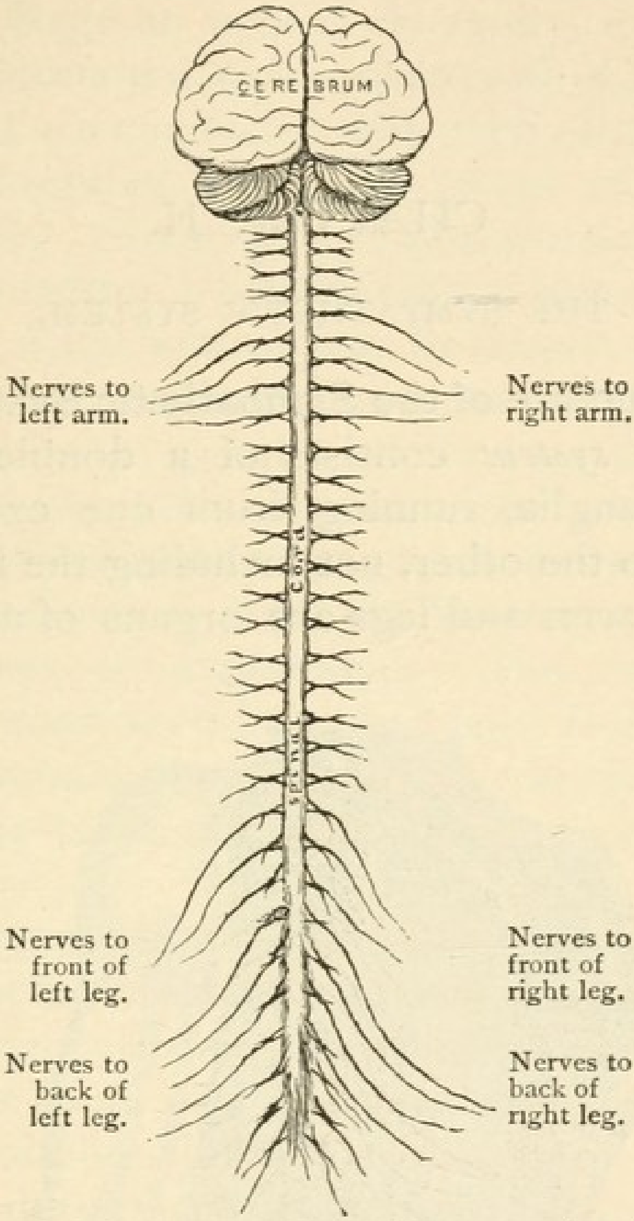

FIG. 53.—Brain and spinal cord, with the thirty-one pairs of spinal nerves.

in these organs. The brain is a very complex organ, being composed of several different ganglia, each of which has its own peculiar functions. In describing the nervous system it will be convenient, therefore, to begin with the sympathetic system, as being the simplest in its structure and functions.

CHAPTER II.

THE SYMPATHETIC SYSTEM.

221. Structure of the Sympathetic System.—The *sympathetic system* consists of a double chain of nervous ganglia, running from one extremity of the body to the other, not including the limbs (Fig. 54). The arms and legs are organs of animal life,

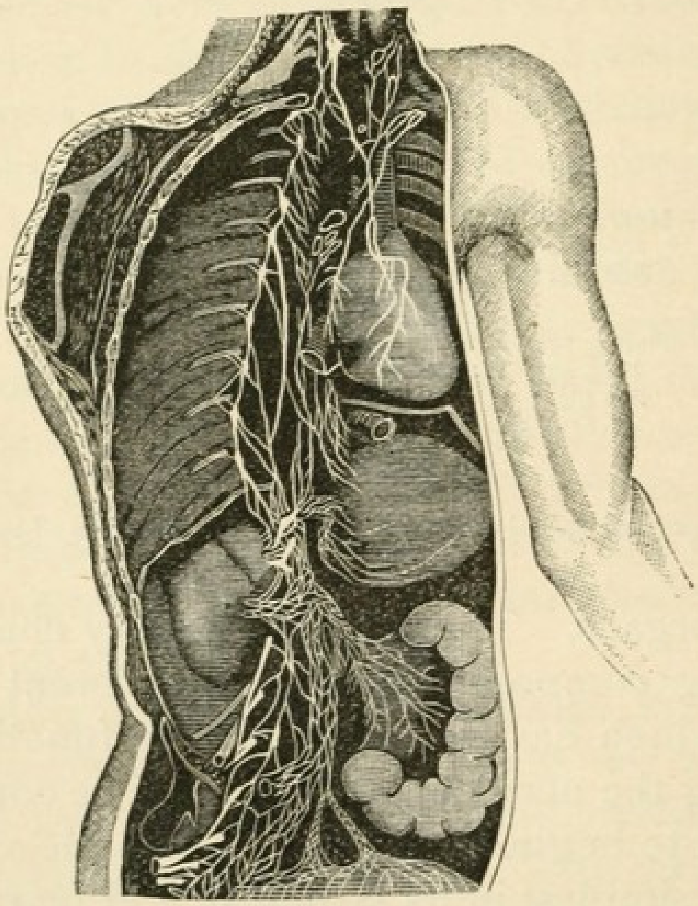

FIG. 54.—The sympathetic system of nerves in the trunk.

and are supplied with cerebro-spinal nerves. The ganglia of the sympathetic vary very much in size, some being only visible with the microscope, and others as large as a pea, or, rarely, even larger. They are composed, as has been said, of gray nerve-matter, and are connected with each other and with the cerebro-spinal nerves by means of communicating fibers. Some of these fibers are of the ordinary white matter, while others are transparent and grayish in color, and appear to consist of an axis-cylinder alone, without any surrounding myelin. The sympathetic ganglia all lie very deep in the cavities of the body, in the vicinity of and surrounding the important organs,* whose functions they control, and it is very difficult to get at them for purposes of experiment. The consequence of this is, that very little has been learned about the real action of the sympathetic system, and many of its functions can at present only be conjectured.

222. Sluggish Action of Sympathetic Nerves.— The sympathetic nerves have been proved to be capable of conveying both sensory and motor impulses; but these properties are very slow in manifesting themselves, in marked contrast to the behavior of the cerebro-spinal nerves. If the extremity of a sympathetic nerve be irritated, it is only after a considerable time that the nervous center is af-

* The large sympathetic ganglia, called the solar plexus, or the semi-lunar ganglia (from their shape), lying behind the pit of the stomach, constitute what has been sometimes called the abdominal brain. A blow in this region is very dangerous, for, if it is powerful enough to paralyze these ganglia by the shock, it is more certain to cause instant death than the severest blow on the head.

fected, and the reflex motion is very slow in its appearance. This fact is illustrated in the inflammations and congestions of internal organs. The sympathetic system mainly furnishes the nervous supply of the organs of digestion and secretion. If any irritation, like the cold air of a draught for instance, affects the body, the result, such as internal congestions, etc., only appear after some time has elapsed. An exposure to injurious influences may produce a serious disease through the sympathetic system, and yet the disease may not declare itself for ten or fifteen or even twenty-four hours after the exposure.

223. Contraction of the Pupil.—Various familiar phenomena show this sluggish action of the sympathetic nerves. One of the most obvious is the contraction of the pupil of the eye under exposure to light. When a strong light is thrown into the eye the pupil grows smaller and shuts out the excess of light. On the other hand, when the supply of light is diminished, the pupil enlarges so as to admit more. Now, these changes in the size of the pupil take place very slowly. When we go from a light room into a dark one it is several seconds, sometimes a minute, before we can see anything, simply because the pupil does not admit enough light and requires time to enlarge sufficiently. When we go from a dark room to a very light one we are dazzled; the pupil is too large and admits too much light, and we are obliged to shade our eyes until contraction has taken place. These phenomena are the result of impressions made on the sympathetic system, and serve as an excellent illustration of the slowness and precision of its action, as well as of the fact that its functions are entirely beyond our conscious control.*

224. Effect of dividing a Sympathetic Nerve.— One of the most remarkable facts relating to the sympathetic system was discovered by the celebrated physiologist, Bernard, by the following experiment: The rabbit's ear is large and well supplied with blood-vessels, and is covered with a thin, transparent skin, which allows all changes underneath it to be easily seen. If, now, the sympathetic nerve running to the ear be divided, the ear becomes red and hot, and the blood-vessels are seen to be enlarged and much fuller of blood than they usually are. There is no stagnation of the circulation, and, after the lapse of a sufficient time, three or four weeks, the divided ends of the nerve unite and the ear returns to its natural condition. If, after the nerve has been divided, as above, while the ear is in its red and hot condition, the end of the nerve nearest the ear be irritated by a galvanic current, the blood-vessels contract, the unusual amount of blood is expelled from them, and the ear resumes its ordinary temperature and color. If the cause of irritation be removed, the redness and heat return. These facts seemed to indicate that the supply of blood in a part was regulated by the sympathetic system of nerves, a supposition which was confirmed by further experiments.

* The iris, i. e., the muscular curtain surrounding the pupil, is supplied with nerves from the cerebro-spinal system as well as from the sympathetic. The relative functions of the two sets of fibers are not well understood, but the sluggish and involuntary character of the changes in the size of the pupil shows that the influence of the sympathetic nerves predominates.

225. Influence of the Sympathetic Nerves on Secretion.—He found that, if the sympathetic nerve supplying any of the glands in the body be divided, an increased supply of blood takes place and increased secretion by the gland follows. If the parotid gland be treated in this way, an increased flow of saliva takes place. The same effect is also produced on this gland by galvanic irritation of the nerve of taste. Any savory substance in the mouth, then, irritating the nerve of taste, gives rise to a reflex action through the sympathetic nerve which goes to the parotid gland and produces a flow of saliva. This is what we call "feeling the mouth water." The same effect may even be produced by purely emotional causes, as the mere sight of an appetizing article of food.

226. Effect of Emotion on the Sympathetic Nerves.—Blushing is another phenomenon depending on the control of the sympathetic nerves over the blood-vessels. The emotion of shame produces a temporary paralysis of the sympathetic nerves, and gives rise to the same effects as a division of the nerve. Blood rushes to the superficial blood-vessels and they become redder and hotter than they ordinarily are. The blush is more evident in the cheeks than elsewhere, because the skin is thinner there, and the blood-vessels more numerous; but the blush extends, in reality, much more widely than is commonly supposed, and covers a large portion of the surface of the body. The peculiar characteristics of the sympathetic system are to be plainly discerned in the blush. It is not instantaneous, but comes on slowly after an indignity, gradually rises to its greatest height, and then gradually disappears. It is also beyond the control of the will. If a person really feels the emotion, he can not restrain the blush. The only means of preventing it lies in such a constant schooling of the mind that feelings of shame, modesty, insulted dignity, etc., shall not be felt. When a person has arrived at this point of self-control he will not blush. But who would wish to purchase exemption at such a price? Many persons are ashamed of blushing, but who would be ashamed of being ashamed? The two can not be separated, and one who has lost the sense of shame entirely has lost much of what commends us to the sympathy and respect of our fellows.

227. **The Vaso-motor Nerves.** — The nerves which thus control the supply of blood to the blood-vessels are called the *vaso-motor* nerves. They have been already referred to in another part of this book. They have received the name of vaso-motor because they control the motion of the walls of the vessels (*vasa*) producing contraction or relaxation. Although they are chiefly of the sympathetic system, they receive fibers from the cerebro-spinal system. The two systems are not entirely distinct from each other, but there are certain functions in which they are so widely different that we can say with certainty this action belongs to the cerebro-spinal system, or that one to the sympathetic; while between these extremes are all sorts of gradations, so that in many cases we are unable to distinguish the characteristics of either system, and must say of them that we do not know how they are produced or that both systems probably unite their functions.

228. **Influence of the Sympathetic System on Di-**

gestion.—The whole process of digestion is presided over and regulated by the sympathetic nervous system. The introduction of food into the stomach stimulates the nervous ganglia in the abdomen, and through their influence is followed by all the phenomena of secretion, muscular movements, and absorption, which have been shown to accompany and form a part of the process of digestion. All of these phenomena are beyond our control, but, as has been shown in the case of the blush, the nervous supply of the sympathetic is favorably or unfavorably affected by strong emotions. And it is through these ganglia and their connections that anger, fear, or other depressing emotions, produce such an injurious effect on the digestive organs during and after a meal.

229. Effect of Cold on the Sympathetic System.—It is through the reflex action of these nerves, also, that hæmorrhage can often be checked by the application of cold, and that inflammation of internal organs may result from the same cause. The mucous membranes, for the same reason, seem to be more exposed to such inflammations than any other portion of the organism. Hence, exposure to a cold draught is very apt to bring on such a disorder. In one person it may affect one mucous membrane, in another another, according to the relative condition of the membranes at the moment. After such an exposure, one person may have a severe cold in the head, another a bronchitis, another a sore throat, another a diarrhœa or inflammation of the mucous membrane of the intestines.* All of these results

* Many persons, instead of catching cold in the nose or throat after exposure, have their bowels affected, and the resulting catarrh causes a

are beyond our control, and the only way to prevent them is to keep out of danger. When a person is in health, food introduced into the stomach will inevitably be digested, whether he wills it or not, and, if he undergoes certain exposures, he will take cold, in like manner, whether he wills it or not.*

230. Exhaustion of the Sympathetic System.— As the sympathetic system is so intimately connected with the processes of nutrition, and indeed with all the functions of those organs which maintain us in life, without our consciousness, it is evident that it should be well taken care of and nothing done to cripple it. We have, then, to bear in mind that nerves require rest as well as any other part of the body, that they easily become exhausted, and that they require a longer period for recuperation than the muscles do. The surest sign, perhaps, of exhaustion of the sympathetic system will be found

diarrhœa. When a person is specially liable to this affection, he should wear a thick flannel bandage around the abdomen, which will furnish almost entire relief from such attacks.

* A cold is generally the result of the sudden chilling of some part or the whole of the surface of the body. The first effect of such a chill is to contract the blood-vessels on the surface and overfill those that lie deeper, and thus to cause congestions of the internal organs. Such an effect seems to be especially apt to follow a cold draught striking the back of the head or neck or the ankles. Now, active muscular exercise tends to drive the blood to the surface, and is therefore a natural preventive of colds. It tends to keep the blood at the surface, where a congestion will be relieved by perspiration, and prevents its accumulation in the deeper organs, where it is more likely to cause trouble. If exposure to cold, therefore, can not be avoided, we must keep up a brisk circulation by physical exercise. Wet clothing should be changed for dry as soon as possible, for so long as it remains in contact with the body it absorbs a great amount of heat from it and keeps up a constant chilling of the surface. When a person is not engaged in physical exertion, he should avoid draughts.

in *failure of nutrition.* If a person grows thin and pale and languid, notwithstanding a good supply of food, or if his food be not appropriated by the body—in short, if his nutrition become impaired, and no organic disease be discoverable—it is probably the result of nervous exhaustion, and means should be taken to relieve the overtasked organs. Rest will accomplish wonders in many cases of illness, especially where there is no disease of any particular organ to be detected.

CHAPTER III.

THE SPINAL CORD.

231. Structure of the Spinal Cord.—The *spinal cord* is that portion of the nervous system which lies within the spinal canal. It extends from the junction of the spinal column with the skull, down to the loins, and is about a foot and a half long and a little less than half an inch in diameter. It weighs about an ounce and a half. It does not occupy the whole spinal canal, but the space around it is filled with membrane, blood-vessels, and nerves. At its upper extremity it passes into the brain, and at its lower, just below the last rib, it divides into a bundle of small nerves, presenting very much the appearance of a tassel at the end of a thick cord.*

The spinal cord consists partly of white and partly of gray matter. The gray portion occupies the central portion of the cord, and is arranged somewhat in the form of the letter H, with the two upright marks curving outward at both ends (Fig. 55). The remainder of the cord, in which this gray substance is imbedded, is composed of white matter.

The spinal cord, throughout its whole length, is divided by fissures, one of which extends from be-

* This part of the spinal cord is called the *caud'a equi'na*—i. e., the *horse's tail*, which it somewhat resembles.

fore backward, and the other from behind forward, the two nearly meeting. They are, however, separated, and the halves of the cord kept in communication by a bridge of gray matter, which passes over from one to the other, forming the cross-line of the letter H.

232. **The Spinal Nerves.**—The spinal cord sends out nerves through its whole course. With the exception of the head and face, all the muscles and the skin of the body receive their nervous supply from this source. These nerves, thirty-one pairs in all, issue from the spinal column between the vertebræ through small openings.

233. **Properties of the Spinal Nerves.**—All parts of the body, which are supplied with spinal nerves, are endowed with two remarkable properties, *sensation* and *motion*. As long as the nervous supply remains in a natural and healthy condition, any portion of the body feels, and any portion can be moved from one place to another. These movements are sometimes voluntary and sometimes we are entirely unconscious of them, and it is only within a few years that physiology has been able to offer any explanation whatever of these facts.

234. **Sensation and Motion.**—When we consider attentively the property of sensation, we find that there are two great divisions of it, easily distinguishable and easily demonstrated, viz., *sensibility to pain* and *ordinary sensation*. When a person is brought under the influence of an anæsthetic, the sensibility to pain disappears before ordinary sensation is lost, and even while the individual is still conscious. In slight surgical operations this fact is often strikingly manifest. A tooth may be pulled,

and the patient be conscious of every step of the proceeding, without feeling the slightest pain. Narcotics, too, may relieve the pain of a neuralgia, while the person who has taken them remains perfectly in possession of his senses. Physiologists have made other discriminations of sensation, which it is not necessary to mention here.

The phenomena of motion are familiar, and require no separate consideration.

235. **Effect of dividing a Nerve.**—If one of the spinal nerves be cut in two, sensation and motion are abolished in the portion of the body supplied by that nerve. This shows that sensation and motion are both conveyed in the same nerve. But here a difficulty arises. Sensation implies the passage of a nerve-current from without inward, toward a nerve-center; whereas motion implies the passage of a current from within outward, from the nerve-center to the muscle. Can both these currents be transmitted at the same time, or can the axis-cylinder of the nerve-fiber be used for the passage of the nerve-current in either direction according to circumstances? This is the problem which waited until this century to be solved. The simplest explanation has been found to be the correct one. As every nerve is made up of many fibers, it would be natural to suppose that some of these fibers might serve as conductors of sensation, and others of motion. This was made all the more probable by the fact that, in many forms of disease, it was seen that the power of sensation might be abolished, while that of motion remained; or, on the other hand, the power of motion might be paralyzed, while that of sensation remained unimpaired.

And, in fact, the above explanation of these phenomena was found to be correct. The first who demonstrated this appears to have been Sir Charles Bell,* although Magendie† has strong counterclaims to the honor. The experiments by which the truth was established were decisive, and have been often repeated by other physiologists. They are the following:

236. The Roots of the Spinal Nerves.—The spinal nerves do not take their origin from the spinal cord as single trunks, but each one arises by two roots. One of these roots is formed of fibers coming from the anterior portion of the cord, and is called the *anterior root;* the other is formed by fibers from the posterior portion of the cord, and is called the *posterior root;* the latter, at a short distance from its source, passes through a small ganglion of gray matter. These two roots, anterior and posterior, approach each other and unite in a single cord just before leaving the spinal canal. This cord, therefore, contains fibers from both portions of the spinal cord, and, after running a short distance, it again divides into two nervous trunks, one of which supplies the front of the body and the other the back.

The experiments referred to consisted in dividing, not the nerves, but the anterior and posterior roots of the nerves, inside the spinal canal, in a liv-

* Sir Charles Bell, a distinguished Scotch anatomist, physiologist, and surgeon (1774–1842), Professor of Surgery in the University of Edinburgh.

† François Magendie, a celebrated French physiologist (1783–1855), Professor of Anatomy in the College of France, especially well known for his experiments on living animals.

ing animal, and watching the result. Severe and painful as these experiments were, and however objectionable from the animal-lover's point of view, they have probably done more to explain the mysteries of the nervous system, and to give a fresh impulse to investigation on the most interesting and important subject with which man can occupy himself, than any similar experiments in the world's history, if we except those which demonstrated the circulation of the blood.

237. **Division of the Anterior Root.**—When the *anterior root* of a spinal nerve is divided (Fig. 55), the portion of the body supplied by the nerve of

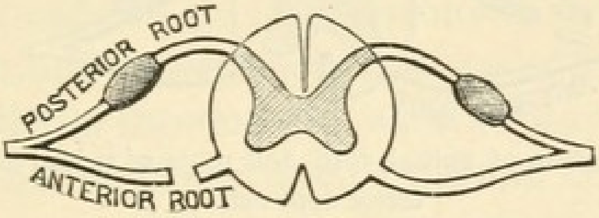

FIG. 55.—Cross section of spinal cord and roots of spinal nerves, with anterior root cut.

which this particular root forms a part, loses its power of motion, but preserves its sensibility unimpaired. If the portion of the body supplied by this nerve be pinched or pricked, the animal gives evident signs of pain, and endeavors to get out of the way of the irritation, but is utterly unable to move the muscles of the part. If, now, the ends of the cut nerve be irritated, the following results are obtained: On irritation of the end nearest the part supplied by the nerve, the muscles of that part become strongly contracted, or convulsed, while the animal gives no indication of feeling anything whatever. If the end nearest the spinal cord be irritated, no effect whatever is produced. There are no convulsive movements of the muscles, and no indication of sensation. This seems to show that, in the fibers of the anterior root, the nervous impulse is transmitted from within outward, and gives rise to the phenomena of motion, while they have nothing to do with sensation.

238. Division of the Posterior Root.—If, now, instead of dividing the anterior root, we divide the *posterior* (Fig. 56), we find that the part supplied by the nerve has lost sensation, but retains the power

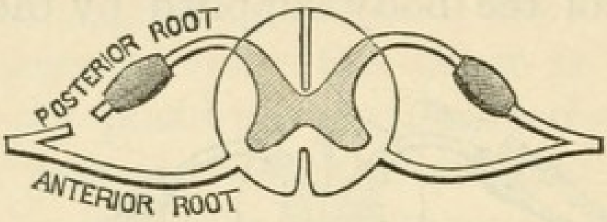

FIG. 56.—Cross section of spinal cord and roots of spinal nerves, with posterior root cut.

of motion. If it be pinched, pricked, or injured in any way, no effect is produced, and the animal appears to take no notice of it whatever. This shows that sensation in the part is abolished. If, now, the cut ends of the root be irritated, we find the following results: On irritation of the end nearest the part no effect whatever is produced. If, on the other hand, the end nearest the cord be irritated, the animal utters cries of pain, and moves the muscles supplied by the nerve which has been operated on, in endeavors to escape. This shows that the power of motion has not been interfered with by the operation, and it also shows that, in the posterior roots of the spinal nerves, the nervous impulse is transmitted from without inward, and has to do with sensation.

239. Two Kinds of Fibers in Each Nerve.—The *anterior* roots, then, are composed of *motor* fibers, and the *posterior* roots of *sensory* fibers. The two unite, as has been shown, to form a single cord, which afterward divides again to supply the front and back of the body. Every spinal nerve in this way is made up of both sensory and motor fibers, or fibers which convey sensation and fibers which convey motion; and thus, from the constitution of the nerve, it is easy to see how the powers of sensation or motion can be abolished separately, one remaining intact while the other disappears.

240. Relation of the Spinal Cord to the Brain.—These properties of sensation and motion have been considered only in their relations to consciousness. The sensations have been spoken of as felt by the animal, and the movements as voluntary. In order for this to be so, there must be some connection between the nerves and the brain, for consciousness has its seat in the latter, as we shall hereafter see. And in fact it has been proved that the nerve-fibers, after entering the spinal cord, pass upward in its interior toward the brain. It is probable that the white matter of the cord is largely composed of fibers which connect the brain in this way with the exterior of the body.

As the nerve-fibers approach the brain, however, at the very summit or upper extremity of the spinal cord, they cross over from one side of the cord to the other, the fibers from the right side passing over to the left, and those from the left going over to the right. The crossing of the motor fibers only takes place at this point, while the sensitive fibers cross to the opposite side of the cord soon after joining it. The consequence of these facts is, that the right side of the body comes into direct communication with the left side of the brain, and the left side with the right brain. An injury to the brain, therefore, on either side, produces paralysis of the opposite side of the body. An apoplexy* affecting the *right* side of the brain brings on paralysis of the *left* side of the body; and conversely, if we see a person whose *left* side is paralyzed, we look for the injury which has caused it on the *right* side of the head.

241. Sensations referred to Extremity of Nerve.—It has already been said that the nerve-fibers act merely as conductors of an impulse, and do not themselves originate nervous force. In consequence of this, an injury to any portion of a nerve always produces the same effect as if it were at its extremity. The pain which results from any impression on a nerve-fiber is always referred by the nerve-center which receives it to the termination of that particular nerve. And this fact clearly explains many things that once were not understood. The ulnar nerve furnishes a good illustration of this. At the inside of the back of the elbow are two bony projections, with a hollow canal between them. At the bottom of this canal, not far below the skin, runs a large nerve called the *ulnar nerve*, because it supplies the ulnar side of the fore-arm and hand. If this nerve be pressed or injured in any way, a tingling sensation is felt in the little finger and the ad-

* Apoplexy, from the Greek, meaning a *sudden stroke*. It is caused by the giving way of some blood-vessel in the brain, and the blood escaping into, compressing, and tearing apart the delicate nerve-tissue, causes paralysis and often entire unconsciousness, or death.

joining side of the ring-finger, the parts supplied by this nerve.* Striking examples of the same phenomenon are often seen in persons who have lost limbs by amputation. If the end of the nerve which remains in the stump be irritated in any way, as by the contraction of the scar, the person feels the irritation precisely as if it were in the lost limb. If any person's arm were cut off, for instance, just below the elbow, and the stump of the ulnar nerve were irritated, he would feel the tingling sensation in the little and ring fingers of his hand just as much as if the hand were still attached to the arm. The sensation is precisely the same, and can only be corrected by the sense of sight or by the individual's own memory or reason. It is this fact which has given rise to the numerous accounts of persons who have felt people maltreating their amputated limbs, when they perhaps were already decayed, or were hundreds of miles away.

242. **Reflex Action of the Spinal Cord.**—All the phenomena which have been described might occur just as well if the spinal cord were merely a large bundle of white fibers running down from the brain, and sending out branches to different parts of the body. It has, however, a considerable amount of gray nerve-matter in its interior, and, as we have seen that this form of nerve-matter originates force, we are prepared to infer that the spinal cord can

* The ulnar nerve supplies the little finger, the adjoining side of the ring-finger, and that side of the hand as far as the wrist. Pressure upon it, therefore, interferes with the nervous supply of those parts, and they tingle and become numb. The queerness of the sensation produced has caused this nerve to be commonly known as the crazy-bone, or the funny-bone, although it is not a bone at all.

originate movements and receive sensations without any connection with or dependence on the brain. And this is found actually to be the case. If the head of a frog be cut entirely off, leaving the body otherwise uninjured, sensation and motion are still manifested in the trunk and limbs. If the toe be pinched, the leg will be drawn up out of the way. This is the same effect that is produced when the animal is entire, with this exception: there is no attempt to escape from further injury. In other words, there is no brain-action, no reasoning. The irritation sends a nerve-current along the sensory nerve to the spinal cord. There it produces certain changes in the cells of the gray matter, and from them another current is sent outward along the motor nerve to the muscles, and movement results. If the nerve be severed, no such effect can be produced. If the spinal cord be destroyed, the nerves remaining intact, no such effect will occur. These facts show that the cord itself has the property of receiving sensations and sending out motor impulses. This action of the spinal cord, by which it produces a movement in response to and in consequence of a sensation, is called *reflex action.*

243. **Diseases of the Spinal Cord.**—Experiments like the above, of course, can not be performed on human beings, but the course of nature often performs them for us. Diseases are not uncommon in which the spinal cord is completely cut across in some portion of its length, so that there is no nervous communication between the brain and that part of the body below the seat of disease or injury. In such cases we have paralysis of the kind called by physicians *paraplegia*—i. e., the lower portion of

the body is no longer under control of the brain, and no longer capable of voluntary movements. It is also entirely beyond the domain of consciousness; injuries to the paralyzed part cause no sensation in the brain. The separation of such a part of the body from all relation to consciousness, whether of sensation or of motion, is as complete as if it formed part of another body. Notwithstanding this fact, we often find the spinal cord below the seat of injury to be in the same condition as that of the decapitated frog. If the disease or injury has been confined to a particular part of the cord, and the portion below, with its nerves, be still in a healthy condition, excepting that it is separated from the brain, a stimulus applied to any of the nerves will produce a response which is immediate and decided. A person in this condition looks on and sees his feet pinched, or pricked, or burned, and sees the irritation followed by violent convulsive kicks and thrusts of the limbs, without the slightest knowledge of what is going on, excepting what he receives through the sense of sight.

244. **Automatic Actions.**—Certain actions, which are at first voluntary, and only accomplished by great effort, become, after a time, so natural and easy, that they seem to be carried on unconsciously, through the action of the spinal cord. Thus, in the act of walking, a harmonious action of several muscles is required to keep the balance, an action which is at first learned only after prolonged and incessant effort. In after-life it becomes so easy as to be carried out without consciousness, as has been often shown in the case of soldiers, who have continued to walk in the ranks and keep up with their comrades on the march while fast asleep.

CHAPTER IV.

THE BRAIN.

245. The Brain.—The *brain* and the *cerebrum* are often spoken of as if they were convertible terms. But this is not correct. The *brain* includes all that part of the nervous system which lies within the cavity of the skull. This great mass of nervous matter is made up of several distinct ganglia, which, to be sure, are connected with one another and interdependent, and yet each of them has its own particular function which the others have not (Fig. 57). The *cerebrum* is merely one of these ganglia, and, although the highest in the scale as regards the character of its functions, it being the ganglion which principally gives man his pre-eminence over the lower animals, it is one of the least important as regards the mere preservation of life. In many of the lower animals it can be entirely removed, and the animal will live for months afterward. In the

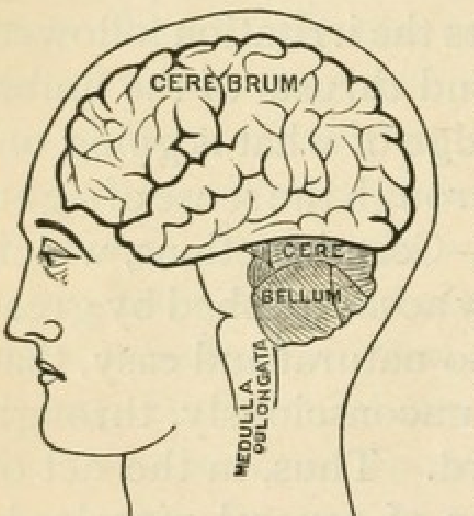

Fig. 57.—Diagram showing the position of the nervous centers in the head.

human being it is so plentifully supplied with blood-vessels that, if its removal should be attempted, the person would die of hæmorrhage. This has been the invariable result of experiments on the higher kinds of animals, as the dog or horse. But there is no doubt that, if the cerebrum could be removed without interfering with the circulation of the blood, even a human being would continue to live without it.

246. Structure of the Cerebrum.—The *cerebrum* (Fig. 58) is the largest part of the brain, forming as

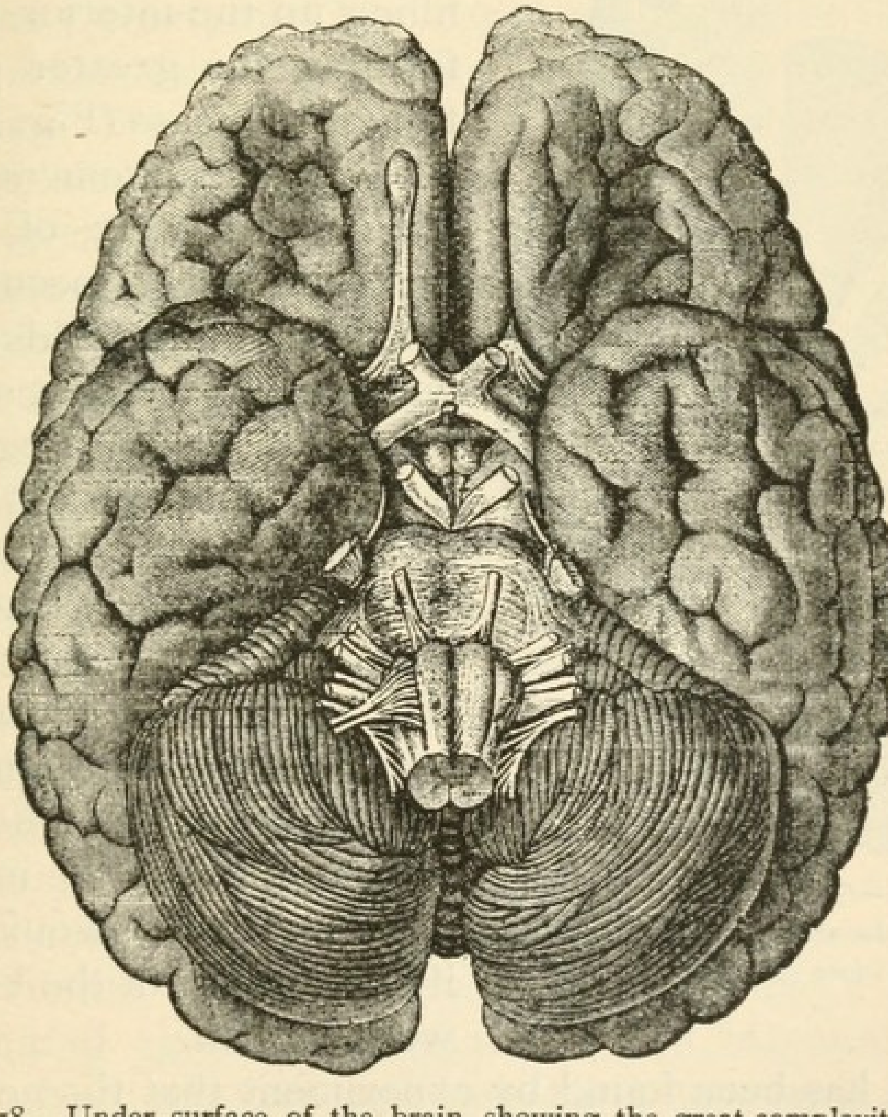

Fig. 58.—Under surface of the brain, showing the great complexity of its structure. At the lower part of the cut is the cerebellum.

it does about nine tenths of the whole mass within the skull. It consists of two halves, called *hemispheres*, the dividing fissure running from the front of the head to the back; but the halves are not entirely separated. On their under side, a bridge or mass of white fibers runs from one to the other, and serves as a means of nervous communication between them. The cerebrum is composed of both white and gray matter, the latter being spread over the surface, and the former filling up the interior, and forming the greater portion of the mass (Fig. 59).

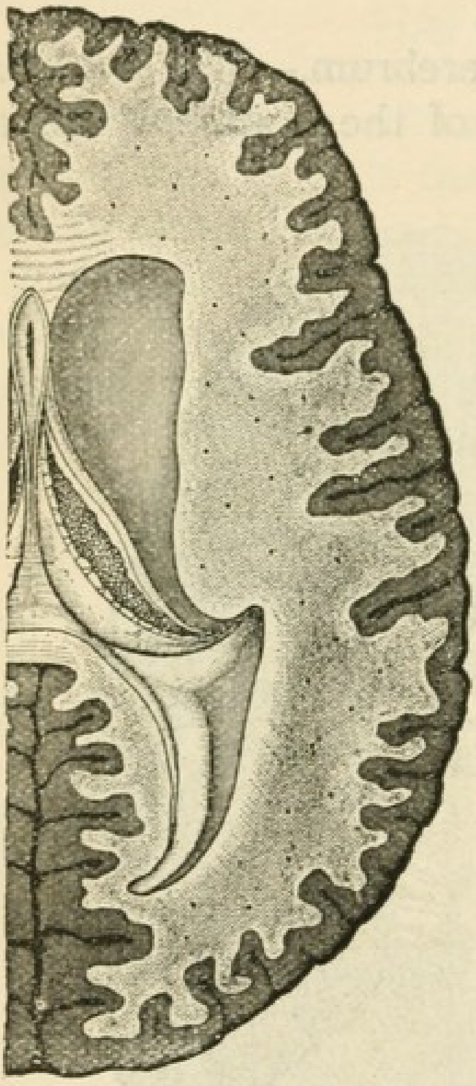

FIG. 59.—Section of the brain, showing the arrangement of the gray and white substance.

The arrangement of the nerve-matter of the cerebrum is very peculiar. It is formed into folds and wrinkles, somewhat like the meat of an English walnut. These folds are called the *convolutions* of the brain, and, as the gray matter follows closely the dipping of the surface between the convolutions, it is evident that the amount of gray matter is much greater than it would be if the surface of the brain were smooth.

It has been found by experiment that the nerve-matter composing the cerebrum is insensible to ordinary irritation. Either the gray or the white matter may be cut, pricked, burned with fire or caustic acids, without producing any sensation. What, then, is the function of the cerebrum?

247. **Function of the Cerebrum.**—It is now acknowledged by all who have paid any attention to the subject, that the *cerebrum* is the *organ of thought.* It is in this part of the brain that all ideas have their origin, and that all processes of reasoning take place. The evidence of this is indirect, but very conclusive, and may be briefly stated as follows:

248. **Intelligence increases with Increase in Size of the Cerebrum.**—The cerebrum increases in size in animals as we pass from the lower forms to the higher. The superiority of one animal over another in the scale of life depends mainly upon what we call intelligence. Now, we find that the intelligence of animals appears to increase in the same ratio that the size of the cerebrum increases in proportion to the rest of the body. In the fish, the cerebrum is very small, and his intelligence is very low. In the reptiles, the cerebrum is somewhat larger, and their intelligence as a class greater. In birds, the relative size of the cerebrum is considerably increased, and their intelligence is proportionally and noticeably higher. From birds we pass to quadrupeds, and here is a great increase in the size of the cerebrum, and a correspondingly finer intelligence. As we go up in the scale of quadrupeds, we find the size of the cerebrum increasing faster than the size of the body does, until, in the elephant, we find a brain weighing eight or ten pounds. The elephant and the whale are the only animals whose brains are larger than man's, and even their immense brains are

much smaller relatively to the size of their bodies. The human brain varies in weight in different persons, but its average weight is fifty ounces, or about three pounds. These facts, then, seem to show a relationship between the cerebrum and the quality of intelligence, for the difference in weight of different brains is mainly due to the varying size of the cerebrum.

249. Size of Human Brains.—When we examine different brains among human beings, we find the same general law holding good. Other things being equal, a larger brain signifies a greater mind. Thus the brain of Cuvier,* the celebrated naturalist, weighed 64⅓ ounces; that of Abercrombie,† physician and philosopher, 63 ounces, and that of Dupuytren,‡ surgeon, 62½ ounces; while the brain of an idiot seldom exceeds thirty ounces in weight. Occasionally men have possessed great intelligence, and have been found after death to have very small brains. An example of this is the brain of a celebrated mineralogist (Haussmann), who is said to have been above medium stature. Its weight was only 43.24 ounces. In such cases, it is usually found that the convolutions are very deep and very much curved and turned about, so that there is a greater amount of gray matter packed away than would have been expected in so small a skull.

* Baron George Chrétien Léopold Frédéric Dagobert Cuvier, one of the most eminent of modern scientific men (1769–1832), Professor of Natural History in the College of France; generally considered the founder of the science of comparative anatomy.

† John Abercrombie, a distinguished Scottish physician (1781–1844), especially celebrated for his metaphysical writings.

‡ Baron Guillaume Dupuytren (1777–1835), during his lifetime considered the most eminent surgeon in France; Professor of Surgery at Paris.

250. Effect of Injuries of the Brain.—It has also been noticed, from the earliest times, that injuries of the brain produce unconsciousness and various other phenomena, which indicate that the organ of the mind has been injured; so that, by almost all men, the fact that the brain is the seat of the mind has been readily acknowledged. In order to determine what particular portion of the brain is the organ of mental processes, experiments have been performed on animals. As has previously been mentioned, the cerebrum can not be removed from the higher animals without causing their death by hæmorrhage, but in birds and rabbits, as well as in the reptiles, it can be done. If the cerebrum be removed from a pigeon, then, what is the effect upon the intelligence?

251. Removal of the Cerebrum of a Pigeon.—The bird passes into a condition of stupor, in

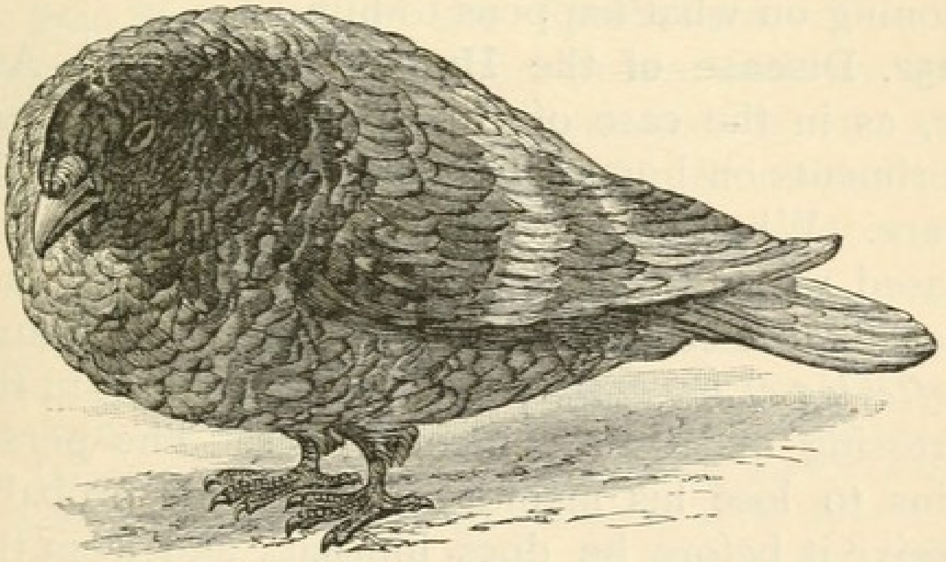

FIG. 60.—Pigeon, after removal of the cerebrum.

which he takes no notice of anything about him (Fig. 60). It is not that he does not see or hear or feel, for he does have all of these sensations. If his foot be pinched, he lifts it up, and then puts it down again, and moves uneasily, showing that he feels the irritation. His eyes will follow a lighted candle, which is moved to and fro, showing that he sees it. If a pistol be fired behind his head, he looks around, showing that he heard the report, and then becomes quiet again, relapsing into his condition of stupor. What do these facts indicate? The bird's senses are perfect; he sees, and hears, and feels, but is stupid. All the impressions upon his senses convey no idea to him, or rather they give rise to no idea. Noises and hurts, which in his natural state would frighten him, hardly disturb him. If food be put into his mouth, he swallows it, but he will make no attempt to feed himself. In fact, every action and every response to irritation goes to show that he has lost his mind; his intelligence is gone; he no longer has the power of reasoning on what happens to him.

252. Disease of the Human Cerebrum.—And here, as in the case of the spinal cord, we find experiments on human beings provided for us by Nature. When the cerebrum of a human being is diseased, we find that the mind is affected. This is noticeably the case in the disease commonly known as *softening of the brain.* The first symptoms in this distressing malady are mental ones. The person begins to lose his memory; his friends probably perceive it before he does himself; and from this first indication of intellectual feebleness the disease goes on, often without any disturbance of the nutrition of the body, until the intelligence is completely abolished, and the person's life is a blank.

When the brain of such a person is examined after death, the cerebrum is the part found diseased, and we see that the gradual impairment and extinction of the mind, which we have watched in a human being as the result of disease, is really the same thing as the sudden destruction of the mind which we produce in a pigeon by a surgical operation.

253. **Recapitulation.**—To recapitulate; *the evidence that the cerebrum is the seat of the intelligence* is the following: *First*, we see that in the lower animals, as well as in man, the development of the mind is proportionate to the development of the cerebrum in comparison with the rest of the body. *Second*, that if the cerebrum be removed from an animal, the mental faculties are the only ones lost. *Third*, when the mind of a human being is impaired or lost, we find a corresponding disease or injury of the cerebrum.*

254. **Structure of the Cerebellum.**—The ganglion next in size to the cerebrum, and one whose functions are of great importance, is the *cerebellum*, or little brain (Figs. 57, 58). It is situated beneath the back part of the cerebrum, occupying

* Also, when the cerebrum is seriously injured, the mental faculties are generally impaired. There have been some cases of recovery after very severe injuries of the brain. In 1850 a young man in Vermont, a farm-hand, was blasting rock, when a tamping-iron, three and a half feet long and an inch and a quarter in diameter, was driven through his head, entering the left cheek and coming out at the top of the head, causing a great loss of brain-substance. He recovered completely from the wound, but from a quiet, home-loving, honest lad, he developed into a tricky, thieving fellow, of a roving disposition, lived in various places in South America and the United States, was subject to epileptic fits, and died in convulsions in California twelve years after the injury.

that portion of the skull immediately behind the ears. Its average weight is five and a quarter ounces, about one ninth of the whole weight of the brain. It is composed of gray and white matter, arranged in much the same way as in the cerebrum, excepting that the convolutions are smaller and dip in deeper, so that in the cerebellum the proportion of gray matter is much greater than in the cerebrum. This fact, of itself, would indicate its importance.

255. Function of the Cerebellum.—The exact function of this part of the brain has not yet been determined. There are difficulties in the way of experiments upon it, which are not found in experiments upon the cerebrum. If the entire cerebellum be removed from a pigeon, the bird dies from hæmorrhage, and nothing can be learned. If the greater part of it be removed, proper precautions being taken against hæmorrhage, very peculiar phenomena are presented. The pigeon sprawls about in frantic efforts to get away, but acts like a drunken man (Fig. 61). He does not seem to possess proper control over his muscles. The muscles act perfectly well; there is no paralysis, but the harmonious action of sets of muscles is apparently interfered with. To move the wings for flying, or the legs in walking, requires the consentaneous action of many muscles, and this the bird is unable to control.

This experiment, which invariably produces the same results, seems to show that the cerebellum in some way controls and harmonizes the voluntary muscular contractions, or, as the physiologists express it, the cerebellum is the seat of the co-ordinating power in voluntary muscular movements. This idea was at one time accepted, but it was

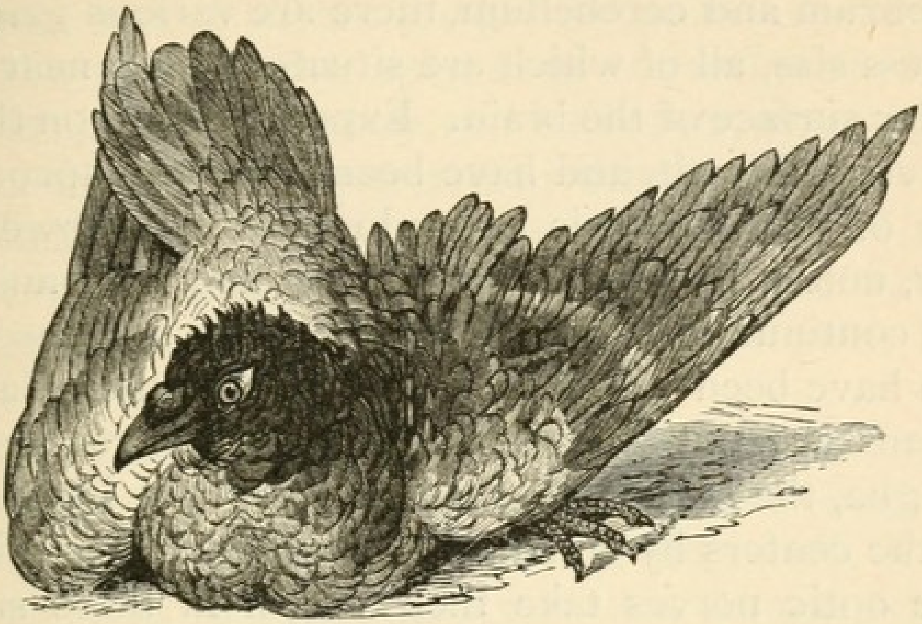

FIG. 61.—Pigeon, after removal of the cerebellum.

found that in pigeons, who did not die from the operation, the power of co-ordinating their movements was after a time regained. And this was not the result of the healing of the injury, for the lost portion of the cerebellum is found on inspection not to have been renewed.

Diseases of this portion of the brain in the human being also give contradictory data. Tumors and injuries of the cerebellum often occasion difficulty in muscular co-ordination, but, on the other hand, no disturbance in the muscular movements has been detected in some cases, where the disease of the cerebellum has been very extensive.

Comparison of the relative development of the cerebellum in different animals seems to favor the theory proposed.

All things considered, however, scientific men are agreed that the *real function of the cerebellum is not yet definitely known*.

256. Other Ganglia of the Brain.—Besides the cerebrum and cerebellum, there are various ganglia of less size, all of which are situated on or near the under surface of the brain. Experiments upon these are very difficult, and have been hitherto unproductive of results. It is an undoubted fact, however, that, unless destroyed by loss of blood, an animal will continue to live after the cerebrum and cerebellum have been removed, showing that these latter organs are not essential to life. Of the remaining ganglia, the *tuber'cula quadrigem'ina** are known to be the centers by which vision is rendered possible. The optic nerves take their origin in these small ganglia, and the fact that they receive the impressions which we call sight is proved in this way: If the optic nerve be cut between the eye and the tubercula quadrigemina, blindness results. The same effect is produced by destruction of these bodies, the optic nerves remaining uninjured. If, on the other hand, the connections between these ganglia and the cerebrum be severed, the ganglia and nerves remaining intact, sight still remains, and vision is also retained, if the cerebrum be removed and the tubercula quadrigemina left untouched. These things are sufficient to show that they are the centers of the sense of vision.

In some one or all of the remaining ganglia, with the exception of the *medulla oblongata*, to be hereafter described, the powers of sensation and

* These small bodies are situated above and in front of the cerebellum, between it and the cerebrum, and so are not shown in any of the cuts.

motion reside. This is known from the fact that, after the removal of the cerebrum and cerebellum, the animal is still capable of sensation and voluntary motion; but, if all the ganglia be removed, excepting the medulla, not only does consciousness disappear, but all sensation and voluntary movements cease, the special senses are abolished, and the only manifestations of life are the continuance of the functions of respiration and circulation, and the reflex movements of the parts connected with the spinal cord.

257. The Medulla Oblongata.—The spinal cord passes upward from the spinal canal into the skull. Just after entering the cavity of the skull, it becomes somewhat enlarged, and this enlarged portion is called the *medulla oblongata* (Figs. 57, 58). It is about an inch and a quarter long, and three quarters of an inch wide, and at its upper extremity is merged in other parts of the brain. Imbedded in this part of the cord is a small mass of gray matter, which is more essential for the actual preservation of life than any other portion of the brain. It has sometimes been called the "vital knot." If this be destroyed, all manifestations of life instantly cease. The cause of this is the intimate relation which this part bears to the function of respiration.

258. The Medulla Oblongata controls Respiration.—The movements of respiration are to a certain extent under the control of the will, but, under ordinary circumstances, we breathe unconsciously. Inspiration and expiration take place regularly and unceasingly, by night and by day, in our sleeping as well as our waking hours. The nervous supply, therefore, by which this function is controlled is, so to speak, automatic. The requisite movements are carried on by reflex action. How is this accomplished?

As the processes of repair and waste go on, carbon dioxide and other waste matters accumulate in the blood. When this venous blood, loaded with impurities, arrives at the lungs, it imparts a peculiar stimulus to the large nerves, which are distributed to these organs. They convey a sensation to the *medulla oblongata*, and the corresponding motor nerves convey the impulse from the gray matter of the medulla oblongata, and cause a contraction of the muscular walls of the chest. Inspiration then takes place, the blood receives oxygen, the air is expired again, and the chest-walls remain passive until venous blood again accumulates in the lungs in sufficient quantity to cause the requisite stimulus in the medulla oblongata; and so the process continues through a long life, independently of the will of the individual.

259. Automatic Action of the Medulla Oblongata. —Respiration, however, is in a measure under the control of our will. We can hold our breath, if we choose, for a short time; but, with the cessation of respiration, the blood becomes more and more charged with impurities, until at length a peculiar sensation begins to be felt, which we call "want of breath," or "shortness of breath." If we still resist the desire to inspire, and hold the chest-walls immovable, this sensation increases until it induces the most intense suffering, and the will is at length unable to assert its power. The automatic action of the medulla oblongata overrides our feeble opposition, and we breathe again, in spite of ourselves. It is a lesser degree of this same sensation, without a doubt, which acts as a constant stimulus to the medulla oblongata, and keeps up the process of respiration without our consciousness. Now, when the portion of the medulla oblongata containing this part, called "the vital knot," is destroyed, respiration instantly ceases, and the circulation soon stops. This is the quickest way known of killing animals, and is much used by physiologists, when they wish to produce sudden death, without injuring the blood-vessels or other organs of the body on which they wish to experiment.*

* In the great slaughtering establishments of the West, cattle are killed by puncture of the medulla oblongata. Men stand upon a raised platform, and, as the animals pass underneath, penetrate this organ with a sharp spear, or with a bullet from a carbine. The *matador*, in the Spanish bull-fights, also aims to strike this vital part, and his reputation depends upon the success with which he does it. The Spaniards execute criminals upon the same plan, by means of the *garotte*, which consists of an iron collar surrounding the throat, with a steel pin projecting inward behind. A single turn of a large wheel forces this pin into the medulla oblongata and causes instant death.

CHAPTER V.

SPECIAL NERVES.—HYGIENE.

260. Nerves of the Head and Face.—In the spinal nerves, we have seen that the motor and sensory fibers are mingled, so that each nerve contains fibers of both kinds. In the nerves coming from the brain this is commonly not the case. As a rule, some nerves are entirely nerves of sensation, and others entirely nerves of motion, and the two functions are not united in a single trunk. These nerves are arranged in pairs, like the spinal nerves, one going to one side of the head or face and the other to the other.

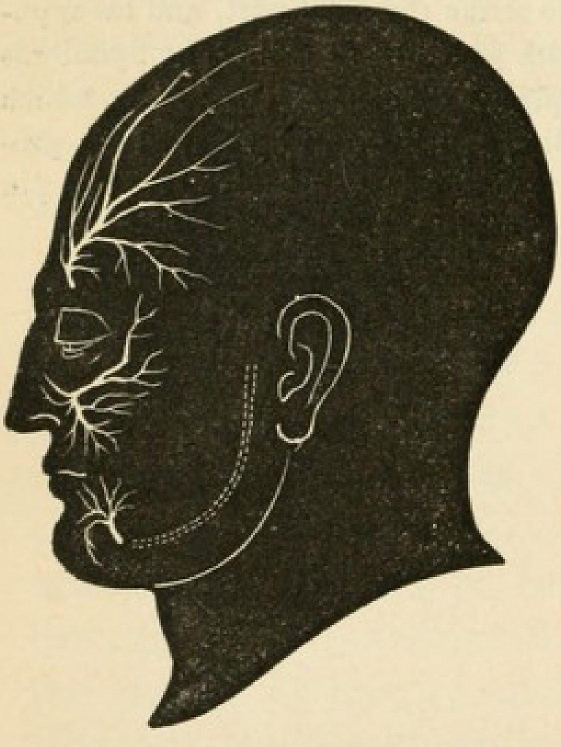

FIG. 62.—Diagram showing the distribution of the fifth nerve to the face.

The two most important nerves of the face are those called the *trigeminal* and the *facial*. The *trigeminal* nerve (Fig. 62) emerges from the skull by three openings, being divided into three branches just before it reaches these openings. One branch supplies the parts surrounding the eye, the forehead, and the inside of the nose; the second comes out just below the eye, after sending branches to the teeth of the upper jaw, and supplies the cheek, the upper lip, and the outside of the nose; while the third comes out at a point near the front of the lower jaw, and supplies the chin and lower lip, besides having sent branches to the teeth and tongue, before emerging from the jawbone. These nerves are the great nerves of sensation of the face, and are generally considered to be the most exquisitely sensitive nerves in the whole body. They are often the seat of neuralgia, and give rise to the most intense and intolerable suffering.

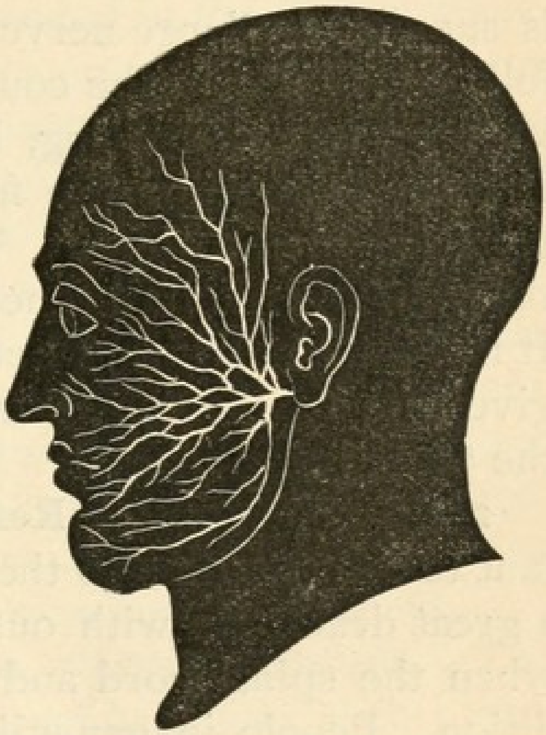

FIG. 63.—Diagram showing the distribution of the facial nerve to the face.

The *facial* nerve (Fig. 63) is the motor nerve of the face; it emerges from the skull just below the ear, and, passing forward through the parotid gland, is distributed to all the muscles of the face. Paralysis of this nerve is far from uncommon, and produces a most singular and characteristic effect upon the countenance. Exactly one half of the face loses all expression, as much as if dead, and the contraction of the muscles of the opposite side, not being in any way counteracted, produces dreadful, though often ludicrous, distortion of the features. This form of paralysis often occurs among hackmen and others who are exposed to stormy weather. If a strong wind, particularly when accompanied by snow or sleet, be allowed to beat upon the side of the face, there is great danger of paralysis of the facial nerve. Such exposure of the place where this nerve emerges from the skull should be carefully avoided.

261. The Sciatic Nerve.—Each limb of the body is supplied by large nerve-trunks, which, as a rule, follow very nearly the course of the arteries. The largest nerve of the leg, however, runs down behind the limb, while the femoral artery runs down the front of the thigh. This nerve is known as the *sciat'ic*, and its branches extend to the foot. It is this nerve which, when pressed upon in sitting, gives rise to the sensation commonly described as the "foot being asleep."

262. Importance of Reflex Action.—It is important to call attention to the fact that *reflex action* has a great deal to do with our health and safety, even when the spinal cord and brain are in perfect condition. People in general are hardly aware how much they owe to this property of the nervous system in time of danger. Familiar illustrations are found in the rapid recovery of the bodily equilibrium, when the foot has slipped; in the involuntary start and assumption of a position of defense, when a horse and wagon suddenly run upon one in the street; in the start of the body at a sudden noise; in the instantaneous withdrawal of a portion of the body when it is burned; in the winking of the eyelids, particularly at indications of danger;

and in hundreds of daily actions, which follow so instantaneously upon the application of a stimulus, that the thought, or mental appreciation of the stimulus, does not come until after the reflex action has already taken place.*

When we consider the immense number of such actions which take place every hour of the day. and the stupendous work of nutrition, with its complicated phenomena, all going on outside of our control, we see that in all probability the greater part of the nervous force expended in the body goes to produce involuntary movements, and to control and preserve the health and integrity of our organism in spite of ourselves. It is a suggestive thought that, much as we appear to be our own masters, independent as we seem to be of the outside world, we are really ruled by the general vital forces which equally rule all animals and even plants, upon which we are all equally dependent, and over which what we call "we" have almost as little control in ourselves as in the lion that roams the desert or in the grass that grows beneath our feet.

263. Education of the Nervous System.—The *hygiene* of the nervous system has to do mainly with the problem of *education*, and with the over- or under-use of its parts. *Education* is a broad subject, and can not be taken up here, but it is undoubtedly

* It is related of a distinguished chemist that a glass vessel once exploded in his hands and was blown into a thousand pieces. His hands were severely lacerated, and he at first feared that his sight was destroyed ; but on examination it was found that he had closed his eyelids involuntarily at the instant of the explosion, and, although the lids had been wounded in many places by the flying bits of glass, the eyes were uninjured. The rapidity of such reflex action far surpasses that of any voluntary movement.

true that in the future much more attention will be paid than in the past to the physical conditions which underlie all development and training of the mental powers. It is known that repetition of the same process in any portion of the nervous system renders it every time more and more easy. The result of such repetition is what we call habit. The more impressible and easily stimulated the different parts of the nervous system are, therefore, the more readily habits will be formed and the more firmly they will become fixed. Now, the cells and fibers of the nervous system of young and growing animals, like those of their muscular system, are especially soft and yielding, and, as they are constantly growing, the changes in them are more frequent, and they are much more easily influenced by any stimulus than those of adults. Consequently children and youths are especially liable to form habits, and, in order to prevent the formation of bad ones, they need the guidance and protection of older persons. The experience of the young is not wide enough to inform them correctly of what is good and what is bad, nor is it, in most cases, sufficient to enable them to appreciate the wisdom of the advice or commands of older persons. For these reasons it is necessary, in the training of the young, to require what often seems to them unreasonable, and to forbid things with what may seem to them foolish pertinacity. It is this readiness with which habits are formed in the young, and the firmness with which they become fixed, that render it so dangerous for them to indulge in sensual gratifications, such as the drinking of liquids containing alcohol, or to join in games which excite the selfish emotions in a high degree, such as lotteries and gambling.

It is this ease of habit-forming in the young, too, that renders childhood and youth the desirable time for both mental and physical training. In fact, the nervous system is, at this time, so impressionable that the training will take place inevitably, whether it is directed or not, and the success or failure of adult life is generally determined by the conditions under which the years below twenty have been passed.

264. Importance of exercising the Brain.—The nervous system, like the muscular, must be sufficiently exercised, in order to remain vigorous and healthy. If the brain be allowed to remain indolent, the faculties of memory and attention, the power of concentrating the thoughts, will be considerably weakened. It will be found that even the inactivity of a few weeks' vacation will render it a matter of some difficulty at first to keep the brain at work at one's ordinary duties. Judicious exercise also will strengthen special mental faculties, just as proper training will develop muscular power. The retentiveness of the memory may be immensely increased, and the facility with which the daily mental labor of the professional man is performed, together with the increased efficiency as age advances, shows the effect of directing the nutritive processes constantly in the same direction. In fact, this tendency is so strong that specialists, all of whose energies for many years are directed upon a particular subject, are very apt to become narrow-minded or "lop-sided," and unable to see more than one side of any subject, and that sometimes the least important one.

265. Danger of Over-Exercise.—On the other hand, too much exercise is as injurious as too little. All brain-work, as well as muscular work, involves a waste of tissue. As we are thinking, our brains are wearing out. And while this organ is actively employed, the waste of tissue is greater than the repair. When this excess of waste has reached such a point that the proper working of the brain is interfered with, we begin to feel incapable of further study, the attention begins to waver, problems seem difficult that at other times would be easy, and perhaps the memory is at fault. Such a condition demands imperative rest, and this rest is obtained by sleep.

266. Sleep.—During sleep, the repair of all the tissues goes on with great rapidity. As the body is inactive, even the brain being in sound sleep entirely unoccupied with thought, the waste of the tissues is very small, almost the whole of it being the result of the organic processes of circulation, respiration, and digestion. In all of these organic processes, which must be practically continuous, rest is obtained at short intervals, the activity of the organs concerned in them being intermittent, and, although the intervals of rest are very short, they are so numerous that they make up together about half of the twenty-four hours. But the muscular and nervous systems have no such frequent intervals of rest during waking hours, the brain, in particular, being constantly active, so that their rest has to be taken continuously in the form of sleep.

During sleep, therefore, the repair of tissue runs vastly ahead of the waste, and the exhausted parts have their vigor and irritability rapidly restored.

As the special senses and the sensitiveness of the muscular and nervous systems had become dulled and torpid because they were wasting away, so now, as they are built up again, their sensitiveness returns, and slight stimuli are sufficient to arouse them into activity. We then wake up. Even the morning light may produce a sufficient effect upon the eye, through the closed lids, to waken the sleeper, and he rises refreshed for the work of another day.

The best time for sleep is night, because it is dark and quiet; the natural stimuli of the eyes and ears are absent, and therefore rest can be obtained with the least likelihood of being broken. It is a good rule for all persons to go to bed before midnight, and rise within ten minutes after waking in the morning. The amount of sleep required by each individual must be determined by himself from experience. For most persons eight hours is not too much, and many can do with less.* Chil-

* Marvelous stories are told of persons who can get along with very little sleep. In most cases, if sleep is dispensed with at one time, it must be made up at another, and some people possess the faculty of falling asleep at odd moments, and making up, by what are sometimes called "cat-naps," for the loss of regular sleep. Thus, Napoleon Bonaparte is said to have been satisfied with four hours' sleep in the twenty-four; but this only refers to the time he spent in bed. He was in the habit of sleeping on horseback during a march, and his traveling-coach was made expressly so that the interior could be arranged as a bed. He often fell asleep, too, for a few minutes at a time, in his study, with his head resting on his arms on a desk in front of him. It may be doubted whether any person could live long with only four hours' sleep a day.

The Chinese sometimes punish criminals by confinement in a cage where they can neither stand up nor sit or lie down. Attendants are stationed to prevent the miserable men from falling asleep; for even under such conditions exhaustion brings on sleep. The unfortunate men are pricked and pinched, and by various means of torture kept awake until, as a rule, in eight or ten days, they die raving maniacs.

dren need more, in proportion to their fewness of years, and old people sometimes need less, because of their comparative inactivity during their waking hours.

267. **Abuse of the Nervous System.**—A word of caution should be spoken about the various forms of indulgence which affect the sympathetic system of nerves. These include all those forms of sensual gratification which are accompanied by a high degree of physical pleasure, followed by a more or less protracted period of depression. This depression, an instance of which is seen in the reaction following intoxication, is the result of a great shock and consequent great waste of tissue in the sympathetic nervous system. Recovery from such shocks is very slow. The sympathetic ganglia have to do with the important function of nutrition. They lie at the very foundation of life in our bodies. Their ordinary duties are severe, and about all they can attend to properly. Therefore, any great shock to this part of the nervous system affects the very centers of life. This is the reason of the "breaking up," as it is called, which results from the various forms of dissipation. This word "dissipation" is well used for such acts as are commonly included under this head, as all kinds of debauchery, abuse of the digestive organs, late hours, insufficient sleep and relaxation, etc., dissipate nervous force with frightful rapidity.

PART V.

ORGANS OF PROTECTION.

CHAPTER I.

THE SKIN.

268. The Skin.—The skin, with its appendages, is a complex organ, and has many functions. It serves for protection, contains nerves of sensation, secretes, absorbs, and excretes, and its functions are so necessary to life that, if in any way it be rendered unable to perform its duty in the organism, death is the result.

269. Structure of the Skin.—The skin is composed essentially of two layers, one called the *cuticle* or *epidermis*, and the other the *cutis* or *derma* (Fig. 63).* The former is the outside layer, and the latter the inside. The *epidermis* consists of small, flattened, dry scales, and receives the brunt of injuries and abrasions. The thickness of this layer is shown in a blister, the epidermis being there separated from the layer beneath by the fluid which fills the vesicle.† The inner layer, or *derma*, constitutes

* *Cutis* is the Latin for *skin*, and *cuticle* means *little skin; derma* is the Greek for *skin*, and *epidermis* means the *outer layer of the skin*, or, literally, "*upon the skin.*"

† *Vesicle* is from the Latin, and means *a bladder*, which a blister somewhat resembles.

what is sometimes called the true skin. This layer alone contains nerves, blood-vessels, hair-bulbs, and

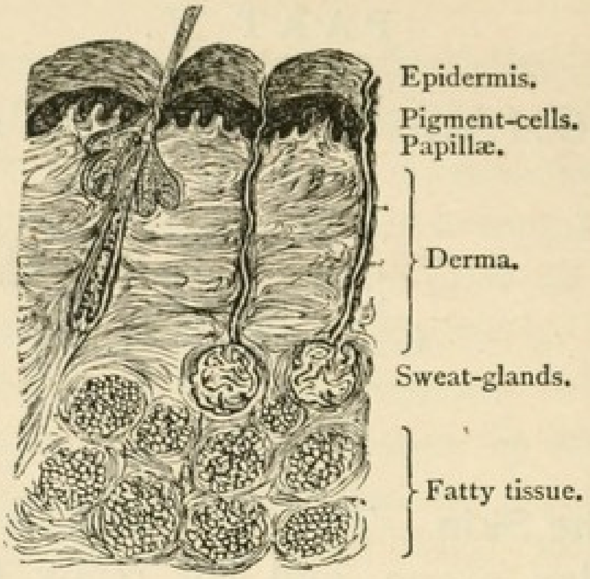

FIG. 64.—Diagram representing a vertical section of the skin. Attached to the hair are two sebaceous glands.

the other appendages of the skin. It is made up of strong interlacing fibers of connective tissue, which form a firm, close covering for the delicate tissues beneath. This layer varies in thickness in different parts of the body, from one fiftieth to about one sixth of an inch. For instance, the skin of the eyelid is very thin, while that of the small of the back is the thickest in the body.

270. The Derma. — The under surface of the derma is merged in the loose connective tissue which lies between the skin and the flesh. It is in this loose tissue that fat accumulates, and, in consequence of its peculiarly loose and flexible structure, the skin can be moved easily in any direction, slipping or gliding, with no pain and no disagreeable sensation, over the tissues immediately beneath it. The upper surface of the derma is covered with little elevations, called *papil'læ*, which, on an average, are about $\frac{1}{100}$ of an inch in length, and $\frac{1}{250}$ of an inch broad at the bottom. They are somewhat conical in shape, and in their interior are found the ends of sensitive nerves. In some parts of the body they are scattered irregularly on the surface of the derma, while in other regions they are arranged in rows, and produce the appearance of small parallel ridges on the surface of the body. This latter arrangement is most distinctly to be seen on the palm of the hand and fingers, and in these parts also the sense of touch is most highly developed.

271. **The Epidermis.**—The *epidermis* lies in immediate contact with the derma, its under surface being accurately molded to fit the papillæ. But, in the under portion of it, the portion into which the papillæ project, the scales, instead of being flat and hard, are rounded and soft, and contain a certain amount of coloring-matter, in the form of small, dark granules. As this part of the epidermis varies in color and thickness, so the complexion of the person varies.* In the negro, these pigment-cells, as they are called, are very dark and numerous, and there are all gradations in the amount of the coloring-matter in different persons, from the coal-black African to the albino, in whom there is no color at all, except the red tinge given by the blood.

* This layer of pigment-cells seems to protect the parts beneath from the action of the sun. The natives of all tropical countries are dark, and exposure to the sun's rays, even in our climate, tans the skin to a darker hue. Sometimes this effect of the sun is more noticeable in particular spots, producing what are known as freckles.

272. The Nails.—Near the ends of the fingers and toes the skin takes on a peculiar appearance. The epidermis is very closely applied to the derma, with no colored cells between them, and the scales of which it is composed are singularly dry and hard, and semi-transparent. These peculiar growths are called the *nails*. The part of the finger from which they grow is called the root of the nail, and the nail grows both in length and thickness. It is formed by the continual pushing forward of new cells, both from the root and from the under surface. The growth from the root makes it grow in length, while the addition of cells on the under surface renders it thicker at the forward end than it is near the root. The nails were probably once a means of defense and offense, when men were in a low, barbarian state; but, at the present day, their chief value appears to be for ornament, and as a support for the pulp of the finger.*

273. The Hair.—The *hairs* are peculiar growths of the skin. At certain points the surface of the skin seems to dip inward, forming a deep pit or pocket, at the bottom of which is a little projection or papilla. From this papilla the hair grows, and, emerging from the pocket, attains in some parts of the body a considerable length.† The body, or shaft, of a hair consists of cells, flattened and hard, but through its center, from one end to the other,

* The nails are of special use in the way last mentioned. The finger-tips are extremely sensitive, and the hard, stiff nail serves as a backing against which it can be pressed by the objects it touches. In this way the nails increase materially the delicacy of touch.

† Instances have been known of women with hair six or seven feet in length, and of men whose beards measured nearly as much. Such cases, however, are very rare.

runs a hollow canal, filled with pigment-cells. These cells, according to the amount of the coloring-matter in them, give the hair the appearance known as black, brown, gray, auburn, etc. Almost the whole surface of the body is covered with hair, excepting the palms of the hands and the soles of the feet, but most of it is of a soft, downy variety, which is not visible without close observation.

274. **The Sebaceous Glands.**—There are certain small glands, situated in the substance of the derma, which are called the *sebaceous* * *glands*, or sometimes the oil-glands. They are composed of minute sacs lined with epithelial cells, which constantly secrete and pour out of their mouths a whitish, tallow-like, fatty substance. Most of them empty into the hair-pits or follicles,† as they are called, and thence their secretion runs along the hair, and out on the surface of the body. They aid in keeping the hair and skin soft and flexible. Sometimes the opening, by which the secretion of the gland is discharged, becomes obstructed, and the gland still goes on secreting. In such a case, a swelling makes its appearance at the seat of the trouble, and the irritation of the retained secretion causes an inflammation to set in, which continues until the contents of the inflamed sac are discharged, or let out by the prick of a needle. This is the cause of the unsightly little pimples or boils which occasionally come on the end of the nose, and give rise to great annoyance.‡

* *Seba'ceous*, from the Latin *sebum*, meaning *fat*, or tallow.

† *Fol'licle*, from the Latin word *folliculus*, meaning a little *sack* or *pouch*.

‡ There are many of these sebaceous glands about the end of the nose, and the little openings, by which their secretion reaches the surface, often become obstructed by dirt, so that the secretion accumulates

275. The Sweat-Glands.—There are still other glands in the skin which have a very important part to play in the maintenance of life itself. These are the *sweat-glands*, or *perspiratory glands*. They are situated either in the lowest layer of the derma or in the loose connective tissue just beneath it. The mass of one of these glands is convoluted—i. e., it is made up of a long tube, rolled about and twisted into a ball. This tube is lined with epithelial cells, like the interior of all glands, and, after leaving the convoluted portion, it passes in quite a direct course through the derma, and then in a spiral course, like the thread of a corkscrew, through the epidermis, on the surface of which it opens. If one of these little glands be unrolled, and its tube stretched out, it is found to be about $\frac{1}{15}$ of an inch in length, while its diameter is about $\frac{1}{400}$ of an inch. Notwithstanding their minute size, however, there are so many of them that their secreting surface is enormous. They are least numerous on the neck and back, where there are 417 to the square inch, and they are found in the greatest numbers on the palm of the hand, where there are no less than 2,700 of them to the square inch. The total number is said not to be less than 2,300,000, and by a simple calculation it will be found that the total length of these minute tubes, if carefully unrolled and placed end to end, would be about two miles and a half!

in the interior. When this is squeezed out, it looks like a small, white worm, the dirt at the outer end resembling the head. Hence the term "black-heads." To be sure, there are sometimes little worms found imbedded in this secretion, but they are only to be seen with the microscope.

CHAPTER II.

FUNCTIONS OF THE SKIN.—HYGIENE.

276. Effects of Pressure on the Skin.—It is evident, without demonstration, that the skin protects the parts beneath it. In the performance of this function, it sometimes resents too great pressure, or unequal pressure, from outside. In such cases the skin becomes thicker in spots where the pressure occurs. If the epidermis only is affected in such cases, and there is merely an increased production of epidermal cells from beneath, the skin becomes, as we say, *callous*. If, however, the derma be affected, the papillæ become enlarged and project above the surface, *warts* are produced, and, where both forms of growth take place, we have *corns*. Pressure is undoubtedly not the only cause of the development of these unpleasant diseases, but it is one cause. But the origin of warts, in particular, is generally obscure.

277. Animal Heat.—The skin also has an important function to perform in maintaining a uniform temperature in the body. Every one knows that a living body is warm. Why is it so? There has been much discussion on this point, and many theories proposed regarding it. When oxygen was first discovered, Lavoisier* supposed that the process of respiration was a process of combustion; that the oxygen which entered the lungs in the air united directly with the carbon in the venous blood, and produced carbon dioxide. In ordinary flame, this is the chemical change which accompanies combustion. The oxygen of the air unites with the carbon of the tallow or oil and produces carbon dioxide, the hydrogen of the oil also uniting with oxygen to produce water. Thus we get, as a result of combustion, a disappearance of oxygen and a production of carbon dioxide and water. Now, in the air which passes in and out of the lungs, we find the same thing. Oxygen passes in, and carbon dioxide and water, in the form of vapor, come out. What more natural, then, than to conclude that respiration was combustion, and the lungs a sort of stove by which the heat of the body was kept up?

It was soon found, however, that the lungs were no warmer than the rest of the body, and particularly that the blood contained carbon dioxide before it reached the lungs, and took away free oxygen from them. These facts showed conclusively that the change did not take place in those organs.

The great chemist, Liebig,† then changed the the-

* Antoine Laurent Lavoisier, a celebrated French chemist (1743–1794). He first discovered the composition of water, and invented a chemical nomenclature which lasted for more than fifty years. He was guillotined during the French Revolution, because, twenty years before, he had been a tax-gatherer under the monarchy.

† Baron Justus von Liebig, a renowned German chemist (1803–1873), Professor of Chemistry at Munich. He was the greatest chemist of his time, made many practical applications of chemistry in agriculture and the arts, and was one of the founders of the science of organic chemistry.

ory, by supposing that the combustion took place, not in the lungs, but in the tissues generally throughout the body, and this theory was for a long time accepted. It is now giving way, however, as it has been found that many other chemical processes, besides the union of carbon and oxygen, give forth heat, and that the amount of oxygen inhaled with the breath hardly ever corresponds with the amount contained in the carbon dioxide expired. It is now considered that the heat of the body is the result, not of one class of chemical phenomena, but of all the molecular changes and combinations which are constantly taking place in all parts of the body.

278. Normal Temperature of the Human Body. —The temperature natural to any animal is found to be such that, if the blood be made very much cooler or very much warmer, it is fatal to life. The proper temperature of the interior of the human body is about 100° Fahr. On the surface, of course, some parts are cooler than others, according to the degree of exposure to which they have been subjected. Physicians usually take the temperature of patients by placing the bulb of a thermometer in the armpit, and the instrument in this spot generally registers about 98½° Fahr. The normal temperature often varies ½° or 1° from this standard, according to the time of day or night, and according to the sleeping or waking condition of the person.

279. Great Variations in External Temperature. —Now, if the blood be cooled much below this point, say down to 80°, death takes place; equally so if it be heated to a temperature of 113°. In the former case, the person is said to have been frozen, for the temperature can not be reduced to this point unless by exposure to a very frigid atmosphere; and, in the latter case, he is said to die of sunstroke, because such a temperature is rarely induced, excepting in extremely hot weather.

But persons are often exposed to a temperature of 10° or 20° below zero, and of from 100° to 130° above zero. The latter figures, perhaps, require a word of explanation. We are apt to think of the temperature to which we are exposed in a hot summer's day as the same which we find registered by a thermometer hanging in a sheltered spot. This is an incorrect way to estimate it. Many of us, perhaps most of us, spend some time every day in the direct rays of the sun, and it is no uncommon thing for a thermometer placed in the same situation to register 130°. How, then, are we enabled to resist such extremes of cold and heat, and maintain our bodily temperature almost unchanged?

280. Effect of Cold on the Body.—When the body is exposed to a low temperature, and the surface is being continually cooled by radiation, the first effect, as the cold reaches the tissues just under the skin, appears to be a stimulating one; the processes of nutrition, of cell destruction and formation, take place with greater rapidity, and therefore more food is required to supply the waste. We all know that in cold weather our appetites are more keen, and, if we digest more, we must waste more, or else accumulate material in our bodies. This latter phenomenon does take place to some extent, and most persons gain flesh during cold weather.* Now, these changes in nutrition, with

* Cold weather produces a craving for fatty foods. The Esquimaux eat enormous quantities of blubber. Dr. Hayes, the Arctic explorer,

increased activity, give rise to an increase of temperature, and, up to a certain point of exposure, this increase of heat is sufficient to balance the increased radiation. When the radiation becomes excessive, and the greatest activity of the bodily functions is insufficient to produce enough heat to compensate for it, the blood begins to grow cool, and the symptoms of drowsiness and stupor come on, which are the precursors of death.

281. Effect of Heat on the Body.—On the other hand, when the temperature is high, the tendency to the accumulation of too much heat in the body is kept down partly by a diminution of activity in the nutritive processes, and partly by the action of the perspiratory glands. In hot weather, the nutritive processes go on much more slowly than in cold, we eat much less food, most of us lose flesh, and the production of animal heat in the interior of the body is thus very much reduced. But this reduction is not sufficient to guard us against the harmful effects of a very high temperature. If cold becomes too great to be resisted by the ordinary forces at work within the body, we put on additional clothing, build ourselves fires, shelter ourselves in houses, etc., and thus keep warm. But in hot weather, if we had no perspiratory glands, we should be badly off indeed.

282. How the Temperature of the Body is regulated.—The way in which these glands regulate the temperature of our bodies is by covering the sur-

states that his men often drank clear oil with great relish, and the Laplanders are said to be fond of tallow-candles. Even in our own climate, fried articles of food, which contain a good deal of fat, are palatable in winter, but very distasteful in warm weather.

face of the skin with a watery fluid, whose evaporation continually abstracts heat. Evaporation consists in the change of a liquid into vapor. The evaporation of any liquid causes a diminution of temperature in whatever lies in contact with it. Liquids which evaporate very rapidly, like ether, produce a very striking sensation of cold, and may even be used, in the form of spray, to freeze a portion of the body. Now when the surface of the body is heated, the vaso-motor nerves are somewhat paralyzed, and an unusual flow of blood takes place to the capillaries of the skin. A great flow of blood to a gland causes an increased secretion, and accordingly the perspiratory glands immediately begin to pour forth their peculiar secretion. The perspiration is composed of water and salts, containing about 99½ per cent of water. This water evaporates rapidly, and abstracts so much heat that the temperature of the body is kept at its normal standard.

283. **Amount of Perspiration.**—The secretion of the perspiration takes place constantly. Under ordinary circumstances, its amount is so small that it does not collect in drops, but evaporates as soon as it reaches the surface. This is called the "insensible perspiration," and takes place at all times. Although so gradually secreted and so quickly evaporated as to be unperceived by the individual, its daily amount is surprisingly large. Lavoisier and Seguin have found it to be a little less than two pounds. This amount is immensely increased when the body is exposed to an elevated temperature, and the perspiration begins to run from the pores in streams. It then often rises to the amount of a

pound an hour, and, as this great loss of fluid from the body has to be resupplied from without, such excessive perspiration is followed by excessive thirst.

284. **Exposure to Dry Heat.**—In order for evaporation to take place rapidly, the air must be dry enough to absorb the vapor into which the water passes. If the air be very dry, and contain very little water, so that it is prepared to absorb an immense amount of it, the human body can endure without injury an incredibly high temperature. Human beings have remained in ovens heated to a temperature of from 350° to 600° Fahr., and remained there while eggs and even beefsteaks were cooked by their side.*

285. **Exposure to Moist Heat.**—If, on the other hand, the air be already so saturated with watery vapor that it can not take up much more (for its capacity in this respect is limited), any great rise in temperature causes extreme discomfort. It is on account of this difference in the moisture of the atmosphere, and consequent diminution or increase of evaporation, that our physical comfort varies so much on different days, when the thermometer registers the same temperature. For this reason, also (the moister atmosphere), a temperature of 85° is almost unendurable in London, while in New York it is usually borne without discomfort.

* "The workmen of the sculptor Chantrey were in the habit, according to Dr. Carpenter, of entering a furnace in which the air was heated up to 350°" (Dalton). A public performer, named Chabert, who called himself the "Fire-King," is said to have exposed himself to a temperature of 600°, and remained in an oven heated to that degree while a beefsteak was cooked by his side. In such experiments care has to be taken that no metal, or other good conductor of heat, comes in contact with the body, for if it does it will cause frightful burns.

286. Respiration and Absorption through the Skin.—There is also a certain amount of what might be called respiration going on through the skin—i. e., it has been shown, by inclosing one of the limbs in an air-tight case, that the contained air loses oxygen and gains carbon dioxide, showing that an interchange of those gases takes place through the skin, as well as through the lungs.* It is also a fact, well known to physicians, that the skin possesses the property of absorbing various substances placed in contact with it.†

The skin is thus seen to be an exceedingly complex organ, and to possess many very important functions. There are certain peculiarities attending injuries and diseases of the skin which have led many physiologists to think it has important functions not yet discovered.‡

The *hygiene* of the skin has mainly to do with the questions of how to keep it cleansed from impurities, and how to regulate its temperature—i. e., with *bathing* and *clothing*.

* The amount of carbon dioxide thrown off by the skin is estimated at about one thirtieth of that exhaled from the lungs.

† Medicines are sometimes administered by rubbing them into the skin. Castor-oil rubbed over the stomach will produce a medicinal effect, and so will mercury. Infants who were too much exhausted by disease to eat, or whose stomachs refused to retain food, have been saved from death by rubbing nutritive substances, oils, etc., upon the surface of the body.

‡ When the surface of the body is completely covered with a coating impervious to air, death ensues very rapidly. At the coronation of Giovanni de' Medici (1475–1521) as Pope Leo X, a little boy was covered with gold-foil to represent a cherub, and add to the splendor of the ceremonies. He became almost immediately ill, however, and, in spite of all that was done, died in a few hours, because the gold and varnish were not removed.

287. Necessity of cleansing the Skin.—The impurities on the surface of the skin come mainly from three sources: 1. The perspiration contains a small amount of solid matter, mostly mineral, which is deposited upon the skin and left there as the water evaporates. 2. The fatty secretion of the sebaceous glands is constantly being poured out in small quantity, and dries upon the surface. 3. The epidermal scales in the outer layer of the skin are being continually shed, pushed off, as it were, by the cells developing under them, and most of them fall away in the form of a fine, branny dust, which clings to the under-clothing, and is brushed and washed from other parts of the body. A certain amount of this refuse epidermis is caught in the drying perspiration and sebaceous secretion, and so remains, as it were, glued to the surface. These different impurities tend to choke the mouths of the perspiratory and sebaceous glands, and prevent their free action. The surface of the body must be kept free from such accumulations.

Much obscurity has been unnecessarily thrown around the subject of the ordinary bath. The rules regarding it are in reality few and simple. The discussions mainly relate to the time, duration, and temperature of the bath, and the results may be summed up thus:

288. Effect of a Cold Bath.—The first effect of a cold bath is to produce a shock to the nervous system, resulting in the contraction of the blood-vessels at the surface of the body. This shock in a healthy person is soon followed by a reaction, in which the heart acts with more vigor than usual, and the contracted blood-vessels are again filled with blood.

The surface of the body then becomes ruddy or rosy, and a pleasurable glow is felt by the bather. The bath should end while this glow of reaction continues, for, if it is allowed to pass away, it is succeeded by a feeling of lassitude and depression, which may last for the rest of the day, and indicates a certain degree of exhaustion of the nervous system. The after-glow may be increased, and the good effect of the cold bath enhanced, by a brisk rubbing of the surface with the hands or a towel.

289. **Effect of a Warm Bath.**—The first effect of a warm bath is to dilate the superficial blood-vessels and cause a flow of blood to the skin. This produces a general relaxation of the pores of the glands, tends to increase their activity, and in weakly persons there is slight stimulation of the nervous system. After such a bath, the skin being full of blood and in a relaxed condition, exposure to the cold air is dangerous, and the bather should not go out-of-doors until the surface of the body is perfectly dry, and any feeling of languor has disappeared.

290. **Rules for Bathing.**—Briefly stated, then, these are the rules for guidance in the bath :

Do not bathe within three hours after a meal, as the change in the circulation produced by the change in temperature of the surface of the body interferes with the proper distribution of blood in the digestive organs.

Do not bathe in cold water, if you have found by previous trials that you always have a chilly feeling afterward. This is a matter to be determined wholly by personal experience, and, when any person finds that a particular kind of bath makes him uncomfortable afterward, it is the part of prudence to shun it thenceforth. As a general rule, it may be stated that a vigorous person will feel better after a cold bath, and a feeble person after a warm one, if not too prolonged.

Do not remain in the bath too long. If you feel chilly when you come out, the bath will do you more harm than good. As a general rule, from ten to fifteen minutes is long enough for a warm bath, and five minutes for a cold one.

291. Washing the Hands and Face.—The hands and face are washed more frequently than any other part of the body, because they are more exposed and become dirty sooner. If they can be kept clean with water alone, soap should be avoided, because it unites with the fatty matters on the surface, a certain amount of which is natural and necessary to keep the skin soft and pliable. Soaps that contain an excess of alkali * are particularly injurious, because they not only remove too much of the sebaceous secretion, but irritate the surface and even produce eruptions. After the hands have been washed, especially in cold weather, they should be carefully and thoroughly dried before exposing them to the cold air. It is the neglect of this precaution, together with the excessive use of soap, that causes "chapping" of the hands. The soap removes the fatty matter from the epidermis, thus depriving it of its pliability, and the water, espe-

* Soap is made by boiling fat with potash or soda; the former makes soft soap and the latter hard soap, such as is commonly used in the toilet. If the proportions of these ingredients are not precisely right, there will be an excess of one of them in the product, and this excess is always alkaline, because special care is taken to neutralize all the fat.

cially if it is warm, is absorbed to a certain extent by the outer cells of the epidermis, so that they swell a little and become softer than before. The epidermis thus becomes less elastic and less tenacious. If it is suddenly exposed to the cold while in this condition, the outer layer contracts and tears apart, in some places making cracks, which often extend down to the derma, and give rise to considerable suffering. Then fatty matter (grease, vaseline, etc.) has to be supplied to take the place of the natural secretion that has been so unthinkingly removed.

To keep the skin of the face and hands smooth and pliable, therefore, soap should be used sparingly,* and they should be thoroughly dried after washing.

292. Care of the Scalp.—The *scalp* should also be kept clean. The epidermis is shed constantly in this region, as well as in other parts of the body, and, together with the dried sebaceous secretion, causes what is known as "dandruff." † The hair should be dressed with a brush that is not stiff enough to scratch the scalp, and the comb should be used only to part the hair and disentangle it, never to relieve itching. Constant scratching of the scalp increases the trouble it is designed to relieve, and makes it rough and inflamed, just as the same treatment will affect the back of the hand or the cheeks. It is well to wash the scalp thoroughly with cold water at least once a week, drying the

* The highly-scented toilet-soaps are often made of rancid fat, and injure the skin. The best soap for ordinary use is the white Castile soap, of Spanish or Italian manufacture, which is made of sweet olive-oil and not perfumed.

† Extreme degrees of dandruff are the result of a disease of the scalp, and are often difficult to cure.

hair before going out-of-doors. The hair of girls should never be cut, if it is possible to avoid it, as it is the universal testimony that it never grows as long after cutting as if it is left alone.

293. **Care of the Nails.**—The finger-nails should be carefully trimmed,* but never cut close to the flesh. If they are cut too short, not only is the delicacy of touch affected, but the ends of the fingers will become club-shaped and ugly. The flesh about the roots and sides of the nails should not be allowed to adhere to them, as it is pulled along and stretched as the nail grows, and produces "hang-nails." The white spots which often appear on the nails are caused by slight blows on the root of the nail during its formation, and therefore are most common in children and in persons whose occupation exposes their hands to such violence. They are of no special importance.

294. **Clothing.**—The object of clothing is to maintain an equable temperature at the surface of the body. For this purpose the best material to be worn next the skin is a poor conductor of heat. Woolen material, from its porous texture, conducts heat very poorly, and flannel should therefore always be worn next the body, summer and winter. No other material can be compared with it for protecting the surface against sudden changes of temperature. Linen, on the other hand, is such a good conductor of heat, that its use next the skin is absolutely dangerous. Cotton is intermediate between the two. As for the outside clothing, that

* It is better to soften the nails slightly in warm water before cutting; otherwise they will often split or break at the edge, especially in cold weather.

may be safely left to be decided by the comfort and taste of every individual.

The clothing that has been worn during the day should be entirely removed at night on going to bed. The under-clothing, which has been for so many hours in contact with the surface of the skin, is more or less loaded with the matters cast off by it, and, if it is not changed daily, should at least be thoroughly aired during the night.

A shoe that can not be worn continuously during the waking hours from the time it is first put on, should not be worn at all. The habit of "breaking-in" new shoes inevitably results in distortion of the feet and the development of corns. High heels are also bad, because the weight of the body drives the toes down into the narrow end of the shoe, and causes the painful and unnecessary affection known as "in-growing" nails.

Always wear, therefore, a good non-conductor of heat next the skin.

Never wear any article of dress that pinches, for it will inevitably result in distortion or disease, or both, especially in the young, whose bones are yielding and whose organs are not fully formed, and need perfect freedom for their healthy development.

PART VI.

ORGANS OF PERCEPTION.

CHAPTER I.

TOUCH—TASTE—SMELL.

295. **Structure of the Papillæ.** — The sense of *touch* has its seat in the papillæ of the skin. The nerves, on entering the papillæ, end in certain oval-shaped bulbs, which are very small, and are composed of connective tissue, quite firm in texture, but containing a soft material at the center. The nerve, on entering this bulb, loses its medullary substance (or myelin), and only the axis-cylinder is continued into the center. The papillæ do not all contain such bulbs or corpuscles, but, as they are found in the greatest numbers in places where the sensibility is most acute, it is reasonable to suppose that their function is intimately connected with the sense of touch.

296. **The Sense of Touch.**—By this sense we gain our knowledge of hardness and softness, heat and cold, roughness and smoothness. The sensitiveness of the skin, as every one knows, varies very much in different parts of the body, and attempts have been made to invent some means of measuring accurately the perfection of this sense. The most

usual method is to apply the points of a pair of compasses to various spots on the surface of the body, and see at what distance apart the two points can be perfectly perceived to be two and not one. At the tips of the fingers they can be separately distinguished when only one eighteenth of an inch apart, while at the small of the back they must be separated to a distance of nearly two inches before they will cease to seem one point. Between these extremes there are many intermediate grades of sensation.*

297. Deception by the Senses.—It is a remarkable fact that the extremes of any kind of sensation can not readily be distinguished from each other. A piece of iron at a white-heat and a frozen solution at 70° below zero will produce much the same sensation in the part touching them. But it is not so familiar a fact that, after all, the conscious sense really lies, not in the termination of the nerve, but in the nerve-center which receives the impulse from it, and that, if this be out of order, the sense may be deceptive. This fact of our liability to be deceived by our senses applies to all of them—the sense of touch as well as to others. A single illustration will suffice. It might seem as if any person would be able to determine by his feelings whether he were hot or cold, and yet it is well known to physicians that, in the chill of fever and ague, when the sufferer, with blue lips and chattering teeth, wants

* The most delicately sensitive part is the tip of the tongue, where the two points are distinguished when only one thirtieth of an inch apart. As every one knows, a fine hair, which can not be felt by the finger, or only with the greatest difficulty and uncertainty, is clearly perceived by the tongue.

to be covered deep with blankets, his temperature by the thermometer is much higher than in health, often running up to 106° Fahr.*

298. **The Special Senses.**—The *special senses* are all modifications of the sense of touch, and were probably developed out of it. They differ, however, from it, and from one another, in the fact that in each a special kind of sensation is roused in response to whatever form of stimulus. Any stimulus to the retina of the eye, for example, produces only the sensation of light—no matter whether it be light, or a blow, or an electric current—and so with the other special senses (excepting that of taste, as hereafter mentioned). In the eye and the ear, the apparatus for the special appreciation of stimuli forms a highly complicated and delicate mechanism. In the description of these special senses, we shall begin with the one which is least removed from the sense of touch, and end with the one in which sense-perception is the most highly developed.

299. **The Tongue.** — The sense of *taste* differs less from ordinary sensibility than any of the other senses. It is located chiefly in the tongue, but it has been found, by careful experiments, that we can perceive the flavor of substances also with the soft palate and a small portion of the throat. The *tongue* is a muscular organ of great mobility, and is supplied with three nerves from the brain. One of

* An easy way to satisfy one's self of the deceptive nature of our sensations, and of the fact that they must often be corrected by the judgment, is this: Put one hand into cold water, and the other into warm; take them out quickly, and plunge them both into water a little cooler than the warm water just used; it will be found that this water will seem cold to one hand and warm to the other.

these nerves presides over its motions, while the other two are sensitive nerves, one of which is distributed to the anterior two thirds of the surface of the organ, and the other to the posterior portion (Fig. 65). The exact method in which these nerves terminate is not known, but the surface of the tongue

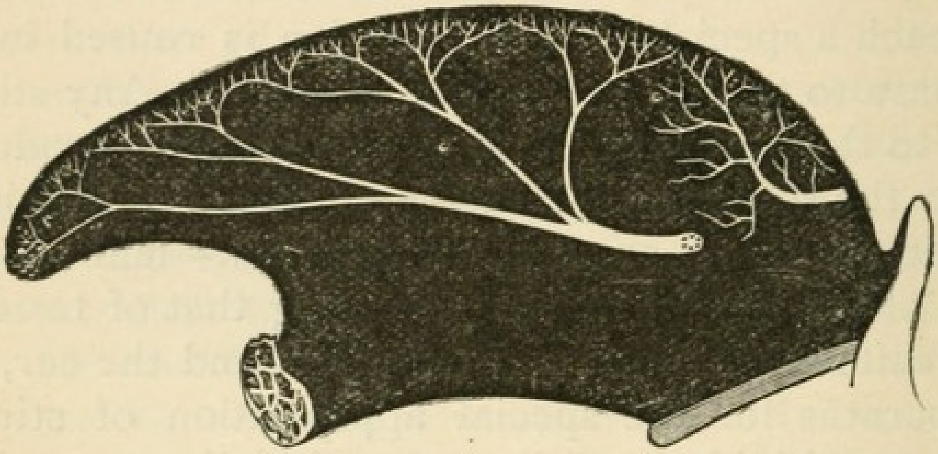

FIG. 65.—Diagram showing the distribution of the nerves of taste in the tongue.

is covered with small papillæ, which can be easily seen with the naked eye, and the delicate extremities of the nerves are known to terminate in these papillæ. It is well known that no substance can be perceived by the taste unless it is soluble, and this renders it almost certain that the matter tasted comes into actual contact with the end of the nerve.

300. The Sense of Taste.—The nerves of taste, in distinction from most nerves of special sense, also convey sensation like the nerves of general sensibility. This fact makes it a little difficult to distinguish between things *felt* by the tongue and things *tasted*. It is considered by many that there are in all only *four modifications of the sense of taste*, viz., *sweetness*, *sourness*, *saltness*, and *bitterness*. To these qualities, or savors, others add such savors as *alkaline*, *styptic*, etc., which are compound sensations, and it is, to say the least, very doubtful whether they should be classed as distinct savors. Qualities which are really the result of feeling, and not of taste, although perceived by the tongue and palate, are *pungency*, *starchiness*, *piquancy*, *oiliness*, etc. Another source of error in estimating savors lies in the fact that there is a communication between the nose and mouth through the throat. It is sometimes very hard to distinguish between what we perceive by the sense of smell and what we taste. This is in some degree the case with liquids which have an *aroma* or *bouquet*, but it may be shown that the *aroma* is perceived entirely by the sense of smell, by closing the nostrils while tasting the aromatic substance. It will then be found that the aroma disappears, although the communication between the nose and throat still remains open. The reason for this will be explained under the section describing the sense of smell.

301. Peculiarities of the Sense of Taste.—It has been stated that the front and back part of the tongue are supplied by different nerves. This state of things gives rise to a curious phenomenon, viz., that certain substances have a decidedly different taste when placed on one part of the tongue from what they have on the other. A few examples of this will suffice:

If *potassium chloride* be put upon the *anterior* portion of the tongue, it tastes *saltish*, but on the *posterior*, *sweetish*. *Sodium sulphate*, on the *anterior* portion, is *salt*, on the *posterior*, *bitter*. *Alum*, on the *anterior* surface, tastes *acid* and *styptic*, while on the *posterior*, it has a decidedly *sweetish* taste, with no acid quality whatever.

The sense of taste persists for a short time after the substance tasted is removed. This is probably because the portion of the substance which penetrated the mucous membrane and affected the nerve has not all been taken up and carried away by the circulation. For this reason, it is impossible to appreciate the true savor of different substances by tasting them in rapid succession. The impression made by the first should be allowed to disappear, and only remain in the memory, before the second is tasted. This only applies to delicate flavors. Where the flavors are coarse and pronounced, the slight masking of one by the other often interferes very little with a correct judgment of their character.

The flavor of any substance is perceived in exact proportion to the amount of surface affected by it. So we see connoisseurs in wine smacking their lips and pressing their tongues against the roof of the mouth, the better to appreciate the flavor, by spreading the liquid over a larger surface. The use of this sense in the detection of impure and unwholesome food has already been referred to. In addition to this function, it affords us great physical pleasure, although it is generally thought to be of a low order.

The sense of taste, like that of touch, requires actual contact with the substances tasted, and can give us no knowledge respecting substances at a distance from our bodies. We now come to a sense which is a step higher in the scale, for it gives us knowledge of substances at a distance, and it does this by means of material emanations which often can not be detected in any other way.

302. **The Sense of Smell.**—The sense of *smell* resides in the mucous membrane lining the upper portion of the cavity of the nose. This portion of membrane is supplied by the *olfactory* nerve, which does not convey ordinary sensation, as do the nerves of taste, but carries to the brain only the special sensation of smell. The nerve is distributed to the upper third of the nasal passages, and the rest of the interior of the nose is supplied by nerves of ordinary sensation (Fig. 66).

The amount of any substance required to affect the sense of smell is inconceivably minute. There

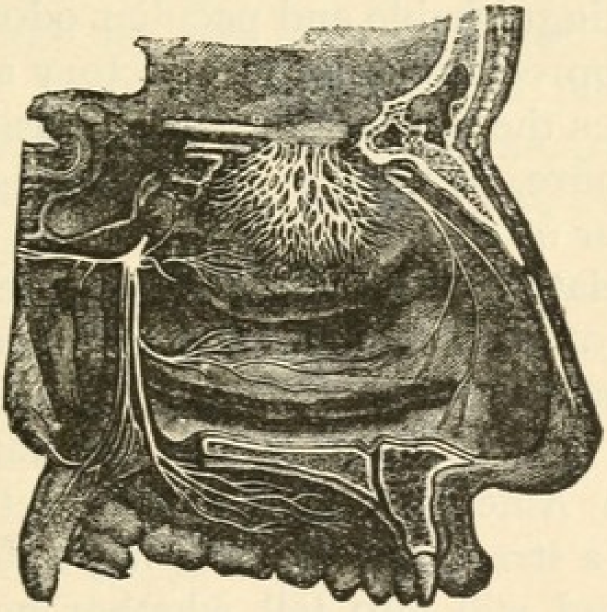

FIG. 66.—The interior of the left nasal passage. The fan-like expansion of nervous fibers is the olfactory nerve. The other nerves shown are nerves of ordinary sensation.

is no chemical or physical means known by which it can be detected in many cases. A grain of musk will perfume a room for months, and lose nothing apparently in weight.

In order to affect the sense of smell, the odorous air must be drawn through the nose. If the air in the nasal passages remains stationary, we smell nothing. This is the reason why closing the nostrils prevents our appreciating aromatic substances in the mouth. For this reason, also, we sniff at whatever has a delicate or faint odor, and, by increasing the rapidity of the air-current through the nose, we add to our appreciation of the odor.* This is very noticeable in the lower animals.

It is necessary to distinguish between substances which really affect the sense of smell and those which merely irritate the mucous membrane. Many substances affect both senses—that of smell and that of general sensibility. *Pepper*, for instance, has a clearly distinguishable and peculiar odor of its own, which is appreciated by the olfactory nerve, and it also irritates the nerves of general sensibility. *Ammonia*, if pure, is merely an irritant, and has no proper odor of its own.

303. Relative Acuteness of the Sense of Smell.—The sense of smell among civilized persons is not educated, and is rather defective. Among savages it is much more acute. Humboldt states that certain South American Indians can detect the approach of a stranger, in a dark night, by the sense of smell, and will also tell whether he is a white man, an Indian, or a negro. But the lower animals far surpass man in this as well as in most other senses. The keenness of the dog's scent is pro-

* The distribution of the olfactory nerve in the upper part of the nose also makes it necessary to sniff at faint odors, for otherwise the air containing them might pass through the lower passages of the nose into the throat, without reaching the nerve of smell.

verbial, and he depends much more upon his sense of smell, for recognition of his master, than on his sense of sight.

The sense of smell, like the sense of taste, acts as a sentinel to guard against the introduction of improper food into our stomachs. It also warns us of impurities in the air. After long exposure, however, to a particular odor, the sense appears to become blunted, and that even when the odor is a peculiarly disagreeable one. It seems as if, when its warnings came to be disregarded, it ceased to give any more.

The sense of smell appreciates a great number of distinct odors, and from delicate and fragrant ones we receive a great deal of pleasure. This sense, undoubtedly, occupies a higher plane than the sense of taste, and a delight in pleasant perfumes marks a higher sense of æsthetic gratification than a devotion to the pleasures of the table.

CHAPTER II.

HEARING.

304. The Sense of Hearing.—As we ascend in the scale, we come to a sense which does not inform us of what is taking place in the world outside of us, by actual contact with matter, like the senses of touch and taste; nor by contact with emanations from matter, like the sense of smell; but impressions are produced upon it by means of motion in the atmosphere which surrounds us. This is the sense of *hearing*. Every movement of every form of matter gives rise to waves or vibrations in the air, which lies in contact with the moving substance. These atmospheric waves are received, and the impression made by them is transmitted to the brain by a special apparatus.

305. The External Ear.—The ear (Fig. 67) is usually described by anatomists as consisting of *three* divisions—the *external* ear, the *middle* ear, and the *internal* ear. The appearance of the *external* ear is familiar to all. It has a somewhat shell-like form, has numerous ridges and hollows, and is composed principally of cartilage covered with skin. This external ear serves to collect the waves of sound, and direct them toward the internal parts. In animals this organ is very movable, and, during their waking hours, is generally in motion, to catch sound from various directions. In the human be-

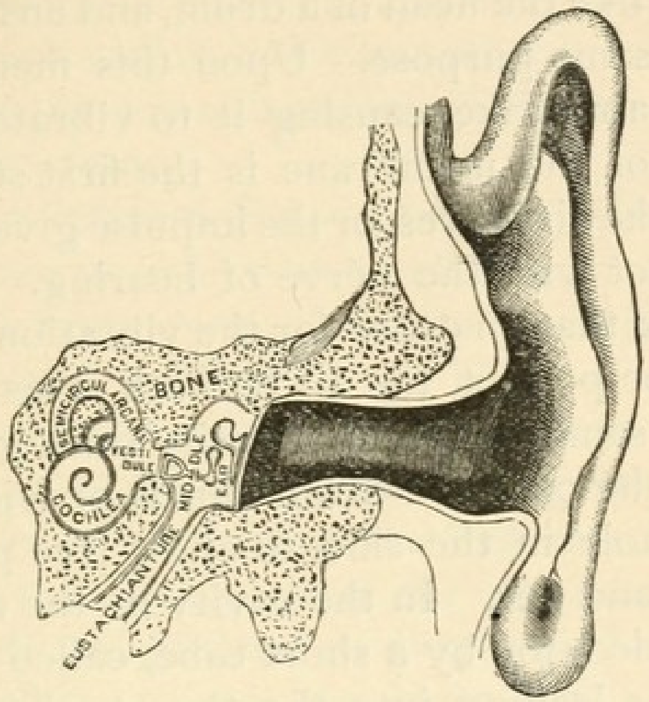

FIG. 67.—Section of the ear, showing the relative positions of the external, middle, and internal ear.

ing there are three small muscles attached to the external ear—one behind, one above, and one in front. These muscles, however, are practically useless, and very few persons have any voluntary control over them. Those who do, can cause the muscle in the rear to contract, and move the ear slightly backward, but the motion is limited, and answers no purpose.

306. The Middle Ear.—From the external ear a canal passes directly inward, toward the interior of the skull, for a distance of about an inch and a quarter. At its inner extremity it is closed by a thin membrane, called the *membrane of the tympanum,* or the *drum* of the ear; and on the other side of this membrane is a small cavity in the bone, about a third of an inch long, a quarter of an inch in height, and a sixth of an inch wide, called the *tympanum*,* or *middle ear*. The membrane of the tympanum is stretched like the head of a drum, and answers somewhat the same purpose. Upon this membrane the waves of air strike, causing it to vibrate; and this vibration of the membrane is the first step toward bringing the air-waves, or the impulse given by them, into contact with the nerve of hearing. And here we remark that, in order for the vibration of a membrane to be perfect, the air on both sides of it must be of the same degree of density during the vibration. In the common drum this is provided for by having a hole in the side, to allow free passage for the air in and out. In the cavity of the middle ear it is provided for by a short tube, called the *Eustachian* † *tube*, leading into the throat. This tube is about an inch and a half or two inches long, and, for perfect hearing, it is necessary that the air should pass in and out through it with freedom.

307. **The Bones of the Ear.**—In the cavity of the middle ear is a *chain of minute bones*, *three* in number, which altogether only weigh a few grains. One of them is attached to the membrane of the tympanum, another is attached to another membrane stretched in drum-like form across a small hole on the opposite side of the middle ear, and the third unites the other two. These small bones have very minute muscles attached to them in such a way that by their contraction or relaxation the bones are made to assume slightly different positions, and the membranes

* *Tym'panum*, a Latin word meaning *drum*.

† *Eusta'chian*, from Bartolomeo Eustachi, a celebrated Italian anatomist (died 1574), who first described it.

to which they are attached are made more or less tense, and therefore more or less sensitive to sounds. It is probable that these muscles are somewhat under the control of the will, and that some of the effort of which we are conscious when we strain our attention to detect a faint sound, is due to their active contraction.

308. **The Internal Ear.**—The second membrane above spoken of, which is smaller than the membrane of the tympanum, closes the passage between the middle and internal ears. The *internal* ear or *labyrinth* is exceedingly complicated, and the functions of its parts are not yet well understood. The difficulties of investigation are immense, partly on account of the minuteness of the organs and partly because they are situated so deeply in the bones of the skull and are so near the brain. It is sufficient to say that the internal ear is made up of many winding channels and spiral tubes, which go by the names of the *cochlea*, the *semicircular canals*, and a cavity called the *vestibule*, with which the others communicate. All these passages are filled with a watery fluid, and on their walls and through their interiors are distributed the filaments* of the nerve of hearing, the *auditory nerve*. As has been said, the cavity of the vestibule is separated from that of the middle ear by a thin membrane, to which one of the bones of the middle ear is attached. Thus, any vibration or impulse imparted to this membrane produces a corresponding pressure on the nerve of hearing, through the medium of the watery fluid which fills all parts of the internal ear.

309. **Recapitulation.**—Thus the air-waves enter-

* *Filaments*, small, delicate, thread-like fibers.

ing the external ear strike upon the membrane of the tympanum and put it in vibration. These vibrations are communicated through the chain of bones to the inner membrane, which is also made to vibrate. These vibrations, again, are communicated to the watery contents of the internal ear, and they in turn press directly upon the extremities of the auditory nerve, which conveys the impulse to the brain. And in this way we hear sounds.

310. **Different Qualities of Sound.**—When we hear sounds, we distinguish many different qualities in them, such as *pitch*, *quality*, *timbre*, *degree*, etc. These differences mainly depend upon the different length, rapidity, height, and character of the air-waves. They are perceived, in a greater or less degree, by every person, but the ease and accuracy with which they are appreciated may be increased by education. The appreciation of musical sounds, for instance, may be immensely increased by practice and proper training.

311. **Determination of the Source of Sound.**—Besides the perception of the foregoing differences in sounds, which is partly the result of natural endowment and partly that of training, there is another fact with regard to sound which has given rise to considerable discussion. It is the power we have of determining with more or less accuracy the locality from which a sound comes. Some physiologists have supposed that, as the semicircular canals, three in number, are always placed at different angles, they serve in some way, not easily explained, to indicate to us the direction from which the air-waves come.* This view has been supported by

* It has been lately suggested that the semicircular canals have

arguments of some plausibility, but it is now the accepted view that our knowledge of the direction and distance of the source of any sound is the result of past experience. We judge partly by the loudness of a familiar noise, partly by the greater impression on one ear than on the other, partly by the difference in the sound when we turn the head a little one way or the other, the direction of the wind, and a hundred other influences, which have become a part of our experience. If we can not, for any reason, use enough of these methods, we find ourselves unable to locate even a loud and distinct sound; e. g., it is very difficult to tell in what part of a closed room to look for a chirping cricket.

312. **Ventriloquism.**—The art of *ventriloquism* depends upon an adroit use of these methods in such a way as to deceive. The ventriloquist slyly robs us of all the means which generally serve us to detect the origin of a sound. He speaks without moving his lips; he modulates his voice so that it appears to come from a distance, on account of its faintness; he calls the attention of the spectator, either by word or by gesture, to the point from which he wishes him to expect the sound, and makes clever use of the slight shades in timbre and pitch, which all of us can distinguish, but which it requires great skill and practice to reproduce as

something to do with the sense of direction, and with the preservation of the bodily equilibrium. It has been found that, when they are cut in a pigeon, the bird sprawls about and seems incapable of co-ordinating its movements. There is a disease of these organs, called Ménière's disease, from the man who first described it, in which giddiness, as well as deafness, is a prominent symptom. It is probable that the frequent attacks of vertigo, with increasing deafness, from which Dean Swift suffered, were caused by this disease.

professors of this art are able to. The common idea that a man's voice can actually be projected or thrown into a spot twenty feet from his larynx is the idea of pure ignorance, and, as soon as one understands the mechanism of the voice, is seen to be as impossible as for any one to see through a solid stone wall, a thick envelope, a book-cover, or anything else through which no light can pass.

313. **Care of the Ear.**—The ear is, in almost all its parts, a very delicate organ, but, excepting the external ear, it is so deeply set in bone that it is not very liable to injury; and yet neglect of the organ or ignorant tampering with it may result in permanent and irreparable harm. The tube leading inward from the external ear, called the *external auditory canal*, is sometimes entered by insects. Its walls are moistened by a peculiar secretion, called "wax," produced by small glands just beneath the skin which lines it. This wax is somewhat sticky, and is intensely bitter, and, together with certain short hairs near the outlet of the canal, serves to protect the membrane of the tympanum from the inroads of insects.* The wax has sometimes a tendency to accumulate and interfere with the hearing; and some persons are in the habit of cleaning their ears with ear-scoops. This is an exceedingly dangerous practice, and can not be too severely condemned. The ear is a delicate organ, and must be treated delicately by a person who thoroughly understands its anatomy.

314. **Danger of Colds in the Head.**—The dan-

* Insects can sometimes be coaxed out of the ear by holding a light in front of, and quite near, the external opening. They are attracted by the light, as moths are, and turn round and crawl toward it.

ger of injury to the hearing apparatus through the Eustachian tube is principally from inflammation. Colds in the head almost always affect the hearing in some degree, on account of the swelling of the membrane around the mouth of the tube. But the inflammation may not stop at this point. It sometimes travels along the tube to the middle ear, and when the exceedingly delicate mucous membrane of the middle ear becomes affected, there is usually more or less permanent impairment of the sense of hearing. The little chain of bones becomes stiffened by the disease, just as an elbow or knee does after an attack of rheumatism, and so they conduct the vibrations of the membrane of the tympanum with less force and accuracy. On the slightest indication, therefore, of inflammation of the Eustachian tube, as indicated by unusual dullness of hearing, during an acute catarrh of the nose or throat, a physician should be consulted. The process just described gives rise, in the climate of New York, to about two thirds of all the cases of deafness.

CHAPTER III.

SIGHT.

315. **The Sense of Sight.**—We now come to the highest and most perfect of all the senses, that of *sight*. The four senses previously considered all depend on material contact, in a greater or less degree, for their appreciation of the external world. Even the last sense considered, that of hearing, depends on contact with waves in the air, which is a form of matter, although attenuated. But we now have to do with an organ which perceives external objects through the intervention of light, and light is something which can not be felt or weighed, or detected in any other way than by sight. There have been many theories regarding the nature of light, but the one most in favor at the present day is the *wave theory*, or *undulatory theory*, so called.

316. **The Nature of Light.**—According to this theory, the universe is pervaded by an exceedingly subtile form of matter called the *ether*, and light consists of waves propagated through this ether with tremendous rapidity. The average number of vibrations in a second is estimated to be over 500,000,000,000,000, and they travel at the rate of about 195,000 miles per second. The wave theory of light is only a theory, and the existence of the

extremely attenuated form of matter called ether, which can neither be weighed, seen, heard, nor felt, but only postulated from certain phenomena supposed to depend upon it, is only inferred ; but still this theory explains almost all the phenomena of light, and, until some better one is suggested, must be retained as a working hypothesis.

From these facts, we can judge of the extraordinary delicacy of the eye as an organ of sense. Here is a stimulus, of unknown origin, which can traverse the widest regions of space, which enables us to appreciate the existence and form and even the structure of bodies which are billions of miles away from us, and gives us more knowledge of the external world, perhaps, than we obtain through all our other senses together, and yet its real nature is as hidden and mysterious and impalpable as the nature of our consciousness. Let us now examine the structure of the organ which perceives this strange stimulus and enables it to affect our brain.

317. Situation of the Eye.—The *eye* is situated in a cavity called the *orbit*, surrounded by bone excepting in front, and padded all about with fatty and muscular tissues, so that, although it is protected from injury by an unyielding bony case, it still reposes on a soft and elastic bed.

318. Structure of the Eyeball. — The *eyeball* (Fig. 68) is nearly spherical, and about an inch in diameter. It is formed of three membranes, arranged concentrically one within the other, and the interior is filled with certain structures necessary to vision. The outer membrane is called the *sclerotic* *

* *Sclerot'ic*, from the Greek σκληρός, *hard*, because it is the hardest and toughest coat of the eye.

coat, and in front, where it is visible, constitutes what is commonly known as the white of the eye.

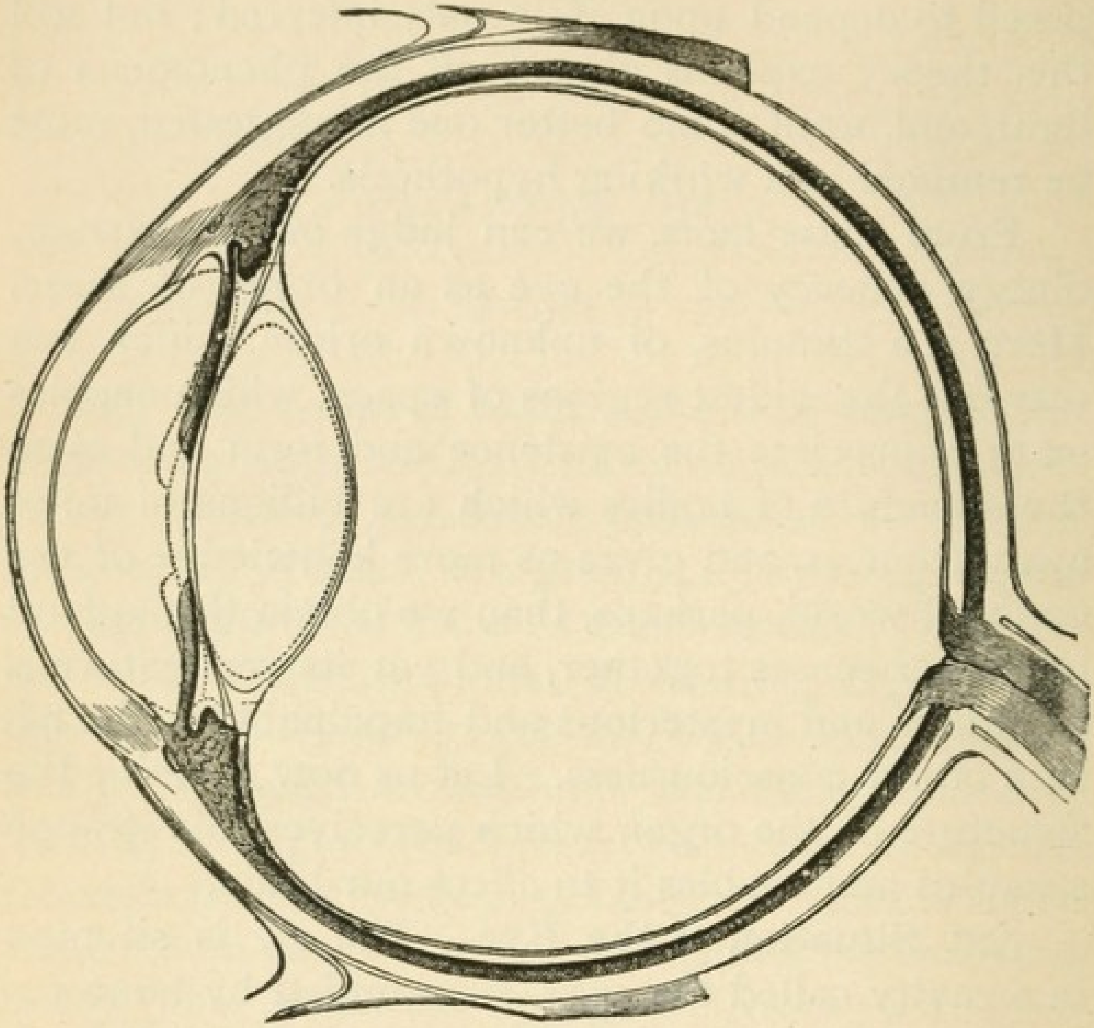

FIG. 68.—Horizontal section of the right eye, showing the relative position of its parts.

It is composed of white, fibrous tissue, and is exceedingly strong, tough, and elastic. It surrounds the whole eyeball, excepting in front, where a transparent membrane, about $\frac{1}{25}$th of an inch thick, is set into it like a watch-glass in the case. The front of the eye must of course be transparent for the admission of light. This portion of the eye is called the *cornea*.*

* *Cor'nea*, from the Latin *cor'nu*, *a horn*, because of its resemblance to transparent horn.

Just inside the sclerotic coat is another coat, called the *choroid*,* which covers the whole interior of the eye, excepting that portion bounded by the cornea. This coat is very plentifully supplied with blood-vessels, and with immense numbers of minute cells, filled with coloring-matter, so that it appears of a dark-brown or chocolate color, and in some persons almost black. Inside this choroid coat, again, is the *retina*,† which is an exceedingly delicate and complicated membrane made up of nervous tissue, and upon which the impressions of light are received. The retina is spread over about two thirds of the inner surface of the eyeball, not reaching quite as far forward as the sclerotic and choroid coats.

319. The Internal Parts of the Eye.—The membranes above mentioned form, so to speak, the incasement or shell of the eyeball. The bulk of the interior of the eye is formed by the *vitreous humor*.‡ This is a soft, semi-fluid, transparent, jelly-like body,#

* *Cho'roid*, from the Greek *χόριον*, *leather*, because, being dark-colored, it resembles leather in appearance.

† *Ret'ina*, a Latin word, meaning in that language just what it means in English. It is derived from *re'te*, *a net*, on account of its mesh-like appearance.

‡ *Vit'reous*, from the Latin *vit'reus*, *glassy*.

\# The vitreous humor contains, even in healthy eyes, minute bodies, which can not be detected from the outside, but which can be seen, greatly magnified, by the person himself. They are called "*muscæ volitantes*" (literally, *flitting flies*), and look like small strings of bright beads, or little transparent spheres or fibers, which move when the eye is moved, and, when the eye is held perfectly still, seem to sink slowly. They really float up toward the top, but appear to go down, their direction being reversed by the optical apparatus of the eye. These little objects are seen most vividly against a bright surface, like the sky, or a white wall, and when perceived for the first time are apt to frighten which fills the ball of the eye, with the exception of a small part, about one sixth of the mass, in front, which contains the *crystalline lens* and the parts between the lens and the cornea. This vitreous humor is surrounded by a very delicate membrane, also transparent, which lies in immediate contact with the whole extent of the retina. Just where this membrane passes in front of the vitreous humor, and just behind the cornea, it splits in two layers, and between these layers is suspended and held in place the *crystalline lens*. This lens is a double-convex one, with the posterior curvature a little greater than the anterior, is about one third of an inch in diameter from side to side and a quarter of an inch thick at its middle. It is, of course, perfectly transparent, and acts precisely as a double-convex lens acts in any optical instrument. Just in front of the lens is a curtain, with a hole in its center, which serves to regulate the admission of light to the interior of the eye. This curtain is called the *i'ris*,* and it contains muscular fibers, to which it owes its power of contraction, and pigment-cells, to which it owes its color, varying in different persons. The hollow space between the cornea in front and the crystalline lens behind is filled by a fluid called the *aqueous humor*,† composed almost entirely of water, with a little salt.

320. Uses of the Two Outer Coats of the Eye.—The *sclerotic* coat serves, by its toughness and

people. They exist, however, in every eye, and are perfectly harmless.

* Ἶρις, a Greek word, meaning *the rainbow*, so called on account of the variety of colors it presents in different eyes.

† *A'queous*, from the Latin *a'queus*, *watery*, because it consists almost entirely of water.

elasticity, to give shape to the organ, and protect the parts within. The *cornea* in front answers the same purpose, and is transparent, in order to allow the passage of light. The *choroid* coat serves as a nest for the blood-vessels which nourish the retina, and also, by its dark color, prevents the rays of light, which have once passed through the retina, from passing back again, and so confusing the sight. When the light which enters the eye is so intense that it can not be absorbed by the choroid, it is thus reflected through the retina, and our sight is not clear, as we have a double impression, coming from two directions, and the rays conflict with each other. We call this "being dazzled." In albinos, the coloring-matter of the choroid is absent, and such persons always are troubled with dimness and confusion of sight.*

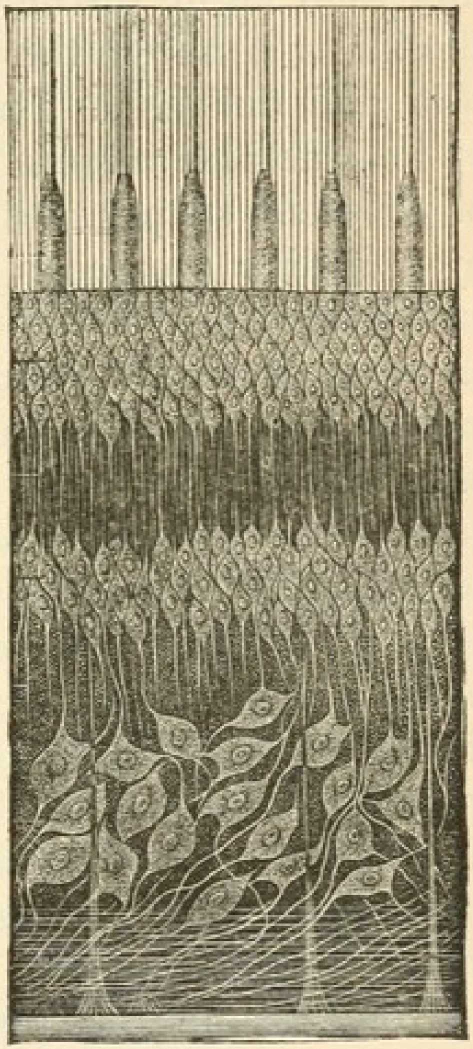

FIG. 69.—Vertical section of the retina, highly magnified. At the upper part of the cut are the rods and cones, while below are several distinct layers of nerve-cells.

* Albinos not only can not see well, because they are dazzled by the light, but their eyes have a constant vibratory motion from side to side, like the pendulum of a clock. This peculiar affection is known to physicians as *nystag'mus*.

321. The Retina.—The *retina* is formed by the expansion of the *optic nerve*, which enters the eye behind and spreads out over the interior. It is exceedingly complicated in its structure (Fig. 69), no less than eight distinct layers being found in its thickness, although the whole taken together is very thin and delicate. The outermost layer is made of innumerable minute cylinders of nervous matter of different shapes and sizes, packed together side by side like the seeds of a sunflower. These are called the *rods* and *cones* of the retina. Inside of these are other layers of tubes, fibers, cells, and granular matter, all of which, doubtless, have their part to play, but the particular function of which is not yet known. This arrangement of the nerve substance is necessary to the sense of sight, for, singularly enough, the spot where the optic nerve enters the eyeball is entirely blind. This nerve can convey the impression of sight to the brain as it receives it from the special sense-organ the retina; but, if light falls directly upon the optic nerve itself, no sensation is produced. This curious and interesting fact can be easily demonstrated.

Make a round black spot and a black cross upon a white card, three inches apart (Fig. 70). Now

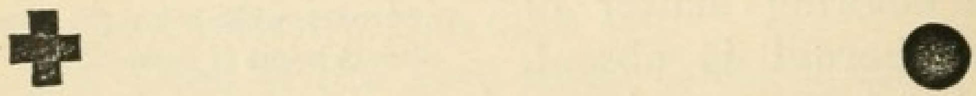

FIG. 70.—Diagram to demonstrate the existence of the blind spot.

hold the card in front, at a distance of about a foot from the eyes, close the left eye, and look at the cross with the right one. Both the cross and the black spot will be seen distinctly. Now move the card slowly toward you, still keeping the right eye fixed upon the cross. At a certain point the round spot will disappear, but, as the card continues to approach the eye, it will reappear within the field of vision. At the point of disappearance, its image falls upon the optic nerve just where it enters the eye (Fig. 71). Now, if this blind spot were just in the axis of the eye, we should be badly off, for it is

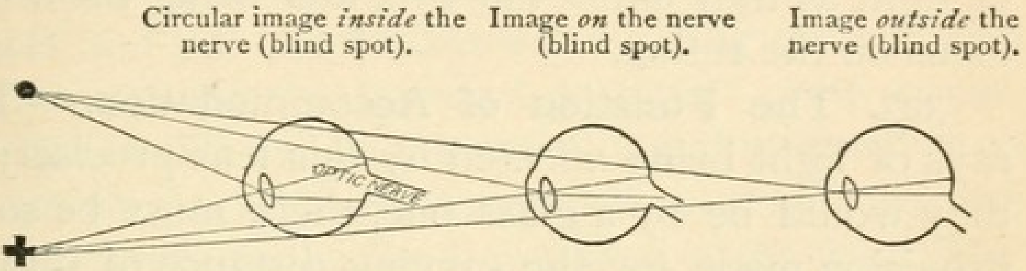

FIG. 71.—Diagram illustrating the blind spot. It represents a horizontal section of the right eye, the axis of the eye in every case being turned toward the cross.

evident that we should be unable to see anything we looked directly at. But the point of entrance of the optic nerve is toward the inner side of the eyeball, and consequently we are not incommoded at all by this small spot, which is insensible to light.

322. Use of the Crystalline Lens.—The interior of the eyeball is, therefore, like the interior of a *camera obscura*. It forms a dark chamber, lined with a dark membrane, to absorb superfluous light, and with a small opening in front to admit light. Just behind this opening is the lens.

If light came directly into the eye, and fell upon the retina, without being brought to a focus, our brains would appreciate the existence of the light, but would not get clear ideas of the appearance of objects. Everything would be dim and confused.

Something of this may be seen in a camera obscura, if the lens be removed. The rays of light, as they enter the camera, still form an image of outside objects, but it is a dull, indistinct, and obscure one. With the lens, however, the picture is bright and distinct in all its details. The reasons for this are too long to be stated here, and will be found in any treatise on optics. Suffice it to say that the function of the *crystalline lens* is to concentrate the rays of light as they enter the eye, and bring them to a focus on the retina.

323. The Function of Accommodation. — The rays of light being affected by this lens precisely as they would be by a glass one, there must be some provision made for the varying distance of objects from the eye. In the camera, as objects are nearer or more distant, we draw out or push in the lens, so as to bring it farther from or nearer to the surface which receives the image. Now, we find that, within certain limits, a healthy eye sees objects a moderate distance away with just as much distinctness as those near at hand. Moreover, we are conscious, as we change rapidly from looking at a distant object to one close by, of a kind of effort in the eye itself. There must be a change of some kind there, corresponding to the pulling out or pushing in of the lens of the camera. What is the change?

There is a short, delicate muscle, called the *ciliary muscle*, one extremity of which is attached to the stout membrane of the sclerotic and cornea at their junction, and the other extremity to the choroid. The muscle is a circular one, reaching all around the eyeball, and is only about an eighth of an inch broad. Now, the crystalline lens is very elastic, and, as has been stated, it lies between two layers of a membrane which passes backward and surrounds the vitreous humor. Under ordinary circumstances, these two layers of membrane, one of which is in front of the lens and the other behind it, are supposed to exercise some pressure on it, and render it a little flatter than it would be, if it were left to take its own shape, in accordance with its elasticity. Now, suppose that we wish to look at an object close at hand. The ciliary muscle contracts and the membranes surrounding the vitreous humor are drawn forward slightly. As a consequence of this the two layers of membrane, between which the lens lies, are somewhat relaxed, and exert less pressure on the front and back of the lens. The pressure being removed from it, the elasticity of the lens makes it assume a more convex shape (Fig. 72), and consequently brings the rays of light to their proper focus. This is supposed to be the method by which the eye accommodates itself to different distances, and its operation is so perfect and exact that, within certain limits, we can see whatever we wish to. Beyond a certain distance, and within a certain distance, this accommodation no longer occurs. These distances vary with different persons, and the inner limit is called the *limit of distinct vision*.

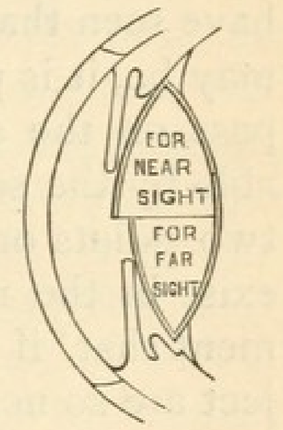

FIG. 72.—Diagram showing how the lens changes its form for near and far sight.

324. The Limit of Distinct Vision.—The limit of distinct vision depends on the accommodation of the lens above described. As any object is brought nearer and nearer to the eye, the effort required to see it distinctly, or, in other words, the effort at accommodation, is greater and greater, until at length it begins to be accompanied by pain and a peculiar sense of fatigue in the eyes. Within this point distinct vision is not possible, for the ciliary muscle can contract no further. In healthy eyes, this limit is usually about six inches from the cornea.

As objects recede, the rays from them come to the eye at a smaller and smaller angle, until, at the distance of fifty feet, they are almost parallel; that is, they are practically so, as far as the perception of the retina is concerned. Beyond this point, vision is distinct enough, and no accommodation of the lens is required; but a new difficulty comes in to hamper us in our perception of objects. We have seen that, however delicate the sense of touch may be, it is possible to press two points of a compass on the skin so near together that we are not able by the sense of touch to say whether they are two points or one. A similar condition is found to exist in the retina. It has been shown by experiment that, if two objects or two points of any object are so near together that both combined subtend an angle of less than one minute at the lens, the retina can not distinguish them apart. Beyond the distance of fifty feet, then, without artificial assistance, the eye is unable to distinguish objects perfectly in their minute details.

325. The Function of the Iris.—The color of the iris is due partly to the blood-vessels which run through it, and partly to small pigment-cells. In new-born children the iris is always blue, and does not take on the color which is to last through life for several weeks after birth. The iris performs two functions. In the first place, in every lens, the whole of which is made of the same substance and of the same density throughout, the rays of light which pass through and near the center are not brought to a focus as soon as those which pass through near the circumference. This fact causes a blurring of the image (spherical aberration) and also a partial decomposition of the light (chromatic aberration), so that the image appears colored at its edges. In optical instruments these difficulties are remedied, partly by constructing the lens of two different substances, which counteract each other's defects, and partly by covering the edge of the lens and only allowing the light to come through the center and the immediately adjacent parts. The latter method is the one carried out by the iris. It is pierced in the center, forming the pupil of the eye, and this pupil is situated immediately in front of the center of the lens, so that in this way the faults above mentioned are corrected. The iris also regulates the admission of light to the eye. Too much light irritates the retina, and by reflex action the iris contracts. If there be too little light the iris is relaxed, and the pupil becomes larger so as to admit more. This process has already been mentioned at length.

326. The Retina and Optic Nerve sensitive only to Light.—The retina is sensitive to other impulses than that of light, but, whatever these impulses may be, the sensation of light is the only one conveyed to the brain. If the eyeball be struck or pressed, or an electrical current be passed through it, we see sparks or flashes of light, and this even when we are in a perfectly dark room. This is due to the shock to the retina, from which every stimulus of whatever kind is transmitted by the optic nerve to the brain under the form of light.

327. **Persistence of Impressions on the Retina.**—When an image is formed on the retina, especially if it is a very bright one, the impression remains a little while after the object that caused it has passed by. The consequence of this is that, if several objects follow each other in very rapid succession, new images are continually formed on the retina before those that immediately preceded them have had time to fade, and so the eye does not detect any interval between them. Thus, when we look at a swiftly-revolving wheel, we do not see the separate spokes, but a continuous, hazy blur; and when a live coal is whirled around fast enough before the eyes, we do not see the coal in its proper shape, but only a luminous circle. In this temporary persistence of impressions on the sense of sight, it is like all the other senses.

328. **Color-Blindness.**—The power of discriminating between different colors varies very much in different individuals. While some can not only distinguish the colors with ease, but can pick out the most delicate shades of any particular color with unfailing accuracy, others are unable to discriminate, for example, between red and green. Such persons are called color-blind, and can not see any difference between the fruit and the leaves of a cherry-tree, excepting by the shape.

329. **Near-Sight and Far-Sight.**—In the natural and healthy eye the rays of light are brought to a focus on the retina, but in some eyes they are

not. In near-sighted persons the eyeball is usually a little too long, and the rays of light, being brought to a focus before they reach the retina, cross each other, and the image is blurred. In far-sighted eyes the eyeball is too short, or the lens is too flat, and the rays are not brought to a focus at all, so that the effect upon vision is to make everything look blurred, as in the former case (Fig. 73). Both of these defects can and should be corrected by proper glasses, for the constant straining to see, of

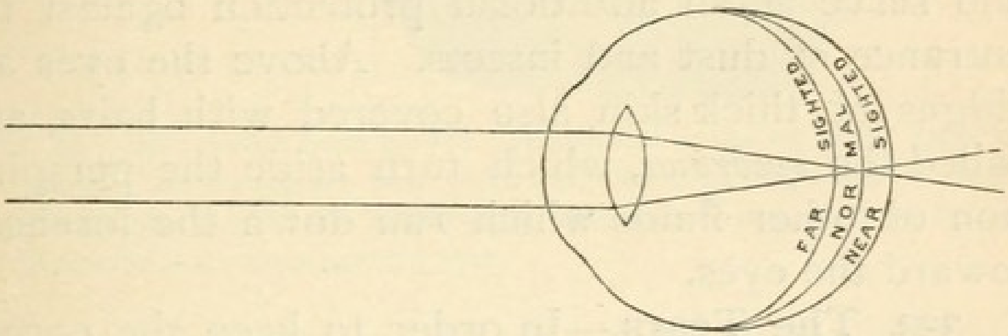

FIG. 73.—Diagram showing the point at which the rays of light are brought to a focus in different eyes.

short-sighted and far-sighted persons who try to get along without glasses, eventually injures the sight.

330. Muscles of the Eyeball.—To the outside of the eyeball are attached six muscles, by means of which it can be moved in any direction. Four of them pass from the four sides of the eyeball straight backward to the bone at the rear of the orbit, and move the eye up or down, and to the right or left. The other muscles are attached, one to the upper and the other to the lower surface of the eye-ball, their other ends being attached to the bones on the inner side of the orbit in such a way that, by their contraction, the eyeball is rolled in one direction or another.

331. The Eyelids and Eyebrows.—This delicate organ—the eye—is protected from injury in front by a number of accessory parts, viz., the *eyelids*, *eyelashes*, and *eyebrows*.

The *eyelids* are composed of thin pieces of cartilage, covered with skin on the outer and lined with mucous membrane on the inner side. They are movable, and, when open, expose nearly all the iris; when shut, they completely cover the eyeball. At their margins are several short, stiff hairs—the *eyelashes*—which project outward and downward, and serve as an additional protection against the entrance of dust and insects. Above the eyes are ridges of thick skin, also covered with hairs, and called the *eyebrows*, which turn aside the perspiration or other fluids which run down the forehead toward the eyes.

332. The Tears.—In order to keep the cornea perfectly smooth and transparent, and to preserve the softness of the mucous membrane lining the interior of the lids, which continually sweep over the cornea, and if rough would irritate and ruin it, a special fluid is provided, called the *tears*, which are continually secreted, and keep those parts constantly moist. The gland which provides the tears, called the *lach'rymal gland* (Fig. 74), is situated inside the orbit, just above and outside of the eyeball, and its secretion is poured out on the eye by several little openings at the upper part of the upper lid, on its inner surface. By the winking of the lids, which occurs frequently and is usually involuntary, it is spread over the surface of the eye. On the edge of the lids, near the inner angle of the eye, may be seen two minute openings, one in each lid.

These are the mouths of two little canals, which pass from these points toward the nose, soon unit-

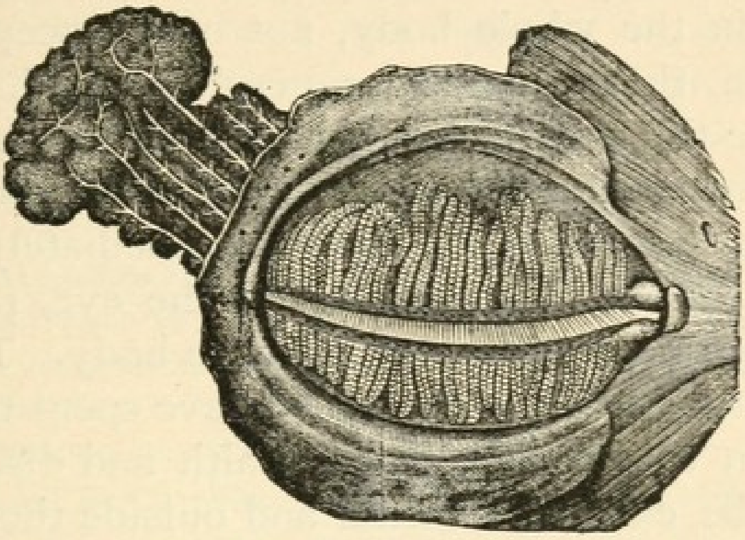

FIG. 74.—Left eyelids from behind. Above and at the left is the lachrymal gland. On the lids are seen what look like strings of beads. They are glands that secrete the fatty matter that coats the edges of the lids, and keeps the tears from running over.

ing in one larger canal, which runs downward into the nasal cavity. Through these minute canals, the superfluous tears run off into the nose. These canals are lined with mucous membrane, and, during a cold in the head, the inflammation often closes them, and the tears, not finding free passage through them, overflow upon the cheeks. This overflow also occurs when from pain or any powerful emotion the tears are increased in amount so that the canals are unable to dispose of the extra supply. This phenomenon we call *crying* or *weeping*. An overflow of tears is guarded against under ordinary circumstances by an oily secretion of certain glands in the lids, which is discharged just along their edges. This secretion keeps the lids from sticking together when closed, and also retains the tears, unless their quantity is greater than common.

333. **Care of the Eyes.**—It is exceedingly important that proper care should be taken of the eyes. They are very delicate, and yet there is hardly an organ in the whole body, not even excepting the stomach, that is more frequently abused. If anything be the matter with the eyes—if they smart, or tingle, or itch, or the sight is dim, or blurred, or indistinct—a good oculist should immediately be consulted. More is known about the eye, probably, than about any other organ in the body. The most eminent scientists in the world have spent their best years in the study of it in health and disease, and it can be examined inside and outside thoroughly. As a consequence, operators who devote their special attention to this organ generally know what they are about, and their advice should be carefully and minutely heeded. It will not do for individuals to treat their own eyes, and therefore it is unnecessary to say anything about its disorders. With regard to proper care of the eye, it is almost enough to say, Do not do anything to produce a feeling of "strain" in the organ. This sensation, as already explained, is produced by the effort of accommodation, and, as the muscular contraction accompanying this act compresses the interior of the eye somewhat, it causes a congestion of the blood-vessels, which is usually only temporary, and passes away when the cause is removed. If a strain like this, however, be often repeated or long continued, it is apt to result in permanent injury to the sight, just as long-continued congestion of the blood-vessels in any other part of the body will impair the working of the organ in which it occurs. The same effect is produced by reading or using the eyes for fine

work while stooping or lying, or during the incessant jarring of a vehicle, especially a railroad-car. The eyes should not be rubbed, or pressed, or squeezed, or used by a bad light, or in any other way treated as if they could bear rough usage.* They can not, and, if they are abused, the sight is apt to fail in a sudden and alarming manner.

* It is supposed by many that the eyes are strengthened by being opened in cold water when the face is washed. This is not so. On the contrary, it is an exceedingly injurious practice, and frequently produces little ulcers on the surface of the eye, which, although perhaps not dangerous, are very painful, and may prevent the use of the affected eye for several days. The eyeball is washed sufficiently by the tears.

PART VII.

ORGAN OF SPEECH.

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334. **Structure of the Larynx.**—In the upper part of the neck, in front, is a hard, projecting mass, which, in the throats of thin persons, is plainly visible, and in every one can be easily felt. This is commonly called *Adam's apple*, and consists of the projecting cartilages which form the sides of the *larynx*. This organ is situated at the upper end of the trachea, and a cross-section of it is nearly triangular in shape. It is composed mainly of cartilage, and forms a stiff, open, box-like organ, covered on the outside with muscles, and on the inside with mucous membrane.

335. **The Vocal Chords.**—The upper end of the larynx is nearly closed by muscular and membranous tissues, which divide it at this point from the throat. But it has a chink-like opening, the *glottis*, previously described, situated at the base of the tongue, just behind the *epiglottis*. This is the essential organ of voice. All the air which passes into or out of the lungs must go through the glottis. Now, in front, the *vocal chords*, which form the

sides of the glottis, are nearly or quite in contact, while the posterior extremities can be separated to quite a distance from each other. These posterior ends are attached to two small cartilages, which can be rotated by certain muscles, so as to separate the vocal chords. When certain other muscles contract, which act in an opposite direction, the cartilages are rotated inward, and the vocal chords are brought nearer together.* Other muscles render the chords tighter or looser, according to circumstances (Fig. 75).

336. How the Voice is produced.—Now, when

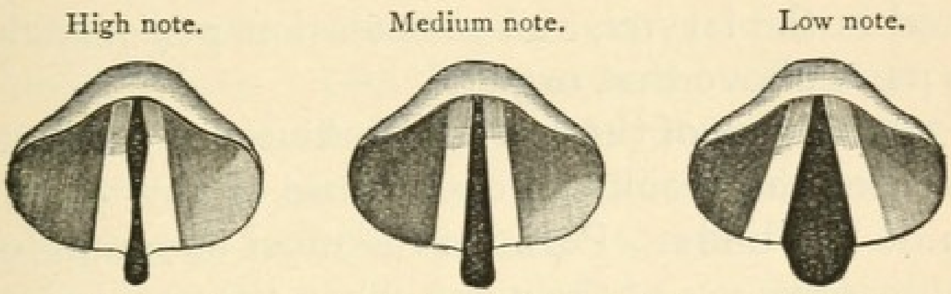

FIG. 75.—The vocal chords in different positions. The opening between the chords is the glottis.

the air is forced through the glottis in expiration with sufficient rapidity, the vocal chords are thrown into vibration, and, vibrations being thus caused in the column of air in contact with them, sound is produced. The quality of this sound, as well as its pitch and tone, depends upon well-known physical laws. The farther apart and the more relaxed the vocal chords are, the lower will be the sound; the

* These cartilages are triangular in shape, and act very much like the triangular pieces of metal to which bell-wires are fastened. The vocal chord being attached to one corner, and the muscle to another, while it rotates about the third angle, it is evident that when one muscle contracts the vocal chord will be moved outward, and when another opposing muscle contracts the end of the chord will be moved inward.

nearer together and tighter drawn they are, the more acute will be the sound. Differences also depend upon the size of the larynx and trachea, the length of the vocal chords, their thickness and smoothness, the condition of the throat and parts adjacent, etc.

In this way the sound is made which we call *voice*, and it is modulated into articulate speech by the action, separate or combined, of the throat, nose, palate, tongue, teeth, and lips. To consider how these variations are produced would require great space, and be foreign to the purpose of this book. It is sufficient to say that the voice is produced in the larynx, and articulation performed by the parts above that organ.

337. **Abuse of the Larynx.**—Abuse of the larynx produces bad results, as does abuse of any other organ of the body. Perhaps the most common form of this is the use of the voice, when the vocal chords are in an inflamed or congested condition. Over-use of the larynx in speaking is apt in many persons to bring on congestion of the chords. This causes them to swell a little, and the voice loses some of its clearness. If rest be not given the organ at such a time, the congestion continues, and becomes chronic. Then the voice is permanently altered, becoming rough and harsh as compared with its original quality. Very often a sore-throat extends to the glottis, and the mucous membrane which covers the vocal chords becomes inflamed. Then the usual results of inflammation of a mucous membrane follow. The chords swell and are covered with a thick secretion, like that which is coughed up during such an attack. This thickening of the

chords affects the voice, and makes it not only harsh but of a lower note than usual, just as in a violin the large strings give forth the low notes and the smaller ones the high notes. The secretion also hinders the vibration of the chords, and sometimes the voice is reduced to a whisper or even extinguished, because the chords are so disabled as not to be able to vibrate at all. A curious phenomenon sometimes occurs in such cases, called the "breaking of the voice." If the mucous secretion be very viscid, as it often is, the chords may stick together at some point during the act of speaking, and the part that vibrates is instantly reduced in length to perhaps three quarters of what it was a moment before. This has the same effect as the shortening of a string of a violin by pressing it with the finger. It makes the voice suddenly take on a higher note. In the next instant the chords become entirely separated, and the former note returns, and so the speech consists of a singular series of growls and squeaks.

338. **Care of the Larynx.**—When the chords are in this condition they ought to be used as little as possible, or permanent injury to the voice will be apt to result. It must be remembered that the mucous membrane of the larynx in such cases is diseased and sore, and ought not to be rasped by a forcible current of air, or it will not readily recover. If one has a sore spot on his hand, he does not rub it violently several times a day; he lets it rest until it is well again. In such a case, the pain which results from rough treatment is a sufficient indication of its harmfulness, but inflamed or congested vocal chords are not usually painful, and the use of the

voice is so necessary a part of our daily life that every one is too apt to neglect warnings regarding it. But Nature is inexorable, and shows no favor. Her penalties are severe and unerring.

QUESTIONS.

PART I.

CHAPTER I.—1. What is anatomy? Physiology? Hygiene? What is an anatomical element? A tissue? An organ? A system? An apparatus? Give examples of each. What is the function of an organ?

CHAPTER II.—2. What is the minute structure of the body? Which is the original element? What causes the different consistency of different organs? 3. What is a fiber? Where found? 4. Why is the cell so important? What is a cell? Nucleus? Nucleolus? 5. What is protoplasm? How large are cells? 6. What other kind of matter exists in the body? 7. What is the difference between living and dead cells? Illustration? 8. How do cells increase in number? 9. What other powers do cells possess? How are wounds healed? What is said of "proud flesh" (foot-note)? Does one cell ever perform the duty of another? Give example (foot-note).

PART II.

CHAPTER I.—10. Why are bones necessary? 11. How does living bone differ from dead bone? 12. What is the composition of bone? What experiments will show this? 13. How are bones affected by age? What is a "green-stick" fracture? 14. How many kinds of bones are there? What is the structure of the shaft? Of the extremities? Why the difference? What is the marrow? 15. What is the periosteum? What is the minute structure of bone? 16. What is the use of the periosteum? Illustrate.

CHAPTER II.—17. How many bones in the body? What is ossification? When complete? 18. What is the spine? What is a vertebra? How are the vertebræ arranged in the spine? What separates them? How is the spinal canal formed, and what does it contain? 19. How movable is the spine? How is it held together? What is the use of the pads between the vertebræ? Is a man taller in the morning or at night? Why? 20. What is the skull? How are its bones peculiar? What is the advantage of its arched shape? What movable bone in the skull? 21. What are the sutures of the skull? What is their use? 22. What are the frontal sinuses? How may they cause headache? 23. Describe the ribs. How many are there? How are they attached to the breastbone? What are the floating ribs? How does the motion of the ribs alter the form of the chest? 24. How do the cartilages of the ribs change with age? How does pressure affect them? What is the natural shape of the chest? 25. How many bones are there in the limbs? What is meant by homologous bones? 26. How are joints formed? What is cartilage? Synovial membrane? Ligaments? Uses of these parts.

CHAPTER III.—27. What is a fracture? A dislocation? How can they be told apart? 28. How are bones generally broken, and why does the limb generally become shorter after a fracture? Why is a fracture near a joint so serious? 29. Why is a dislocation so painful? In what joints are dislocations most common? How are they generally caused? What is a sprain (foot-note)? 30. How long does it take a broken bone to unite? 31. How should a broken limb be cared for before the doctor comes? How can the patient be carried?

CHAPTER IV.—32. How are the bones moved? What two kinds of muscle are there? 33. What is a voluntary muscle? What is connective tissue (foot-note)? Use of muscle. How does voluntary muscular fiber look under the microscope? What is striation? 34. What is the minute structure of involuntary muscular fiber? 35. How do voluntary and involuntary muscles differ in their action? Peculiarity of the heart-muscle. Where are involuntary muscles found? 36. Do muscles vary much in size? Illustrate. 37. How are the muscles connected with the bones? What is a tendon? Describe the peculiar arrangement of tendons at the wrist and ankle. 38. Describe the disadvantages under which a muscle exerts its force during contraction. 39. What is the irritability of muscle? Give illustrations. 40. What is meant by the muscular sense? Of what use is this sense? 41. Illustrate the use of this sense in standing. 42. What is the effect of contraction on the muscle itself? 43. What is the effect of muscular overwork? 44. What is the result of muscular inactivity? Give illustrations. How is curvature of the spine produced (foot-note)? 45. What is the best exercise? What is said of gymnastic training? 46. Why is exhaustion dangerous? 47. Why is rest necessary? What simple rules for exercise are given?

PART III.

CHAPTER I.—48. Why do we need food? 49. Can people live without eating? Why? 50. What are the two great divisions of foods? 51. What proportion of the body is water? How much water is needed daily? 52. Illustrate the importance of salt (foot-note). 53. What other inorganic substances are taken in food? Why is lime so important? 54. What are the non-nitrogenous foods? 55. In what foods is starch found? What peculiarity has starch? 56. In what foods is sugar found? Name some of the varieties of sugar. What is said of glucose (foot-note)? 57. What is the use of fat in the body? Is the fat all taken into the body with the food? What articles of food tend to produce fat? Illustrate. Describe Mr. Banting's case (foot-note). 58. What are nitrogenous foods? What other name are they known by to physiologists? In what foods are the nitrogenous substances found? Are similar substances found in vegetable foods? 59. Why do we need variety in our food? 60. Which is the most essential of all articles of food or drink? Illustrate. 61. How much of each kind of food is needed daily? 62. What is the effect of cooking on food?

CHAPTER II.—63. What is the use of the digestive apparatus? 64. What are the five stages in the preparation of food for the needs of the body? 65. Which of these stages is under control of the will? Why must all the stages be properly carried through? 66. Use of the senses of taste and smell. 67. Use of the teeth. Of the cheeks and tongue. What is the masseter muscle? What is said of the sound accompanying muscular contraction? 68. What is the saliva? What are the parotid glands? How does their secretion differ from that of the other salivary glands? Does the secretion of saliva vary in amount at different times? Illustrate (foot-note). 69. What are the properties of the saliva? Its effect upon starch? Its use in the preparation of food. Illustrate. How much saliva is secreted daily? What is said of the care of the teeth (note)?

CHAPTER III.—70. What is the alimentary canal? 71. What is mucous membrane? Its minute structure? What are epithelial and epidermal cells (foot-note)? 72. Describe the character and arrangement of the muscles in the alimentary canal. What is the result of their contraction? 73. What is serous membrane? Its use? 74. What are the pharynx and œsophagus? How do we swallow? 75. How large is the stomach? What is its shape? Where are its two openings, and what are they called? What is the great pouch of the stomach? In what direction do substances pass through the stomach, and how is this regulated? 76. What portions of the food are digested in the stomach? 77. Describe the accident to St. Martin, and its result. 78. What is the appearance of the interior of a healthy stomach? 79. How does the gastric juice appear during secretion? When is it secreted? 80. What two necessary ingredients has the gastric juice? Can food be digested outside of the body? How much gastric juice is secreted daily? 81. What part do the muscles of the stomach perform during digestion? 82. What is the appearance of the interior of the stomach during indigestion? Is the gastric juice secreted at such times? How is the tongue affected? 83. How long a time is required for stomach-digestion? 84. How does thorough mastication assist digestion, and why? 85. What is said of eating too little? 86. Why is it harmful to eat too much? 87. Why should we not eat between meals? 88. What is hunger? Why is plain food the best? 89. How are we to know when we have eaten enough? How far apart should our meals be? 90. How are we to judge of what to eat? 91. What is said of pepper and mustard? What is the golden rule about eating? 92. What is the natural drink? 93. What are the immediate effects of drinks containing alcohol? 94. What is the peculiarity of narcotic poisons? 95. What is the earliest symptom of narcotic poisoning? 96. What is the effect of alcohol on growing persons? 97. What are the effects of habitual excess in the use of alcoholic drinks? 98. What effect has alcohol upon the powers of endurance? Does it enable men to bear heat and cold better? Why does it seem to? Does it ward off disease? 99. What effects have tea and coffee on growing persons? Also tobacco (foot-note)? 100. How is candy adulterated? What kinds are to be avoided? Why? 101. What is the trichina spiralis? The cysticercus cellulosæ? How can they be killed? What are the general rules about eating?

CHAPTER IV.—102. What becomes of the fats, sugars, and starches in the stomach? What is the chyme? 103. What is the structure of the small intestine? How does it join the large intestine? What is the course of the latter? What is the appendix vermiformis (foot-note)? 104. How do the muscular fibers of the intestine contract? What is the result? 105. What is the duodenum? 106. What is the pancreas? What is its use? 107. What is the liver? Its secretion? 108. What other function has the liver? 109. What is the bile? Where is it discharged into the intestine? What reason is there for supposing that it is an excrementitious fluid? What is jaundice? What is the result if the bile is prevented from entering the intestine? Illustrate. Does the bile leave the body? What is the inference from these facts? 110. What are the intestinal juices? How are they useful? 111. How is it shown that food is absorbed from the intestine?

What vessels absorb it? Origin of the name lacteal (foot-note)? 112. What is the peritonæum? Its use? How do the blood-vessels and lacteals get to the intestine? Where do they terminate? 113. What are the villi? Their size, number, and structure? 114. What are the lymphatics? The lymph? The lymphatic glands? What is the function of the lymphatics? What are the lacteals? The thoracic duct? 115. Where is the blood from the intestines carried? 116. What is the function of the villi? What is the chyle? How is it absorbed (foot-note)? 117. Describe the changes in the blood during digestion. 118. What is the spleen? Why would it seem to be an important organ? What is the result of its removal? What is probably its function (foot-note)?

CHAPTER V.—119. What is the blood? Its physical properties? 120. What are the red blood-corpuscles? Their appearance and size? How do they differ in different animals? 121. What are the white blood-corpuscles? How numerous are they? What is their appearance and size? How much of the blood is made up of corpuscles? 122. What is the plasma? Its composition? 123. What is coagulation? What is the clot? The serum? Why is the clot red? How does serum differ from plasma? 124. What conditions affect the rapidity of coagulation? Will blood coagulate inside of the body? Illustrate. 125. What is the total amount of blood in the human body? 126. What gas is absorbed by the blood from the air? How important is it to life? Illustrate. 127. What process causes the blood to change color?

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