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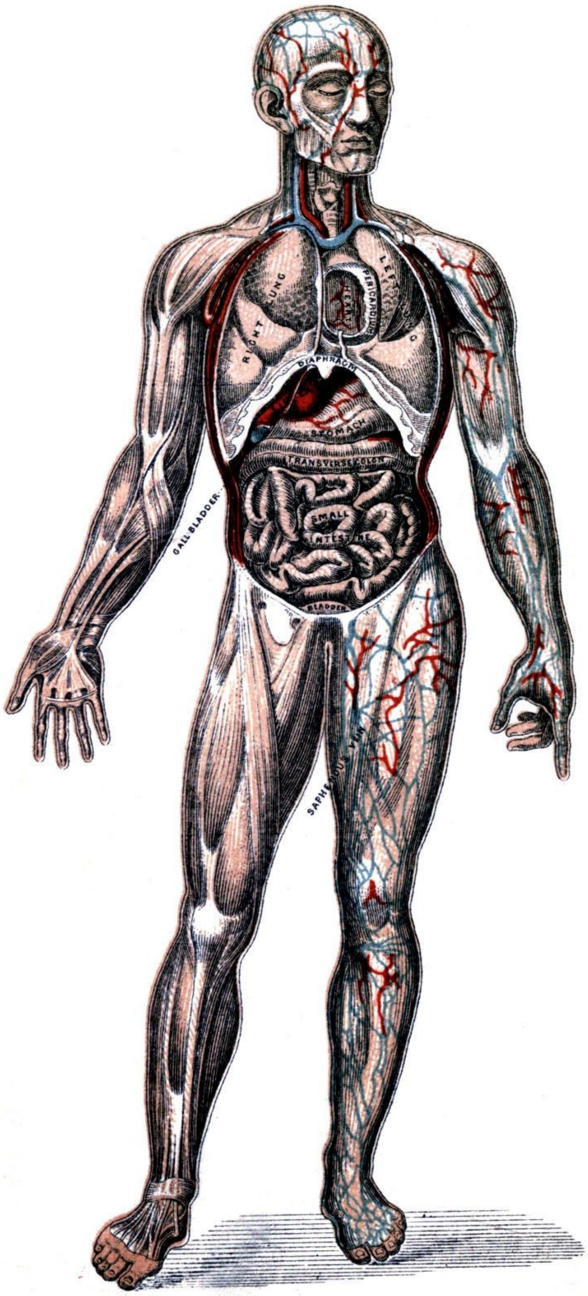


THE VISCERA IN POSITION.

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A

# TREATISE

ON

# PHYSIOLOGY AND HYGIENE

FOR

**EDUCATIONAL INSTITUTIONS AND GENERAL READERS.**

*FULLY ILLUSTRATED.*

BY

**JOSEPH C. HUTCHISON, M. D.,**

*President of the New York Pathological Society, Vice-President of the New York Academy of Medicine, Surgeon to the Brooklyn City Hospital, late President of the Medical Society of the State of New York, etc.*

NEW YORK:

**CLARK & MAYNARD, PUBLISHERS,**

5 BARCLAY STREET.

**1872.**



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645 and 647 Broadway.

**TO MY WIFE,**

WHOSE SYMPATHY HAS, FOR MORE THAN TWENTY YEARS, LIGHTENED THE CARES INCIDENT TO

***AN ACTIVE PROFESSIONAL LIFE,***

THIS HUMBLE VOLUME

**IS AFFECTIONATELY INSCRIBED.**

## PREFACE. {3}

———•———

This work is designed to present the leading facts and principles of human Physiology and Hygiene in clear and concise language, so that pupils in schools and colleges, and readers not familiar with the subjects, may readily comprehend them. Anatomy, or a description of the structure of an organ, is of course necessary to the understanding of its Physiology, or its uses. Enough of the former study has, therefore, been introduced, to enable the pupil to enter intelligently upon the latter.

Familiar language, as far as practicable, has been employed, rather than that of a technical character. With a view, however, to supply what might seem to some a deficiency in this regard, a Pronouncing Glossary has been added, which will enable the inquirer to understand the meaning of many scientific terms not in common use.

In the preparation of the work the writer has carefully examined all the best material at his command, and freely used it; the special object being to have it abreast of the present knowledge on the subjects treated, as far as such is possible in a work so elementary as this. The discussion of disputed points has been avoided, it being manifestly inappropriate in a work of this kind.

Instruction in the rudiments of Physiology in schools does not necessitate the general practice of dissections, or of experiments upon animals. The most important subjects may be illustrated by drawings, such as are contained in this work. Models, especially those constructed by Auzoux of {4} Paris, dried preparations of the human body, and the organs of the lower animals, may also be used with advantage.

The writer desires to acknowledge his indebtedness to R. M. Wyckoff, M.D., for valuable aid in the preparation of the manuscript for the press; and to R. Cresson Stiles, M.D., a skilful microscopist and physician, for the chapter "On the Use of the Microscope in the Study of Physiology." Mr. Avon C. Burnham, the well-known teacher of gymnastics, furnished the drawing of the parlor gymnasium and the directions for its use.

*Brooklyn, N. Y., 1870.*

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The Human Body is the abode of an immortal spirit, and is the most complete and perfect specimen of the Creator's handiwork. To examine its structure, to ascertain the uses and modes of action of its various parts, how to protect it from injury, and maintain it in a healthy condition, is the design of this work.

The departments of knowledge which are concerned in these investigations, are the science of Human Physiology and the art of Hygiene.

Physiology treats of the vital actions and uses of the various parts of living bodies, whether vegetable or animal. Every living thing, therefore, has a Physiology. We have a *Vegetable* Physiology, which relates to plants; and an *Animal* Physiology, relating to the animal kingdom. The latter is also divided into *Comparative* Physiology, which treats of the inferior races of animals, and *Human* Physiology, which teaches the uses of the various parts of the human body.

Hygiene, or the art of preserving health, is the practical use of Physiology. It teaches us how to cultivate our bodily and mental powers, so as to increase our strength and to fit us for a higher enjoyment of life. It also shows us how to prevent some of the accidents which may befall the body, and to avoid disease. It is proper that we should understand the construction and powers of {12}
our bodies; but it is our duty, as rational beings, to know the laws by which health and strength may be maintained and disease warded off.

There are various means by which we gain important information respecting the Physiology of man. Plants aid us in understanding the minute structure of the human body, its circulation, and absorption. From inferior animals we learn much in respect to the workings of the different *organs*, as we call those parts of the system which have a particular duty to perform. In one of them, as in the foot of the frog, we can study the circulation of the blood; in another, we can study the action of the brain.

By *vivisection*, or the laying bare of some organ of a living animal, we are able to investigate certain vital processes which are too deeply hidden in the human body to be studied directly. This is not necessarily a cruel procedure, as we can, by the use of anæsthetics, so blunt the sensibility of the animal under operation, that he need not suffer while the experiment is being performed. There are other means by which we gather our information. There are occasionally men, who, from some accident, present certain parts, naturally out of view, in exposed positions. In these cases, our knowledge is of much greater value than when obtained from creatures lower in the scale of being than man.

We are greatly aided, also, by the use of various instruments of modern invention. Chief among these is the microscope, which is, as we shall learn hereafter, an arrangement and combination of lenses in such a way as greatly to magnify the objects we wish to examine. {13}

We have much to say of Life, or vital activity, in the course of our study of Physiology; but the most that we know of it is seen in its results. What Life is, or where its precise position is, we are not able to determine. We discover one thing, however, that all the parts of the body are united together with wonderful sympathy, so that one part cannot be injured and other parts not suffer damage. It is further evident that all organs are not equally important in carrying on the work of Life; for some may temporarily suspend their action, without serious results to the system, while others must never cease from acting. Yet there is nothing superfluous or without aim in our frames, and no part or organ can suffer harm without actual loss to the general bodily health. On this point Science and Holy Writ strictly agree.

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# PHYSIOLOGY,

AND

# HYGIENE.

## CHAPTER I.

### The Framework of the Body.

*The Bones—Their Form and Composition—The Properties of Bone—The Skeleton—The Joints—The Spinal Column—The Growth of Bone—The Repair of Bone.*

**1.** The framework of the body? The superstructure? Softness and delicacy of the organs? How protected?

**1. The Bones.**—The framework which sustains the human body is composed of the *Bones*. The superstructure consists of the various organs on which the processes of life depend. These organs are soft and delicately formed, and, if unprotected, would, in most cases, rapidly be destroyed when subjected to violence, however slight. The bones, having great strength and power of resistance, afford the protection required.

**2.** The more delicate the organ? Example in relation to the brain? The eye? The lungs? The services performed by the bones?

**2.** The more delicate the organ, the more completely does Nature shield it. For example: the brain, which is soft in structure, is enclosed on all sides by a complete box of bone; the eye, though it must be near the surface of the body to command an extensive view, is sheltered from injury within a deep recess of bone; the lungs, requiring freedom of motion as well as protection, are surrounded by a large case of bone and muscle. The bones serve other useful purposes. They give permanence of form to the body, by holding the softer parts in their proper places. They assist in {16} movement, by affording points of attachment to those organs which have power of motion—the muscles.

**3.** Their shape and size? Of what composed? Possibility of being separated? Effect of fire? Of dilute acid?

**3. The Form and Composition of the Bones.**—Their shape and size vary greatly in different parts of the body, but generally they are arranged in pairs, one bone for each side of the body. They are composed of both mineral and animal substances, united in the proportion of two parts of the former to one of the latter; and we may separate each of these substances from the other for examination. First, if we expose a bone to the action of fire, the animal substance is driven off, or "burned out." We now find that, though the shape of the bone is perfectly retained, what is left is no longer tough, and does not sustain weight as before. Again, we may remove the mineral portion, which is a form of lime, by placing a bone into a dilute acid. The lime will be dissolved out, and the shape of the bone remain as before; but now its firmness has disappeared, and it may be bent without breaking.

**4.** Effect of deficiency of ingredient? Usefulness of the lime? Of the animal substance? Effect of their union? Condition, in youth? Old age?

**4.** If, for any reason, either of these ingredients is disproportionate in the bone during life, the body is in danger. The lime is useful in giving rigidity of form, while the animal substance insures toughness and elasticity. By their union, we are able to withstand greater shocks and heavier falls than would be possible with either alone. In youth, the period of greatest activity, the animal constituent is in excess: a bone then does not break so readily, but, when broken, unites with great rapidity and strength. On the other hand, the bones of old persons are more easily broken, and in some cases fail to unite. The mineral matter being then in excess, indicates that the period of active exertion is drawing to a close.

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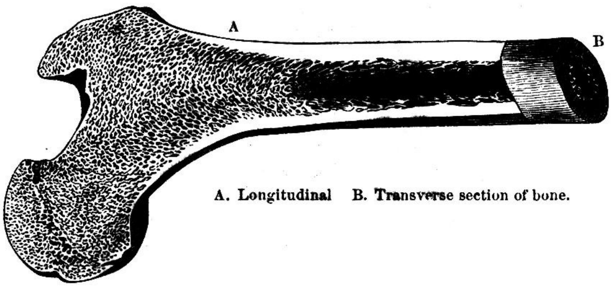


FIG. 1.—SECTION OF BONE.

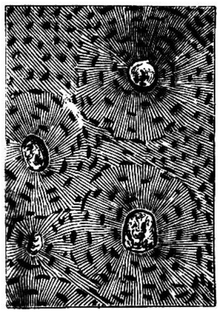

FIG. 2.
Structure of bone enlarged.

**5.** In what respect admirably fashioned? Its formation? Microscopic examination? The inference? "Line of beauty?"

**5. The Structure of the Bones.**—If we examine one of the long bones, which has been sawn through lengthwise, we observe that it is admirably fashioned for affording lightness as well as strength (Fig. 1). Its exterior is hard and resisting, but it is porous at the broad extremities, while through the central portion there is a cavity or canal which contains an oily substance, called *marrow*. Let us now take a thin section of bone, and examine it under the microscope; we discover that it is pierced by numerous fine tubes (Fig. 2), about which layers of bone-substance are arranged. Accordingly, though a bone be as hard as stone externally, it is by no means as heavy as stone, by reason of its light interior texture. Another element of power is found in the curved outline of the bones. The curved line is said to be "the line of beauty," as it certainly is the line of strength, and is uniformly employed in the bones whose position exposes them to accident.

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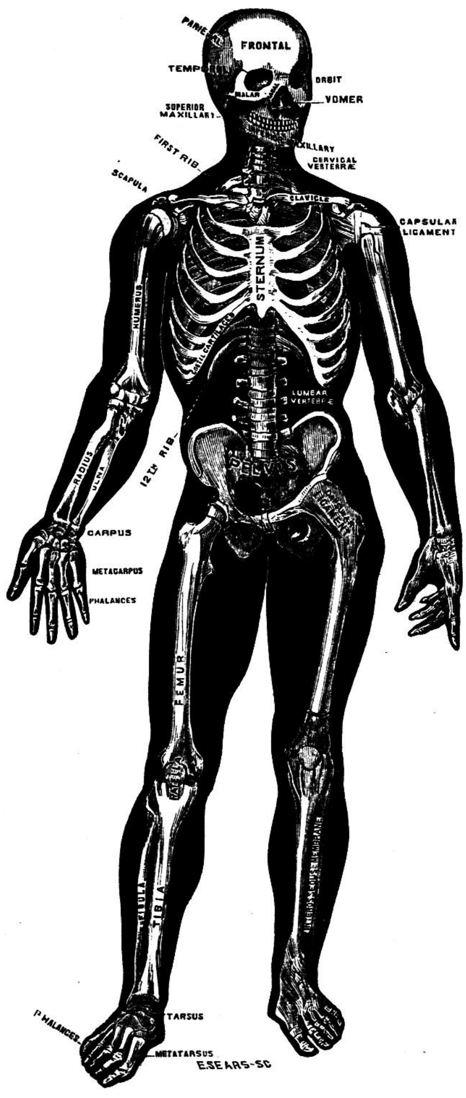


FIG. 3.—THE SKELETON

**6.** Number of bones? Skeleton? The skull? Chest? The trunk? The trunk and skull, how maintained? What of the arms? Legs?

**6. The Skeleton.**—The number of bones in the human body exceeds two hundred. {19}
When these are joined together in the proper places, they form what is termed the *Skeleton* (Fig. 3). It embraces three important cavities. The first, surmounting the frame, is a box of bone, called the *skull;* below this, is a bony case, or "chest;" and lower down is a bony basin, called the *pelvis*. The two latter compose the trunk. The trunk and skull are maintained in their proper relations by the "spinal column."

Branching from the trunk are two sets of limbs: the arms, which are attached to the chest by means of the "collar-bone" and "shoulder-blade;" and the legs, directly joined to the lower part of the trunk.

**7.** Design of the cavities? Give the examples.

**7.** The cavities of which we have spoken, are designed for the lodgment and protection of the more delicate and perishable parts of the system. Thus, the skull, together with the bones of the face, shelters the brain and the organs of four senses—sight, hearing, smell, and taste. The chest contains the heart, lungs, and great blood-vessels, while the lower part of the trunk sustains the liver, stomach, and other organs.

**8.** Joint or articulation? Movable joints, how compacted? The ligaments of the movable joints? What is a sprain? Consequence of a serious sprain?

**8. The Joints.**—The point of union of two or more bones forms a joint or *articulation*, the connection being made in various ways according to the kind and amount of motion desired. The movable joints are compacted together by certain strong fibrous bands, called ligaments. These ligaments are of a shining, silvery whiteness, and very unyielding; so much so, that when sudden violence is brought to bear in the vicinity of a joint, the bone to which a ligament is attached may be broken, while the ligament itself remains uninjured. When this connecting material of the joints is strained or lacerated by an accident, a "sprain" is the consequence. An injury of this sort may be, {20}
and frequently is, quite as serious as the breaking of a bone.

**9.** Office of the ligament? What must it have? How accomplished? Describe it. Synovia?

**9.** The ligament, then, secures firmness to the joint; it must also have flexibility and smoothness of motion. This is accomplished by a beautiful mechanism the perfection of which is only feebly imitated by the most ingenious contrivance of man. The ends of the bones are covered by a thin layer of *cartilage*, which being smooth and elastic, renders all the movements of the joint very easy. In addition to this, there is an arrangement introduced for "lubricating" the joint, by means of a delicate sac containing fluid. This fluid is constantly supplied in small quantities, but only so fast as it is used up in exercise. In appearance, it is not unlike the white of an egg, and hence its name *synovia*, or egg-like.

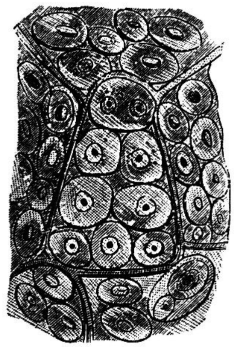

Fig. 4.—Cells of Cartilage.

**10.** What do we observe as regards the composition of a joint? The ligament and cartilage? What varies? Example of the skull? Other examples? The ball-and-socket joint?

**10.** Thus, we observe, that two very different substances enter into the composition of a joint. The ligament, very unyielding, affords strength, while the cartilage, elastic and moist, gives ease and smoothness of motion. The amount of motion provided for varies greatly in different joints. In some there is none at all, as in the skull, where one bone is dove-tailed into another by what are termed *sutures*. Others have a hinge-like motion, such as those of the elbow, wrist, ankle, and knee; the most complete of these being the elbow-joint (Fig. 5). Belonging to another class, the ball-and-socket joint, is that at the {21}
shoulder, possessing a freedom of motion greater than any other in the body.

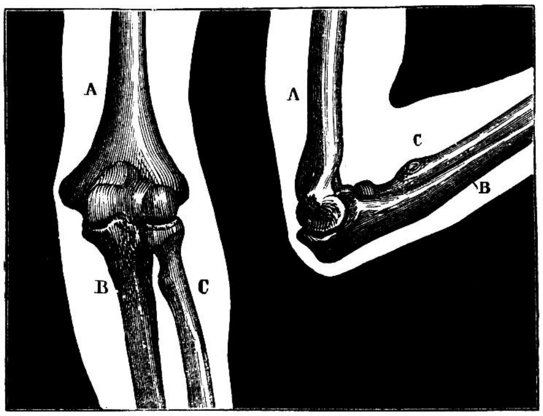


Fig. 5.—Elbow Joint. A, Bone of the arm; B, C, Bones of the fore-arm.

**11.** What is the spinal column? What does it connect and form? Joints of the vertebræ? Amount of motion? Result?

**11. The Spinal Column.**—The spinal column is often spoken of as the "back-bone," as if it were a single bone, while, in reality, it is composed of a chain of twenty-six small bones, called *vertebræ*. The spinal column is a wonderful piece of mechanism. It not only connects the important cavities of the body, as has already been shown, but, also, itself forms a canal, which contains the spinal cord. The joints of the vertebræ are remarkable for the thick layers of cartilage which separate the adjacent surfaces of bone. The amount of motion between any two of these bones is not great; but these little movements, taken together, admit of very considerable flexibility, in several directions, without endangering the supporting power of the column.

**12.** Elasticity of the frame? Protection of the brain from shocks? Tallness of persons? Effects of

**12.** The abundant supply of intervertebral cartilage has another important use, {22}
namely, it adds greatly to the elasticity of the frame. It is due, in part, to this elastic material, and in part to the frequent curves of the spine, that the brain and other delicate organs are protected from the shock of sudden falls or jars. During the day, the constant pressure upon these joints, while the body is erect, diminishes the

reclining?

thickness of the cartilages; so that a person is not so tall in the evening as in the morning. The effects of this compression pass away when the body reclines in a horizontal position.

**13.** Change in bone? Example—animal and madder. Rapidity of change in color? Waste and repair?

**13. The Growth of Bone.**—Bone, like all the other tissues of the body, is constantly undergoing change, old material being withdrawn, and new particles taking their place. This has been shown conclusively by experiments. If an animal be fed with madder—a red coloring matter—for a day or two, the bones soon become tinged; then, if the madder be discontinued for a few days, the original color returns. If, however, this material be alternately given and withheld, at short intervals, the bone will be marked by a succession of red and white rings. In very young animals, all the bones become colored in a single day; in older ones, a longer time is required. The process of waste and repair, therefore, is constantly taking place in this hard substance, and with astonishing rapidity.

Fig. 6—The Spinal Column.

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**14. The Repair of Bone.**—Nature's provision for uniting broken bones is very complete. At first, blood is poured out around the ends of the bone, as a result of the injury. This is gradually absorbed, and gives place to a watery fluid, which, thickening from day to day, acquires, at the end of two weeks, the consistency of jelly. This begins to harden, by a deposit of new bone-substance, until, at the expiration of five or six weeks, the broken bone may be said to be united. It is, however, still fragile, and must be used carefully a few weeks longer. The process of hardening continues, and months must pass before the union can be said to be complete.

QUESTIONS FOR TOPICAL REVIEW.

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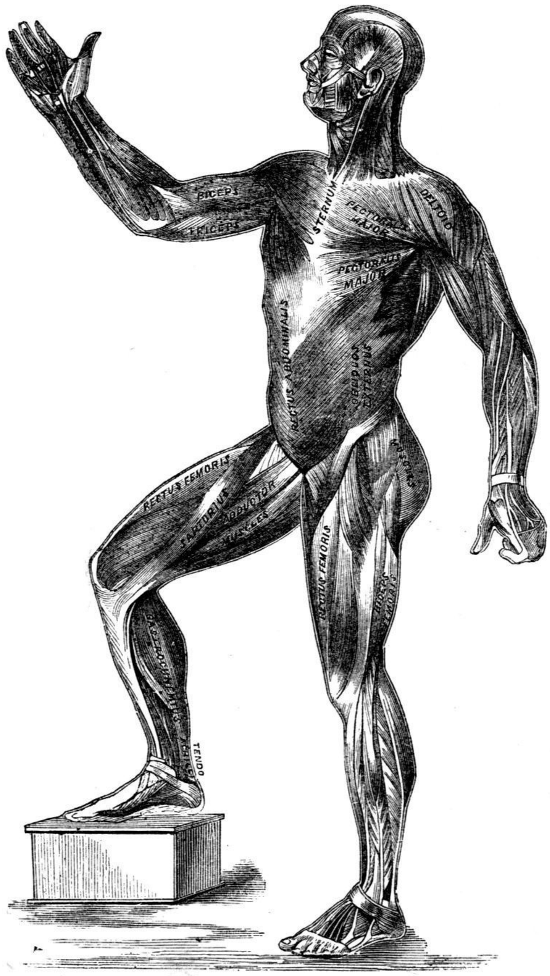


FIG. 7.—THE MUSCLES.

## CHAPTER II. {25}

## THE MUSCLES.

*The Muscles—Flexion and Extension—The Tendons—Contraction—Physical Strength—Necessity for Exercise—Its Effects—Forms of Exercise—Walking—Riding—Gymnastics—Open-air Exercise—Sleep—Recreation.*

**1.** What are the muscles? Their number? The design of most of them? Of a few?

**1. The Muscles.**— The great mass of the body external to the skeleton, is composed of the flesh, or *Muscles*, which largely determines its outline and weight. The muscles are the organs of motion. Their number is about four hundred, and to each of them is assigned a separate and distinct office. They have all been studied, one by one, and a name given to each, by the anatomist. Each is attached to bones which it is designed to move. A few are circular in form, and enclose cavities, the size of which they diminish by contraction.

**2.** The structure of flesh? Its color, etc.? The composition of the fibres? How marked?

**2.** If we examine a piece of flesh, we observe that it is soft, and of a deep red color. Its structure appears to be composed of layers and bundles of small fibres. Let us further examine these fibres under the microscope. We now discover that they are, in turn, made up of still finer fibres, of *fibrillæ*: these are seen in Fig. 8. The fibres are beautifully marked by parallel wavy lines, about ten thousand to an inch, which give the fibre its name of the *striped* muscular fibre. All of the voluntary muscles present this appearance. {26}

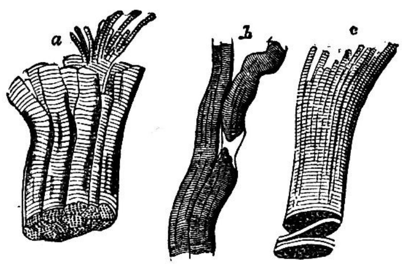

FIG. 8.—MUSCULAR TISSUE.
*a*, *b*, Striped muscular fibres: *c*, The same more highly magnified.

**3.** Arrangement of the muscles? Their action? Flexion and extension? Action of the muscles when we stand erect?

**3. Flexion and Extension.**—The muscles are, for the most part, so arranged in pairs, or corresponding sets, that when motion is produced in one direction by one set, there is, opposite to it, another muscle, or group of muscles, which brings the limb back to its place. When they act alternately, a to-and-fro movement results. When a joint is bent, the motion is called *flexion*; and when it is made straight again, it is called *extension*. When both sets act equally, and at the same moment, no motion is produced, but the body or limb is maintained in a fixed position: this occurs when we stand erect. The muscles which produce extension are more powerful than those opposite to them.

**4.** Kinds of muscles? The voluntary? Involuntary? The heart? Give the example. The hand? Arm?

**4.** The muscles are also distinguished, on the other hand, as the voluntary and involuntary muscles, according as they are, or are not, under the control of the will. The heart is an example of the involuntary variety. We cannot change its action in the least by an effort of the will. When we sleep, and the will ceases to act, the heart continues to beat without cessation. The voluntary muscles, on the other hand, are such as are used only when we wish or *will* to use them—as the muscles of the hand or arm (Fig. 9).

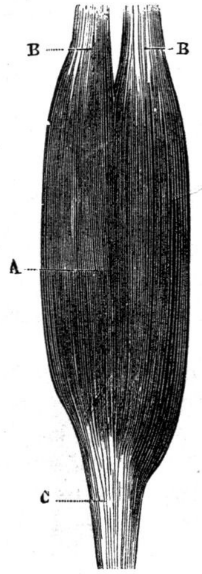

Fig. 9.—A, Biceps muscle of the arm: B, C, Its tendons.

**5.** What are the tendons or sinews? Their strength? Color? Location? Tendon of Achilles? The fable? Muscles of the leg?

**5. The Tendons.**—Tendons, or sinews, are the extremities of muscles, and are compactly fastened upon bone. They are very {27}
strong, and of a silvery whiteness. They may be felt just beneath the skin, in certain parts of the body, when the muscles are being used, as at the bend of the elbow or knee. The largest tendon of the body is that which is inserted into the heel, called the tendon of Achilles, after the hero of the Grecian poet, the fable relating that it was at this point that he received his death-wound, no other part of his body being vulnerable. The muscles which extend into the leg unite to form a single and very powerful tendon, and enclose a small bone called the knee-pan, which, acting like a pulley, greatly increases their power, and at the same time protects the front of the knee-joint (Fig. 10).

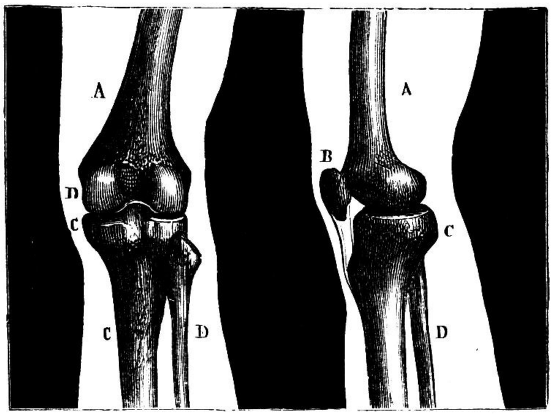

Fig. 10.—View of Knee-joint. A, Thigh bone: B, Knee-pan: C, D, Leg bones.

**6.** Contraction of the muscles? Bending of the arm or finger? Other agencies? Automatic movements? In cold-blooded animals?

**6. Muscular Contraction.**—The muscles, when acted upon by the appropriate
stimulus, contract, or so change their shape, that their extremities are brought nearer {28}
together. The bending of the arm, or of a finger, is effected in this manner, by the will; but the will is not the only means of producing this effect. Electricity, a sharp blow over a muscle, and other stimuli, also cause it. Contraction does not always cease with life. In man, after death from cholera, automatic movements of hands and feet have been observed, lasting not less than an hour. In certain cold-blooded animals, as the turtle, contraction has been known to take place for several days after the head has been cut off.

**7.** Contractility? Give the illustration. What was supposed? What is the case?

**7.** The property which, in muscle, enables these movements to take place is called *contractility*. If we grasp a muscle while in exercise (for example, the large muscle in the front of the arm), we notice the alternate swelling and decrease of the muscle, as we move the forearm to and fro. It was at one time supposed that the muscle actually increased in volume during contraction. This, however, is not the case; for the muscle, while gaining in thickness, loses in length in the same proportion; and thus, the volume remains the same in action and at rest.

**8.** What further in relation to contraction? Weariness of a muscle? Beating of the heart? Standing and walking?

**8.** Contraction is not the permanent, or normal, state of a muscle. It cannot long remain contracted, but after a shorter or longer time, it wearies and is obliged to relax. After a short rest, it can then again contract. It is for this reason that the heart can beat all through life, night and day, by having, as we shall hereafter see, a brief interval of rest between successive pulsations. For the same reason, it is more fatiguing to stand for any great length of time in one position, than to be walking the same period.

**9.** Muscular power of animals? How tested? Man's power? Horse's? The comparison?

**9. Relative Strength of Animals.**—The amount of muscular power which different
animals can exert, has been tested by experiment. By determining the number of {29}
pounds which an animal can drag upon a level surface, and afterward comparing that with its own weight, we can judge of its muscular force. It is found that man is able to drag a little less than his own weight. A draught-horse can exert a force equal to about two-thirds of his weight. The horse, therefore, though vastly heavier than man, is relatively not so powerful.

**10.** Power of

**10.** Insects are remarkable for their power of carrying objects larger and heavier insects? Beetles? Give the conclusion.

than themselves. Many of them can drag ten, and even twenty times their weight. Some of the beetles have been known to move bodies more than forty times their own weight. So far, therefore, from it being a fact that animals have strength in proportion to their weight and bulk, the reverse of that statement seems to be the law.

**11.** Difference in strength of individuals? How caused?

**11. Physical Strength.**—The difference in strength, as seen in different individuals, is not due to any original difference in their muscles. Nature gives essentially the same kind and amount of muscles to each person, and the power of one, or the weakness of another, arises, in great part, from the manner in which these organs are used or disused.

**12.** Complaint in relation to degeneracy? How true? How determined by armor? The fair supposition?

**12.** Many authors complain of the physical degeneracy of men at the present day, as compared with past generations. There is room for doubt as to the correctness of this statement. Certain experiments have recently been made with the metallic armor worn seven hundred years ago, by which it is found that any man, of ordinary height and muscular development, can carry the armor and wield the weapons of an age supposed to be greatly our superior in strength. When we consider that in those days, only very strong men could endure the hardships of soldier-life, it is fair to suppose {30}
that our age has not so greatly degenerated in respect to physical strength.

**13** Action? Use of organs? Training of the mind? The child's brain? Education of the body?

**13. Importance of Exercise.**—Action is the law of the living body. Every organ demands use to preserve it in full vigor, and to obtain from it its best services. The value of that training of the mind, which we call education, is everywhere recognized. The child is early put to school, and for many years continues to study, in order that his brain, which is the great centre of mental power, may act healthfully and with force. It is important that the body, also, should receive its education by exercise. This is especially true of persons belonging to certain classes of society, whose occupation confines them within doors, and requires chiefly brain-work.

**14** Work in the open air? A perfect business? The consequence of universal perfect business? Occupation of children?

**14.** Persons who are engaged in manual labor in the open air obtain all the exercise necessary for bodily health in their regular business: their need is more likely to be a discipline or exercise of the mind. A perfect business of life, therefore, would be one which would combine both physical and mental labor in their proper proportions. If such a business were possible for all the human race, life would thereby be vastly prolonged. Such is, in fact, to a large extent, the occupation pertaining to one period of life—childhood. A part of the time is spent by the child in improving his mind by study, and another part of the time he has physical exercise in his games and sports.

**15** In what does exercise consist? Effects of it?

**15. The Effects of Exercise.**—Exercise consists in a well-regulated use of the voluntary muscular system. The effects, however, are not limited to the parts used. Other organs, which are not under the control of the will, are indirectly influenced by it. For instance, the heart beats more rapidly, the skin acts more freely, and becomes {31}
hotter, as well as the parts beneath it, and the appetite and power of digestion are increased. An increased exhalation from the lungs and skin purifies the current of the circulation, and the body as a whole thrives under its influence.

**16.** General effect upon the muscles? Special effect? Effects of inaction? Of excessive exercise?

**16.** The immediate effect of exercise, however, is upon the muscles themselves; for by use they become firm and large, and increase in power. If we examine a muscle thus improved by exercise, we find that its fibres have become larger and more closely blended together, that its color is of a darker red, and that the supply of blood-vessels has increased. Without exercise the muscle appears thin, flabby, and pale. On the other hand, excessive exercise, without sufficient relaxation, produces in the muscle a condition not very different from that which follows disuse. The muscle is worn out faster than nature builds it up, and it becomes flabby, pale, and weak.

**17.** Of violent and spasmodic efforts? Strength, how attained? Give the particulars.

**17.** Violent exercise is not beneficial; and spasmodic efforts to increase the muscular strength are not calculated to secure such a result. Strength is the result of a gradual growth, and is most surely acquired if the exercise be carried to a point short of fatigue, and after an adequate interval of rest. To gain the most beneficial results, the exercise should be at regular hours, and during a regular period. The activity of the exercise, and the time devoted to it must vary, of course, with the strength of the individual, and should be carefully measured by it.

**18.** What may walking be called? What further is said of walking?

**18. Different Modes of Exercise.**—There are very few who have not the power to walk. There is required for it no expensive apparatus, nor does it demand a period of preliminary training. *Walking may be called the universal exercise.* With certain foreign nations, the English especially, it is a very popular exercise, and is practised {32}
habitually by almost every class of society; by the wealthy as well as by those who have no carriages; by women as well as by men.

**19.** What is said of running, and other like movements? What, as related to childhood? What instances are alluded to? Example?

**19.** Running, leaping, and certain other more rapid and violent movements, are the forms of exercise that are most enjoyed in childhood. For the child, they are not too severe, but they may be so prolonged as to become injurious. Instances have been recorded where sudden death has resulted after violent playing, from overtaxing the heart: for example, we have the case of a young girl who, while skipping the rope, and endeavoring to excel her playmates by jumping the greatest number of times, fell dead from rupture of the heart.

**20.** Carriage-riding? Horseback-riding?

**20.** Carriage-riding, as a means of passive exercise, is particularly well suited to invalids, and persons advanced in life. Horseback exercise brings into use a greater number of muscles than any other one exercise, and with it there is an exhilaration of feeling which refreshes the mind at the same time. It is one of the manliest of exercises, but not less suitable for women than for men. To be skilful in riding, it is best to begin its practice in youth; but there are very few kinds of exercise of which the same is not equally true.

**21.** Boating, swimming, and skating?

**21.** For those who live near streams or bodies of water, there are the delightful recreations of boating, swimming, and skating. Certain of these exercises have a practical importance aside from and above their use in increasing the physical vigor. This is especially true of boating and swimming, since they are often the means of saving life. Practice in these exercises also teaches self-reliance, courage, and presence of mind. Persons who have become proficient in these vigorous exercises are generally the ones, who, in times of danger, are the quickest to act and the most {33}
certain to do so with judgment.

**22.** What kind of exercise yields the best results? What advice is given?

**22. Physical Culture.**—That form of exercise which interests and excites the mind, will yield the best results; but to some persons no kind of exertion whatever is, at first, agreeable. They should, nevertheless, make a trial of some exercise, in the expectation that, as they become proficient in it, it will become more pleasant. In exercise, as many sets of muscles should be employed as possible, open-air exercise being the best. Parlor gymnastics, and the discipline of the gymnasium are desirable, but they should not be the sole reliance for physical culture. No in-door exercise, however excellent in itself, can fill the place of hearty and vigorous activity in the open air.

**23.** Physical culture among the ancients? In Greece? In schools and colleges at the present time? Result to the body and mind?

**23. Gymnastic Exercises for Schools and Colleges.**—In the system of education among the ancients, physical culture predominated. In ancient Greece, physical exercises in schools were prescribed and regulated by law, and hence these schools were called *gymnasia*. At the present time, on the contrary, this culture is almost wholly unknown, as a part of the course of education, in our schools and colleges. In a few of our institutions of learning, however, physical exercises have been introduced, with manifest advantage to the students, and they form a part of the regular curriculum of exercises,—as much so as the recitations in geography, grammar, or Greek. The good effect of the experiments, as shown in improved scholarship as well as increased bodily vigor, in the institutions where the plan has been tried, will, it is hoped, lead to its universal adoption. We should then hear less frequently of parents being obliged to withdraw their children from school, because they become exhausted or, perchance, have lost their health from intense and protracted mental {34}
application.

**24.** The result of gymnastics in our colleges and other institutions of learning?

**24.** Were gymnastics more common in our educational institutions we should not so often witness the sad spectacle of young men and women leaving our colleges and seminaries, with finished educations it may be, but with constitutions so impaired, that the life which should be devoted to the accomplishment of noble purposes must be spent in search of health. Spinal curvatures, which, according to the experience of physicians, are now extremely frequent, especially among ladies, would give place to the steady gait and erect carriage which God designed his human creatures should maintain.

**25.** All the exercises necessary for the proper development of the body may be obtained from the use of a few simple contrivances that every one can have at home, at little cost—less by far than is spent for useless toys. Many of these may be made available in the parlor or chamber, though all exercises are far more useful in the open air. A small portion of the day thus spent will afford agreeable recreation as well as useful exercise. The Indian club, the wand, the ring, and the dumb-bells answer ordinary purposes very well. Illustrations are here introduced of a few simple contrivances that may be useful for general exercises, and are specially suitable for persons with *weak spines*, or with spines that are the subject of lateral curvature.

**26.** One of the simplest appliances for strengthening the muscles of the spine, designed chiefly to exercise the muscles on either side of the spine, consists of two wooden handles attached to india-rubber cords, one of which is attached to a hook made fast in the ceiling, or in the top of the door-case; and the other to another hook fastened in the wall, door-post, or window-casing, about the height of the shoulder. {35}
When traction is made with the left hand, it exercises the muscles on the left side of the spine, while those on the opposite side are left almost at rest, owing to the oblique direction given to the shoulders when the right hand grasps the horizontal cord. (This appliance will be understood by referring to Fig. 13.)

Fig. 11.

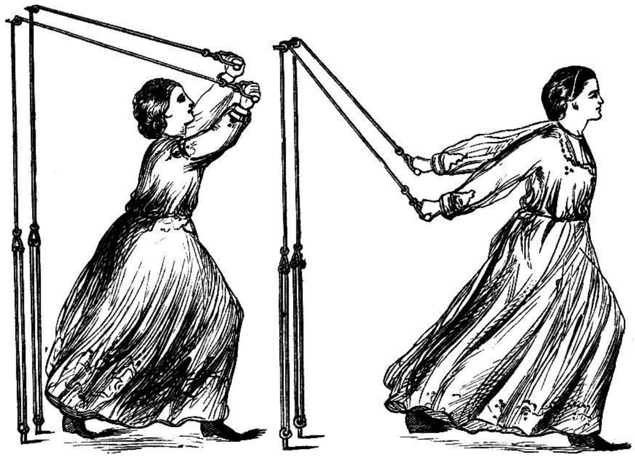

Fig. 12.

**27.** Fig. 11 shows an appliance consisting of two strong elastic cords, with handles, secured to a hook in the floor, so arranged that the patient has to stoop forward to reach them. On raising the body the spinal muscles are powerfully exercised. Fig. 12 shows other modes of using the elastic cords for strengthening the spine and chest. {36}

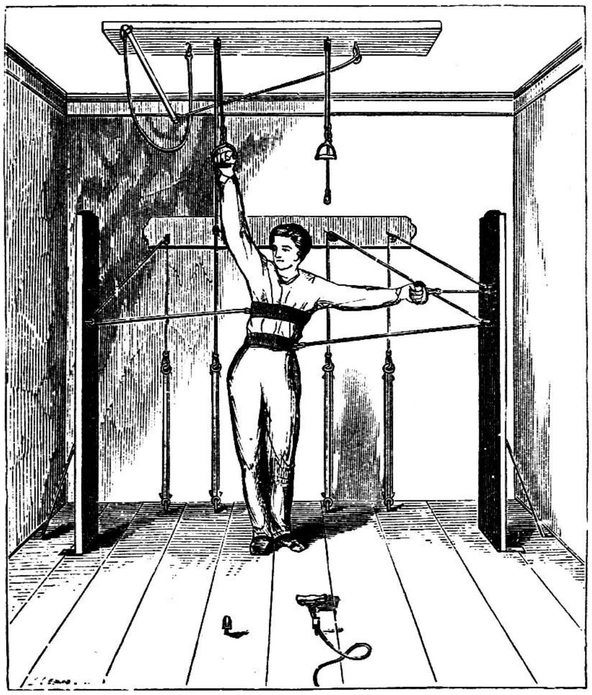

Fig. 13.

**28.** These various appliances have been combined so as to form a system of gymnastics suitable for parlor use; other appliances have been added by which the muscles of the legs may be called into action as well as those of the spine and upper {37} part of the body (Fig. 13). Combinations of cords suitable for particular cases may also be made, and by using one or several cords on the same hook, their power may be adapted to the strength of the most robust as well as to that of the invalid, or of the most delicate child. The entire apparatus is quite simple in its construction and inexpensive, requiring but little space, and at the same time affording a great variety of exercises.

EXERCISE I. (Fig. 13).—Stand erect under the cords and place the heels together. Grasp the handles firmly, keeping the knees and elbows stiff, and pull downward and forward until the fingers nearly touch the toes. Return slowly to the erect position. Repeat.

EXERCISE II. (Fig. 13).—Stand erect, and having grasped the handles overhead firmly, separate them and bring them down slowly until they touch the sides: then return them slowly to the original position. Repeat.

EXERCISE III. (Fig. 13).—Stand erect, heels together, grasp the handles overhead, and charge forward with the right foot. Return to first position, and then charge with the left. Repeat, using the right and left foot alternately.

EXERCISE IV. (Fig. 13).—Stand erect, heels together. Grasp the handle overhead, and charge forward with the right foot, knee bent. Remain in this position and bring the arms down to the sides so that the arm and fore-arm may form a right angle. Still holding the handles, thrust forward, first the right hand and then the left, until the arm is straight. Repeat. Return to first position, then charge forward with the left foot, performing the same movements as before.

EXERCISE V. (Fig. 13).—In this exercise we change to the pulleys leading from the side posts, which can be used in several different ways. 1st. Stand erect, heels together, facing one of the posts, grasp the handle with the right hand, the arm being extended, then flex the fore-arm on the arm. Repeat. Perform the same movements with the left hand. 2d. Stand with back to the post; grasp the pulley behind with the right hand, then gradually bring the hand forward until it is extended in a straight line in front. Repeat. Perform the same exercise with the left hand.

EXERCISE VI. (Fig. 13).—This exercise is especially adapted to the legs. Stirrups {38}
are so arranged that they can be attached to the pulleys overhead, and can hang down to within three or four feet of the floor. Place the foot in the stirrup, and then press down until it touches the floor. Repeat. Exercise the left foot in the same way.

EXERCISE VII. (Fig. 13.)—This exercise requires a little attention in the adjustment of the apparatus. Under the pulleys in the floor are passed ropes which can be attached to the snap-hooks that hold the handles overhead. Stoop forward with the knees stiff, and take hold of the handles, and then raise the body to the erect position. Repeat.

EXERCISE VIII. (Fig. 13).—Sit on the floor or on a seat three or four inches high; bend forward, take hold of the handles, and perform the same movements that you would in rowing a boat.

EXERCISE IX. (Fig. 13).—The trapeze can now be let down; take hold of it with both hands, sustaining the weight of the body with the arms, then rotate the body first from right to left, then from left to right alternately. This exercise is especially suitable for females.

EXERCISE X. (Fig. 13).—Grasp the trapeze as before, bearing all the weight with the arms: then draw the body up slowly until you can place the chin over the bars. This requires strength of muscle, and might strain if done too violently; if slowly performed there is no danger.

These are but a few of the exercises that can be practised with this apparatus. As these become familiar they can easily be modified, and new ones can be arranged to meet the requirements of particular cases. Most of the exercises described can be practised with one hand so as to strengthen the muscles on one side.

**29.** Need of repose? How do we obtain rest? Alfred the Great? The eight-hour division of time?

**29. Rest.**—We cannot always be active: repose must succeed labor. We obtain this rest partly by suspending all exertion, as in sleep, and partly by a change of employment. It is said that Alfred the Great recommended that each day should be divided in the following manner: "Eight hours for work, eight hours for recreation, and eight hours for sleep." This division of time is as good as any that could now be made, if it be borne in mind that, when the work is physical, the time of recreation should be devoted to the improvement of the mind; and when mental, we should then {39}
recreate by means of physical exercise.

**30.** Cessation of voluntary activity? Temperature of the body? Consequence? Body and mind during sleep? Nutrition? Describe it. Consequences of

**30.** During sleep, all voluntary activity ceases, the rapidity of the circulation and breathing diminishes, and the temperature of the body falls one or two degrees. In consequence, the body needs warmer coverings than during the hours of wakefulness. During sleep, the body seems wholly at rest, and the mind is also inactive, if we except those involuntary mental wanderings which we call dreams. Nevertheless a very active and important physical process is going on. Nutrition, or the nourishing of the tissues, now takes place. While the body is in action, the process insufficient sleep?

of pulling down predominates, but in sleep, that of building up takes place more actively. In this way we are refreshed each night, and prepared for the work and pleasures of another day. If sleep is insufficient, the effects are seen in the lassitude and weakness which follow. Wakefulness is very frequently the forerunner of insanity, especially among those who perform excessive mental labor.

**31.** Amount of sleep in different persons? Cases? Frederick the Great? Bonaparte? Instances of long deprivation of sleep?

**31.** All persons do not require the same amount of sleep, but the average of men need from seven to nine hours. There are well-authenticated cases where individuals have remained without sleep for many days without apparent injury. Frederick the Great required only five hours of sleep daily. Bonaparte could pass days with only a few hours of rest. But this long continued absence of sleep is attended with danger. After loss of sleep for a long period, in some instances, stupor has come on so profoundly, that there has been no awaking.

**32.** Instances of sailors? French soldiers? During torture?

**32.** There are instances related of sailors falling asleep on the gun-decks of their ships while in action. On the retreat from Moscow, the French soldiers would fall asleep on the march, and could only be aroused by the cry, "The Cossacks are coming!" Tortured persons are said to have slept upon the rack in the intervals of their torture. In early life, while engaged in a laborious country practice, the writer not unfrequently slept soundly on horseback. These instances, and others, show the imperative demand which nature makes for rest in sleep. {40}

QUESTIONS FOR TOPICAL REVIEW.

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## CHAPTER III. {41}

## The Integument, or Skin.

*The Integument—Its Structure—The Nails and Hair—The Complexion—The Sebaceous Glands—The Perspiratory Glands—Perspiration and its Uses—Importance of Bathing—Different kinds of Baths—Manner of Bathing—The Benefits of the Sun—Importance of Warm Clothing—Poisonous Cosmetics.*

**1.** What is the skin? Parts directly beneath? What is shown?

**1. The Integument.**—The skin is the outer covering of the body. The parts directly beneath it are very sensitive, and require protection. This is shown whenever by accident the skin is broken, pierced, or torn off, the bared surface being very tender, and painful to the touch. Nature has provided the body with a garment that is soft, pliable, close-fitting, and very thin, and yet sufficiently strong to enable us to come in contact with the objects that surround us, without inconvenience or suffering.

**2.** Microscopic examination? What is the cutis? The cuticle? Their union? How separated? What further is said of the cuticle?

**2. The Structure of the Skin.**—When examined with the aid of the microscope, the skin is found to be made up of two layers—the outer and the inner. The inner one is called the *cutis*, or true skin; the outer one is the *epidermis*, or scarf-skin. The latter is also known as the *cuticle*. These two layers are closely united, but they may be separated from each other. This separation takes place whenever, from a burn, or other cause, a blister is formed; a watery fluid is poured out between the two layers, and lifts the epidermis from the true skin.

Of the two layers, the cuticle is the thinner in most parts of the body, and has the appearance of a whitish membrane. It is tough and elastic, is without feeling, and does not bleed, when cut. Examine it more closely, and we observe that it is {42}
composed of minute flat cells, closely compacted, and arranged layer upon layer.

**3.** Wearing out of the cuticle? What then? Variety in thickness of cuticle? How accounted for?

**3.** The outer layer is constantly being worn out, and falls from the body in the form of very fine scales. It is, also, continually forming anew on the surface of the inner layer. Its thickness varies in different parts of the body. Where exposed to use, it is thick, hard, and horn-like, as may be seen on the soles of the feet, or on the palms of the hands, especially of those who are accustomed to perform much manual labor. This is an admirable provision for the increased protection of the sensitive parts below the skin against all extraordinary exposure. Even the *liabilities* of these parts to injury, are thus kindly provided for by "the Hand that made us."

**4.** Location and office of the cutis? What further is said of it? Papillæ? Touch?

**4.** The cutis, or true skin, lies beneath the epidermis, and is its origin and support. It is firm, dense, elastic, very sensitive, and is freely supplied with blood-vessels. It is closely connected with the tissues below it, but may be separated by means of a sharp instrument. The surface of the cutis is not smooth, but is covered here and there with minute elevations, called *papillæ*. These are arranged in rows, along fine lines, or ridges, such as those which mark the palm and fingers; their number is about 80 to the square line (a line being one-twelfth of an inch). These *papillæ* contain the blood-vessels which carry the supply of blood needed by the ever-wasting skin. They contain nerves also, and are largely concerned in the sense of touch; hence they are particularly abundant where the touch is most delicate, as at the ends of the fingers.

**5.** What are the nails and hair? The growth of the nail? The rapidity of its growth? Accident to the nail?

**5. The Nails and Hair.**—These are appendages of the skin, and although very unlike the cuticle as it appears on the surface of the body, they are, in reality, modified forms of that layer of the skin. The nail grows from a fold of the cuticle at the root, and from the under surface. As fast as it is formed, it is constantly being pushed outward. The rapidity of its growth can be ascertained by filing a slight groove on its surface, and noticing how the space between it and the root of the nail increases, in the course of a few weeks. When the nail is removed by any accident, it will be replaced by a new one, if the root be not injured. {43}

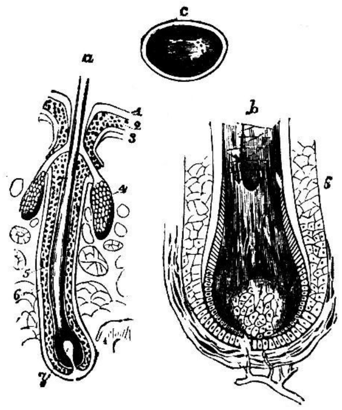

Fig. 14.
*a, b.* The Root of a Hair.
1, 2, 3. The skin forming the hair sac. 4. Sebaceous glands. 5. The hair sac.
*c.* Transverse Section of a Hair.

**6.** How are the hairs produced? Difference in their length?

**6.** The hairs are produced in a similar manner; the skin forming depressions, or hair sacs, from the bottom of which they grow and are nourished (Fig. 14). They are found, of greater or less length, on almost all parts of the surface, except the palms of the hands and soles of the feet. On certain parts of the body, they grow to great length; on other parts they are so short, that they do not rise beyond the hair sac in which they originate.

**7.** Root of the hair? Shaft? Firmness and softness of the hair?

**7.** The bulb, or root, from which the hair arises, is lodged in a small pouch, or depression in the skin. The shaft is the part which grows out beyond the level of the skin. Its growth is altogether in one direction, in length alone. The outer part of the hair is quite firm, while its interior is softer, and probably conveys the fluids by which {44}
it is nourished. The hair is more glossy in health than at other times.

**8.** Office of the nail? Of the hair? Give the illustrations.

**8.** The nail serves as a protection to the end of the finger, and also enables us to grasp more firmly, and to pick up small objects. The hair, too, is a protection to the parts it covers. On the head, it shields the brain from extremes of heat and cold, and moderates the force of blows upon the scalp. On the body, it is useful in affording a more extensive surface for carrying off the perspiration.

**9.** On what does the complexion depend? Light and dark races? Freckles?

**9. Complexion.**—In the deeper cells of the cuticle lies a pigment, or coloring matter, consisting of minute colored grains. On this pigment *complexion* depends; and, according as it is present in less or greater amount, occasions the difference of hue, that exists between the light and dark races of men, and between the blonde and brunette of the white races. Freckles are due to an irregular increase of coloring matter.

**10.** Influence of the

**10.** The sun has a powerful influence over the development of this pigment, as is sun? How illustrated? Jews?

shown by the swarthy hue of those of the white race who have colonized in tropical climates. It is also well illustrated by the fact, that among the Jews who have settled in northern Europe, there are many who are fair complexioned, while those residing in India, are as dark as the Hindoos around them.

**11.** What is an Albino? Where are Albinos found?

**11.** An Albino is a person who may be said to have no complexion; that is, there is an entire absence of coloring matter from the skin, hair, and *iris* of the eye. This condition more frequently occurs among the dark races, and in hot climates, although it has been observed in almost every race and clime.

**12.** What are sebaceous glands? How do they act? Sebaceous glands of the face? How do they act?

**12. Sebaceous Glands.**—There are in the skin certain small glands, which produce an oily substance, called *sebaceous* matter. These glands are little rounded sacs, usually connected with the hair-bulbs; and upon these bulbs, they empty their product of oil, which acts as a natural and adequate dressing for the hair (4, Fig. 14). A portion of the sebaceous matter passes out upon the surface, and prevents the cuticle from becoming dry and hard. The glands situated upon the face and forehead, open directly upon the skin. In these, the sebaceous matter is liable to collect, and become too hard to flow off naturally. {45}

**13.** Black points, called worms? Animalcules? Service performed by sebaceous matter?

**13.** These glands on the face and forehead frequently appear, on the faces of the young, as small black points, which are incorrectly called "worms." It is true, that occasionally living animalcules are found in this thickened sebaceous matter, but they can only be detected by the aid of the microscope. This sebaceous matter acts not only to keep the skin flexible, and furnish for the hair an oily dressing, but it especially serves to protect the skin and hair, from the acridity arising from the perspiration.

**14.** Perspiration? Sweat glands? Of what do they consist? Dimension of the tubes?

**14. The Perspiratory Glands.**—The chief product of the skin's action is the perspiration. For the formation of this, there are furnished countless numbers of little sweat-glands in the true skin. They consist of fine tubes, with globe-like coils at their deeper extremity. Their mouths or openings may be seen with an ordinary magnifying glass, upon the fine ridges which mark the fingers. These tubes, if uncoiled, measure about one-tenth of an inch in length. In diameter, they are about one three-hundredth of an inch, and upon certain parts of the body there are not far from three thousand of these glands to the square inch. Their whole number in the body is, therefore, very great; and, in fact, it is computed if they were all united, end to end, their combined measurement would exceed three miles. {46}

**15.** What is sensible perspiration? Insensible perspiration?

**15. The Sensible and Insensible Perspiration.**—The pores of the skin are constantly exhaling a watery fluid; but, under ordinary circumstances, there is no moisture apparent upon the surface, for it evaporates as rapidly as it is formed. This is called insensible perspiration. Under the influence of heat or exercise, however, this fluid is excreted more abundantly, and appears on the surface in the form of minute, colorless drops. It is then termed sensible perspiration.

**16.** Components of perspiration? Upon what does perspiration depend? Amount of perspiration daily?

**16.** Water is the chief component of this fluid, there being about ninety-eight parts of water to two parts of solid matter. The quantity escaping from the body varies greatly, according to the temperature of the air, the occupation of the individual, and other circumstances. The average daily amount of this excretion, in the adult, is not far from thirty ounces, nearly two pints, or more than nine grains each minute.

**17.** What does perspiration set free from the blood? What other service does perspiration perform? Explain the process.

**17. The Uses of the Perspiration.**—Besides liberating from the blood this large amount of water, with the effete matter it contains, the perspiration serves to regulate the temperature of the body. That is to say, as evaporation always diminishes temperature, so the perspiration, as it passes off in the form of fine vapor, cools the surface. Accordingly, in hot weather this function is much more active, and the cooling influence increases in proportion. When the air is already charged with moisture, and does not readily receive this vapor of the body, the heat of the atmosphere apparently increases, and the discomfort therefrom is relatively greater.

**18.** Effect of interruption of excretion? What experiments are mentioned?

**18.** The importance of this excretion is shown by the effects that often follow its temporary interruption, namely, headache, fever, and the other symptoms that accompany "taking cold." When the perspiration is completely checked, the {47}
consequences are very serious. Experiments have been performed upon certain smaller animals, as rabbits, to ascertain the results of closing the perspiratory tubes. When they are covered by a coating of varnish impervious to water and gases, death ensues in from six to twelve hours; the attendant symptoms resembling those of suffocation.

**19.** Give the story in relation to the boy covered with gold foil.

**19.** It is related that, at the coronation of one of the Popes about three hundred years ago, a little boy was chosen to act the part of an angel; and in order that his appearance might be as gorgeous as possible, he was covered from head to foot with a coating of gold foil. He was soon taken sick, and although every known means were employed for his recovery, except the removal of his fatal golden covering, he died in a few hours.

**20.** Give the quotation.

**20. The Importance of Bathing.**—From these considerations, it is evident that health must greatly depend upon the free action of the skin. "He who keeps the skin

Perspiration?

ruddy and soft, shuts many gates against disease." When the watery portion of the perspiration evaporates, the solid matter is left behind on the surface. There, also, remain the scales of the worn-out cuticle, and the excess of sebaceous matter. In order to secure the natural action of the skin, these impurities require to be removed by the frequent application of water.

**21.** Ablution in warm climates? What advice is given?

**21.** In warm climates, and during hot weather, ablution should be more frequently practised. For a person in good health, a daily cold bath is advisable. To this should be added occasionally a tepid bath, with soap, water alone not being sufficient to remove impurities of a greasy nature. Soap facilitates this, by forming with such substances a chemical mixture, which is readily soluble in water, and is by it removed from the body. {48}

**22.** Liebig's maxim? What further is added?

**22.** There is a maxim by the chemist Liebig, to the effect, that the civilization of a nation is high, in proportion to the amount of soap that it consumes; and that it is low, in proportion to its use of perfumes. In some degree, we may apply the same test to the refinement of an individual. The soap removes impurity; the perfume covers, while retaining it.

**23.** What is said about cold bathing?

**23. The different kinds of Baths.**—All persons are not alike able to use the cold bath. When the health is vigorous, and the system does not feel a shock after such a bath, a prompt reaction and glow upon the surface will show that it is beneficial. Where this pleasurable feeling is not experienced, but rather a chill and sense of depression ensues, we are warned that the system will not, with impunity, endure cold bathing.

**24.** What is said about warm bathing?

**24.** It should also be borne in mind, that the warm or hot bath cannot be continued so long, or repeated so frequently as the cold, on account of the enervating effect of unusual heat so applied to the body. For persons who are not in robust health, one warm bath each week is sufficient; this class should be careful to avoid every extreme in reference to bathing, clothing, and whatever greatly affects the action of the skin.

**25.** What is said about sea-bathing?

**25.** Sea-bathing is even more invigorating than fresh-water bathing. Those who cannot endure the fresh water, are often benefited by the salt-water baths. This may be accounted for, in part, by the stimulant action upon the surface, of the saline particles of the sea-water; but the exciting scenes and circumstances of sea-bathing also exert an important influence. The open-air exercise, the rolling surf, the genial weather, and usually the cheerful company, add to its intrinsic benefits. {49}

**26.** What is said as to the time and manner of bathing?

**26. Time and Manner of Bathing.**—A person in sound health may take a bath at almost any time, except directly after a full meal. The most appropriate time is about three hours after a meal, the noon-hour being probably the best. For the cold bath, taken rapidly, no time is better than immediately after rising. Those beginning the use of cold baths should first try them at 70° Fahr., and gradually use those of a lower temperature. From five to twenty minutes may be considered the proper limit of time to remain in a bath; but a sensation of chilliness is a signal to withdraw instantly, whether at home, or at the sea-side. Two sea-baths may be taken daily; one of any other kind is sufficient.

**27.** Condition of the body when bathing? Direction, after bathing?

**27.** The body should be warm, rather than cold, when stepping into the bath; and after it, the skin should be thoroughly dried with a coarse towel. It is best to continue friction until there is a sensation of warmth or "glow" throughout the entire surface. This reaction is the test of the good effects of the bath. If reaction is still incomplete, a short walk may be taken, especially in the sunshine. It is very congenial, however, both to health and comfort, to rest for a short time directly after bathing, or to take some light refreshment. This is better than severe exercise or a full meal.

**28.** Bathing among the ancients? Baths of Rome?

**28. Bathing among the Ancients.**—The Romans and other nations of antiquity made great use of the vapor-bath as a means of preserving the health, but more particularly as a luxury. Their method was not unlike that employed in northern Europe at the present day. The public baths of Rome and other cities are among the grandest and most interesting monuments of ancient luxury and splendor; and from their ruins have been recovered some of the most beautiful works of art. {50}

**29.** After the bath? Swimming among the ancients?

**29.** The Thermæ, as the baths of Rome were called, were of great extent, built very substantially, and ornamented at vast expense. They were practically free to all, the cost of a bath having been less than a cent. It is related that some persons bathed seven times a day. After the bath their bodies were anointed with perfumed oil. If the weather was fine, they passed directly from the Thermæ into the gymnasium, and engaged in some gentle exercise previous to taking the midday meal. Between two and three in the afternoon was the favorite hour for this ancient luxury. Swimming was a favorite exercise, and a knowledge of it was regarded as necessary to every educated man. Their common expression, when speaking of an ignorant person, was, "He can neither read nor swim."

**30.** The Sun-bath? The story of Pliny?

**30. The Sun-Bath.**—Some also were accustomed daily to anoint themselves, and lie or walk in apartments arranged for the purpose, with naked bodies exposed to the direct rays of the sun. There is an interesting allusion to this practice, in a letter of the younger Pliny to the historian Tacitus, describing the destruction of Pompeii by an eruption of Vesuvius. "My uncle," (Pliny the elder,) "was at that time in command of the fleet at Misenum. On the 24th of August, about one in the afternoon, my mother desired him to notice a cloud which seemed of unusual shape and dimensions. He had just returned from *taking the benefit of the sun*, and after a cold bath, and a slight repast, had retired to his study." Then follows a description of the destruction of Pompeii, and the death of the elder Pliny.

**31.** Benefit of the sun? Effect upon plants? Skin?

**31.** We may judge somewhat of "the benefits of the sun," by observing the unnatural and undeveloped condition of plants and animals which are deprived of light. Plants become blanched and tender; the fish of subterranean lakes, where no light enters, {51} are undersized, and have no eyes; tadpoles kept in the dark do not develop into frogs; men growing up in mines are sallow, pale, and deformed. Besides the well-known effect of solar light in tanning the skin, it also makes it thicker and better able to resist exposure; though the complexion may be thereby injured, the health gains more than compensate for the loss of beauty. "To make good the loss of the lily, where the sun has cast his ray, he seldom fails to plant the rose."

**32.** Direction about clothing? Exposing limbs of children? Clothing, night and day?

**32. Clothing.**—In reference to clothing, we are far more apt, in our changeful climate, to use too little than too much. An aphorism of Boerhaave, worth remembering, if not of adopting, is, "We should put off our winter clothing on midsummer's day, and put it on again the day after." He also says, "Only fools and beggars suffer from the cold; the latter not being able to get sufficient clothes, the others not having the sense to wear them." The practice of exposing the limbs and necks of young children, for the alleged purpose of "hardening" them, is quite hazardous. It is not to be denied that some seem to be made tough by the process; but it is so only with the rugged children, the delicate ones will invariably suffer under this fanciful treatment. As has been stated before, the skin is constantly acting, by night as well as by day. It is therefore conducive both to cleanliness and comfort to change entirely the clothing on retiring for the night. The day-clothing should be aired during the night, and the bedding should be aired in the morning, for the same reason.

**33.** Cosmetics? Painters' colic?

**33. Poisonous Cosmetics.**—The extensive use of *cosmetics* for the complexion is a fertile source of disease. The majority of these preparations contain certain poisonous mineral substances, chiefly lead. Now, the skin rapidly absorbs the fine particles of lead, and the system experiences the same evil effects that are observed among the {52} operatives in lead works and painters, namely, "painters' colic," and paralysis of the hands, called "wrist-drop."

**34.** Certain hair-dyes also contain lead, together with other noxious and filthy ingredients. These do not work as great harm as the cosmetics, since they are purposely kept away from the skin, but they rob the hair of its vitality. Eye-washes, too, are made from solutions of lead, and many an eye has been ruined by their use. They deposit a white metallic scale on the surface of the eye, which becomes a permanent obstruction to the vision.

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## CHAPTER IV. {53}

### The Chemistry of Food.

*The Source of Food—Inorganic Substances—Water—Salt—Lime—Iron—Organic Substances—Albumen, Fibrin, and Casein—The Fats or Oils—The Sugars, Starch, and Gum—Stimulating Substances—Necessity of a Regulated Diet.*

**1.** The term food? Source of food? Need of preparing food?

**1. The Source of Food.**—The term *food* includes all those substances, whether liquid or solid, which are necessary for the nourishment of the body. The original source of all food is the earth, which the poet has fitly styled the "Mother of all living." In her bosom, and in the atmosphere about her, are contained all the elements on which life depends. But man is unable to obtain nourishment directly from such crude chemical forms as he finds in the inorganic world. They must, with a few exceptions, be prepared for his use, by being transformed into new and higher combinations, more closely resembling the tissues of his own body.

**2.** Usefulness and hurtfulness of plants? What then must man do? Parts of the same plant or tree?

**2.** This transformation is effected, first, by the vegetable world. But all plants are not alike useful to man; while some are absolutely hurtful. Accordingly, he must learn to discriminate between that which is poisonous and that which is life-supporting. Again, all parts of the same plant or tree are not alike beneficial: in some, the fruit, in others, the leaves, and in others, the seeds only are sufficiently refined for his use. These he must learn to select; he must also learn the proper modes of preparing each kind for his table, whether by cooking or other processes. {54}

**3.** Certain forms of vegetable creation? Example of the bee? Cattle? The inference?

**3.** Again, certain forms of the vegetable creation which are unfit, in their crude state, for man's food, and which he rejects, are chosen as food by some of the lower animals, and are, by them, made ready for his use. Thus the bee takes the clover, that man cannot eat, and from it collects honey. The cattle eat the husks of corn and the dried grass, that are by far too coarse for man, and in their own flesh convert them into tissues closely resembling his muscular tissue. In this way, by the aid of the transforming processes of the vegetable and animal creations, the simple chemical elements of the mineral kingdom are elaborated into our choice articles of food.

**4.** What classification? Define organic substances. Inorganic. Organic, how spoken of? The inorganic? Water and salt?

**4. Inorganic Substances.**—The substances we use as food are classified as *organic* and *inorganic*. By organic substances are meant those derived from living forms, such as vegetables and animals. Inorganic substances are those simpler inanimate forms which belong to the mineral kingdom. The former alone are commonly spoken of as food, but the latter enter very largely into the constitution of the body, and must therefore be present in our food. With the exception of two articles, water and common salt, these substances only enter the system when blended with organic substances.

**5.** Water in physiology? Where found? Computation? Water in the teeth? Muscle, tendons, and ligaments? How ascertained? Water in the fluids of the body? What is the advantage?

**5. Water.**—Water, from a physiological point of view, is the most important of all the articles of food. It is everywhere found in the body, even in the bones and the teeth. It has been computed that as large a proportion as two-thirds of the body is water. The teeth, the densest of the solids in the human system, contain ten per cent. of water. The muscles, tendons, and ligaments are more than half water; for it is found that they lose more than half their weight when dried with moderate heat. But it is in the {55} *fluids* of the body that water is found most abundantly. It gives to them the power of holding a great variety of substances in solution, and is the great highway by which new supplies are conveyed to the point where they are required, and by which old particles of matter, that have served their uses, are brought to the outlets of the body to be thus removed from the system.

**6.** Length of time man can do without food or water? Give the comparison? Bulk of drinks? Constituent of meats, etc.? Fruits?

**6.** Man can remain a longer time without solid food than without water. He may be deprived of the former for ten to twelve hours without great suffering, but deprivation of water for the same length of time will produce both severe pain and great weakness. The food should contain not less than two parts of water to one of solid nutriment. Water constitutes the great bulk of all our drinks, and is also a large constituent of the meats, vegetables, and fruits which come upon the table. Fruits, especially, contain it in great abundance, and, in their proper season, furnish most agreeable and refreshing supplies of the needed fluid.

**7.** Salt, how obtained? Where found? In the human body? Importance of

**7. Common Salt.**—Salt, or sodium chloride, as an article of food, is obtained chiefly from the mineral kingdom; although plants contain it in small quantities, and it is also found in the tissues of nearly all animals used as food. In the human body, it is an ingredient of all the solids and fluids. The importance of salt to animal life in general, salt? What else can you state of the value of salt?

is shown by the great appetite for it manifested by domestic animals, and also by the habitual resort of herds of wild beasts to the "salt-licks" or springs. In those parts of the world where salt is obtained with difficulty, man places a very high price upon it.

**8.** Experiments upon animals?

**8.** Experiments upon domestic animals show that the withdrawal of salt from their food, not only makes their hides rough and causes the hair to fall out, but also {56}
interferes with the proper digestion of food. If it be withheld persistently, they become entirely unable to appropriate nourishment, and die of starvation.

**9.** Salt, how taken into the system? Its use in cooking? Consumption?

**9.** Salt is usually taken into the system in sufficient quantities in our food. Even the water we drink often has traces of it. The habitual use of much salt in cooking, or as a seasoning at the table, is not wise; and while it may not lead to consumption, as some writers declare, it is a bad habit in itself, and leads to the desire for other and more injurious condiments.

**10.** Lime in the bones? What does it impart? Chief ingredient of the bones and teeth? Where else found?

**10. Lime.**—This is the mineral substance which we have spoken of before as entering very largely into the composition of the bones. It is the important element which gives solidity and permanence to the framework upon which the body is built. Calcium tri-phosphate, or "bone-earth," is the chief ingredient of the bones and teeth, but is found in the cartilages and other parts of the body in smaller quantities.

**11.** How does lime find its way into the body? Early life? Effect of its derivation?

**11.** How does this substance find its way into the body? Meat, milk, and other articles obtained from the animal kingdom contain it, and it is abundantly stored away also in the grains from which our bread is made, in wheat, rye, and Indian corn. In early life, while the body is growing, the supplies of this substance should be carefully provided. The evil effects of the deprivation of it are too often and painfully evident in the softening of the bones, and in the predisposition to curvature of the spine—deformities which are most deplorable and which continue through life.

**12.** Iron, its abundance and diffusion? Where found? What part of the blood is it? How supplied to the system? In case of loss of blood or wasting disease?

**12. Iron.**—This substance is probably the most abundant and widely diffused of the metals. It is found in most of the vegetables, and is a very important component of {57}
animal tissues. It enters into the composition of human blood in about one part per thousand. Ordinarily, the food conveys to the system enough iron for its use, but it must sometimes be introduced separately as a remedy, especially after great loss of blood, or after some wasting disease. Under its influence the blood seems to be rapidly restored, and a natural color of the lips and skin replaces the pallor caused by disease.

**13.** Soda, potash, and magnesia? How do they occur?

**13. Other Inorganic Substances.**—In addition to the substances mentioned, the mineral kingdom supplies compounds of soda, potash, and magnesia, which are essential for the use of the body. They occur in small quantities in the body, and enter it in combination with the various articles of diet.

**14.** Organic substances, whence derived? What do they comprise? Groups?

**14. Organic Substances.**—These substances are derived from the vegetable and animal creations. They comprise all those articles which are commonly spoken of as "food," and which are essential to sustain the body in life and strength. They are divided into three groups, namely: the Albuminoid substances, the Fats, and Sugars.

**15.** The Albuminoid class, includes what? These compounds constitute what? The food? Their importance? Their properties?

**15. The Albuminoids.**—This class includes three important nutritive substances—(1) *Albumen*, which gives it its name; (2) *Fibrin*, including *gluten*; and (3) *Casein*. These compounds constitute a large part of the human body, and the food contains them in proportionally large quantities. Their importance is so great, and the system so promptly suffers from their absence, that they have been styled the "*nutritious* substances." The properties which they hold in common are, that they do not crystallize, and have a jelly-like form, except when heat is applied to them, when they harden, or *coagulate*. {58}

**16.** Decomposition? Effect of cold? Illustrations? Elephants?

**16.** They likewise decompose, or *putrefy*, under the influence of warmth and moisture. Hence the decay of all dead animal tissues. Cold arrests this process. It is well known that milk, eggs, and the like, "keep" much longer in winter than at other seasons. The bodies of elephants, caught in the ice many hundred years ago, are occasionally borne by the icebergs to the coast of Siberia, completely frozen, but preserved almost perfectly in form and limb.

**17.** In what substances does albumen exist? What further is said of the egg?

**17. Albumen** exists in milk, meat, the grains, and the juices of many plants; but the purest form is obtained from the white of egg. When we consider that an egg is composed chiefly of albumen and water—namely, six parts in seven; and when we also consider the numerous, diverse, and complex tissues—the muscles, bones, internal organs, bill, claws, and feathers—with which the chick is equipped on leaving his shell, we are impressed with the importance of these apparently simple constituents of the food and body.

**18.** Fibrin, gluten, clotting of the blood?

**18. Fibrin** is derived from meats, and exists in the blood both of man and the lower animals. *Gluten*, or vegetable fibrin, resembles closely true fibrin, and is abundantly furnished in wheat and other grains from which flour is commonly made. Animal fibrin coagulates spontaneously when it is removed from the body, and thus causes the "clotting" of the blood.

**19.** Casein? Its coagulation? Effect of rennet? Making of cheese?

**19. Casein** is the curdy ingredient of milk, and a highly important food-substance. Its coagulation in milk takes place not from heat, but by the addition of an acid, and also when milk becomes sour from exposure to the air. It is commonly effected, however, by introducing a piece of *rennet*, a preparation made from a calf's stomach. The *curds*, or casein, may then be separated from the *whey*, and made into cheese, by {59}
pressing it sufficiently to drive off the water.

**20.** What are the fats? The oils? How supplied? How alike? Emulsifying? Example? How do we know it?

**20. The Fats or Oils.**—This is the second group of organic foods. Those which are more solid are called *fats*: the more fluid ones are the *oils*. Oleaginous substances are supplied in both animal and vegetable food; but, from whatever source derived, they are chemically much alike. They are insoluble in water, and yet they unite readily with the watery fluids of the body, and are by them conveyed to its various parts for their nourishment. This is due to their property of "emulsifying;" that is, they are held in suspension, in a finely divided state, in water. Ordinary milk is an example of an *emulsion*. We know that it contains fat; for butter is obtained from it, and, under the microscope, the minute oil-globules may be distinctly seen.

**21.** Whence are fatty articles of food derived?

**21.** In our country and climate, and also in colder climates, fatty articles of food are principally derived from the animal creation, such as meat or flesh, milk and butter. But most of the bread-stuffs contain more or less fat or oil; Indian meal as much as nine parts in a hundred.

**22.** Appetite of persons in cold climates? What do they require? Upon what must they rely? Why? The Esquimaux? Laplander? Olive and palm?

**22.** Among persons living in cold climates, the appetite for oleaginous food is especially eager; and they require large quantities of it to enable them to resist the depressing influences of cold. Since vegetation is scanty and innutritious, and the waters of the frozen regions abound in animal life, they must rely wholly upon a diet derived from the latter source. The Esquimaux consumes daily from ten to fifteen pounds of meat or blubber, a large proportion of which is fat. The Laplander will drink train-oil, and regards tallow-candles as a great delicacy. In hot climates, on the contrary, where flourish the olive and the palm, this kind of food may be obtained {60}
from vegetable sources in abundant quantities.

**23.** Which are the third of the organic groups? What do they embrace? Points of resemblance?

**23. The Sugars, or the Saccharine Substances.**—These constitute the third, and last, group of the organic substances, which are employed as food. This group embraces, in addition to the different kinds of *Sugar*, the varieties of starch and gum, from whatever source derived. The two substances last named do not, at first sight, present many points of similarity to sugar; but they closely resemble it in respect to their ultimate chemical composition, being made up of the same elements, in nearly the same proportions. And their office in the system is the same, since they are all changed into sugar by the processes of digestion.

**24.** Origin of the sugars? Ordinary sugar? Beetroot? Maple-sugar? Grape-sugar? Cane-sugar?

**24. Sugar** is chiefly of vegetable origin; the animal varieties being obtained from honey and milk. The most noticeable characteristic of this substance is its agreeable, sweet taste, which makes it everywhere a favorite article of food. But this quality of sweetness is not possessed by all the varieties of sugar in the same degree; that obtained from milk, for instance, has a comparatively feeble taste, but rather imparts a gritty feeling to the tongue. The other important properties of sugar are, its power to crystallize when evaporated from watery solutions, such as the juices of many plants; a tendency to ferment, by which process alcohol is produced; and a ready solubility in water. This latter quality renders it very easy of digestion, and more so than any other of the saccharine group. It is computed that the annual production of sugar, in all parts of the world, is more than one million of tons. The kind of sugar that is in ordinary use, in this country, is prepared from the juice of the sugar-cane, which contains eighteen per cent. of sugar. In France it is manufactured from the beet root, which holds about nine per cent.; the maple-tree of our climate yields a {61}
similar sugar. The sweet taste of fruits is due to the presence of grape-sugar: the white grains seen on raisins belong to this variety. Cane-sugar is more soluble than the latter, and has twice the sweetening power.

**25.** Starch, how widely distributed? Its qualities? Its constituents? Its solubility?

**25. Starch.**—This is the most widely distributed of the vegetable principles. It is tasteless, inodorous, and does not crystallize. It consists of minute rounded granules, which, under the microscope, reveal a somewhat uniform structure (Fig. 15). Starch will not dissolve in cold water, but in boiling water the small grains burst open, and may then be dissolved and digested.

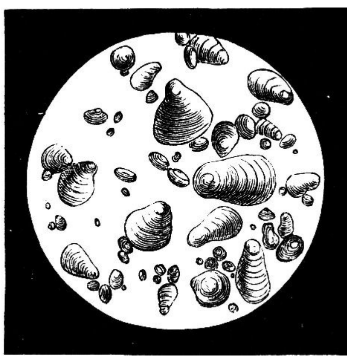

Fig. 15.—Granules of Potato Starch.

**26.** How much starch in bread-stuffs? In rice? Unripe fruits? Ripe fruits?

**26.** The bread stuffs, wheat, corn, and rye flours, are more than one-half starch. Rice, which is the "staff of life" to one-third of the human family, contains eighty per cent. Unripe fruits have much starch in them, which renders them indigestible when eaten uncooked; for the grains of raw starch are but slightly acted upon within the body. But, under the potent chemistry of the sun's ray, this crude material is converted into sugar. Thus are the fruits prepared by the careful hand of Nature, so that when ripe they may be freely used without further preparation.

**27.** Gum, where found? Its composition? Gum Arabic?

**27. Gum** is commonly found in those articles which also contain starch; and has the same chemical composition as the latter, but is much less nutritious. In the East, gum-arabic and similar substances are largely employed as food. Persons who travel by caravan across vast, sandy deserts, find such substances well adapted to their wants, since they are not perishable, and are easily packed and carried. {62}

**28.** The three classes of food principles? What besides? What is said of them? Name the articles not nutritious.

**28. Stimulating Substances.**—The three classes of food-principles already considered—the Albuminoids, the Fats, and the Sugars—comprise all the more important organic ingredients of our food. There are, besides, a great variety of coloring and flavoring matters that stimulate or increase the appetite for food by appealing to the eye and taste; but they are not nutritious, and are quickly separated from the truly useful substances, and do not long remain in the body. Among these may be classed spices, flavors of fruits, tea, coffee, and vegetable acids.

**29.** What is said of experiments that have been tried?

**29. Necessity of a Regulated Diet.**—A great variety of experiments have been tried in order to test the relative value of the different nutritive principles. They have been practised to some extent upon man, but chiefly upon those inferior animals which require a similar diet to man.

**30.** What has been demonstrated in the first place? Example? Second demonstration? Example? Give the illustration in relation to convertibility.

**30.** By this means it has been demonstrated that—first, when any one of these substances is eaten exclusively, the body is imperfectly nourished, and life is shortened. Dogs fed exclusively upon either albumen, fat, or sugar, soon die of starvation. Second, a diet long deprived of either of these principles, is a fertile cause of disease; for example, on ship-board, where fresh vegetables are not dealt out for a long period, *scurvy* becomes prevalent among the sailors. They are, however, to a certain extent mutually convertible, and thus the missing article is indirectly supplied. For instance, sugar changes to fat in the body; and hence, as is well known, {63} the "hands" on a sugar plantation grow fat during the sugar season, by partaking freely of the ripened juices of the cane.

**31.** That is the best diet therefore which contains some of each of these principles, in due proportion; and that is the worst which excludes the most of them. The cravings and experience of man had unerringly guided him to a correct regulation of his diet, long before the chemistry of food was understood; so that his ordinary meals long ago combined these various principles, the necessity and value of which are now explained.

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## CHAPTER V. {64}

# FOOD AND DRINK.

*Necessity for Food—Waste and Repair—Hunger and Thirst—Amount of Food—Renovation of the Body—Mixed Diet—Milk—Eggs—Meat—Cooking—Vegetable Food—Bread—The Potato—Fruits—Purity of Water—Action of Water upon Lead—Coffee, Tea, and Chocolate—Effects of Alcohol.*

**1.** What follow activity? Examples? Necessity for food?

**1. Necessity for Food.**—Activity is everywhere followed by waste. The engine uses up coal and water to produce motion, the stream wears away its bank, the growing corn-blade draws tribute from the soil. When the human body acts, and it is always in action during life, some of its particles are worn out and thrown off. This waste must constantly be repaired, or the body suffers. In this fact is seen the necessity for food. The particles, thus worn out, being henceforth useless, are removed from the body. Our *food* and *drink* are rapidly transformed into a new supply of living, useful material, to be in turn used up and replaced by a fresher supply.

**2.** Give the theory in relation to waste and repair.

**2. Waste and Repair.**—In this way the healthful body, though always wasting, is always building up, and does not greatly change in size, form, or weight. At two periods of life the processes of waste and repair are not exactly balanced. In early life the process of building up is more active, and in consequence the form is plump, and the stature increases. Repair now exceeds waste. On the other hand, when old age comes on, the wasting process is more active, the flesh and weight diminish, the skin falls in wrinkles, and the senses become dull. Only during the prime of life—from about twenty to sixty years of age—is the balance exact between loss and gain. {65}

**3.** System deprived of food? Warning? What is the pain? How proved?

**3. Hunger and Thirst.**—When the system is deprived of its supply of solid food during a longer time than usual, nature gives warning by the sensation of hunger, to repair the losses that have taken place. This sensation or pain appears to be located in the stomach, but it is really a distress of the system at large. Let a sufficient quantity of nourishment be introduced into the system in any other way than by the mouth, and it will appease hunger just as certainly as when taken in the usual manner.

**4.** Feeling of thirst? Seat of the pain? How proved? Time a person can exist without food?

**4.** The feeling of thirst, in like manner, is evidence that the system is suffering from the want of water. The apparent seat of the distress of thirst is in the throat; but the injection of water into the blood-vessels is found to quench thirst, and by the immersion of the body in water, the skin will absorb sufficient to satisfy the demands of the system. The length of time that man can exist without food or drink is estimated to be about seven days. If water alone be supplied, life will last much longer; there being cases recorded where men have lived twenty days and over, without taking any solid food.

**5.** Amount of food required? The young and others? Those living in hot and cold climates? Habits?

**5. Quantity of Food.**—The quantity of food required varies greatly, according to the individual and his mode of life. The young, and others who lead active lives, or who live in the open air, require more food than the old, the inactive, or the sedentary. Those who live in cold regions require more than the inhabitants of hot climates. Habit, also, has much to do with the quantity of food required. Some habitually eat and drink more than they actually need, while a few eat less than they should.

**6.** Quantity of food daily? How divided? Compare with the weight of the body?

**6.** The average daily quantity of food and drink for a healthy man of active habits is estimated at six pounds. This amount may be divided in about the following proportions: the mineral kingdom furnishes three and one-half pounds, including {66} water and salt; the vegetable kingdom, one and one-half pounds, including bread, vegetables, and fruits; the animal kingdom, one pound, comprising meat, eggs, butter, and the like. This quantity is about one twenty-fourth the weight of the body, as it is generally computed; the average weight of an adult man being placed at 140 pounds. A man, therefore, consumes an amount of solid and liquid nutriment every twenty-four days equal in weight to that of his body, a corresponding amount being *excreted*, or removed from the system in the same time.

**7.** How often then might the body be renewed? Why is it not? Opinion? How correct? What further is stated?

**7. Renovation of the Body.**—By this process, so far as weight is concerned, the body might be renewed every twenty-four days; but these pounds of food are not all real nutriment. A considerable portion of that which we eat is innutritious, and though useful in various ways, is not destined to repair the losses of the system. An opinion has prevailed that the body is renewed throughout once in seven years; how correct this may be it is not easy to decide, but probably the renovation of the body takes place in a much shorter period. Some parts are very frequently renewed, the nutritive fluids changing more or less completely, several times during the day. The muscles, and other parts in frequent exercise, change often during a year; the bones not so often, and the enamel of the teeth probably never changes after being once fully formed.

**8.** Habits of nations? Give the different cases.

**8. Mixed Diet.**—The habits of different nations in respect to diet exhibit the widest and strangest diversity. The civilized, cook their food, while savages often eat it in a raw state. Some prefer it when fresh, others allow it to remain until it has become tainted with decay. Those dwelling in the far north subsist almost wholly on animal {67} food, while those living in hot climates have bountiful supplies of delicious fruits with which to satisfy all their bodily wants. One race subsists upon the banana, another upon the blubber of seals. In temperate climates, a diet composed partly of vegetable and partly of animal food is preferred.

**9.** The point to consider? Vegetable diet? Louis Cornaro? John the Baptist?

**9.** The important point to consider is, however, not one of origin, but whether the chemical principles (mentioned in the last chapter) enter into the composition of the diet. A purely vegetable diet may be selected which would contain all the principles necessary to sustain life. It is recorded of Louis Cornaro, a Venetian noble, that he supported himself comfortably for fifty-eight years on a daily allowance of twelve ounces of vegetable food, and about a pint of light wine. On the other hand, the food of John the Baptist, consisting of "locusts and wild honey," is an example of the sustaining power of a diet chiefly animal in its origin.

**10.** What has been found in our climate? Exclusive vegetable diet?

**10.** In our climate, those who lead active lives crave an allowance of animal food; and it has been found by experience that with it they can accomplish more work and are less subject to fatigue, than without it. Among nations where an exclusively vegetable diet is employed, indigestion is a disorder especially prevalent.

**11.** Necessity for change in diet? Continuous use of the same diet? Exception? Why? Too rich diet? Horses?

**11.** The necessity for occasionally changing or varying the diet, is seen in the fact that no single article comprises all the necessary principles of food, and that the continuous use of any one diet, whether salt or fresh, is followed by defective nutrition and disease. There is one exception to this rule: in infancy, milk alone is best calculated to support life; for then the digestive powers are incompletely developed, and the food must be presented in the simplest form possible. It should also be remembered that too rich diet is injurious, just as truly as one that is {68} inadequate. When the food of horses is too nutritious, instinct leads them to gnaw the wood-work of their mangers.

**12.** Milk as a model food? Cow's milk? The constituents when separated?

**12. Different Articles of Diet—Milk.**—Milk is the earliest nutriment of the human race, and in the selection and arrangement of its constituents, may be regarded as a model food, no other single article being capable of sustaining life so long. Cow's milk holds casein, one of the albuminoids, about five parts in one hundred; a fatty principle, when separated, known as butter, about four parts; sugar of milk four parts; water and salts eighty-seven parts. The casein and fatty substance are far more digestible in milk, than after they have been separated from it in the form of cheese and butter.

**13.** Milk as a beverage? Milk sold in cities? How to detect the cheat?

**13.** Since milk, in itself, is so rich an article of food, the use of it as a beverage is unwise, unless the quantity of the other articles consumed be reduced at the same time. The milk sold in cities is apt to be diluted with water. The way to detect the cheat is by testing the specific gravity of the article. Good milk is about 1030; skimmed milk 1035; but milk diluted one-fifth is 1024. An instrument called the lactometer is also used, by which the amount of cream present is ascertained.

**14.** Composition of eggs? Yolk? How should eggs be eaten? Why? How boiled? Why?

**14. Eggs.**—The egg is about two-thirds water, the balance is pure albumen and fat in nearly equal proportions. The fat is in the yolk, and gives it its yellow color. Eggs contain none of the sugar-principles, and should be eaten with bread or vegetables that contain them. Soft-boiled eggs are more wholesome than those which are hard-boiled or fried, as the latter require longer time to digest.

**15.** Meats, whence derived? Why important? Flesh of young animals?

**15. Meats.**—The meats, so called, are derived from the muscular parts of various animals. They are most important articles of food for adults, inasmuch as they are {69} richly stored with albuminoid substances, and contain more or less fat. Such food is very nourishing and easily digested if eaten when fresh,—veal and pork being exceptions. The flesh of young animals is more tender and, in general, more digestible than that of older ones. All meat is more tough immediately after the killing of the animal, but improves by being kept a certain length of time.

**16.** Preference of persons? Venison? Mutton? Cheese? Uncooked flesh?

**16.** Some persons prefer flesh that has begun to show signs of decomposition, or is unmistakably putrid. By some, venison is not considered to have its proper flavor until it is tainted. In England, people prefer mutton that is in a similar condition, just as on the continent of Europe many delight in cheese that is in a state of decomposition. In certain less civilized countries flesh is not only eaten uncooked, but in a mouldy, rotten condition. The use of such food is not always immediately injurious, but it predisposes to certain diseases, as indigestion and fevers.

**17.** Cold as a preserver? Meat in Russia? Beef and

**17.** Cold is one means of preserving meat from decay. In the markets of northern Russia, the frozen carcases of animals stand exposed for sale in the winter air for a considerable time, and are sawn in pieces, like sticks of wood, as the purchases are pork, how preserved? Salted meat as food? Scurvy?

made; such meat, when thawed, being entirely fit for food. Beef and pork are preserved by salting down in brine, and in this condition may be carried on long voyages or kept for future use. Salted meat is not as nutritious as fresh, since the brine absorbs its rich juices and hardens its fibres. Long continued use of salt meats, without fresh vegetables, gives rise to the disease called scurvy, formerly very prevalent on shipboard and in prisons; but now scarcely known.

**18.** The antiquity of the custom of cooking food? Object of cooking? The oyster? Raw meat as an occasional food?

**18. Cooking.**—The preparation of food by the agency of fire is of almost universal {70}
practice, even among the rudest nations. The object of cooking is to render food more easy of digestion by softening it, to develop its flavor, and to raise its temperature more nearly to that of the body. A few articles of flesh-food are eaten uncooked in civilized lands, the oyster being an instance. Raw meat is occasionally eaten by invalids with weak digestive powers, and by men training for athletic contests.

**19.** Effect of boiling meat? How may the cooking be done? The proper method? Effect? Making of soup?

**19.** In boiling meat, the water in which it is placed tends to dissolve its nutrient juices. In fact, the cooking may be so conducted as to rob the meat of its nourishment, its tenderness, and even of its flavor. The proper method, in order to preserve or promote these qualities, is to place the meat in boiling water, which, after a few minutes, should be reduced in temperature. In this way the intense heat, at first, coagulates the exterior layers of albumen, and imprisons the delicate juices; after that, moderate heat best softens it throughout. When soup is to be made, an opposite course should be pursued; for then the object is to extract the juices and reject the fibre. Meat, for such purpose, should be cut in small pieces and put into cold water, which should then be gradually raised to boiling heat.

**20.** Roasting? How should it be done? Give the philosophy of the process. Frying?

**20.** Roasting is probably the best method of cooking meat, especially "joints" or large pieces, as by this process the meat is cooked in its own juices. Roasting should begin with intense heat, and be continued at a moderate temperature, in order to prevent the drying out of the nutritious juices, as by this process an outer coating or crust of coagulated albumen is formed. During this process the meat loses one-fourth of its
weight, but the loss is almost wholly water, evaporated by the heat. Too intense or {71}
prolonged heat will dry the meat, or burn it. Frying is the worst possible method, as the heated fat, by penetrating the meat, or other article placed in it, dries and hardens it, and thus renders it indigestible.

**21.** What is "Trichina?" How guarded against?

**21. Trichina.**—It should be remembered that ham, sausages, and other forms of pork, should never be eaten in a raw or imperfectly cooked condition. The muscle of the pig is often infested by a minute animal parasite, or worm, called *trichina spiralis*. This worm may be introduced alive into the human body in pork food, where it multiplies with great rapidity, and gives rise to a painful and serious disease. This disease has been prevalent in Germany, and cases of it occur from time to time in this country.

**22.** What part of fish is eaten? What does it resemble? Fish as food for digestion? Fish as a diet?

**22. Fish.**—The part of fish that is eaten is the muscle, just as in the case of the meats and poultry. It closely resembles flesh in its composition, but is more watery. Some varieties are very easy of digestion, such as salmon, trout, and cod; others are quite indigestible, especially lobsters, clams, and shell-fish generally. A diet in which fish enters as the chief article, is ill adapted to strengthen mind or body, while its continued use is said to be the fertile source of nearly every form of disease of the skin. Some persons are so constituted that they can eat no kind of fish without experiencing unpleasant results.

**23.** List of vegetable articles? Usefulness of the different vegetables? Strychnia? What further is said in relation to the nourishing and other qualities of vegetables?

**23. Vegetable Food.**—The list of vegetable articles of diet is a very long one, including the grains from which our bread-stuffs are made, the vegetables from the garden, and the fruits. All the products of the vegetable kingdom are not alike useful. Some are positively hurtful; indeed, the most virulent poisons, as strychnia and
prussic acid, are obtained from certain vegetables. Again, of such articles as have {72}
been found good for food, some are more nourishing than others: some require very little preparation for use, while others are hard and indigestible, and can only be used after undergoing many preparatory processes. Great care must therefore be exercised, and many experiments made, before we can arrive at a complete knowledge in reference to these articles of diet. Tea, coffee, and other substances from which drinks are made, are of vegetable origin.

**24.** Wheat? "Staff of life?" White flour? Hard-grain wheats? Bolting? Graham bread?

**24. Bread.**—Wheat is the principal and most valuable kind of grain for the service of man. Bread made from wheat-flour has been in use for many hundreds of years, and on this account, as well as because of its highly nourishing properties, has been aptly called "the staff of life." We never become tired of good bread as an article of daily food.

The white kinds of flour contain more starch and less gluten than the darker, and are therefore less nutritious. The hard-grain wheat yields the best flour. In grinding wheat, the chaff or bran is separated by a process called "bolting." Unbolted flour is used for making brown or Graham bread.

**25.** Leavened bread? Unleavened? Hot bread?

**25.** The form of bread most easily digested is that which has been "leavened," or rendered porous by the use of yeast, or by some similar method. Unleavened bread requires much more mastication. Hot bread is unwholesome, because it is not firm enough to be thoroughly masticated, but is converted into a pasty, heavy mass that is not easily digested.

**26.** Wheaten bread? Bread and butter? Experiment on the dog?

**26.** Wheaten bread contains nearly every principle requisite for sustaining life, except fat. This is commonly added in other articles of diet, especially in butter, —"bread and butter," consequently, forming an almost perfect article of food. The {73}
following experiment is recorded: "A dog eating *ad libitum* of white bread, made of pure wheat, and freely supplied with water, did not live beyond fifty days. He died at the end of that time with all the signs of gradual exhaustion." Death took place, not because there was anything hurtful in the bread, but because of the absence of one or more of the food-principles.

**27.** State what is said of the Irish potato?

**27. The Potato.**—The common or Irish potato is the vegetable most extensively used in this country and Great Britain. Among the poorer classes in Ireland it is the main article of food. While it is not so rich in nutritious substances as many others, it has some very useful qualities. It keeps well from season to season, and men do not weary of its continuous use. It is more than two-thirds water, the balance being chiefly starch, with a little albumen.

**28.** Sweet potato? Nightshades? Potatoes when germinating?

**28.** The sweet potato differs from the white or common, in containing more water and a small proportion of sugar. The common potato and the tomato belong to the same botanical order as the "nightshades," but do not possess their poisonous qualities, unless we except potatoes that are in the process of germination or sprouting, when they are found injurious as food.

**29.** Fruits? Use of ripe fruit? Nutriment they contain? Starch in unripe fruits? Cooking of unripe fruits?

**29. Fruits.**—These are produced, in this country, in great abundance, and are remarkable alike for their variety and delicious flavor; consequently they are consumed in large quantities, especially during the warmer months. The moderate use of ripe fruits, in their season, is beneficial, because they offer a pleasant substitute for the more concentrated diet that is used in cold weather. The amount of solid nutriment they contain is, however, small. The percentage of water in cherries is seventy-five, in grapes eighty-one, in apples eighty-two. Unripe fruits contain starch, which, during the process of ripening, is converted into sugar. Such fruits are {74}
indigestible and should be avoided: cooking, however, in part removes the objections to them.

**30.** How should drinking-water be as regards color and smell? Chemically pure water? How obtained? Agreeableness of perfectly pure water?

**30. Pure Water.**—It is important that the water we drink and use in the preparation of food should be pure. It should be clear and colorless, with little or no taste or smell, and free from any great amount of foreign ingredients. Chemically pure water does not occur in nature: it is only obtained by the condensation of steam, carefully conducted, and is not as agreeable for drinking purposes as the water furnished by springs and streams. Rain-water is the purest occurring in nature; but even this contains certain impurities, especially the portion which falls in the early part of a shower; for in its descent from the clouds, the particles floating in the air are caught by the falling drops.

**31.** Spring and well water? Whence the sparkle, or life? The water supply of cities? Croton water? Ridgewood?

**31.** Water from springs and wells always contains more or less foreign matter of mineral origin. This imparts to the drink its pleasant taste—the sparkle, or "life," coming from the gases absorbed by the water during its passage under ground. The ordinary supply of cities is from some pure stream or pond conveyed from a distance through pipes, the limpid fluid containing generally only a small amount of impurity. Croton water, the supply of New York City, is very pure, and contains only four and a half grains to a gallon: the Ridgewood water of Brooklyn holds even less foreign matter.

**32.** Impurities in drinking-water? Mineral springs?

**32.** Drinking-water may contain as large a proportion as sixty to seventy grains per gallon of impurity, but a much larger quantity renders it unwholesome. The mineral spring waters, used popularly as medicines, are highly charged with mineral substances. Some of them, such as the waters at Saratoga, contain three hundred {75}
grains and more to the gallon.

**33.** What is stated of the action of water upon lead?

**33. Action of Water upon Lead.**—The danger of using water that has been in contact with certain metals is well known. Lead is one of the most readily soluble, and probably the most poisonous of these substances in common use. When pure water and an untarnished surface of lead come in contact, the water gradually corrodes the metal, and soon holds an appreciable quantity of it in solution. When this takes place the water becomes highly injurious: the purer the water, and the more recent the use of the metal, the greater will be the danger.

**34.** Lead in pipes and other things? Advice? What takes place after the articles of lead have been used much? What is wise?

**34.** In cities, lead pipes are commonly used to convey water through the houses; lead being also used in the construction of roofs, cisterns, and vessels for keeping water and other liquids. After the articles of lead have been in use several months, the danger of lead-poisoning diminishes. An insoluble coating of the sulphate of lead forms upon the exposed surface, thus protecting it from further corrosion. It is, however, a wise precaution, at all times to reject the water or other fluid that has been in contact with leaden vessels over night, or for a number of hours. Allow the water in pipes to run freely before using.

**35.** Coffee as an article of diet? Of what does it consist? How does the water affect the coffee? The peculiar stimulant? How does it affect most persons?

**35. Coffee.**—This is an important addition to diet, and if moderately used is beneficial to persons of adult age. As commonly employed, it consists of an infusion in boiling water of the roasted and ground berry. The water extracts certain flavoring and coloring matters, but that which gives it its peculiar stimulant qualities is the alkaloid *caffein*. With most persons its action is that of a gentle stimulant, without any injurious reaction. It produces a restful feeling after exhausting efforts of mind or body; it tranquilizes, but does not disqualify for labor; and hence it is highly esteemed {76} by persons of literary pursuits.

**36.** Another property of coffee? Miners of Belgium? The Caravans? Among armies? Taken with meals?

**36.** Another property of coffee is, that it diminishes the waste of the tissues, and consequently permits the performance of excessive labor upon an economical and inadequate diet. This has been tested among the miners of Belgium. Their allowance of solid food was below that found necessary in prisons and elsewhere; but, with the addition of about four pints of coffee daily, they were enabled to undergo severe labor without reducing their muscular strength. The caravans which traverse the deserts are supported by coffee during long journeys and lengthened privation of food. Among armies it is indispensable in supplementing their imperfect rations, and in relieving the sense of fatigue after great exposure and long marches. When taken with meals, coffee is also thought to promote digestion.

**37.** Effects of tea-drinking? Peculiar principle? The tea beverage, how made? Black and green tea? Excessive use of tea or coffee?

**37. Tea.**—The effects of tea-drinking are very similar to those of coffee, and are due to a peculiar principle called *thein*. This principle is probably the same as that found in coffee, *caffein*, since the chemical composition of both is precisely alike. Tea, as a beverage, is made from the dried leaves of the plant by the addition of hot water; if the tea is boiled, the oil which gives it its agreeable flavor is driven off with the steam. There are two kinds of tea—the black and the green: the latter is sometimes injurious, producing wakefulness and other nervous symptoms. The excessive use of either coffee or tea will cause wakefulness.

**38.** Experiments made during Kane's expedition?

**38.** During Dr. Kane's expedition in the Arctic regions, the effects of these articles were compared. "After repeated trials, the men took most kindly to coffee in the {77} morning and tea in the evening. The coffee seemed to continue its influence throughout the day, and they seemed to grow hungry less rapidly than after drinking tea, while tea soothed them after a day's hard labor, and the better enabled them to sleep. They both operated upon fatigued men like a charm, and their superiority over alcoholic stimulants was very decided."

**39.** State what is said of chocolate.

**39.** Chocolate is made from the seeds of the cocoa-tree, a native of tropical America. Its effects resemble somewhat those of tea and coffee, but it is very rich in nutriment. Linnæus, the botanist, was so fond of this beverage, that he gave to the cocoa-tree the name, *Theobroma*—"the Food of the Gods." Its active principle is *theobromin*.

**40.** Use of alcoholic drinks, how general? The rule given?

**40. Alcohol.**—The list of beverages that are consumed for the sake of the alcohol they contain is a very long one. Their use is almost universally prevalent, every civilized nation, and nearly every barbarous one, having its favorite alcoholic drink; and, as a general rule, the nations which stand the highest in civilization have the greatest varieties of these beverages,—at the same time using them the most intelligently and wisely.

**41.** The beverages produced by fermentation? The ardent spirits? Grains and fruits employed? Long use of wine? Of distilled liquors?

**41.** The wines and malt liquors that contain a small amount of alcohol are produced by fermentation. The beverages that hold a large proportion of alcohol, the "ardent spirits," are made by distillation. Enormous quantities of grains and fruits are thus yearly diverted from their proper uses as food; some of these being corn, wheat, rye, barley, potatoes, and rice; also the grape, apple, pear, peach, sugar-cane, cherry, fig, and orange. Wine, the fermented juice of the grape, has been in use from time immemorial, while the introduction of distilled liquors dates from a comparatively recent period. {78}

**42.** Describe the action of alcohol upon the human system? Experience of Dr. Hayes and others?

**42.** What is the physiological action of alcohol? Its first and most evident action is stimulation: this effect is transient, and is followed by a variable degree of depression. At first it sharpens the appetite and quickens digestion, but its habitual use impairs both. This stimulation is efficient in giving the system an artificial strength during some temporary derangement, and in enabling the endurance of unusual fatigue or exposure. The experience of Dr. Hayes, and other explorers of the polar regions, is that alcohol does not enable the body to resist the influence of cold, but, on the contrary, is always injurious.

**43.** Another property of alcohol? How do we explain the restorative influence of wines and liquors?

**43.** Another property it has in common with tea and coffee. It supports the powers of life, economizes food, and retards the waste of tissues; in other words, it "banks the fires," and prevents their burning wastefully. On this principle we explain the restorative influence of wines or liquors during exhausting diseases, in convalescence, and after excessive labors of mind or body.

**44.** Alcohol, a poison? Moderate stimulants?

**44.** Pure alcohol, or an excessive quantity of ardent spirits, is an undoubted poison, and has been frequently known to produce fatal results. Stimulants in moderate quantities have been thought to increase strength, and in this view they have been

Prevailing opinion? Hence?

called "alcoholic foods." This is not now conceded by scientific men. The prevailing opinion is, that they serve no useful purpose as an article of diet, and that their beneficial influence is limited to cases where the system is enfeebled, where some unnatural demand is made upon the vital powers, or where the supply of food is insufficient. Hence, while alcohol has not the power to build up, it may obstruct the process of pulling down. {79}

QUESTIONS FOR TOPICAL REVIEW.

CHAPTER VI. {80}

## DIGESTION.

*The Principal Processes of Nutrition—The General Plan of Digestion—Mastication—The Teeth—Preservation of the Teeth—Insalivation—The Stomach and the Gastric Juice—The Movements of the Stomach—Gastric Digestion—The Intestines—The Bile and Pancreatic Juice—Intestinal Digestion—Absorption by means of Blood-vessels and Lacteals—The Lymphatic or Absorbent System—The Lymph—Conditions which affect Digestion—The Quality, Quantity, and Temperature of the Food—The Influence of Exercise and Sleep.*

**1.** Design of food? How accomplished?

**1. Nutrition.**—The great design of food is to give *nutriment* or nourishment to the body. But this is not accomplished directly, as the food must first pass through certain preparatory changes, as follows: (1), *Digestion*, by which the food is reduced to a soluble condition; (2), *Absorption*, by which, when digested, it is imbibed into the blood; (3), *Circulation*, which carries the enriched blood to the various parts of the system; and (4), *Assimilation*, by which each tissue derives from the blood the materials necessary for its support.

**2.** Sustaining power of food? Simile of the engine? Operation in the human body?

**2.** By these means the sustaining power of food is gradually developed and employed, and the vital machinery kept in working order, somewhat after the manner of the steam-engine. To operate the latter, the force imprisoned within the coal and water is set free and converted into motion by the combustion of the fuel and the vaporization of the water. It will be seen, however, when we come to study these operations in the human body, that they are conducted silently and harmoniously, with marvellous delicacy and completeness, and without that friction, and consequent loss of power, {81}
which attend the working of the most perfect machinery of man's invention.

**3.** Change of food in digestion? Process of digestion? Describe the alimentary canal.

**3. General Plan of Digestion.**—The great change which food undergoes in digestion is essentially a reforming process, reducing articles of diet, which are at first more or less solid, crude, and coarse, to a liquid and finely comminuted condition, suitable for absorption into the blood. The entire process of digestion takes place in what is called the alimentary canal, a narrow, tortuous tube, about thirty feet in its entire length. This canal begins in the mouth, extends thence downward through the gullet to the stomach (a receptacle in which the principal work of digestion is performed), and thence onward through the small and large intestines.

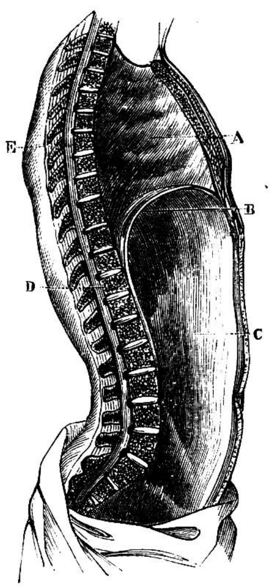



Fig. 16.—Section of the Trunk Showing the Cavities of the Chest and Abdomen.
A, Cavity of Chest;
B, Diaphragm;
C, Abdomen;
D, E, Spinal Column.

**4.** Situation of the stomach and intestines? Action of the food?

**4.** The stomach and intestines are situated in the cavity of the abdomen (Fig. 16, C, and Fig. 22), and occupy about two-thirds of its space. The action to which the food is subjected in these organs is of two kinds—mechanical and chemical. By the former it

Mechanical action? Chemical?

is crushed, agitated, and carried onward from one point to another; by the latter it is changed in form through the solvent power of the various digestive juices. {82}

**5.** Describe the process of mastication? How many and what movements?

**5. Mastication.**—As soon as solid food is taken into the mouth, it undergoes mastication, or chewing. It is caught between the opposite surfaces of the teeth, and by them is cut and crushed into very small fragments. In the movements of chewing, the lower jaw plays the chief part; the upper jaw, having almost no motion, acts simply as a point of resistance, to meet the action of the former. These movements of the lower jaw are of three sorts: a vertical or cutting, a lateral or grinding, and a *to-and-fro* or gnawing motion.

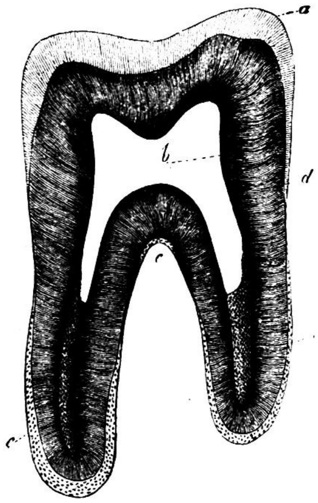



FIG. 17.—SECTION OF A TOOTH.
*a*, Enamel; *b*, Cavity; *c c*, Roots; *d*, Body of the Tooth.

**6.** Composition of the teeth? Enamel of the teeth? Interior of teeth?

**6.** The teeth are composed of a bone-like material, and are held in place by roots running deeply into the jaw. The exposed portion, or "crown," is protected by a thin layer of enamel (Fig. 17, *a*), the hardest substance in the body, and, like flint, is capable of striking fire with steel. In the interior of each tooth is a cavity, containing blood-vessels and a nerve, which enter it through a minute opening at the point of the root (Fig. 19).

**7.** The milk teeth? The permanent teeth?

**7.** There are two sets of teeth; first, those belonging to the earlier years of childhood, called the milk teeth, which are twenty in number and small. At six or eight years of age, when the jaw expands, and when the growing body requires a more powerful and numerous set, the roots of the milk teeth are absorbed, and the latter are "shed," {83}
or fall out, one after another (Fig. 18), to make room for the permanent set.

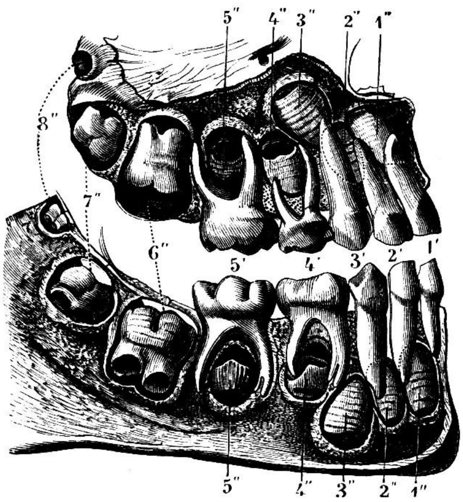



FIG. 18.—SECTION OF THE JAWS.
1' 2' 3' 4' 5', The Milk Teeth; 1" to 8", The Germs of the Permanent Set.

**8, 9.** Number of teeth? How distributed?

**8.** There are thirty-two teeth in the permanent set, as many being in one jaw as the other. Each half-jaw has eight teeth, similarly shaped and arranged in the same order: thus, two incisors, one canine, two bicuspids, and three molars. The front teeth are small, sharp, and chisel-edged, and are well adapted for cutting purposes; hence their name incisors. The canines stand next, one on each side of the jaw; these receive their name from their resemblance to the long, pointed tusks of the dog (Fig. 19). {84}

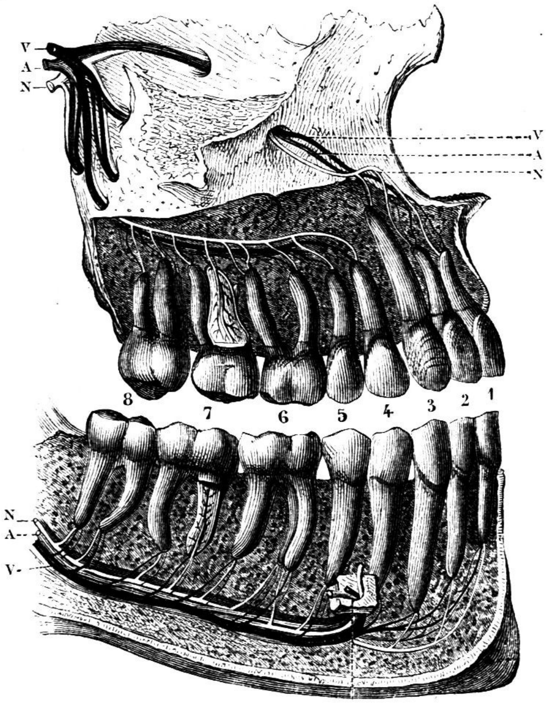
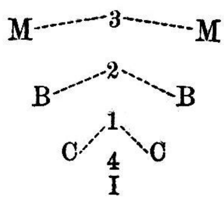



FIG. 19.—SECTION OF THE JAWS—RIGHT SIDE.
V, A, N, Veins, Arteries, and Nerves of the Teeth.
The root of one tooth in each jaw is cut vertically to show the cavity and the blood-vessels, etc., within it.
1 to 8, Permanent Teeth.

**9.** The bicuspids, next in order, are larger and have a broader crown than the former; while behind them are the molars, the largest and most powerful of the entire set. These large back teeth, or "grinders," present a broad, rough surface, suitable for holding and crushing the food. The third molar, or "wisdom tooth," is the last to be cut, and does not appear until about the twenty-first year. The order of arrangement {85}
of the teeth is indicated by the following dental formula:—




**10.** Different forms of teeth? Human teeth? The inference?

**10.** It is interesting, at this point, to notice the different forms of teeth in different animals, and observe how admirably their teeth are suited to the respective kinds of food upon which they subsist. In the *carnivora*, or flesh-feeders, the teeth are sharp and pointed, enabling them both to seize their prey, and tear it in pieces; while the *herbivora*, or vegetable-feeders, have broad, blunt teeth, with rough crowns, suitable for grinding the tough grasses and grains upon which they feed. Human teeth partake of both forms; some of them are sharp, and others are blunt; they are therefore well adapted for the mastication of both flesh and vegetables. Hence we argue that, although man may live exclusively upon either vegetable or animal food, he should, when possible, choose a diet made up of both varieties.

**11.** Cleaning of teeth? Effects of not cleaning?

**11. Preservation of the Teeth.**—In order that the teeth shall remain in a sound and serviceable condition, some care is of course requisite. In the first place, they require frequent cleansing; for every time we take food, some particles of it remain in the mouth; and these, on account of the heat and moisture present, soon begin to putrefy.
This not only renders the breath very offensive, but promotes decay of the teeth. {86}

**12.** Effects upon the saliva? Formation of tartar? How prevented? How destroyed?

**12.** The saliva, or moisture of the mouth, undergoes a putrefactive change, and becomes the fertile soil in which a certain minute fungus has its growth. This fluid, too, if allowed to dry in the mouth, collects upon the teeth in the form of an unsightly, yellow concretion, called tartar. To prevent this formation, and to remove other offensive substances, the teeth should be frequently cleaned with water, applied by means of a soft tooth-brush. The destruction of the tartar fungus is best effected by the use of a weak solution of carbolic acid.

**13.** Destruction of the enamel? How guarded against?

**13.** Again, it should be borne in mind that the enamel, Nature's protection for the teeth, when once destroyed, is not formed anew; and the body of the tooth thus exposed, is liable to rapid decay. On this account, certain articles are to be guarded against; such as sharply acid substances that corrode the enamel, and hard substances that break or scratch it—as gritty tooth powders, metal tooth picks, and the shells of hard nuts. Sudden alternations from heat to cold, when eating or drinking, also tend to crack the enamel.

**14.** Mixing of food with the saliva? What is the saliva? How secreted? The salivary glands?

**14. Insalivation.**—When the morsel of food is cut and ground by the teeth, it is at the same time also intimately mixed with the saliva, or fluids of the mouth. This constitutes the second step of digestion, and is called insalivation. The saliva, the first of the digestive solvents, is a colorless, watery, and frothy fluid. It is secreted (*i. e.* separated from the blood) partly by the mucous membrane which lines the mouth; but chiefly by the salivary glands, of which there are three pairs situated near the mouth.

**15.** The flow of saliva? The thought of food? Anxiety and grief? Animals fed upon dry and coarse food?

**15.** These glands consist of clusters of very small pouches, around which a delicate {87}
network of blood-vessels is arranged: they empty into the mouth by means of little tubes, or ducts. The flow from these glands is at all times sufficient to maintain a soft and moist condition of the tongue and mouth; but when they are excited by the presence and taste of food, they pour forth the saliva more freely. Even the mere thought of food will at times cause the saliva to flow, as when the appetite is stimulated by the sight or smell of some savory article; so that the common expression is correct that "the mouth waters" for the favorite articles of food. Anxiety and grief prevent its flow, and cause "the tongue to cleave to the roof of the mouth." In the horse and other animals, that feed upon dry and coarse fodder, and require an abundant supply of saliva, we find large salivary glands, as well as powerful muscles of mastication.

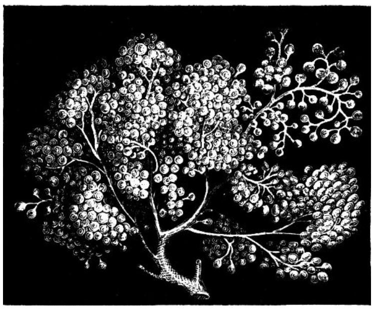


FIG. 20.—STRUCTURE OF A SALIVARY GLAND.

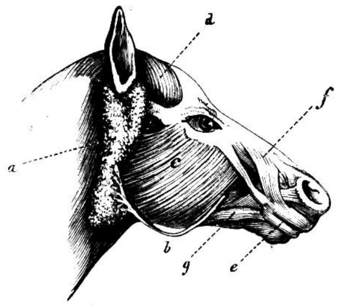



FIG. 21.—THE HEAD OF A HORSE, showing the large salivary gland (*a*), its duct (*b*), the muscles of mastication (*c*, *d*, *e*, *f*, and *g*).

**16.** Importance of the process? The first place? The second? The third?

**16.** The mingling of the saliva with the food seems a simple process, but it is one that
plays an important part in digestion. In the first place, it facilitates the motions of {88}
mastication, by moistening the food and lubricating the various organs of the mouth. Secondly, it prepares the way for other digestive acts: by the action of the teeth, the saliva is forced into the solid food, softens the harder substances, and assists in converting the whole morsel into a semi-solid, pulpy mass, that can be easily swallowed, and readily permeated by other digestive fluids. The saliva also, by dissolving certain substances, as sugar and salt, develops the peculiar taste of each; whereas, if the tongue be dry and coated, they are tasteless. Hence, if substances are insoluble, they are devoid of taste.

**17.** Its final importance? Starch? How effected? Ptyalin?

**17.** Finally, the saliva has the property of acting chemically upon the food. As we have before stated (Chap. IV.), starch, as starch, cannot enter the tissues of the body; but, in order to become nutriment, must first be changed to grape sugar. This change is, in part, effected by the saliva, and takes place almost instantly, whenever it comes in contact with cooked starch. This important function is due to an organic ingredient of the saliva called *ptyalin*. This substance has been extracted from the saliva by the chemist, and has been found, by experiment, to convert into sugar two thousand times its own weight of starch.

**18.** Each of the processes? Why is a knowledge of the digestive functions important? How shown?

**18. Importance of Mastication and Insalivation.**—Each of these processes complements the other, and makes the entire work available; for, by their joint action, they prepare the food in the best possible manner for further digestive changes. The knowledge of these preliminary functions will appear the more important, when we reflect that they are the only ones which we can regulate by the will. For, as soon as the act of swallowing begins, the food not only passes out of
sight, but beyond control; and the subsequent acts of digestion are consequently {89}
involuntary and unconsciously performed.

**19.** Rapid eating? Describe the process and effects.

**19.** It is generally known that rapid eating interferes with digestion. How does this occur? In the first place, in rapid eating, the flow of the saliva is insufficient to moisten the solid parts of the food, so that they remain too hard and dry to be easily swallowed. This leads to the free and frequent use of water, or some other beverage, at meals, to "wash down" the food,—a most pernicious practice. For these fluids, not only cannot take the place of the natural digestive juices, but, on the contrary, dilute and weaken them.

**20.** Loss of taste? Another effect of rapid eating? Mistakes?

**20.** Secondly, the saliva being largely the medium of the sense of taste, the natural flavors of the food are not developed, and consequently it appears comparatively insipid. Hence the desire for high-seasoned food, and pungent sauces, that both deprave the taste and over excite the digestive organs. Rapid eating also permits the entrance of injurious substances which may escape detection by the taste, and be unconsciously received into the system. In some instances, the most acrid and poisonous substances have frequently been swallowed "by mistake," before the sense of taste could act, and demand their rejection.

**21.** Effect of imperfectly broken food in the stomach? Dyspepsia? Overeating?

**21.** Thirdly, the food, being imperfectly broken up by the teeth, is hurried onward to the stomach, to be by it more thoroughly divided. But the task thus imposed upon the stomach, it is not at all adapted to perform; so that the crude masses of food remain a heavy burden within the stomach, and a source of distress to that organ, retarding the performance of its legitimate duty. Hence persons who habitually eat too rapidly, frequently fall victims to dyspepsia. Rapid eating also conduces to overeating. The food is introduced so rapidly, that the system has not time to recognize that its real {90}
wants are met, and that its losses have been made good; and hence the appetite continues, although more nutriment has been swallowed than the system requires, or can healthfully appropriate.

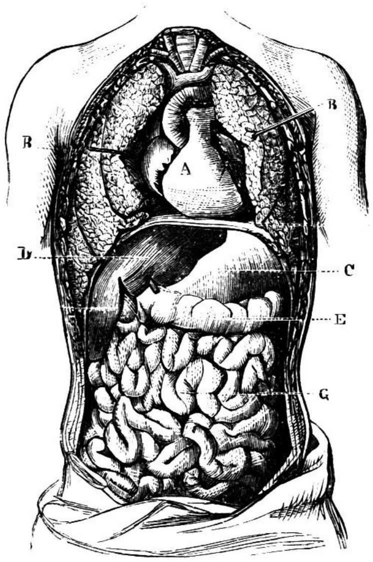



Fig. 22.—Section of Chest and Abdomen.
A, Heart. B, The Lungs.
C, Stomach. D, The Liver. E, Large Intestine. G, Small Intestine.

**22.** Gullet? Describe the stomach and its location. Effects of gormandizing?

**22. The Stomach.**—As soon as each separate portion of food is masticated and insalivated, it is swallowed; that is, it is propelled downward to the stomach, through a narrow muscular tube about nine inches in length, called the *œsophagus*, or gullet (Fig. 23). The stomach is the only large expansion of the digestive canal, and is the most important organ of digestion. It is a hollow, pear-shaped pouch, having a capacity of three pints, in the adult. Its walls are thin and yielding, and may become unnaturally distended, as in the case of those who subsist on a bulky, innutritious diet, and of those who habitually gormandize.

**23.** Heart-orifice? Gatekeeper? Coins, etc.? Indication of the soft and yielding texture of the stomach?

**23.** The stomach has also two openings; that by which food enters, being situated near the heart, is called the *cardiac*, or heart orifice; the other is the *pylorus*, or "gatekeeper," which guards the entrance to the intestines, and, under ordinary {91}
circumstances, permits only such matters to pass it as have first been properly acted upon in the stomach. Coins, buttons, and the like are, however, readily allowed to pass, because they can be of no use if retained. The soft and yielding texture of this organ—the stomach—indicates that it is not designed to crush and comminute solid articles of food.

**24. The Gastric Juice.**—We have seen how the presence of food in the mouth excites the salivary glands, causing the saliva quickly to flow. In the same manner, when food reaches the stomach, its inner lining, the mucous membrane, is at once excited to activity. (At first its surface, which while the stomach is empty presents a pale pink hue, turns to a bright red color, for the minute blood-vessels which course through it, are filled with blood. Presently a clear, colorless, and acid fluid exudes, drop by drop, from its numerous minute glands or "tubules," until finally the surface is moistened in every part, and the fluid begins to mingle with the food. This fluid is termed the gastric juice. {92}

**24.** What is meant by the gastric juice?

**25.** What is the office of the gastric juice? Acidity of the gastric juice? Quantity of gastric juice used? What becomes of it?

**25.** The gastric juice is the proper solvent of certain articles of food, especially those belonging to the albuminoid class. This solvent power is due to its peculiar ingredient, *pepsin*; in digestion, this substance acts like a ferment; that is, it induces changes in the food simply by its presence, but does not itself undergo change. The acidity of the gastric juice, which is due to *lactic acid*, is not accidental; for we find that the pepsin cannot act in an alkaline solution—that is, one which is not acid or neutral. The quantity of gastric juice secreted daily is very large, probably not less than three or four pints at each meal. Though this fluid is at once used in the reduction of the food, it is not lost; since it is soon re-absorbed by the stomach, together with those parts of the food which it has digested and holds in solution.

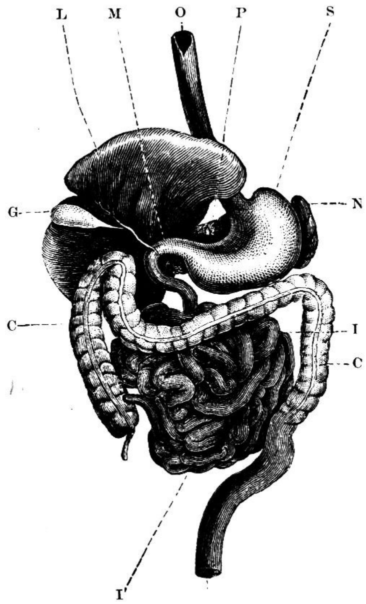



Fig. 23.—The Organs of Digestion.
O, Œsophagus. S, Stomach. L, Liver. M, Pylorus. C, Large Intestines. P, Pancreas. I, Small Intestines. N, Spleen. G, Gall-bladder.

**26.** Muscular coat of the stomach? Expansion and contraction of its fibres? Action of the fibres?

**26. Movements of the Stomach.**—The inner coating of the stomach is the mucous membrane, which, as we have seen, furnishes the gastric juice. Next to this coating lies another, called the muscular coat, composed of involuntary muscular fibres, some of which run circularly, and others in a longitudinal direction. These expand to accommodate the food as it is introduced, and contract as it passes out. In addition, these fibres are in continual motion while food remains in the stomach, and they act in such manner that the contents are gently turned round from side to side, or from one end of it to the other.

**27.** Peristaltic movements? What is said of our consciousness of and power over these movements? Describe the movements of the pylorus.

**27.** By these incessant movements of the stomach, called the *peristaltic* movements, the gastric juice comes in contact with all parts of the food. We are, however, not conscious that these movements take place, nor have we the power to control them. When such portions of the food as are sufficiently digested approach the pylorus, it expands to allow them to pass out, and it closes again to confine the residue for {93}
further preparation.

**28.** How has the knowledge and the workings of the stomach been ascertained? St. Martin? How else?

**28.** The knowledge of these and other interesting and instructive facts has been obtained by actual observation; the workings of the stomach of a living human being have been laid open to view and examined—the result of a remarkable accident. Alexis St. Martin, a Canadian *voyageur*, received a gun-shot wound which laid open his stomach, and which, in healing, left a permanent orifice nearly an inch in diameter. Through this opening the observer could watch the progress of digestion, and experiment with different articles of food. Since that occurrence, artificial openings into the stomach of the inferior animals have been repeatedly made, so that the facts of stomach-digestion are very well ascertained and verified.

**29.** What was formerly thought? What do we now know? What else do we now know? Water, salt, and sugar? Absorption?

**29. Gastric Digestion.**—What portions of the food are digested in the stomach? It was formerly thought that all the great changes of digestion were wrought here, but later investigation has taught us better. We now know that the first change in digestion takes place in the mouth, in the partial conversion of starch into sugar. We also know that, of the three organic food principles (considered in Chapter IV.) two—the fats and the sugars—are but slightly affected by the stomach; but that its action is confined to that third and very important class, from which the tissues are renewed, the albuminoids. A few articles need no preparation before entering the system, as water, salt, and grape-sugar. These are rapidly taken up by the blood-vessels of the stomach, which everywhere underlie its mucous membrane in an intricate and most delicate network. In this way the function of absorption begins.

**30.** Albuminose? The process? Chyme?

**30.** The albuminoid substances are speedily attacked and digested by the gastric {94}
juice. From whatever source they are derived, vegetable or animal, they are all transformed into the same digestive product, called *albuminose*. This is very soluble in water, and is readily absorbed by the blood-vessels of the stomach. After a longer or shorter time, varying from one to five hours, according to the individual and the quantity and quality of his food, the stomach will be found empty. Not only has the digested food passed out, but also those substances which the stomach could not digest or absorb have passed little by little through the pylorus, to undergo further action in the intestines. At the time of its exit, the digested food is of a pulpy consistence, and dark color, and is then known as the *chyme*.

**31.** What are the intestines? The small intestines? The large intestines? Their structure?

**31. The Intestines.**—The intestines, or "bowels," are continuous with the stomach, and consist of a fleshy tube, or canal, twenty-five feet in length. The small intestine, whose diameter is about one inch and a half, is twenty feet long and very tortuous. The large intestine is much wider than the former, and five feet long (Fig. 23). The general structure of these organs resembles that of the stomach. Like it, they are provided with a mucous membrane, or inner lining, whence flow their digestive juices; and, just outside of this, a muscular coat, which propels the food onward from one point to another.

**32.** Peritoneum? The work of digestion?

**32.** Moreover, both the intestines and stomach are enveloped in the folds of the same outer tunic or membrane, called the *peritoneum*. This is so smooth and so well lubricated, that the intestines have the utmost freedom of motion. In the small intestines, the work of digestion is completed, the large intestine receiving from them the indigestible residue of the food, and in time expelling it from the body.

**33.** The presence of food in the intestines? Bile?

**33. Intestinal Digestion.**—As soon as the food passes the pylorus and begins to accumulate in the upper part of the intestines, it excites the flow of a new digestive {95}
fluid, which enters through a small tube, or *duct*, about three inches below the stomach. It is formed by the union of two distinct fluids—the *bile* and the *pancreatic* juice. The bile is secreted by the liver, which is the largest gland of the body, and is situated on the right side and upper part of the abdomen (Fig. 22). The bile is constantly formed, but it flows most rapidly during digestion. During the intervals of digestion it is stored in the *gall-bladder*, a small membranous bag attached to the under side of the liver. This fluid is of a greenish-yellow color, having a peculiar smell, and a very bitter taste.

**34.** The pancreatic juice? The joint action of these fluids?

**34.** The pancreatic juice is the product of a gland called the *pancreas*, situated behind the stomach. This fluid is colorless, viscid, and without odor. Like the digestive juices previously described, it owes its solvent power to its peculiar ferment principle, called *pancreatin*. By the joint action of these fluids, the fatty parts of the food are prepared for absorption. By previous steps of digestion the fats are merely separated from the other components of the food; but here, within the intestines, they are reduced to a state of minute division, or *emulsion*, resembling the condition of butter in milk, before it has been churned. There results from this action a white and milky fluid, termed the *chyle*, which holds in solution the digestible portions of the food, and is spread over the extensive absorbent surface of the small intestines.

**35.** The mucous membrane? Experiments on inferior animals?

**35.** The mucous membrane of the intestines, also, secretes or produces, a digestive fluid by means of numerous "follicles," or minute glands; this is called the intestinal juice. From experiments on the inferior animals, it has been ascertained that this fluid exerts a solvent influence over each of the three organic food principles, and in this way may supplement and complete the action of the fluids previously mentioned, {96}
viz.:—of the saliva in converting starch into sugar, of the gastric juice in digesting the albuminoids, and of the pancreatic juice and bile in emulsifying the fats.

**36, 37.** How much thus far has been done with the food? The next process? Give the first way.

**36. Absorption.**—With the elaboration of the chyle, the work of digestion is completed; but, in a certain sense, the food is yet outside of the body; that is, the blood is not yet enriched by it, and it is not in a position to nourish the tissues. The process by which the liquefied food passes out of the alimentary canal into the blood is called absorption. This is accomplished in two ways; first, by the *blood-vessels*. We have seen how the inner membrane of the stomach is underlaid by a tracery of minute and numerous vessels, and how some portions of the food are by them absorbed. The supply of blood-vessels to the intestines is even greater; particularly to the small intestines, where the work of absorption is more actively carried on.

**37.** The absorbing surface of the small intestines, if considered as a plane surface, amounts to not less than half a square yard. Besides, the mucous membrane is formed in folds with an immense number of thread-like prolongations, called *villi*, which indefinitely multiply its absorbing capacity. These minute processes, the villi, give the surface the appearance and smoothness of velvet; and during digestion, they dip into the canal, and, by means of their blood-vessels, absorb its fluid contents, just as the *spongioles* which terminate the rootlets of plants, imbibe moisture from the surrounding soil.

**38.** How is absorption effected in another way? Describe it. Name of the lacteals? Thoracic duct?

**38.** Secondly, absorption is also effected by the *lacteals*, a set of vessels peculiar to the small intestines. These have their beginnings in the little villi just mentioned, side by side with the blood-vessels. These two sets of absorbents run in different courses, but their destination is the same, which is the right side of the heart. The lacteals {97}
receive their name from their milky-white appearance. After a meal containing a portion of fat, they are then distended with chyle, which they are specially adapted to receive: at other times they are hardly discernible. The lacteals all unite to form one tube, the *thoracic duct*, which passes upward through the *thorax*, or chest, and empties into a large vein, situated just beneath the left collar-bone.

**39. The Absorbents.**—The lacteals belong to a class of vessels known as absorbents, or lymphatics, which ramify in nearly all parts of the body, except the brain and spinal cord. The fluid which circulates through the lymphatics of the limbs, and all the organs not concerned in digestion, is called *lymph*. This fluid is clear and colorless, like water, and thus differs from the milky chyle which the lacteals carry after digestion: it consists chiefly of the watery part of the blood, which was not required by the tissues, and is returned to the blood by the absorbents or lymphatics.

**39.** The absorbents? Lymph? What further of the lymph?

**40.** What can you state as to the time required for digestion?

**40. Circumstances affecting Digestion.**—What length of time is required for the digestion of food? From observations made, in the case of St. Martin, the Canadian already referred to, it has been ascertained that, at the end of two hours after a meal, the stomach is ordinarily empty. How much time is needed to complete the digestion of food, within the small intestines, is not certain; but, from what we have learned respecting their functions, it must be evident that it largely depends upon the amount of starch and fat which the food contains. {98}

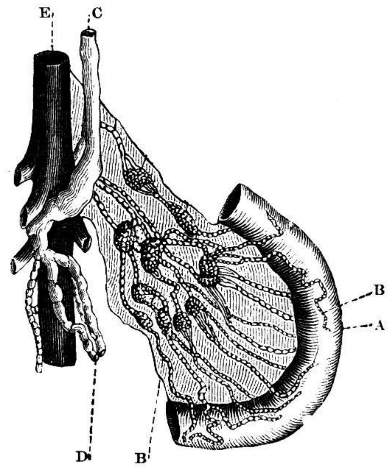



Fig. 24.—The Lacteals.
A, Small Intestine. B, Lacteals. C, Thoracic Duct. D, Absorbents. E, Blood-vessel.

**41.** Circumstances affecting duration of digestion? Fresh food?

**41.** In addition to the preparations which the food undergoes in cooking, which we have already considered, many circumstances affect the duration of digestion; such as the quality, quantity, and temperature of the food; the condition of the mind and body; sleep, exercise, and habit. Fresh food, except new bread and the flesh of animals recently slain, is more rapidly digested than that which is stale; and animal food more rapidly than that from the vegetable kingdom.

**42.** Food in concentrated form? A large quantity of food? Experiment on the dog? Ice-water? Variety of articles?

**42.** Food should not be taken in too concentrated a form, the action of the stomach being favored when it is somewhat bulky; but a large quantity in the stomach often retards digestion. If the white of one egg be given to a dog, it will be digested in an hour, but if the white of eight eggs be given it will not disappear in four hours. A wineglassful of ice-water causes the temperature of the stomach to fall thirty degrees; and it requires a half-hour before it will recover its natural warmth—about a hundred degrees—at which the operations of digestion are best conducted. A variety of articles, if not too large in amount, is more easily disposed of than a meal made of a single article; although a single indigestible article may interfere with the reduction of articles that are easily digested.

**43.** Strong emotion? The tongue of the patient?

**43.** Strong emotion, whether of excitement or depression, checks digestion, as do also a bad temper, anxiety, long fasting, and bodily fatigue. The majority of these conditions make the mouth dry, that is, they restrain the flow of the saliva; and {99} without doubt they render the stomach dry also, by preventing the flow of the gastric juice. And, as a general rule, we may decide, from a parched and coated tongue, that the condition of the stomach is not very dissimilar, and that it is unfit for the performance of digestive labor. This is one of the points which the physician bears in mind when he examines the tongue of his patient.

**44.** Eating between meals? Severe exercise? Sleep after meals?

**44.** The practice of eating at short intervals, or "between meals," as it is called, has its disadvantage, as well as rapid eating and over-eating, since it robs the stomach of its needed period of entire rest, and thus overtasks its power. With the exception of infants and the sick, no persons require food more frequently than once in four hours. Severe exercise either directly before or directly after eating retards digestion; a period of repose is most favorable to the proper action of the stomach. The natural inclination to rest after a hearty meal may be indulged, but should not be carried to the extent of sleeping; since in that state the stomach, as well as the brain and the muscles, seeks release from labor.

## QUESTIONS FOR TOPICAL REVIEW. {100}

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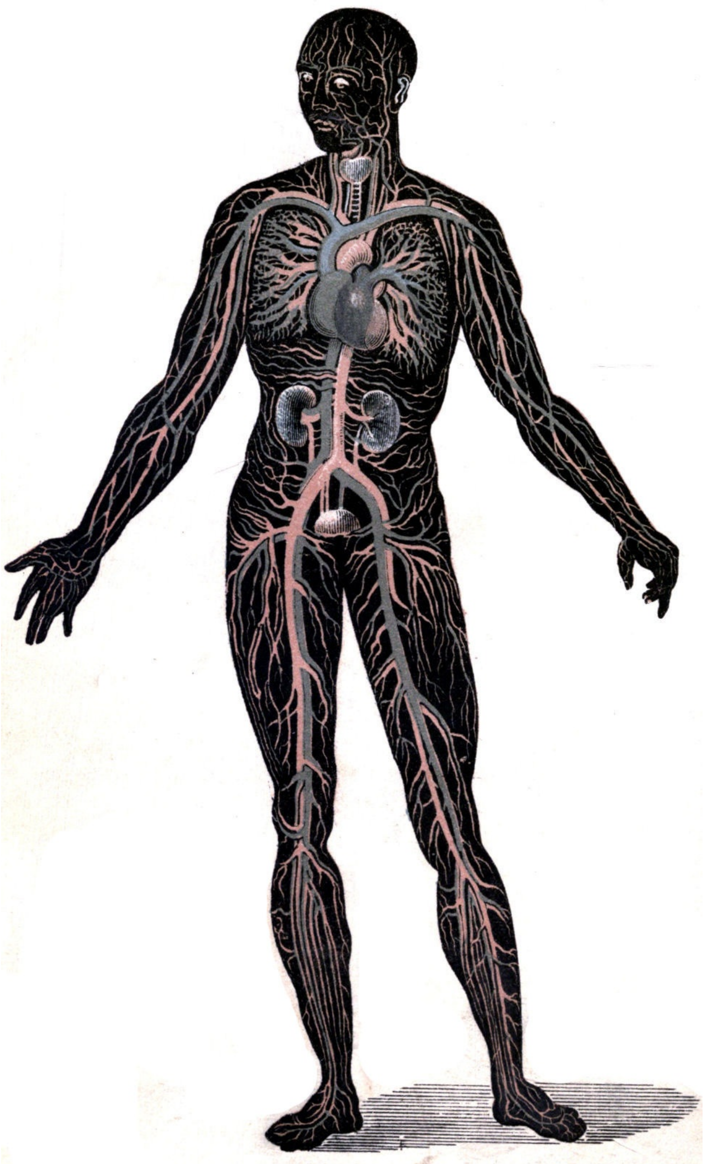

CIRCULATION OF THE BLOOD.
[Heart, Lungs, Arteries & Veins.]



## CHAPTER VII.

## The Circulation.

*The Blood—Its Plasma and Corpuscles—Coagulation of the Blood—The Uses of the Blood—Transfusion—Change of Color—The Organs of the Circulation—The Heart, Arteries, and Veins—The Cavities and Valves of the Heart—Its Vital Energy—Passage of the Blood through the Heart—The Frequency and Activity of its Movements—The Pulse—The Sphygmograph—The Capillary Blood-vessels—The Rate of the Circulation—Assimilation—Injuries to the Blood-vessels.*

**1.** What is required by every living organism? In plants? Insects? Reptiles? Man?

**1. The Blood.**—Every living organism of the higher sort, whether animal or vegetable, requires for the maintenance of life and activity, a circulatory fluid, by which nutriment is distributed to all its parts. In plants, this fluid is the sap; in insects, it is a watery and colorless blood; in reptiles and fishes, it is red but cold blood; while in the nobler animals and man, it is the red and warm blood.

**2.** Importance and abundance of blood? Dependence of life? Abel? Mosaic law? In what part of the body is blood not found? Quantity of blood in the body?

**2.** The blood is the most important, as it is the most abundant, fluid of the body; and upon its presence, under certain definite conditions, life depends. On this account it is frequently, and very properly, termed "the vital fluid." The importance of the blood, as essential to life, was recognized in the earliest writings. In the narration of the death of the murdered Abel, it is written, "the voice of his *blood* crieth from the ground." In the Mosaic law, proclaimed over thirty centuries ago, the Israelites were forbidden to eat food that contained blood, for the reason that "the life of the flesh is in the blood." With the exception of a few tissues, such as the hair, the nails, and the *cornea* of the eye, blood everywhere pervades the body, as may be proven by puncturing any part with a needle. The total quantity of blood in the body is {102}
estimated at about one-eighth of its weight, or eighteen pounds.

**3.** Color of blood? Its consistence? Odor?

**3.** The color of the blood, in man and the higher animals, as is well known, is red; but it varies from a bright scarlet to a dark purple, according to the part whence it is taken. "Blood is thicker than water," as the adage truly states, and has a glutinous quality. It has a faint odor, resembling that peculiar to the animal from which it is taken.

**4.** What is stated of the blood as viewed under the microscope?

**4.** When examined under the microscope, the blood no longer appears a simple fluid, and its color is no longer red. It is then seen to be made up of two distinct parts: first, a clear, colorless fluid, called the *plasma*; and secondly, of a multitude of minute solid bodies, or corpuscles, that float in the watery plasma. The plasma, or nutritive liquid, is composed of water richly charged with materials derived from the food, viz., albumen, which gives it smoothness and swift motion; fibrin; certain fats; traces of sugar; and various salts.

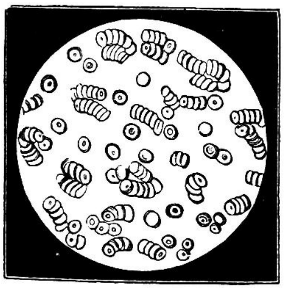

Fig 25.—The Blood Corpuscles.

**5.** State what you can of the little bodies called corpuscles.

**5. The Blood Corpuscles.**—In man, these remarkable "little bodies," as the word *corpuscles* signifies, are of a yellow color, but by their vast numbers impart a red hue to the blood. They are very small, having a diameter of about 1/3500 of an inch, and being one-fourth of that fraction in thickness; so that if 3,500 of them were placed in line, side by side, they would only extend one inch; or, if piled one above another, it {103}
would take at least 14,000 of them to stand an inch high. Although so small in size, they are very regular in form. As seen under the microscope, they are not globular or spherical, but flat, circular, and disc-like, with central depressions on each side, somewhat like a pearl button that has not been perforated. In freshly-drawn blood they show a disposition to arrange themselves in little rolls like coins (Fig. 25).

**6.** The size and shape of the blood corpuscles vary in different animals, so that it is possible to discriminate between those of man and the lower animals (Fig. 26). This is a point of considerable practical importance. For example, it is sometimes desirable to decide in a court of justice the source, whether from man or an inferior animal, of blood stains upon the clothing of an accused person, or upon some deadly weapon. This may be done by a microscopical examination of a minute portion of the dried stain, previously refreshed by means of gum-water. Certain celebrated cases are recorded in which the guilt of criminals has been established, and they have been condemned and punished upon the evidence which science rendered on this single point, the detecting of the human from other blood.

**6.** The size and shape of corpuscles? Why is the fact important?

**7.** The character of the blood of dead animals? Means of detecting such blood?

**7.** The character of the blood of dead, extinct, and even fossil animals, such as the mastodon, has been ascertained by obtaining and examining traces of it which had been shut up, perhaps for ages, in the circulatory canals of bone. A means of detecting blood in minute quantities is found in the spectroscope, the same {104} instrument by which the constitution of the heavenly bodies has been studied. If a solution containing not more than one-thousandth part of a grain of the coloring matter of the corpuscle, be examined, this instrument will detect it.

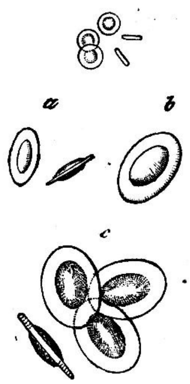


FIG. 26.
*a*, Oval Corpuscles of a fowl. *b*, Corpuscles of a frog. *c*, Those of a shark.
The five small ones at the upper part of the figure, represent the human corpuscles magnified 400 times.

**8.** White corpuscles? Total number of corpuscles in the body?

**8.** The corpuscles, just described, are known as the red blood corpuscles. Besides these, and floating along in the same plasma, are the white corpuscles. These are fewer in number, but larger and globular in form. They are colorless, and their motion is less rapid than that of the other variety. The total number of both varieties of these little bodies in the blood is enormous. It is calculated that in a cubic inch of that fluid there are eighty-three millions, and at least five hundred times that number in the whole body.

**9.** The blood in its natural condition in the body? Describe the process by which the coagulation of blood takes place?

**9. Coagulation.**—The blood, in its natural condition in the body, remains perfectly fluid; but, within a few minutes after its removal from its proper vessels, whether by accident or design, a change takes place. It begins to coagulate, or assume a semi-solid consistence. If allowed to stand, after several hours it separates into two distinct parts, one of them being a dark red jelly, the coagulum, or clot, which is heavy and sinks; and the other, a clear, straw-colored liquid, called serum, which covers the clot. This change is dependent upon the presence in the blood of fibrin, which possesses the property of solidifying under certain circumstances; one of these circumstances being when the blood is separated from living tissues. The color of the clot is due to the entanglement of the corpuscles with the fibrin.

**10.** If coagulation were impossible? How is it in fact?

**10.** In this law of the coagulation of the blood is our safeguard against death by hæmorrhage, or against undue loss of blood. If coagulation were impossible, the slightest injury in drawing blood would prove fatal. Whereas now, in vastly the larger {105} proportion of cases, bleeding ceases spontaneously, because the blood, as it coagulates, stops the mouths of the injured blood-vessels. In another class of cases, where larger vessels are cut or torn, it is simply necessary to close them by a temporary pressure; for in a few minutes the clot will form and seal them up. In still more serious cases, where the blood-vessel is of large size, the surgeon is obliged to tie a "ligature" about it, and thus prevent the force of the blood-current from washing away the clots, which, forming within and around the vessel, would close it effectually.

**11.** What is worthy of remark? Coagulation of the blood of inferior animals? Of the blood of birds?

**11.** It is worthy of remark that this peculiarity is early implanted in the blood, even before birth, and in advance of any existing necessity for it; thus anticipating and guarding against danger. But this is not all. Of most of the inferior animals, which, as compared with man, are quite helpless, the blood coagulates more rapidly, and in the case of the birds, almost instantly. The relative composition of fluid and coagulated blood may be thus represented:

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   Fluid Blood.               Coagulated Blood.

     Plasma----------Serum---------Serum
           \
            \
             --------Fibrin--------
                                  \
                                   \
    Corpuscles------Corpuscles-------Clot.
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**12.** The blood, as a provider and purifier? What uses does the blood subserve? Experiments? Transfusion?

**12. The Uses of the Blood.**—The blood is the great provider and purifier of the body. It both carries new materials to all the tissues, and removes the worn out particles of matter. This is effected by the plasma. It both conveys oxygen and removes carbonic acid. This is done through the corpuscles. Some singular experiments have been tried to illustrate the life-giving power of the blood. An animal {106} that has bled so freely as to be at the point of dying, is promptly brought back to life by an operation called transfusion, by which fresh blood from a living animal is injected into the blood-vessels of his body.

**13.** The case of the deaf and feeble dog? Horse? Dead dog?

**13.** It is related that a dog, deaf and feeble from age, had hearing and activity restored to him by the introduction into his veins of blood taken from a young dog; and, that a horse, twenty-six years old, having received the blood of four lambs acquired new vigor. And further, that a dog, just dead from an acute disease, was so far revived by transfusion, as to be able to stand and make a few movements.

**14.** Transfusion, as a fashionable remedy? What further of transfusion?

**14.** Transfusion has been practised upon man. At one time, shortly after Harvey's discovery of the "Circulation of the Blood," it became quite a fashionable remedy, it being thought possible by it to cure all forms of disease, and even to make the old young again. But these claims were soon found extravagant, and many unhappy accidents occurred in its practice; so that being forbidden by government and interdicted by the Pope, it rapidly fell into disuse. At the present time, however, it is sometimes resorted to in extreme cases, when there has been a great and rapid loss of blood; and there are upon record several instances where, other means having failed, life has been restored or prolonged by the operation of transfusion.

**15.** The seat of the reviving power of the blood? What further is related?

**15.** This reviving power of the blood seems to reside in the corpuscles; for transfusion, when attempted to be performed with the serum alone, has, in every case, proved fruitless. Now, though so much depends upon the blood and its corpuscles, it is a mistake to suppose that in them alone is the seat of life, or that they are, in an exclusive manner, alive. All the organs and parts of the body are mutually dependent one upon the other; and the complete usefulness of the blood, or of any {107}
other part, flows out of the harmonious action of all the parts.

**16.** Changes in the blood? What further is stated?

**16. Change of Color.**—The blood undergoes a variety of changes in its journey through the system. As it visits the different organs it both gives out and takes up materials. In one place it is enriched, in another it is impoverished. By reason of these alterations in its composition, the blood also changes its color. In one part of the body it is bright red, or arterial; in another it is dark blue, or venous. In the former case it is pure and fit for the support of the tissues; in the latter, it is impure and charged with effete materials. (The details of the change from dark to bright will be given in the chapter on Respiration.)

**17.** Motion of the blood? What is meant by the circulation of the blood? How confined? Discovery made by Harvey?

**17. Circulation.**—The blood is in constant motion during life. From the heart, as a centre, a current is always setting toward the different organs; and from these organs a current is constantly returning to the heart. In this way a ceaseless circular movement is kept up, which is called the Circulation of the Blood. This stream of the vital fluid is confined to certain fixed channels, the blood-vessels. Those branching from the heart are the arteries; those converging to it are the veins. The true course of the blood was unknown before the beginning of the seventeenth century. In 1619 it was discovered by the illustrious William Harvey. Like many other great discoverers, he suffered persecution and loss, but unlike some of them, he was fortunate enough to conquer and survive opposition. He lived long enough to see his discovery universally accepted, and himself honored as a benefactor of mankind.

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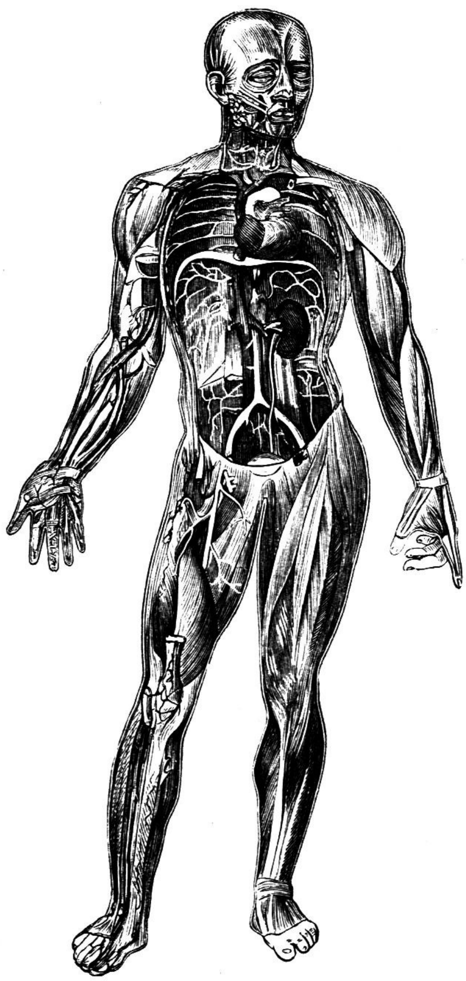

FIG. 27.—THE ORGANS OF CIRCULATION.

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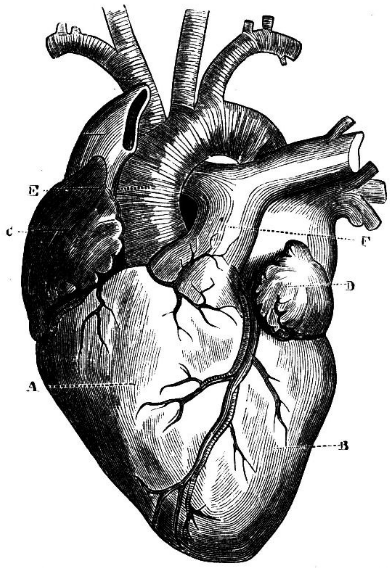


FIG. 28.—THE HEART AND LARGE VESSELS.
A, Right Ventricle. B, Left Ventricle.
C, Right Auricle. D, Left Auricle.
E, Aorta. F, Pulmonary Artery.

**18.** Office of the heart? Location of the heart? Its beat? Its shape? Protection to the heart? What else is said in relation to the heart?

**18. The Heart.**—The heart is the central engine of the circulation. In this wonderful little organ, hardly larger than a man's fist, resides that sleepless force by which, during the whole of life, the current of the blood is kept in motion. It is placed in the middle and front part of the chest, inclining to the left side. The heartbeat may be felt and heard between the fifth and sixth ribs, near the breast-bone. The shape of the heart is conical, with the apex or point downward and in front. The base, which is upward, is attached so as to hold it securely in its place, while the apex is freely moveable. In order that loss of power from friction may be obviated, the heart is enclosed between two layers of serous membrane, which forms a kind of sac. This membrane is as smooth as satin, and itself secretes a fluid in sufficient quantities to keep it at all times well lubricated. The lining membrane of the heart, likewise, is extremely delicate and smooth.

**19.** Formation of the heart? Right and left heart?

**19. The Cavities of the Heart.**—The heart is {110}
hollow, and so partitioned as to contain four chambers or cavities; two at the base, known as the *auricles*, from a fancied resemblance to the ear of a dog, and two at the apex or point, called *ventricles*. An auricle and a ventricle on the same side, communicate with each other, but there is no opening from side to side. It is customary to regard the heart as a double organ, and to speak of its division into the right and left heart. For while both halves act together in point of time, each half sustains an entirely distinct portion of the labor of the circulation. Thus, the right heart always carries the dark or venous blood, and the left always circulates the bright or arterial blood.

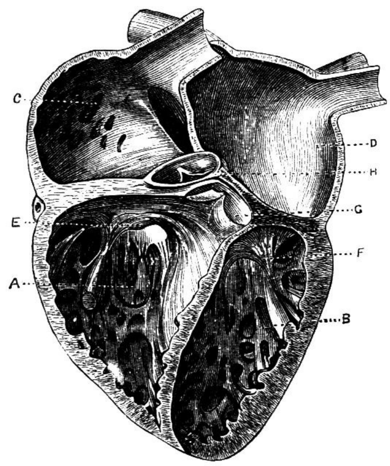


FIG. 29.—SECTION OF THE HEART.
A, Right Ventricle. B, Left Ventricle.
C, Right Auricle. D, Left Auricle.
E, F, Inlets to the Ventricles.
G, Pulmonary Artery. H, Aorta.

**20.** Capacity of the chambers of the heart? What wise provision is mentioned? The auricles?

**20.** If we examine the heart, we at once notice that though its various chambers have about the same capacity, the walls of the ventricles are thicker and stronger than those of the auricles. This is a wise provision, for it is by the powerful action of the former that the blood is forced to the most remote regions of the body. The auricles, on the contrary, need much less power, for they simply discharge their contents into the
cavities of the heart near at hand and below them—into the ventricles. {111}

**21.** Substance of the heart? Its fibres? Its movements? The advantage of such movements? Action of the heart? Its period of repose?

**21. Action of the Heart.**—The substance of the heart is of a deep red color, and its fibres resemble those of the voluntary muscles by which we move our bodies. But the heart's movements are entirely involuntary. The advantage of this is evident; for if it depended upon us to will each movement, our entire attention would be thus engaged, and we would find no time for study, pleasure, or even sleep. The action of the heart consists in alternate contractions and dilatations. During contraction the walls come forcibly together, and thus drive out the blood. In dilatation, they expand and receive a renewed supply. These movements are called *systole* and *diastole*. The latter may be called the heart's period of repose; and although it lasts only during two-fifths of a heart-beat, or about a third of a second, yet during the day it amounts to more than nine hours of total rest.

**22.** Remarkable property of the tissue of the heart? How shown? How interesting? In cold-blooded animals? Heart of a turtle? Of a frog? Alligator?

**22.** A remarkable property of the tissue of the heart is its intense vitality. For while it is more constantly active than any other organ of the body, it is the last to part with its vital energy. This is especially interesting in view of the fact that after life is apparently extinguished, as from drowning, or poisoning by chloroform, there yet lingers a spark of vitality in the heart, which, by continued effort, may be fanned into a flame so as to revivify the whole body. In cold-blooded animals this irritability of the heart is especially remarkable. The heart of a turtle will pulsate, and the blood circulate for a week after its head has been cut off; and the heart will throb regularly many hours after being cut out from the creature's chest. The heart of a frog or serpent, separated entirely from the body, will contract at the end of ten or twelve hours: that of an alligator has been known to beat twenty-eight hours after the death of the animal. {112}

**23.** Course of the blood through the heart? Course of heart-currents?

**23. Passage of the Blood through the Heart.**—Let us now trace the course of the blood through the several cavities of the heart. In the first place, the venous blood, rendered dark and impure by contact with the changing tissues of the body, returns to the right heart by the veins. It enters and fills the right auricle during its dilatation: the auricle then contracts and fills the right ventricle. Almost instantly, the ventricle contracts forcibly and hurries the blood along the great artery of the lungs, to be purified in those organs. Secondly, having completed the circuit of the lungs, the pure and bright arterial blood enters the left auricle. This now contracts and fills the left ventricle, which cavity, in its turn, contracts and sends the blood forth on its journey again through the system. This general direction from right to left is the uniform and undeviating course of heart-currents.

**24.** Openings of the ventricles? How guarded? How do the valves operate? The consequence? Heart-sounds?

**24.** The mechanism which enforces and regulates it, is as simple as it is beautiful. Each ventricle has two openings, an inlet and an outlet, each of which is guarded by strong curtains, or valves. These valves open freely to admit the blood entering from the right, but close inflexibly against its return. Thus, when the auricle contracts, the inlet valve opens; but as soon as the ventricle begins to contract, it closes promptly. The contents are then, so to speak, cornered, and have but one avenue of escape, that through the outlet valve into the arteries beyond. As soon as the ventricle begins to dilate again, this valve shuts tightly and obstructs the passage. The closing of these valves occasions the two heart-sounds, which we hear at the front of the chest.

**25.** Heart-beats? The heart as a susceptible organ? Heat, exercise, etc.? Posture?

**25. Frequency of the Heart's Action.**—The alternation of contraction and dilation constitutes the heartbeats. These follow each other not only with great regularity, but {113} with great rapidity. The average number in an adult man is about seventy-two in a minute. But the heart is a susceptible organ, and many circumstances affect its rate of action. Heat, exercise, and food will increase its action, as cold, fasting, and sleep will decrease it. Posture, too, has a curious influence; for if while sitting, the beats of the heart number seventy-one; standing erect will increase them to eighty-one, and lying down will lower them to sixty-six.

**26.** Mental emotions? Sudden excitement? Excessive joy? The heart-beat rate? Bonaparte and Wellington?

**26.** The modifying influence of mental emotions is very powerful. Sudden excitement of feeling will cause the heart to palpitate, or throb violently. Depressing emotions sometimes temporarily interrupt its movements, and the person faints in consequence. Excessive joy, grief, or fear, has occasionally suspended the heart's action entirely, and thus caused death. The rate of the heart-beat may be naturally above or below seventy-two. Thus it is stated that the pulse of the savage is always slower than that of the civilized man. Bonaparte and Wellington were very much alike in their heart's pulsations, which were less than fifty in the case of each.

**27.** Average number of heart-beats? In one hour? Year? Lifetime?

**27. Activity of the Heart.**—The average number of heart-beats during a lifetime may be considered as at the rate of seventy-two per minute, although this estimate is probably low; for during several years of early life the rate is above one hundred a minute. In one hour, then, the heart pulsates four thousand times; in a day, one hundred thousand times; and in a year, nearly thirty-eight million times. If we compute the number during a lifetime, thirty-nine years being the present average longevity of civilized mankind, we obtain as the vast aggregate, fourteen hundred millions of pulsations. {114}

**28.** Amount of blood expelled? Theories of the ancients?

**28.** Again, if we estimate the amount of blood expelled by each contraction of the ventricles, at four ounces, then the weight of the blood moved during one minute will amount to eighteen pounds. In a day it will be about twelve tons; in a year, four thousand tons; and in the course of a lifetime, over one hundred and fifty thousand tons. These large figures indicate, in some measure, the immense labor necessary to carry on the interior and vital operations of our bodies. In this connection, we call to mind the fanciful theories of the ancients in reference to the uses of the heart. They regarded it as the abode of the soul, and the source of the nobler emotions—bravery, generosity, mercy, and love. The words courage and cordiality are derived from a Latin word signifying heart. Many other words and phrases, as hearty, heart-felt, to learn by heart, and large-hearted, show how tenaciously these exploded opinions have fastened themselves upon our language.

**29.** The tendency at the present time?

**29.** At the present time the tendency is to ascribe purely mechanical functions to the heart. This view, like the older one, is inadequate; for it expresses only a small part of

Why is this view inadequate?

our knowledge of this organ. The heart is unlike a simple machine, because its motive power is not applied from without, but resides in its own substance. Moreover, it repairs its own waste, it lubricates its own action, and it modifies its movements according to the varying needs of the system. It is more than a mere force-pump, just as the stomach is something more than a crucible, and the eye something more than an optical instrument.

**30.** What are the arteries? Their walls? Their membrane?

**30. The Arteries.**—The tube-like canals which carry the blood away from the heart are the arteries. Their walls are made of tough, fibrous materials, so that they sustain the mighty impulse of the heart, and are not ruptured. In common with the heart, the arteries have a delicately smooth lining membrane. They are also elastic, and thus re- {115}
enforce the action of the heart: they always remain open when cut across, and after death are always found empty.

**31.** Early anatomists? The service of the illustration?

**31.** The early anatomists observed this phenomenon, and supposing that the same condition existed during life, came to the conclusion that these tubes were designed to act as air-vessels, hence the name artery, from a Greek word which signifies containing air. This circumstance affords us an illustration of the confused notions of the ancients in reference to the internal operations of the body. Cicero speaks of the arteries as "conveying the breath to all parts of the body."

**32.** The arterial system? The branches and sub-branches of the arteries?

**32.** The arterial system springs from the heart by a single trunk, like a minute and hollow tree, with numberless branches. As these branches leave the heart they divide and subdivide, continually growing smaller and smaller, until they can no longer be traced with the naked eye. If, then, we continue the examination by the aid of a microscope, we see these small branches sending off still smaller ones, until all the organs of the body are penetrated by arteries.

**33.** Successive undulations from the heart? Course of the arteries? Protection of the arteries? General location of the arteries?

**33. The Pulse.**—With each contraction of the left heart, the impulse causes a wave-like motion to traverse the entire arterial system. If the arteries were exposed to view, we might see successive undulations speeding from the heart to the smallest of the branches, in about one-sixth part of a second. The general course of the arteries is as far as possible from the surface. This arrangement is certainly wise, as it renders them less liable to injury, the wounding of an artery being especially dangerous. It also protects the arteries from external and unequal pressure, by which the force of the heart would be counteracted and wasted. Accordingly, we generally {116}
find these vessels hugging close to the bones, or hiding behind the muscles and within the cavities of the body.

**34.** Where do the arteries lie? If we apply the finger? Pulse? Where felt?

**34.** In a few situations, however, the arteries lie near the surface; and if we apply the finger to any of these parts, we will distinctly feel the movement described, taking place in harmony with the heart-beat. This is part of the wave-motion just mentioned, and is known as the pulse. All are more familiar with the pulse at the wrist, in the *radial* artery; but the pulse is not peculiar to that position, for it may be felt in the *carotid* of the neck, in the *temporal* at the temple, and elsewhere, especially near the joints.

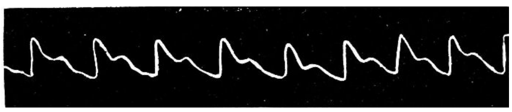

Fig. 30.—The Form of the Pulse.

**35.** The pulse as an index? Of what does it inform the physician? Instrument for recording pulsation?

**35.** Since the heart-beat makes the pulse, whatever affects the former affects the latter also. Accordingly, the pulse is a good index of the state of the health, so far as the health depends upon the action of the heart. It informs the physician of the condition of the circulation in four particulars: its rate, regularity, force, and fullness; and nearly every disease modifies in some respect the condition of the pulse. A very ingenious instrument, known as the sphygmograph, or pulse-writer, has recently been invented, by the aid of which the pulse is made to write upon paper its own signature, or rather to sketch its own profile. This instrument shows with great accuracy the difference between the pulses of health and those of disease. In Fig. 30 is traced the form of the pulse in health, which should be read from left to right. That part of the trace which is nearly perpendicular coincides with the contraction of the {117}
ventricles; while the wavy portion marks their dilatation.

**36.** What are the veins? How do they form? What do they resemble?

**36. The Veins.**—The vessels which convey the blood on its return to the heart are the veins. They begin in the several organs of the body, and at first are extremely small; but uniting together as they advance, they constantly increase in size, reminding us of the way in which the fine rootlets of the plant join together to form the large roots, or of the rills and rivulets that flow together to form the large streams and rivers. In structure, the veins resemble the arteries, but their walls are comparatively inelastic. They are more numerous, and communicate with each other freely in their course, by means of interlacing branches.

**37.** But the chief point of distinction is in the presence of the valves in the veins. These are little folds of membrane, disposed in such a way, that they only open to

**37.** Valves in the veins? What are they? Their position? Experiment with the cord?

receive blood flowing toward the heart, and close against a current in the opposite direction. Their position in the veins on the back of the hand may be readily observed, if we first obstruct the return of blood by a cord tied around the forearm or wrist. In a few minutes the veins will appear swollen, and upon them will be seen certain prominences, about an inch apart. These latter indicate the location of the valves, or, rather, they show that the vessels in front of the valves are distended by the blood, which cannot force a passage back through them.

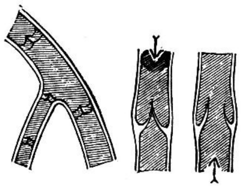

FIG. 31.—THE VALVES OF THE VEINS.

**38.** What will be proved by the experiment? What inference is drawn?

**38.** This simple experiment proves that the true direction of the venous blood is toward the heart. That the color of the blood is dark, will be evident, if we compare {118}
the hand thus bound by a cord with the hand not so bound. It also proves that the veins lie superficially, while the arteries are beneath the muscles, well protected from pressure; and that free communication exists from one vein to another. If now we test the temperature of the constricted member by means of a thermometer, we will find that it is colder than natural, although the amount of blood is larger than usual. From this fact we infer, that whatever impedes the venous circulation tends to diminish vitality; and hence, articles of clothing or constrained postures, that confine the body or limbs, and hinder the circulation of the blood, are to be avoided as injurious to the health.

**39.** Capillaries? How regarded? Harvey?

**39. The Capillaries.**—A third set of vessels completes the list of the organs of the circulation, namely, the *capillary* vessels, so called (from the Latin word *capillaris*, hair-like), because of their extreme fineness. They are, however, smaller than any hair, having a diameter of about 1/3000 of an inch, and can only be observed by the use of the microscope. These vessels may be regarded as the connecting link between the last of the arteries and the first of the veins. The existence of these vessels was unknown to Harvey, and was the one step wanting to complete his great work. The capillaries were not discovered until 1661, a short time after the invention of the microscope.

**40.** The circulation of the blood in the web of a frog's foot? Describe it. How general is the existence of the tissues?

**40.** The circulation of the blood, as seen under the microscope, in the transparent web of a frog's foot, is a spectacle of rare beauty, possessing more than ordinary interest, when we consider that something very similar is taking place in our own bodies, on a most magnificent scale. It is like opening a secret page in the history of our own frames. We there see distinctly the three classes of vessels with their moving contents; first, the artery, with its torrent of blood rushing down from the heart, {119}
secondly, the vein, with its slow, steady stream flowing in the opposite direction; and between them lies the network of capillaries, so fine that the corpuscles can only pass through "in single file." The current has here an uncertain or swaying motion, hurrying first in one direction, then hesitating, and then turning back in the opposite direction, and sometimes the capillaries contract so as to be entirely empty. Certain of the tissues are destitute of capillaries; such are cartilage, hair, and a few others on the exterior of the body. In all other structures, networks of these vessels are spread out in countless numbers: so abundant is the supply, that it is almost impossible to puncture any part with the point of a needle without lacerating tens, or even hundreds of these vessels.

**41.** Elasticity of the capillaries? Grain of sand in the eye? Blush? Other cases?

**41.** The capillaries are elastic, and may so expand as to produce an effect visible to the naked eye. If a grain of sand, or some other foreign particle, lodge in the eye, it will become irritated, and in a short time the white of the eye will be "blood-shot." This appearance is due to an increase in the size of these vessels. A blush is another example of this, but the excitement comes through the nervous system, and the cause is some transient emotion, either of pleasure or pain. Another example is sometimes seen in purplish faces of men addicted to drinking brandy; in them the condition is a congestion of the capillary circulation, and is permanent, the vessels having lost their power of elastic contraction. {120}

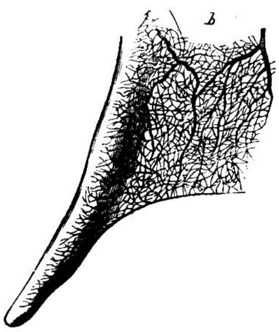

FIG. 32.—WEB OF A FROG'S FOOT, slightly magnified.

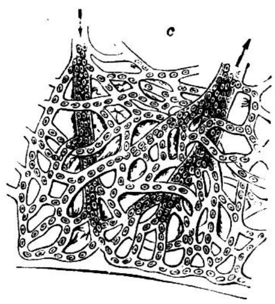

FIG. 33.—MARGIN OF FROG'S WEB magnified 30 diameters.

**42.** Show what time is required for a given portion of blood to travel once around the body.

**42. Rapidity of the Circulation.**—That the blood moves with great rapidity is evident from the almost instant effects of certain poisons, as prussic acid, which act through the blood. Experiments upon the horse, dog, and other inferior animals, have been made to measure its velocity. If a substance, which is capable of a distinct chemical reaction (as *potassium ferrocyanide*, or *barium nitrate*), be introduced into a vein of a horse on one side, and blood be taken from a distant vein on the other side, its presence may be detected at the end of twenty or thirty-two seconds. In man, the blood moves with greater speed, and the circuit is completed in twenty-four seconds.

**43.** Time required for all the blood to circulate completely around?

**43.** What length of time is required for all the blood of the body to make a complete round of the circulation? This question cannot be answered with absolute accuracy, since the amount of the blood is subject to continual variations. But, if we assume this to be one-eighth of the weight of the body, about eighteen pounds, it will be sufficiently correct for our purpose. Now to complete the circuit, this blood must pass once through the left ventricle, the capacity of which is two ounces. Accordingly, we find that, under ordinary circumstances, all the blood makes one complete rotation every two minutes; passing successively through the heart, the capillaries of the lungs, the arteries, the capillaries of the extremities, and through the veins. {121}

**44.** What is meant by assimilation? What can you say of its use, etc.? Time?

**44. Assimilation.**—The crowning act of the circulation, the furnishing of supplies to the different parts of the body, is effected by means of the capillaries. The organs have been wasted by use; the blood has been enriched by the products of digestion. Here, within the meshes of the capillary network, the needy tissues and the needed nutriment are brought together. By some mysterious chemistry, each tissue selects and withdraws from the blood the materials it requires, and converts them into a substance like itself. This conversion of lifeless food into living tissue is called assimilation. The process probably takes place at all times, but the period especially favorable for it is during sleep. Then the circulation is slower, and more regular, and most of the functions are at rest. The body is then like some trusty ship, which after a long voyage is "hauled up for repairs."

**45.** What is stated of the injuries to the blood-vessels?

**45. Injuries to the Blood-vessels.**—It is important to be able to discriminate between an artery and a vein, in the case of a wound, and if we remember the physiology of the circulation we may readily do so. For, as we have already seen, hæmorrhage from an artery is much more dangerous than that from a vein. The latter tends to cease spontaneously after a short time. The arterial blood flows away from the heart with considerable force, in jets; its color being bright scarlet. The venous blood flows toward the heart from that side of the wound furthest from the heart; its stream being continuous and sluggish; its color dark. In an injury to an artery, pressure should be made between the heart and the wound; and in the case of a vein that persistently bleeds, it should be made upon the vessel beyond its point of injury. {122}

## QUESTIONS FOR TOPICAL REVIEW.

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| 1. In what organisms is the so-called circulatory fluid found? | 101 |
| 2. How is it designated in the different organisms? | 101 |
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| 19. What changes take place in the color of the blood in its journey through the system? | 107 |
| 20. State all you can in relation to the circulation of the blood. | 107 |
| 21. All, in relation to the size, shape, and location of the heart. | 107, 109 |
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CHAPTER VIII. {123}

## RESPIRATION.

*The Objects of Respiration—The Lungs—The Air-Passages—The Movements of Respiration—Expiration and Inspiration—The Frequency of Respiration—Capacity of the Lungs—The Air we breathe—Changes in the Air from Respiration—Changes in the Blood—Interchange of Gases in the Lungs—Comparison between Arterial and Venous Blood—Respiratory Labor—Impurities of the Air—Dust—Carbonic Acid—Effects of Impure Air—Nature's Provision for Purifying the Air—Ventilation—Animal Heat—Spontaneous Combustion.*

**1.** Difference between the two sets of capillaries? Change effected by respiration or breathing?

**1. The Object of Respiration.**—In one set of capillaries, or hair-like vessels, the blood is impoverished for the support of the different members and organs of the body. In another capillary system the blood is refreshed and again made fit to sustain life. The former belongs to the greater or *systemic* circulation; the latter to the lesser or *pulmonary*, so called from *pulmo*, the lungs, in which organs it is situated. The blood, as sent from the right side of the heart to the lungs, is venous, dark, impure, and of a nature unfit to circulate again through the tissues. But, when the blood returns from the lungs to the left side of the heart, it has become arterial, bright, pure, and no longer hurtful to the tissues. This marvellous purifying change is effected by means of the very familiar act of respiration, or breathing.

**2.** What are the lungs? How many lungs are there? Lung-substance? Its properties? The pleura?

**2. The Lungs.**—The lungs are the special organs of respiration. There are two of them, one on each side of the chest, which cavity they, with the heart, almost wholly occupy. The lung-substance is soft, elastic, and sponge-like. Under pressure of the finger, it *crepitates*, or crackles, and floats when thrown into water; these properties being due to the presence of air in the minute air-cells of the lungs. To facilitate the {124} movements necessary to these organs, each of them is provided with a double covering of an exceedingly smooth and delicate membrane, called the *pleura*. One layer of the pleura is attached to the walls of the chest, and the other to the lungs; and they glide, one upon the other, with utmost freedom. Like the membrane which envelops the heart, the pleura secretes its own lubricating fluid, in quantities sufficient to keep it always moist.

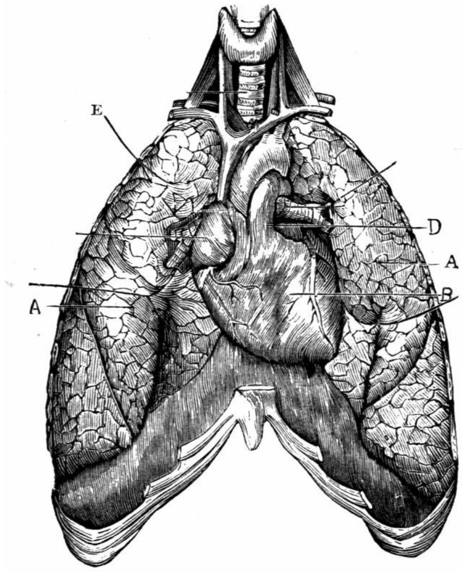


FIG. 34.—ORGANS OF THE CHEST.
A, Lungs. B, Heart. D, Pulmonary Artery.
E, Trachea.

**3.** Communication of the lungs with the external air? Bronchial tubes?

**3. The Air-Passages.** —The lungs communicate with the external air by means of certain air-tubes, the longest of which, the *trachea*, or windpipe, runs along the front of the neck (Fig. 34, E, and 35). Within the chest this tube divides into two branches, one entering each lung; these in turn give rise to numerous branches, or bronchial tubes, as they are called, which gradually diminish in size until they are about one-twenty-fifth of an inch in diameter. Each of these terminates in a cluster of little pouches, or "air-cells," having very thin walls, and covered with a capillary network, the most intricate in the body (Fig. 36). {125}

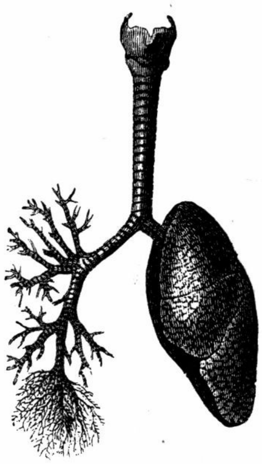

FIG. 35.—LARYNX, TRACHEA, AND BRONCHIAL TUBES.

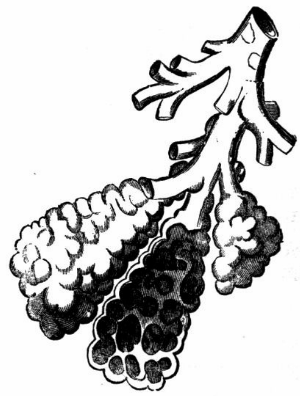

FIG. 36.—DIAGRAM AND SECTION OF THE AIR-CELLS.

**4.** Office of the bronchial tubes? What further can you state of them?

**4.** These tubes are somewhat flexible, sufficiently so to bend when the parts move in which they are situated; but they are greatly strengthened by bands or rings of cartilage which keep the passages always open; otherwise there would be a constantly-recurring tendency to collapse after every breath. The lung-substance essentially consists of these bronchial tubes and terminal air-cells, with the blood-vessels ramifying about them (Fig. 37). At the top of the trachea is the larynx, a sort of box of cartilage, across which are stretched the vocal cords. Here the voice is {126} produced chiefly by the passage of the respired air over these cords, causing them to vibrate.

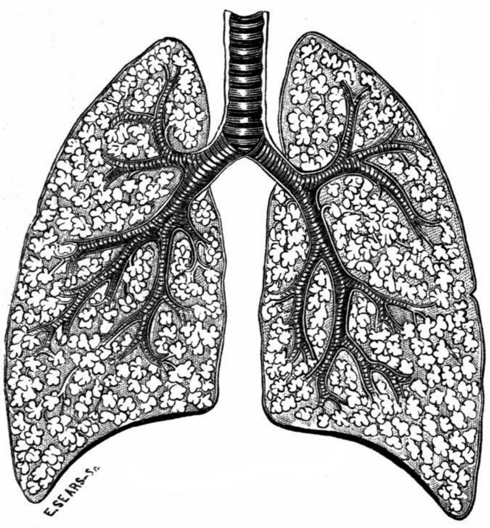

FIG. 37.—SECTION OF THE LUNGS.

**5.** The epiglottis? When it does not close in time, what is the consequence?

**5.** Over the opening of the larynx is found the *epiglottis*, which fits like the lid of a box at the entrance to the lungs, and closes during the act of swallowing, so that food and drink shall pass backward to the œsophagus, or gullet (Fig. 38). Occasionally it does not close in time, and some substance intrudes within the larynx, when we at once discover, by a choking sensation, that "something has gone the wrong way," and, by coughing, we attempt to expel the unwelcome intruder. The epiglottis is one of the many safeguards furnished by nature for our security and comfort, and is {127}
planned and put in place long before these organs are brought into actual use in breathing and in taking food.

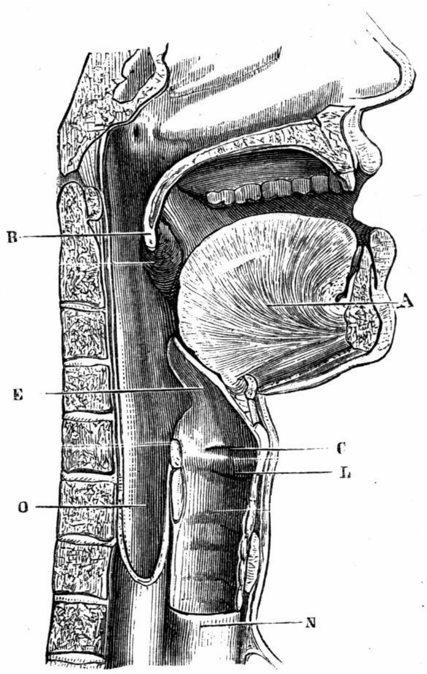


FIG. 38.—SECTION OF MOUTH AND THROAT.
A, The Tongue. B, The Uvula C, Vocal Cord. E, Epiglottis. L, Larynx. N, Trachea. O, Œsophagus.

**6.** Lining of the air-passages? Ciliated cells? Their uses? The three diseases of the lungs?

**6.** The air-passages are lined through nearly their whole {128}
extent with mucous membrane, which maintains these parts in a constantly moist condition. This membrane has a peculiar kind of cells upon its outer surface. If examined under a powerful microscope, we may see, even for a considerable time after their removal from the body, that these cells have minute hair-like processes in motion, which wave like a field of grain under the influence of a breeze (Fig. 39). This is a truly beautiful sight; and since it is found that these little *cilia*, as they are called, always produce currents in one direction, from within outward, it is probable that they serve a useful purpose in catching and carrying away from the lungs dust and other small particles drawn in with the breath (Fig. 39). The three diseases which more commonly affect the lungs, as the result of exposure, are pneumonia, or inflammation of the lungs, implicating principally the air-cells; bronchitis, an inflammation of the large bronchial tubes; and pleurisy, an

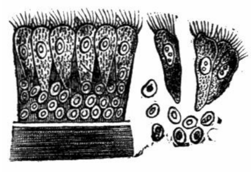

FIG. 39.—CILIATED CELLS.

inflammation of the investing membrane of the lungs, or pleura. Among the young, an affection of the trachea takes place, known as croup.

**7.** The act of breathing? Extension of the chest by breathing?

**7. The Movements of Respiration.**—The act of breathing has two parts—(1), *inspiration*, or drawing air into the lungs, and (2), *expiration*, or expelling it from the lungs again. In inspiration, the chest extends in its length, breadth, and height, or width. We can prove that this is the case as regards the two latter, by observing the effect of a deep breath. The ribs are elevated by means of numerous muscles, some of which occupy the entire spaces between those bones. But the increase in length, or vertically, is not so apparent, as it is caused by a muscle within the body called the *diaphragm*, it being the thin partition which separates the chest from the abdomen, rising like a dome within the chest. (Fig. 16). {129}

**8.** Contraction of the diaphragm? Power of the diaphragm? Effects of extending the walls of the chest? The habit of taking frequent and deep inspirations?

**8.** With every inspiration, the diaphragm contracts, and in so doing, approaches more nearly a plane, or horizontal, surface, and thus enlarges the capacity of the chest. Laughing, sobbing, hiccoughing, and sneezing are caused by the spasmodic or sudden contraction of the diaphragm. The special power of this muscle is important in securing endurance, or "long wind," as it is commonly expressed; which may be obtained mainly by practice. It is possessed in a marked degree by the mountaineer, the oarsman, and the trained singer. As the walls of the chest extend, the lungs expand, and the air rushes in to fill them. This constitutes an inspiration. The habit of taking frequent and deep inspirations, in the erect position, with the shoulders thrown back, tends greatly to increase the capacity and power of the organs of respiration.

**9.** Expiration? The mechanism of expiration?

**9. Expiration** is a less powerful act than inspiration. The diaphragm relaxes its contraction, and ascends in the form of a dome; the ribs descend and contract the chest; while the lungs themselves, being elastic, assist to drive out the air. The latter passes out through the same channels by which it entered. At the end of each expiration there is a pause, or period of repose, lasting about as long as the period of action.

**10.** Frequency of respiration? Effect of hurried action of the heart?

**10. Frequency of Respiration.**—It is usually estimated that we breathe once during every four beats of the heart, or about eighteen times in a minute. There is, of course, a close relation between the heart and lungs, and whatever modifies the pulse, in like manner affects the breathing. When the action of the heart is hurried, a larger amount of blood is sent to the lungs, and, as the consequence, they must act more rapidly. Occasionally, the heart beats so very forcibly that the lungs cannot keep pace with it, and then we experience a peculiar sense of distress from the want of air. This {130} takes place when we run until we are "out of breath." At the end of every fifth or sixth breath, the inspiration is generally longer than usual, the effect being to change more completely the air of the lungs.

**11.** Respiration controlled by the will? Advantage of the knowledge to us?

**11.** Although, as a general rule, the work of respiration goes on unconsciously and without exertion on our part, it is nevertheless under the control of the will. We can increase or diminish the frequency of its acts at pleasure, and we can "hold the breath," or arrest it altogether for a short time. From twenty to thirty seconds is ordinarily the longest period in which the breath can be held; but if we first expel all the impure air from the lungs, by taking several very deep inspirations, the time may be extended to one and a half or even two minutes. This should be remembered, and acted upon, before passing through a burning building, or any place where the air is very foul. The arrest of the respiration may be still further prolonged by training and habit; thus it is said, the pearl-fishers of India can remain three or four minutes under water without being compelled to breathe.

**12.** Capacity of the lungs? Time required to renovate the air in the lungs? In tranquil respiration? Importance of the provision?

**12. Capacity of the Lungs.**—The lungs are not filled and emptied by each respiration. For while their full capacity, in the adult, is three hundred and twenty cubic inches, or more than a gallon, the ordinary breathing air is only one-sixteenth part of that volume, or twenty cubic inches, being two-thirds of a pint. Accordingly, a complete renovation, or rotation, of the air of the lungs does not take place more frequently than about once in a minute; and by the gradual introduction of the external air, its temperature is considerably elevated before it reaches the delicate pulmonary capillaries. In tranquil respiration, less than two-thirds of the breathing power is called into exercise, leaving a reserve capacity of about one hundred and {131} twenty cubic inches, equivalent to three and one half pints. This provision is indispensable to the continuation of life; otherwise, a slight embarrassment of respiration, by an ordinary cold, for instance, would suffice to cut off the necessary air, and the spark of life would be speedily extinguished.

**13.** The atmosphere? How high or deep? How essential to life? Marine life in perfectly pure water and air?

**13. The Air we breathe.**—The earth is enveloped on all sides by an invisible fluid, called the atmosphere. It forms a vast and shoreless ocean of air, forty-five miles deep, encircling and pervading all objects on the earth's surface, which is absolutely essential for the preservation of all vegetable and animal life,—in the sea, as well as on the land and in the air. At the bottom, or in the lower strata of this aerial ocean, we move and have our being. Perfectly pure water will not support marine life, for a fish may be drowned in water from which the air has been exhausted, just as certainly as a mouse, or any other land animal, will perish if put deeply into the water for a length of time. The cause is the same in both cases: the animal is deprived of the requisite amount of air. It is also stated, that if the water-supply of the plant be deprived of air, its vital processes are at once checked.

**14.** Composition of the air? Properties of the two gases?

**14.** The air is not a simple element, as the ancients supposed, but is formed by the mingling of two gases, known to the chemist as oxygen and nitrogen, in the proportion of one part of the former to four parts of the latter. These gases are very unlike, being almost opposite in their properties: nitrogen is weak, inert, and cannot support life; while oxygen is powerful, and incessantly active; and is the essential element which gives to the atmosphere its power to support life and combustion. The discovery of this fact was made by the French chemist, Lavoisier, in 1778. {132}

**15.** Air once breathed? An animal in it? A candle? Analysis of expired air? Change in volume?

**15. Changes in the Air from Respiration.**—Air that has been once breathed is no longer fit for respiration. An animal confined within it will sooner or later die; so too, a lighted candle placed in it will be at once extinguished. If we collect a quantity of expired air and analyze it, we shall find that its composition is not the same as that of the inspired air. When the air entered the lungs it was rich in oxygen; now it contains twenty-five per cent. less of that gas. Its volume, however, remains nearly the same; its loss being replaced by another and very different gas, which the lungs exhaled, called *carbonic acid*, or, as the chemist terms it, *carbon dioxide*.

**16.** What else has the expired air gained? When and where noticed?

**16.** The expired air has also gained moisture. This is noticed when we breathe upon a mirror, or the window-pane, the surface being tarnished by the condensation of the watery vapor exhaled by the lungs. In cold weather, this causes the fine cloud which is seen issuing from the nostrils or mouth with each expiration, and contributes in forming the feathery crystals of ice which decorate our window-panes on a winter's morning.

**17.** Nature of the watery vapor? Its effects upon animals?

**17.** This watery vapor contains a variable quantity of animal matter, the exact nature of which is unknown; but when collected it speedily putrefies and becomes highly offensive. From the effects, upon small animals, of confinement in their own exhalations, having at the same time an abundant supply of fresh air, it is believed that the organic matters thrown off by the lungs and skin are direct and active poisons; and that to such emanations from the body, more than to any other cause, are due the depressing and even fatal results which follow the crowding of large numbers of persons into places of limited capacity. {133}

**18.** Give some of the instances furnished by history.

**18.** History furnishes many painful instances of the ill effects of overcrowding. In 1756, of one hundred and forty-six Englishmen imprisoned in the Black Hole of Calcutta, only twenty-three, at the end of eight hours, survived. After the battle of Austerlitz, three hundred prisoners were crowded into a cavern, where, in a few hours, two-thirds of their number died. On board a steam-ship, during a stormy night, one hundred and fifty passengers were confined in a small cabin, but when morning came, only eighty remained alive.

**19.** Change in the blood from blue to red. Upon what does the change depend? How shown?

**19. Changes in the Blood from Respiration.**—The most striking change which the blood undergoes by its passage through the lungs, is the change of color from a dark blue to bright red. That this change is dependent upon respiration has been fully proved by experiment. If the trachea, or windpipe, of a living animal be so compressed as to exclude the air from the lungs, the blood in the arteries will gradually grow darker, until its color is the same as that of the venous blood. When the pressure is removed the blood speedily resumes its bright hue. Again, if the animal be made to breathe an atmosphere containing more oxygen than atmospheric air, the color changes from scarlet to vermilion, and becomes even brighter than arterial blood. This change of color is not of itself a very important matter, but it indicates a most important change of composition.

**20.** What does the air lose and gain by respiration? What, the blood? Air as food?

**20.** The air, as we have seen, by respiration loses oxygen and gains carbonic acid: the blood, on the contrary, gains oxygen and loses carbonic acid. The oxygen is the food of the blood corpuscles; while the articles we eat and drink belong more particularly to the plasma of the blood. The air, then, it is plain, is a sort of food, and we should undoubtedly so regard it, if it were not for the fact that we require it constantly, {134}
instead of taking it at stated intervals, as is the case with our articles of diet. Again, as the demand of the system for food is expressed by the sensation of hunger, so the demand for air is marked by a painful sensation called suffocation.

**21.** Moist animal membranes? How shown with the bladder?

**21. Interchange of Gases in the Lungs.**—As the air and the blood are not in contact, they being separated from each other by the walls of the air-cells and of the blood-vessels, how can the two gases, oxygen and carbonic acid, exchange places? Moist animal membranes have a property which enables them to transmit gases through their substance, although they are impervious to liquids. This may be beautifully shown by suspending a bladder containing dark blood in a jar of oxygen. At the end of a few hours the oxygen will have disappeared, the blood will be brighter in color, and carbonic acid will be found in the jar.

**22.** Gaseous diffusion? If oxygen be not received? If

**22.** If this interchange takes place outside of the body, how much more perfectly must it take place within, where it is favored by many additional circumstances! The carbonic acid be retained?

walls of the vessels and the air-cells offer no obstacle to this process, which is known as gaseous diffusion. Both parts of the process are alike of vital importance. If oxygen be not received, the organs cease to act; and if carbonic acid be retained in the blood, its action is that of a poison; unconsciousness, convulsions, and death following.

**23.** Difference in the appearance and composition of the blood? Temperature of the blood? The blood while passing through the lungs? The consequence?

**23. Difference between Arterial and Venous Blood.**—The following table presents the essential points of difference in the appearance and composition of the blood, before and after its passage through the lungs:— {135}

| | *Venous Blood.* | *Arterial Blood.* |
|---|---|---|
| Color, | Dark blue, | Scarlet. |
| Oxygen, | 8 per cent., | 18 per cent. |
| Carbonic Acid, | 15 to 20 per cent., | 6 per cent., or less. |
| Water, | More, | Less. |

The temperature of the blood varies considerably; but the arterial stream is generally warmer than the venous. The blood imparts heat to the air while passing through the lungs, and consequently the contents of the right side of the heart has a higher temperature than the contents on the left side.

**24.** What do we learn by means of the spectroscope? "Carriers of oxygen?" Blue blood in the system?

**24.** By means of the spectroscope, we learn that the change of color in the blood has its seat in the corpuscles; and that, according as they retain oxygen, or release it, they present the spectrum of arterial or venous blood. There evidently exists, on the part of these little bodies, an affinity for this gas, and hence they have been called "carriers of oxygen." It was long ago thought that blue blood was a trait peculiar to persons of princely and royal descent, and boastful allusions to the "*sang azure*" of kings and nobles are quite often met with. Physiology, however, informs us that blue blood flows in the veins of the low as well as the high, and that so far from its presence indicating a mark of purity, it, in reality, represents the waste and decay of the system.

**25.** The amount of air that passes in and out of the lungs?

**25. Amount of Respiratory Labor.**—During ordinary calm respiration, we breathe eighteen times in a minute; and twenty cubic inches of air pass in and out of the lungs with every breath. This is equivalent to the use of three hundred and sixty cubic inches, or more than ten pints of air each minute. From this we calculate that the quantity of air which hourly traverses the lungs is about thirteen cubic feet, or seventy-eight gallons; and daily, not less than three hundred cubic feet, an amount {136}
nearly equal to the contents of sixty barrels.

**26.** Air absorbed in its transit through the lungs? The loss? Carbonic acid exhaled? Effect of excitement or exertion? What estimate?

**26.** Of this large volume of air five per cent. is absorbed in its transit through the lungs. The loss thus sustained is almost wholly of oxygen, and amounts to fifteen cubic feet daily. The quantity of carbonic acid exhaled by the lungs during the day is somewhat less, being twelve cubic feet. Under the influence of excitement or exertion, the breathing becomes more frequent and more profound; and then the internal respiratory work increases proportionately, and may even be double that of the above estimate. It has been estimated that in drawing a full breath, a man exerts a muscular force equal to raising two hundred pounds placed upon the chest.

**27.** Importance of the oxygen in the atmosphere? Injurious character of gases?

**27. Impurities of the Air.**—The oxygen in the atmosphere is of such prime importance, and its proportion is so nicely adjusted to the wants of man, that any gas or volatile substance which supplants it must be regarded as a hurtful impurity. All gases, however, are not alike injurious. Some, if inhaled, are necessarily fatal; *arsenuretted hydrogen* being one of these, a single bubble of which destroyed the life of its discoverer, Gehlen. Others are not directly dangerous, but by taking the place of oxygen, and excluding it from the lungs, they become so. Into this latter class we place carbonic acid.

**28.** Pungency of gases? The inference? Our safeguard?

**28.** Most of the actively poisonous gases have a pungent or offensive odor; and, as may be inferred, most repugnant odors indicate the presence of substances unfit for respiration. Accordingly, as we cannot see or taste these impurities, the sense of smell is our principal safeguard against them; and we recognize the design which has planted this sense, like a sentinel at the proper entrance of the air-passages, the {137}
nostrils, to give us warning of approaching harm. Take, as an example, the ordinary illuminating gas of cities, from which so many accidents happen. How many more deaths would it cause if, when a leak occurs, we were not able to discover the escape of the gas by means of its disagreeable odor.

**29.** The air of rooms in which fever-sick persons are confined?

**29.** Organic matters exist in increased measure in the expired breath of sick persons, and impart to it, at times, a putrid odor. This is especially true in diseases which, like typhus and scarlet fever, are referable to a blood poison. In such cases the breath is one of the means by which nature seeks to expel the offending material from the system. Hence, those who visit or administer to fever-sick persons should obey the oft-repeated direction, "not to take the breath of the sick." At such times, if ever, fresh air is demanded, not alone for the sick, but as well for those who are in attendance.

**30.** Animalcula in

**30. Dust in the Air.**—Attention has lately been directed to the dust, or haze, that the water? Dust in the air?

marks the ray of sunshine across a shaded room. Just as, many years ago, it was discovered that myriads of animalcula infested much of the water we drank, so now the microscope reveals "the gay motes that dance along a sunbeam" to be, in part, composed of multitudes of animal and vegetable forms of a very low grade, the germs of fermentation and putrefaction, and the probable sources of disease.

**31.** The best air filter? The remarks of Prof. Tyndall?

**31.** It is found that the best filter by which to separate this floating dust from the air is cotton wool, although a handkerchief will imperfectly answer the same purpose. In a lecture on this subject by Prof. Tyndall, he remarks that, "by breathing through a cotton wool respirator, the noxious air of the sick room is restored to practical purity. Thus filtered, attendants may breathe the air unharmed. In all probability, the {138} protection of the lungs will be the protection of the whole system. For it is exceedingly probable that the germs which lodge in the air-passages are those which sow epidemic disease in the body. If this be so, then disease can certainly be warded off by filters of cotton wool. By this means, so far as the germs are concerned, the air of the highest Alps may be brought into the chamber of the invalid."

**32.** Carbonic acid in volcanic regions? In Java? At Lake Avernus? In mines?

**32. Carbonic Acid in the Air.**—We have already spoken of this gas as an exhalation from the lungs, and a source of impurity; but it exists naturally in the atmosphere in the proportion of one half part per thousand. In volcanic regions it is poured forth in enormous quantities from fissures in the earth's surface. Being heavier than air, it sometimes settles into caves and depressions in the surface. It is stated that in the island of Java, there is a place called the "Valley of Poison," where the ground is covered with the bones of birds, tigers, and other wild animals, which were suffocated by carbonic acid while passing. The Lake Avernus, the fabled entrance to the infernal regions, was, as its name implies, bird-less, because the birds, while flying over it, were poisoned by the gas and fell dead into its waters. In mines, carbonic acid forms the dreaded *choke-damp*, while carburetted hydrogen is the *fire-damp*.

**33.** In the open air? Amount of carbonic acid exhaled by a man? A gas-burner? A room fire? From furnaces?

**33.** In the open air, men seldom suffer from carbonic acid, for, as we shall see presently, nature provides for its rapid distribution, and even turns it to profitable use. But its ill effects are painfully evident in the abodes of men, in which it is liable to collect as the waste product of respiration and of that combustion which is necessary for lighting and warming our homes. A man exhales, during repose, not less than one-half cubic foot of carbonic acid per hour. One gas-burner liberates five cubic feet in the same time, and spoils about as much air as ten men. A fire burning {139} in a grate or stove emits some gaseous impurity, and at the same time abstracts from the air as much oxygen as twelve men would consume in the same period, thus increasing the relative amount of carbonic acid in the air. From furnaces, as ordinarily constructed, this gas, with other products of combustion, is constantly leaking and vitiating the air of tightly-closed apartments.

**34.** Effects of inhaling carbonic acid alone? In small quantities?

**34. Effects of Impure Air.**—Carbonic acid, in its pure form, is irrespirable, causing rapid death by suffocation. Air containing forty parts per thousand of this gas (the composition of the expired breath) extinguishes a lighted candle, and is fatal to birds; when containing one hundred parts, it no longer yields oxygen to man and other warm-blooded animals; and is of course at once fatal to them. In smaller quantities, this gas causes headache, labored respiration, palpitation, unconsciousness, and convulsions.

**35.** Effects of the air in crowded and badly ventilated rooms?

**35.** In crowded and badly ventilated apartments, where the atmosphere relatively contains from six to ten times the natural amount of carbonic acid, the contaminated air causes dulness, drowsiness, and faintness; the dark, impure blood circulating through the brain, oppressing that organ and causing it to act like a blunted tool. This is a condition not uncommon in our schools, churches, court-rooms, and the like, the places of all others where it is desirable that the mind should be alert and free to act; but, unhappily, an unseen physiological cause is at work, dispensing weariness and stupor over juries, audience, and pupils.

**36.** A cause of consumption? How was the fact illustrated?

**36.** Another unmistakable result of living in and breathing foul air is found in certain diseases of the lungs, especially consumption. For many years the barracks of the {140} British army were constructed without any regard to ventilation; and during those years the statistics showed that consumption was the cause of a very large proportion of deaths. At last the government began to improve the condition of the buildings, giving larger space and air-supply; and as a consequence, the mortality from consumption has diminished more than one-third.

**37.** How, in the case of the lower animals? Tendency of certain occupations?

**37.** The lower animals confined in the impure atmosphere of menageries, contract the same diseases as man. Those brought from a tropical climate, and requiring artificial warmth, generally die of consumption. In the Zoological gardens of Paris, this disease affected nearly all monkeys, until care was taken to introduce fresh air by ventilation; and then it almost wholly disappeared. The tendency of certain occupations to shorten life is well known; disease being occasioned by the fumes and dust which arise from the material employed, in addition to the unhealthful condition of the workshop or factory where many hours are passed daily.

**38.** Give the fact as set forth in the table.

**38.** The following table shows the comparative amount of carbonic acid in the air under different conditions and the effects sometimes produced:—

| Proportion of Carbonic Acid. | In 1000 parts of Air. |
|---|---|
| Air of country. | .4 |
| " " city. | .5 |
| In hospital, well ventilated. | .6 |
| In school, church, etc., fairly ventilated. | 1.2 to 2.5 |
| In court-house, factory, etc., without ventilation. | 4. to 40. |
| In bedroom, before being aired. | 4.5 |
| In bedroom, after being aired. | 1.5 |
| Constantly breathed, causing ill health. | 2. |
| Occasionally breathed, causing discomfort. | 3. |
| Occasionally breathed, causing distress. | 10. |
| Expired air. | 40. |
| Air no longer yielding oxygen | 100. |

**39.** What can you state of the diffusive power of gases? The added influence of the winds?

**39. Nature's Provision for Purifying the Air.**—We have seen that carbonic acid is {141}
heavier than air, and is poisonous. Why, then, does it not sink upon and overwhelm mankind with a silent, invisible wave of death? Among the gases there is a more potent force than gravity, which forever precludes such a tragedy. It is known as the diffusive power of gases. It acts according to a definite law, and with a resistless energy compelling these gases, when in contact, to mingle until they are thoroughly diffused. The added influence of the winds is useful, by insuring more rapid changes in the air; air in motion being perfectly wholesome. The rains also wash the air.

**40.** How is the constant purity of the air secured? Explain the process?

**40.** We have seen that the whole animal creation is constantly abstracting oxygen from the atmosphere, and as constantly adding to it vast volumes of a gas injurious alike to all, even in small quantities. How, then, does the air retain, unchanged, its life-giving properties? The constant purity of the air is secured by means of the vegetable creation. Carbonic acid is the food of the plants, and oxygen is its waste product. The leaves are its lungs, and under the stimulus of sunlight a vegetable respiration is set in motion, the effects of which are just the reverse of the function we have been considering. Thus nature purifies the air, and at the same time builds up beautiful and useful forms of life from elements of decay.

**41.** What process occurs in the sea? How is the fact illustrated?

**41.** In the sea, as in the air, the same circle of changes is observed. Marine animals consume oxygen and give off carbonic acid; while marine plants consume carbonic acid and liberate oxygen. Taking advantage of this fact, we may so arrange aquaria with fishes and sea-plants, in their proper combinations, so that each supplies the
needs of the other, and the water requires seldom to be renewed. This affords us, on {142}
a small scale, an illustration of the mutual dependence of the two great kingdoms of nature; as well as of those compensating changes which are taking place on such a grand scale in the world about us.

**42.** Character of the external air? Of the air in our dwellings? What becomes imperative? Imperfect ventilation of our dwellings?

**42. Ventilation.**—Since the external atmosphere, as provided by nature, is always pure, and since the air in our dwellings and other buildings is almost always impure, it becomes imperative that there should be a free communication from the one to the other. This we aim to accomplish by ventilation. As our houses are ordinarily constructed, the theory of ventilation, "to make the internal as pure as the external air," is seldom carried out. Doors, windows, and flues, the natural means of replenishing the air, are too often closed, almost hermetically, against the precious element. Special means, or special attention, must therefore be used to secure even a fair supply of fresh air. This is still more true of those places of public resort, where many persons are crowded together.

**43.** What hints are given for the ventilation of our dwellings?

**43.** If there are two openings in a room, one as a vent for foul air, and the other an inlet for atmospheric air, and if the openings be large, in proportion to the number of air consumers, the principal object will be attained. Thus, a door and window, each opening into the outer air, will ordinarily ventilate a small apartment; or a window alone will answer, if it be open both above and below, and the open space at each end be not less than one inch for each occupant of the room, when the window is about a yard wide. The direction of the current is generally from below upward, since the foul, heated air tends to rise; but this is not essential. Its rate need not be rapid; a "draught," or perceptible current, is never necessary to good ventilation. The temperature of the air admitted may be warm or cold. It is thought by many that if
the air is cold, it is pure; but this is an error, since cold air will receive and retain the {143}
same impurities as warm air.

**44.** State what Florence Nightingale says about inhaling night air?

**44.** Shall we open our bedrooms to the night air? Florence Nightingale says, in effect, that night air is the only air that we can then breathe. "The choice is between pure air without and impure air within. Most people prefer the latter,—an unaccountable choice. An open window, most nights in the year, can hurt no one. In great cities, night air is the best and purest to be had in twenty-four hours. I could better understand, in towns, shutting the windows during the day than during the night."

45. Warmth of the bird as compared with that of the air? Of the fish and the water? Heat in animals and plants? How illustrated with the thermometer?

**45. Animal Heat.**—Intimately connected with respiration is the production of animal heat, or the power of maintaining the temperature of the body above that of the medium in which the creature moves; thus, the bird is warmer than the air, and the fish than the water. This elevation of temperature is a result of the various chemical changes which are constantly taking place in the system. Although common to all animals, in a greater or less degree, heat is not peculiar to them; since plants also generate it, especially at the time of sprouting and flowering. If a thermometer be placed in a cluster of geranium flowers, it will indicate a temperature several degrees above that of the surrounding air.

46. Amount of heat in animals, how apportioned? As regards the birds? Frogs, and other sluggish animals? Arrangement made by zoologists?

**46.** Among animals great differences are noticed in this respect, but the degree of heat produced is always proportional to the activity of respiration and the amount of oxygen consumed. Accordingly, the birds, whose habits are extremely active, and whose breathing capacity is the greatest, have uniformly the highest temperature. Sluggish animals, on the contrary, as frogs, lizards, and snakes, have little need for oxygen, and have incompletely developed lungs; these animals are cold to the touch, {144}
that is, they have relatively a lower temperature than man, and their positive temperature is but little above that of the external air. Accordingly, zoologists have so arranged the animal kingdom that *warm-blooded* animals, including man, the birds, and the quadrupeds, are classified together; while the *cold-blooded* animals, such as the fish, tortoise, frog, and all that have no vertebral column, are classed by themselves.

47. State what is said respecting the temperature of the human body.

**47.** The temperature of the human body is about 100° Fahrenheit, and remains about the same through winter and summer, in the tropics as well as in the frozen regions of the north. It may change temporarily within the range of about twelve degrees; but any considerable, or long-continued elevation or diminution of the bodily heat is certain to result disastrously.

48. Ability of man to adapt himself to different climates? In what does the power to resist cold consist? What is said about warm clothing?

**48.** Man is able to adapt himself to all extremes of climate; and, in fact, by means of clothing, shelter, and food, is able to create for himself an artificial climate where-ever he choses to reside. The power to resist cold consists chiefly in preventing the heat which is generated by the vital processes of the body from being lost by radiation. Warm clothing, such as we wear in winter, has, in reality, the same temperature as that which is worn in summer; but, by reason of being thick and porous, it is a bad conductor of heat, and thus prevents the escape of that produced by the body. If woollen fabrics were intrinsically warm, no one would wrap a piece of flannel, or blanket, around a block of ice to prevent its melting in summer.

49. Men in an atmosphere above the boiling-point? In foundries and glass works?

**49.** The faculty of generating heat explains how it is that we are enabled to resist the effects of cold; but how does the body withstand a temperature higher than its own? {145}
Men have been known to remain several minutes in an atmosphere heated above the boiling-point of water, and yet the temperature of their own bodies was not greatly elevated. Those who labor in foundries and glass-works are habitually subjected to very high degrees of temperature, but they do not suffer in health more than those engaged in many other occupations.

50. The regulation of the temperature of the body. Give the explanation.

**50.** The regulation of the temperature of the body is effected by means of perspiration, and by its evaporation. So long as the skin acts freely and the air freely absorbs the moisture, the heat of the body does not increase, for whenever evaporation takes place, it is attended by the abstraction of heat—that is, the part becomes relatively colder. This may be tested by moistening some part of the surface with cologne, ether, or other volatile liquid, and then causing it to evaporate rapidly by fanning. The principle that evaporation produces cold has been ingeniously and practically employed, in the manufacture of ice, by means of freezing machines.

51, 52. State what is said of spontaneous combustion.

**51. Spontaneous Combustion.**—Is it possible that the temperature of the living body can be so increased, that its tissues will burn spontaneously? From time to time, cases have been reported in which, by some mysterious means, considerable portions of the human body have been consumed, apparently by fire, the victim being found dead, or incapable of explaining the occurrence. Hence, the theory has been current that, under certain conditions, the tissues of the body might become self-ignited; and the fact that this so-called *spontaneous combustion* has ordinarily taken place in those who had been addicted to the use of alcoholic drinks, has given a color of probability to the opinion. It has been supposed that the flesh of these unfortunate persons becoming saturated with the inflammable properties of the alcohol thus taken into the system, took fire upon being exposed to a flame, as of a lighted candle, {146}
or, indeed, without any external cause. But, whether this be possible or not, one thing is certain, this strange kind of combustion has never been actually witnessed by any one competent to give a satisfactory account of it.

**52.** The results that have been observed may be satisfactorily explained by the accidental ignition of the clothes, or other articles near the body, and by the supposition that the individual was at the time too much stupefied by intoxication, to notice the source of danger, and provide for his safety. The highest temperature that has been observed in the body, about 112° Fahrenheit, is too low to ignite the vapor of alcohol; much less will it cause the burning of animal tissues. It is undoubtedly true that when the tissues are filled with alcohol, combustion will more easily take place than when the body is in a normal state; but, under any condition, the combustion of the body requires a higher degree of heat than can be generated by the body itself, or the mere *proximity* of a lighted candle, or any cause of a similar character. {147}

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## CHAPTER IX. {148}

## The Nervous System.

*Animal and Vegetative Functions—Sensation, Motion, and Volition—The Structure of the Nervous System—The White and Gray Substances—The Brain—Its Convolutions—The Cerebellum—The Spinal Cord and its System of Nerves—The Anterior and Posterior Roots—The Sympathetic System of Nerves—The Properties of Nervous Tissue—Excitability of Nervous Tissues—The Functions of the Spinal Nerves and Cord—The Direction of the Fibres of the Cord—Reflex Activity, and its Uses—The Functions of the Medulla Oblongata and the Cranial Ganglia—The Reflex Action of the Brain.*

**1.** What processes are known as the vegetative functions? Why so called? What properties and functions does the plant possess? Their object?

**1. Animal Functions.**—The vital processes which we have been considering, in the three previous chapters, of digestion, circulation, and respiration—belong to the class of functions known as *vegetative* functions. That is, they are common to vegetables as well as animals; for the plant, like the animal, can originate nothing, not even the smallest particle of matter; and yet it grows, blossoms, and bears fruit, by reason of obtaining and digesting the nutriment which the air and soil provide. The plant has its circulatory fluid and channels, by which the nutriment is distributed to all its parts. It has, also, a curious apparatus in its foliage, by which it abstracts from the air those gaseous elements so necessary to its support; and thus it accomplishes vegetable respiration. These vegetative functions have their beginning and end within the organism of the plant; and their object is the preservation of the plant itself, as well as of the entire species.

**2.** What second set of powers has the animal? What functions are mentioned? The advantage they give?

**2.** The animal, in addition to these vegetative functions, has another set of powers, by the use of which he becomes conscious of a world external to himself, and brings himself into active relations with it. By means of the vegetative processes, his life and {149}
species are maintained; while, by means of certain animal functions, he feels, acts, and thinks. These functions, among which are sensation, motion, and volition, not only distinguish the animal from the plant, but, in proportion to their development, elevate one creature above another; and it is by virtue of his pre-eminent endowment, in these respects, that man holds his position at the head of the animal creation.

**3.** Animals whose structure is simple? As we approach man? Dependence of the animal functions of man?

**3.** Among animals whose structure is very simple, the hydra, or fresh-water polyp, being an example, no special organs are empowered to perform separate functions; but every part is endowed alike, so that if the animal be cut into pieces, each portion has all the properties of the entire original; and, if the circumstances be favorable, each of the pieces will soon become a complete hydra. As we approach man, in the scale of beings, we find that the organs multiply, and the functions become more complete. The function of motion, the instruments of which—the muscles and bones—have been considered in former chapters, and all the other animal functions of man, depend upon the set of organs known as the nervous system.

**4.** The nervous tissues, of what composed? When examined by the aid of the microscope? The white substance? The gray substance?

**4. The Nervous System.**—The intimate structure of this system differs from any tissue which we have before examined. It is composed of a soft, pulpy substance, which, early in life, is almost fluid, but which gradually hardens with the growth of the body. When examined under the microscope, it is found to be composed of two distinct elements:—(1) the white substance, composing the larger proportion of the nervous organs of the body, which is formed of delicate cylindrical filaments, about 1/6000 of an inch in diameter, termed the nerve-fibres; and (2) the gray substance, composed of grayish-red, or ashen-colored cells, of various sizes, generally possessing {150}
one or more off-shoots, which are continuous with the nerve-fibres just mentioned.

**5.** Nervous centres and ganglia? Nerves? What do they serve? Cerebro-spinal system?

**5.** The gray, cellular substance constitutes the larger portion of those important masses, which bear the name of *nervous centres* and *ganglia* (from *ganglion*, a knot), and in which all the nerve-fibres unite. These white nerve-fibres are found combined together in long and dense cords, called *nerves* (from *neuron*, a cord), which serve to connect the nervous centres with each other, and to place them in communication with all the other parts of the body which have sensibility or power of motion. That part of the nervous system which is concerned in the animal functions, comprises the brain, the spinal cord, and the nerves which are derived therefrom; these are, together, called the *cerebro-spinal* system (Fig. 40); while that other set of organs, which presides over, and regulates the vegetative functions, is called the sympathetic system of nerves.

**6.** Location of the brain? Its weight? Its shape? Of what it consists? What organs at the base?

**6. The Brain.**—The brain is the great volume of nervous tissue that is lodged within the skull. It is the largest and most complex of the nervous centres, its weight, in the adult, being about fifty ounces, or one-fortieth of that of the whole body. The shape of the brain is oval, or egg-shaped, with one extremity larger than the other, which is placed posteriorly in the skull, to the concavity of which it very closely conforms. The brain consists chiefly of two parts; the *cerebrum*, or brain proper, and the *cerebellum*, or "little brain." In addition to these, there are several smaller organs at the base, among which is the commencement or expansion of the spinal cord, termed the *medulla oblongata*, or oblong marrow.

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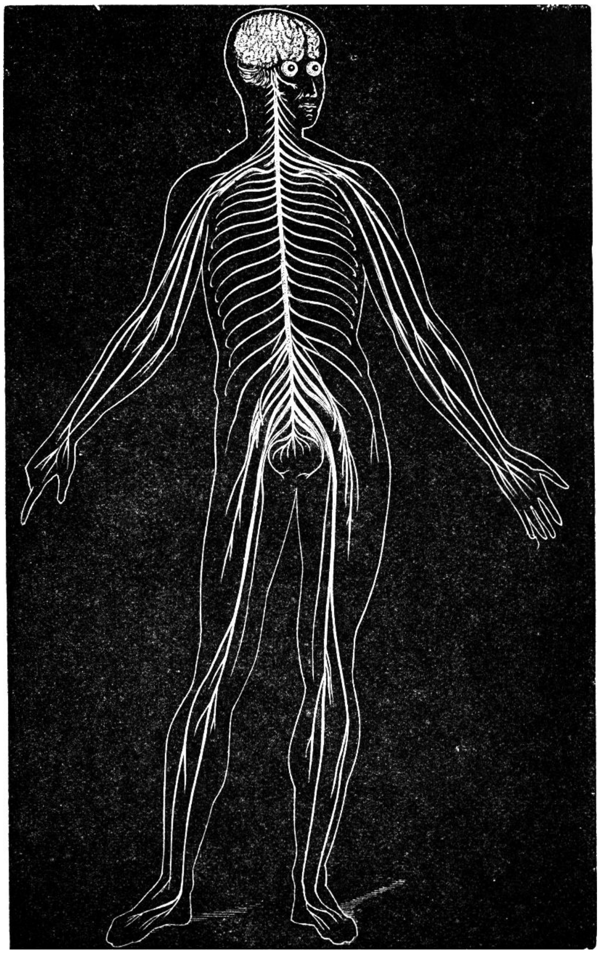

FIG. 40.—THE CEREBRO-SPINAL SYSTEM.

**7.** The tissue of the brain? What, therefore, is required? Blows on the head? Membranes of the brain? Blood sent to the brain?

**7.** The tissue of the brain is soft and easily altered in shape by pressure; it therefore {152}
requires to be placed in a well-protected position, such as is afforded by the skull, or *cranium*, which is strong without being cumbrous. In the course of an ordinary lifetime, this bony box sustains many blows, with little inconvenience; while, if they fell directly upon the brain, they would at once, and completely, disorganize that structure. Within the skull, the brain is enveloped by certain membranes, which at once protect it from friction, and furnish it with a supply of nutrient vessels; they are called the *arachnoid*, or "spider's web," the *dura mater* and the *pia mater*, or the "tough" and "delicate coverings." The supply of blood sent to the brain is very liberal, amounting to one-fifth of all that the entire body possesses. The brain of man is heavier than that of any other animal, except the elephant and whale.

**8.** Size of the brain proper? How divided? The exterior of the hemispheres? The interior?

**8. The Cerebrum.**—The brain proper, or *cerebrum*, is the largest of the intracranial organs, and occupies the entire upper and front portion of the skull. It is almost completely bisected, by a fissure, or cleft, running through it lengthwise, into two equal parts called *hemispheres*. The exterior of these hemispheres is gray in color, consisting chiefly of nerve-cells, arranged so as to form a layer of gray matter one-fifth of an inch in thickness, and is abundantly supplied with blood-vessels. The interior of the brain, however, is composed almost wholly of white substance, or nerve-fibres.

**9.** The surface of the cerebrum, how marked? The gray matter of the surface? Extent of the entire brain surface? Source of nervous power? What further?

**9.** The surface of the cerebrum is divided by a considerable number of tortuous and irregular furrows, about an inch deep, into "convolutions," as shown in Fig. 41. Into these furrows the gray matter of the surface is extended, and, in this manner, its
quantity is vastly increased. The extent of the entire surface of the brain, with the {153}
convolutions unfolded, is computed to be equal to four square feet; and yet it is easily enclosed within the narrow limits of the skull. When it is stated that the gray matter is the true source of nervous power, it becomes evident that this arrangement has an important bearing on the mental capacity of the individual. And it is noticed that in children, before the mind is brought into vigorous use, these markings or furrows on the surface are comparatively shallow and indistinct; the same fact is true of the brain in the less civilized races of mankind and in the lower animals. It is also noticeable, that among animals, those are the most capable of being educated which have the best development of the cerebrum.

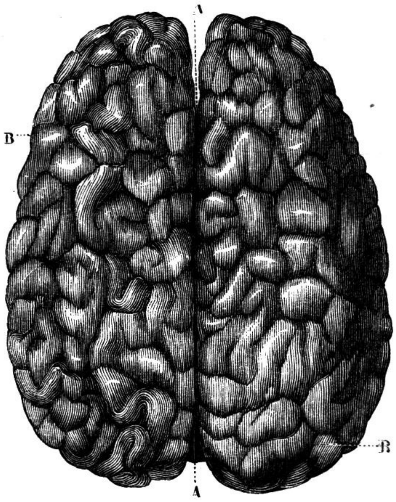


FIG. 41.—UPPER SURFACE OF THE CEREBRUM.
A, Longitudinal Fissure. B, The Hemispheres.

**10.** Location of the "little brain?" How divided? Its surface and interior? Its subdivisions? Its size?

**10. The Cerebellum.**—The "little brain" is placed beneath the posterior part of the cerebrum, and, like the latter, is divided into hemispheres. Like it, also, the surface of the cerebellum is composed of gray matter, and its interior is chiefly white matter. It has, however, no convolutions, but is subdivided by many crescentic, parallel ridges, which, sending down gray matter deeply into the white, central portion, gives the {154}
latter a somewhat branched appearance. This peculiar appearance has been called the *arbor vitæ*, or the "tree of life," from the fact that when a section of the organ is made, it bears some resemblance to the trunk and branches of a tree (Fig. 42, F). In size, this cerebellum, or "little brain," is less than one-eighth of the cerebrum.

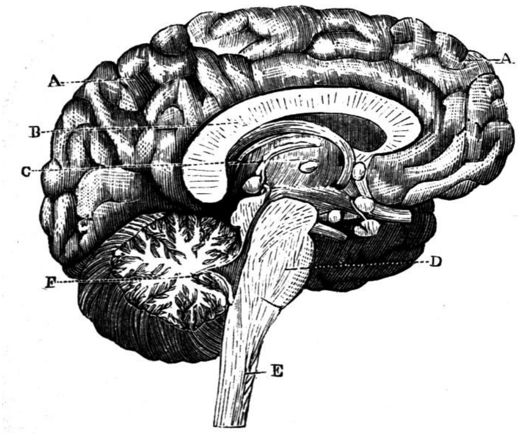


FIG. 42.—VERTICAL SECTION OF THE BRAIN.
A, Left Hemisphere of Cerebrum. B, Corpus Callosum. C, Optic Thalamus. D, The Pons Varolii. E, Upper extremity of the Spinal Cord. F, The Arbor Vitæ.

**11.** Medulla oblongata? Cranial nerves? Their shape and position?

**11.** From the under surface of the cerebrum, and from the front margin of the cerebellum, fibres collect together to form the *medulla oblongata* (Fig. 43, MA), which, on issuing from the skull, enters the spinal column, and then becomes known as the spinal cord. From the base of the brain, and from the sides of the medulla originate, also, the *cranial nerves*, of which there are twelve pairs. These nerves are round cords of glistening white appearance, and, like the arteries, generally lie {155}
remote from the surface of the body, and are well protected from injury.

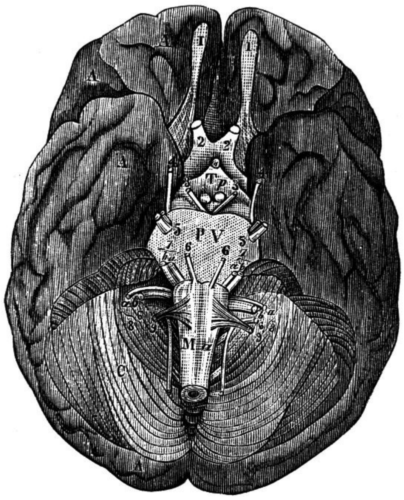

FIG. 43.—THE BASE OF THE BRAIN.

**12.** The spinal cord? Of what composed? How divided? Each half?

**12. The Spinal Cord.**—The spinal cord, or "marrow," is a cylindrical mass of soft nervous tissue, which occupies a chamber, or tunnel, fashioned for it in the spinal column (Fig. 44). It is composed of the same substances as the brain; but the arrangement is exactly reversed, the white matter encompassing or surrounding the gray matter instead of being encompassed by it. The amount of the white substance is also greatly in excess of the other material. A vertical fissure partly separates the cord into two lateral halves, and each half is composed of two separate bundles of fibres, which are named the anterior and posterior columns.

**13.** Uses of these columns? Importance of this part of the nervous system? How protected?

**13.** These columns have entirely different uses, and each of them unites with a different portion of the nerves which have their origin in the spinal cord. The importance of this part of the nervous system is apparent from the extreme care taken to protect it from external injury. For, while a very slight disturbance of its structure suffices to disarm it of its power, yet so staunch is its bony enclosure, that only by very severe injuries is it put in peril. The three membranes that cover the brain are continued downward so as to envelope and still further shield this delicate organism. {156}


FIG. 44.
A, Cerebrum.
B, Cerebellum. D, D, Spinal Cord.

**14.** The spinal nerves? The posterior root? The nerves, how arranged? Their office?

**14. The Spinal Nerves.**—The spinal nerves, thirty-one pairs in number, spring from each side of the cord by two roots, an anterior and a posterior root, which have the same functions as the columns bearing similar names. The posterior root is distinguished by possessing a ganglion of gray matter, and by a somewhat larger size. The successive points of departure, or the off-shooting of these nerves, occur at short and nearly regular intervals along the course of the spinal cord. Soon after leaving these points, the {157}
anterior and posterior roots unite to form the trunk of a nerve, which is distributed, by means of branches, to the various organs of that part of the body which this nerve is designed to serve. The spinal nerves supply chiefly the muscles of the trunk and limbs and the external surface of the body.

**15.** The nerve tissue? Its character? Course of each nerve fibre?

**15.** The tissue composing the nerves is entirely of the white variety, or, in other words, the nerve-fibres; the same as we have observed forming a part of the brain. But the nerves, instead of being soft and pulpy, as in the case of the brain, are dense in structure, being hardened and strengthened by means of a fibrous tissue which surrounds each of these delicate fibres, and binds them together in glistening, silvery bundles. Delicate and minutely fine as are these nerve-fibres, it is probable that each of them pursues an unbroken, isolated course, from its origin, in the brain or elsewhere, to that particular point which it is intended to serve. For, although their extremities are often only a hair's breadth distant from each other, the impression which any one of them communicates is perfectly distinct, and is referred to the exact point whence it came.

**16.** How may we illustrate the fact? The fibre connecting the brain with a point in the foot?

**16.** This may be illustrated in a simple manner, thus: if two fingers be pressed closely together, and the point of a pin be carried lightly across from one to the other, the eyes may be closed, and yet we can easily note the precise instant when the pin passes from one finger to the other. If the nerve-fibres were less independent, and if it were necessary that they should blend with and support each other, all accuracy of

perception would be lost, and all information thus afforded would be pointless and confused. These silvery threads must, therefore, be spun out with an infinite degree of nicety. Imagine, for instance, the fibre which connects the brain with some point {158}
on the foot,—its length cannot be less than one hundred thousand times greater than its diameter; and yet it performs its work with as much precision as fibres that are comparatively much stronger and less exposed.

**17.** The sympathetic system of nerves? Of what does it consist?

**17. The Sympathetic System.**—The *sympathetic system* of nerves remains to be described. It consists of a double chain of ganglia, situated on each side of the spinal column, and extending through the cavities of the trunk, and along the neck into the head. These ganglia are made up for the most part of small collections of gray nerve-cells, and are the nerve-centres of this system. From these, numerous small nerves are derived, which connect the ganglia together, send out branches to the cranial and spinal nerves, and form networks in the vicinity of the stomach and other large organs. A considerable portion of them also follows the distribution of the large and small blood-vessels, in which the muscular tunic appears. Branches also ascend into the head, and supply the muscles of the eye and ear, and other organs of sense.

**18.** Association of the various regions of the body? If one member suffers? Blushing?

**18.** In this manner, the various regions of the body are associated with each other by a nervous apparatus, which is only indirectly connected with the brain and spinal cord; and thus it is arranged that the most widely separated organs of the body are brought into close and active sympathy with each other, so that, "if one member suffers, all the other members suffer with it." From this fact, the name *sympathetic system*, or the *great sympathetic nerve*, has been given to the complicated apparatus we have briefly described. Blushing and pallor are caused by mental emotions, as modesty and fear, which produce opposite conditions of the capillaries of the face by means of these sympathetic nerves. {159}

**19.** Properties of nervous tissue? Office of the gray substance? Of the white? The nervous centres? White fibres?

**19. The Properties of Nervous Tissue.**—We have seen that in all parts of this system, there are only two forms of nervous tissue; namely, the gray substance and the white substance, so called from their difference of color as seen by the naked eye; or the nerve-cell, and the nerve-fibre, so called from their microscopic appearance. Now these two tissues are not commonly mingled together, but either form separate organs, or distinct parts of the same organs. This leads us to the conclusion that their respective uses are distinct. And this proves to be the simple fact; wherever we find the gray substance, we must look upon it as performing an active part in the system, that is, it originates nervous impulses; the white matter, on the contrary, is a passive agent, and serves merely as a conductor of nervous influences. Accordingly, the nervous centres, composed so largely of the gray cells, are the great centres of power, and the white fibres are simply the instruments by which the former communicate with the near and distant regions of the body under their control.

**20.** What comparison is made between the brain and the nation's capitol? The vital property, excitability? What example is given?

**20.** We may compare the brain, then, to the capital, or seat of government, while the various ganglia, including the gray matter of the cord, like so many subordinate official posts, are invested with authority over the outlying provinces; and the nerves, with the white matter of the cord, are the highways over which messages go and return between these provinces and the local or central governments. But both forms of nervous tissue possess the same vital property, called excitability; by which term is meant, that when a nerve-cell or fibre is stimulated by some external agent, it is capable of receiving an impression and of being by it excited into activity. A ray of light, for example, falling upon one extremity of a fibre in the eye, excites it throughout its whole length; and its other extremity, within the brain, communicating {160}
with a nerve-cell, the latter, in its turn, is excited, and the sensation of sight is produced.

**21.** Change in the nervous tissues? Nerve force and electricity?

**21.** What sort of change takes place in the nervous tissue when its excitability is aroused, is not known; certainly none is visible. On this account, it has been thought by some, that the nerve-fibre acts after the manner of a telegraph wire; that is, it transmits its messages without undergoing any material change of form. But, though the comparison is a convenient one, it is far from being strictly applicable; and the notion that nerve-force is identical with electricity has been fully proved to be incorrect.

**22.** Functions of the nerves? In the case of the nerve of a living animal? Of the human body?

**22. The Functions of the Nerves.**—The nerves are the instruments of the two grand functions of the nervous system, Sensation and Motion. They are not the true centres of either function, but they are the conductors of influences which occasion both. If the nerve in a limb of a living animal be laid bare, and irritated by pinching, galvanizing, or the like, two results follow, namely: the animal experiences a sensation, that of pain, in the part to which the nerve is distributed, and the limb is thrown into convulsive action. When a nerve in a human body is cut by accident, or destroyed by disease, the part in which it ramifies loses both sensation and power of motion; or, in other words, it is paralyzed. We accordingly say that the nerves have a twofold use, a *sensory* and *motor* function.

**23.** If an exposed nerve be divided? What is proved? The

**23.** If a nerve that has been exposed be divided, and the inner end, or that still in connection with the nerve-centres, be irritated, sensation is produced, but no movement takes place. But if the outer end, or that still connected with the limb, be course of the sensory set of fibres? Of the motor set? To what are they likened?

irritated, then no pain is felt, but muscular contractions are produced. Thus we prove that there are two distinct sets of fibres in the nerves; one of which, the *sensory* fibres, conduct toward the brain, and another, the *motor* fibres, conduct to the muscles. The former may be said to begin in the skin and other organs, and end in the brain; while the latter begin in the nervous centres and end in the muscles. They are like a double line of telegraph wires, one for inquiries, the other for responses. {161}

**24.** The two roots of the spinal nerves? What has been found? Difference of the two sorts of fibres? Result of their union?

**24.** We have already spoken of the two roots of the spinal nerves, called from their points of origin in the spinal cord, the anterior and posterior roots. These have been separately cut and irritated in the living animal, and it has been found that the posterior root contains only sensory fibres, and the anterior root has only motor fibres. So that the nerves of a limb may be injured in such a way that it will retain power of motion and yet lose sensation; or the reverse condition, feeling without motion, may exist. Between these two sorts of fibres, no difference of structure can be found; and where they have joined to form a nerve it is impossible to distinguish one sort from the other.

**25.** Transient paralysis? When such is the case with the leg? What other fact is observed?

**25.** Occasionally a nerve is so compressed as to be temporarily unable to perform its functions: a transient paralysis then takes place. This is the case when the leg or arm "gets asleep," as it is expressed. When such is the condition with the leg, and the person suddenly attempts to walk, he is liable to fall, inasmuch as the motor fibres cannot convey orders to the muscles of the limb. Another fact is observed: there is no sensation in this nerve at the point of its compression; but the whole limb is numb, and tingling sensations are felt in the foot, the point from which the sensory fibres arise.

**26.** What does this illustrate? Sensation? The feeling after a limb has been amputated? Striking of the "funny bone?"

**26.** This illustrates the manner in which the brain interprets all injuries of the trunk of a nerve. Sensation or pain is not felt at the point of injury, but is referred to the outer extremities of the nerve, where impressions are habitually received. This is the reason why, after a limb has been amputated by the surgeon, the patient appears to suffer pain in the member that has been severed from the body; while some form of irritation at the end of the nerve in the wound, or stump, is the real source of his distress. Again, when the "funny-bone"—that is, the ulnar nerve at the elbow,—is accidentally struck, the tingling sensations thus produced are referred to the outer side of the hand and the little finger, the parts to which that nerve is distributed. {162}

**27.** The spinal nerves, and two from the brain? Of the remainder? Difference in the nerves? How accounted for? The rate of conduction along a nerve? As compared with electricity?

**27.** All the spinal nerves, and two from the brain, are concerned in both sensation and motion. Of the remainder of the cranial nerves, some are exclusively motor, others exclusively sensory; and still others convey, not ordinary sensations, but special impressions, such as sight, hearing, and smell, which we have yet to consider. However much the functions of the nerves seem to vary, there is but little difference discoverable in the nerves themselves, when examined under the microscope. Whatever difference exists must be accounted for in consequence of the nerves communicating with different portions of the gray matter of the brain. The rate of motion of a message, to or from the brain along a nerve, has been measured by experiment upon the lower animals, and estimated in the case of man at about two hundred feet per second. As compared with that of electricity, this is a very slow rate, but, in respect to the size of the human body, it is practically instantaneous.

**28.** Functions of the anterior and posterior columns of the cord? If the cord be divided?

**28. The Functions of the Spinal Cord.**—As the anterior and posterior roots of the spinal nerves have separate functions, so the anterior and posterior columns of the cord are distinct in function. The former are concerned in the production of motion, the latter in sensation. If the cord be divided, as before in the case of the nerve, it is found that the parts below the point of injury are deprived of sensation and of the power of voluntary motion on both sides of the body, a form of paralysis which is called *paraplegia*. {163}

**29.** Paraplegia? Result and danger to life? When the injury occurs in the neck?

**29.** This form of disease, paraplegia, is sometimes seen among men, generally as the result of a fall, or some other severe accident, by which the bones of the spine are broken, and the cord is crushed, or pierced by fragments of bone. The parts which are supplied by nerves from the cord above the point of injury are as sensitive and mobile as before. The results are similar, whether the division happens at a higher or lower portion of the spinal cord; but the danger to life increases proportionally as the injury approaches the brain. When it occurs in the neck, the muscles of inspiration are paralyzed, since they are supplied by nerves issuing from that region; and as a result of this paralysis, the lungs are unable to act, and life is speedily brought to a close.

**30.** Experiment of cutting the spinal cord of an animal? What inference is drawn?

**30.** When the spinal cord of an animal has been cut, in experiment, it may be irritated in a manner similar to that alluded to when considering the nerves. If, then, the upper cut surface be excited, it is found that pain, referable to the parts below the cut, is produced; but when the lower cut surface is irritated, no feeling is manifested. So we conclude that in respect to sensation, the spinal cord is not its true centre, but that it is merely a conductor, and is therefore the great sensory nerve of the body. When the lower surface of the cut is irritated, the muscles of the parts below the section are {164}
violently contracted. Hence, we conclude that, in respect to the movements ordered by the will, the spinal cord is not their source; but that it acts only as a conductor,

and is, accordingly, the great motor nerve of the body.

**31.** What singular fact is noticed? What does the result show?

**31. Direction of the Fibres of the Cord.**—If one lateral half of the spinal cord be cut, or injured, a very singular fact is observed. All voluntary power over the muscles of the corresponding half of the body is lost, but the sensibility of that side remains undiminished. This result seems to show that the motor fibres of the cord pursue a direct course, while its sensory fibres are bent from their course. And this has been proved to be the fact; for immediately after the posterior roots—the conductors of sensory impressions—join the posterior columns, they enter the gray matter of the cord, and passing over, ascend to the brain on the opposite side. Accordingly, the sensory fibres from the right and left sides interlace each other in the gray matter; this arrangement has been termed the *decussation*, or crossing of these fibres. This condition serves to explain how a disease or injury of the cord may cause a paralysis of motion in one leg, and a loss of sensation in the other.

**32.** Direction of the anterior or motor columns? In the cord itself? In the medulla oblongata? The decussation?

**32.** The direction of the anterior, or motor columns of the cord, is downward from the brain. In the cord itself, the course of the motor fibres is for the most part, a direct one; but in the medulla oblongata, or upper extremity of the cord, and therefore early in their career, these fibres decussate, or cross from side to side in a mass; and not separately, as in the case of the posterior fibres just mentioned. This arrangement is termed the *decussation* of the anterior columns of the medulla.

**33.** Result of the double interlacing of fibres? Where is the seat of pain when the right hand is hurt? The moving of the foot? Loss of sensation in one side of the body?

**33.** From this double interlacing of fibres results a crossed action between the original and terminal extremity of all nerve-fibres which pass through the medulla; {165}
namely, those of all the spinal nerves. Consequently, if the right hand be hurt, the left side of the brain feels the pain; and if the left foot move, it is the right hemisphere which dictates its movement. For the same reason, when a loss of sensation and power of motion affecting the right side of the body alone is observed, the physiologist understands that the brain has been invaded by disease upon its left side. This affection is termed *hemiplegia*, or the "half-stroke." The full-stroke, which often follows the rupture of a blood-vessel in the brain, is commonly called *paralysis*.

**34.** What other important use has the cord? What is the activity denominated?

**34. The Reflex Action of the Cord.**—We have already considered the cord as the great motor and sensory nerve of the body, but it has another and extremely important use. By virtue of the gray matter, which occupies its central portion, it plays the part of an independent nerve centre. The spinal cord not only conducts some impressions to the brain, but it also arrests others; and, as it is expressed, "reflects" them into movements by its own power. This mode of nervous activity is denominated the *Reflex Action* of the cord.

**35.** Example of the fowl? Centipede? Frog? What do they prove?

**35.** A familiar example of this power of the cord is found in the violent movements which agitate a fowl after its head has been cut off. The cold-blooded animals also exhibit reflex movements in an astonishing degree. A decapitated centipede will run rapidly forward, and will seemingly strive to overturn, or else climb over obstacles placed in its way. A frog similarly mutilated will sustain its headless body upon its feet, in the standing posture, just as it might do if it were still alive. If pushed over, it
will regain its feet; and if the feet are irritated, it will jump forward. There can be no {166}
doubt that, in the lower animals, movements may take place which are completely divorced from the will, sensation, and consciousness; for in those animals, as well as in man, these faculties have their principal seat within the brain.

**36.** What is necessary in most cases to awaken reflex movements? In the case of the fowl? Convulsions which follow decapitation?

**36.** An irritation is necessary, in most instances, to awaken reflex movements. In the case of the decapitated fowl, its muscles are excited to convulsive action by reason of its being thrown upon the hard ground and roughly handled. Let it be treated differently, and the convulsions will not take place: let it be laid gently upon soft cotton, and the body will remain comparatively quiet. It may comfort some people to know that the convulsions which follow decapitation are not attended with pain; nor are they a necessary part of the "act of death," as some suppose.

**37.** Actions in the human body distinct from voluntary efforts?

**37.** In the human body, likewise, actions are excited that are entirely distinct from the ordinary voluntary efforts. It is not permissible, desirable, nor even necessary to decapitate a man that the body may be disconnected from his brain, in order to test the effect of irritation upon the spinal cord; although the bodies of beheaded criminals have been experimented upon, and caused to move by powerful galvanic batteries. The resort to such means of experiment is rendered unnecessary by the occurrence of certain deplorable cases of disease and injury, which effectually sever all communication between the brain and a large part of the body.

**38.** Reflex action after injury of the cord? Why not due to the muscles?

**38.** Thus, the cord may be so far injured, as the result of accident, as to terminate all sensation and voluntary motion in the lower half of the body, the patient seemingly becoming lifeless and powerless from the waist downward. And yet, by tickling or
pinching either foot, the leg of the same side may be made to jerk, or even to kick {167}
with considerable force; but, unless the patient is observing his limbs, he is wholly unconscious of these movements, which are, therefore, performed independently of the brain. And they are in nowise due to the muscles of the limb; for, if the cord itself becomes diseased below the point of injury, the muscles cease to contract.

**39.** What are the requisites for the production of this form of nervous action?

**39.** For the production of this form of nervous action three things are requisite—(1) a nerve to conduct messages from the surface of the body, one of that variety formerly described as sensory, but which are now incapable of awakening sensation; (2) a portion of uninjured spinal cord which shall reflect or convert impressions into impulses; and (3) a motor nerve to conduct impulses outward to the muscles. The power of the cord to enforce reflex acts resides in the gray matter, into which the reflex nerves enter and from which they depart, by means of their posterior and anterior roots respectively.

**40.** Why do we not readily recognize the reflex activity of the cord in our own bodies? How best studied in others? Example?

**40. The Uses of the Reflex Action.**—The reflex activity of the cord is exhibited in the healthy body in many ways, but since it is never accompanied with sensation, we do not readily recognize it in our own bodies. Reflex movements are best studied in the cases of other persons, when the conditions enable us to distinguish between acts that are consciously, and those that are unconsciously performed. For example, if the foot of a person soundly asleep be tickled or pinched, it will be quickly withdrawn from the irritation.

**41.** Similar movements? Arm of a person? Melted wax or heated coin on the hand?

**41.** Similar movements may be observed in cases where the consciousness and sensation are temporarily obliterated by disease, or by means of narcotic poisons. If the arm of a person who has been rendered insensible by chloroform, be raised, and {168} then allowed to fall, it will be noticed that the limb does not drop instantly, like a lifeless member, but a certain amount of rigidity remains in its muscles, which resists or breaks the force of its descent. Again, when a substance like melted sealing-wax, or a heated coin, falls upon the hand, the limb is snatched away at once, even before the feeling of pain has been recognized by the brain. When jolted in a rapidly moving car, we involuntarily step forward or backward, so as to preserve the centre of gravity of the body.

**42.** Result of healthful reflex activity? When may the reflex energy be deficient?

**42.** These and similar acts are executed by the same mechanism as that previously described in the case of paralysis from an injury of the spinal cord. The muscles thus called into play, are those which are ordinarily under the sway of the will, but which in these cases act through this reflex action of the cord, altogether independently of the will. A healthful reflex activity produces an elasticity, or "tone," of the voluntary muscular system, which, in a great measure, explains the existence in the young and vigorous of a feeling of buoyancy and reserve power. Its possessor is restlessly active, and it may appropriately be said of him, "he rejoiceth as a strong man to run a race." But this reflex energy may be deficient. This is true when the blood is poor and wanting in its solid ingredients, or the circulation is feeble; the muscles, then, are flabby and weak, and the person himself is said to be "nerveless," or indisposed to exertion. Shivering from cold, and trembling from fear, may, in part, be referred to a temporary loss of tone, resulting from a powerful impression upon the brain.

**43.** Excess of this activity in disease? Hydrophobia, etc.? The difference in severity of the convulsions?

**43.** An excess of this activity may also be observed in disease. In this condition, the excitability of the cord is unnaturally aroused, and frequent and violent movements of {169} the limbs and body, called convulsions, are the result. The convulsions of young children, and the nervous agitation of *chorea*, or St. Vitus's dance, are reflex in character; as are also the symptoms attending poisoning by strychnine, and those terrible diseases, *tetanus*, or "locked jaw," and *hydrophobia*. The severity of the convulsions is not the same in all cases of these disorders; but, in those last mentioned the most violent spasmodic movements are provoked by the slightest form of irritation—such as the sound of pouring water, the sight of any glittering object, the glancing of a mirror, the contact of cool air, or even the touch of the bedclothes.

**44.** Another variety of reflex motions? What are they? What is stated of the mind in connection with these movements?

**44.** Another variety of reflex motions takes place in certain involuntary muscles, and over these the cord exercises supreme control. They are principally those movements which aid the performance of digestion and nutrition, the valve-action of the pylorus, and other movements of the stomach and intestines. In these movements the mind shares no part. And it is well that this is so; for since the mind is largely occupied with affairs external to the body, it acts irregularly, becomes fatigued, and needs frequent rest. The spinal cord, on the contrary, is well fitted for the form of work on which depends the growth and support of the body, as it acts uniformly, and with a machine-like regularity.

**45.** Consciousness in these operations? Physical wants?

**45.** These operations are not accompanied by consciousness; for, as a general rule, the attention is only called to them when they become disordered. Many a person does not know where his stomach is situated, until he discovers its position by reason of a feeling of distress within it, produced by giving that organ improper work to perform. In this manner the higher and nobler faculties of the mind are liberated from the simply routine duties of the body; and we are thus left to direct the {170} attention, the reason, and the will to the accomplishment of the great ends of our existence. If it were otherwise, we could only find time to attend to our ordinary physical wants.

**46.** How many objects may the reflex activity be said to have? State

**46.** The objects of the reflex activity of the cord are threefold. In the first place, it acts as the protector of man, in his unconscious moments. It is his unseen guardian, always ready to act, never growing weary, and never requiring sleep. Nor does its faithful action wholly cease with the cessation of life in other parts. In the second the first. The second. The third.

place, it is the regulator of numerous involuntary motions that are necessary to the nutrition of the body. Here its actions are entirely independent of the brain, and are performed in a secret and automatic manner. And, thirdly, it acts as a substitute, and regulates involuntary movements in the muscles usually under the influence of the will. It thus takes the place of the higher faculties in performing habitual acts, and permits them to extend their operations more and more beyond the body and its material wants.

**47.** How does the medulla oblongata resemble the cord?

**47. The Functions of the Medulla Oblongata.**—The prolongation of the spinal cord, within the skull, has been previously spoken of as the medulla oblongata. It resembles the cord, in being composed of both white and gray matter, and in conducting sensory and motor influences. It likewise gives rise to certain nerves, which are here called cranial nerves (from *cranium*, the skull). All except two of these important nerves spring from the medulla, or the parts immediately adjoining it; the exceptions are the two nerves taking part in the special senses of sight and smell, which nerves have their origin at the base of the cerebrum.

**48.** What final fact is observed in the crossing of the motor columns?

**48.** The decussation, or crossing of the motor columns, has been previously described, when treating of the direction of the nerve-fibres of the cord; and the {171} singular fact has been alluded to, that when one side of the brain is injured, its effects are limited to the opposite side of the body. One more fact remains to be observed in this connection, namely, this crossed action does not usually take place in the cranial nerves. Accordingly, when apoplexy, or the rupture of a blood-vessel, occurs in the right hemisphere of the cerebrum, the left side of the body is paralyzed, but the right side of the face is affected; this is because that part of the body is supplied by the cranial nerves.

**49.** The pneumogastric nerve? The feelings aroused by it? The "vital knot?"

**49.** A portion of the medulla presides over the important function of respiration, and from it arises the *pneumogastric* nerve, so called because its branches serve both the lungs and stomach. The feelings of hunger, thirst, and the desire for air are aroused by means of this nerve. The wounding of the gray matter of the medulla, even of a small portion of it, near the origin of the pneumogastric nerve, at once stops the action of the lungs and causes death. In consequence of the importance of this part, it has been termed the "vital knot." We find, also, that its location within the skull is exceedingly well protected, it being quite beyond the reach of any ordinary form of harm from without.

**50.** The uses of the smaller gray masses at the base of the brain?

**50. The Functions of the Cranial Ganglia.**—The uses of the smaller gray masses lying at the base of the brain are not well ascertained; and, on account of their position, so remote from the surface, it would, at first, seem well-nigh impossible to study them. But, from the results following diseases in these parts, and from experiments upon inferior animals, they are becoming gradually better understood; and there is reason to believe that eventually the physiological office of each part will be clearly ascertained and defined. It is believed, however, but not absolutely proven, {172} that the anterior masses, like the anterior roots of the spinal nerves and the anterior columns of the cord, are concerned in the production of motion; in fact, that they are the central organs of that function. The posterior gray masses are, on the contrary, supposed to be the seat of sensation.

**51.** Function of the cerebellum? When it is diseased?

**51. The Function of the Cerebellum.**—The function of the cerebellum, or "little brain," is the direction of the movements of the voluntary muscles. When this organ is the seat of disease or injury, it is usually observed that the person is unable to execute orderly and regular acts, but moves in a confused manner as if in a state of intoxication. Like the larger brain, or cerebrum, it appears to be devoid of feeling; but it takes no part in the operations of the mind.

**52.** Where is the seat of the mind? The subordination of the other organs? The gray matter?

**52. The Function of the Cerebrum.**—The cerebrum, or brain proper, is the seat of the mind; or, speaking more exactly, it is the material instrument by which the mind acts; and, as it occupies the highest position in the body, so it fulfils the loftiest uses. All the other organs are subordinate to it: the senses are its messengers, which bring it information from the outer world, and the organs of motion are its servants, which execute its commands. Here, as in the nervous apparatus of lower grade already considered, the gray matter is the element of power; and, in proportion as this substance increases in extent, and in proportion to the number of convolutions in the hemispheres, do the mental faculties expand.

**53.** What is stated of men in connection with the size of their brain? With the brains of other animals?

**53.** There have been a few, but only a few, men of distinguished ability whose brains have been comparatively small in size; the rule being that great men possess large brains. The relative weight of the brain of man, as compared with the weight of the {173} body, does not, in all instances, exceed that of the inferior animals; the canary and other singing-birds have a greater relative amount of nervous matter than man; but man surpasses all other creatures in the size of the hemispheres of the cerebrum, and in the amount of gray substance which they contain.

**54.** Sensitiveness of the brain substance? The removal of a

**54.** It is a singular fact that this cerebral substance is insensitive, and may be cut without causing pain. The removal of a considerable quantity of the brain has taken place, as the result of accident, without causing death, and without even affecting portion of the brain? State the remarkable case mentioned?

seriously the intellect. A remarkable case of injury of the brain is recorded, in which, from the accidental explosion of gunpowder used in blasting a rock, the "tamping-iron" was driven directly through the skull of a man. This iron rod, three feet and seven inches long, an inch and a quarter in diameter, and weighing more than thirteen pounds, entered the head below the ear and passed out at the top of the skull, carrying with it portions of the brain and fragments of bone. The man sustained the loss of sight on one side, but otherwise recovered his health and the use of his faculties. Moreover, disease has occurred, compromising a large portion of the brain, without impairing the faculties of the mind, when the disease was limited to one side only.

**55.** Thought, emotion, and will? What power do they give us?

**55.** Impressions conveyed to the hemispheres from the external world arouse the mental operations called thought, emotion, and the will. These are the godlike attributes which enable man to subjugate a world, and afterward cause him to "sigh for other worlds to conquer;" which enable him to acquaint himself with the properties of planets millions of miles distant from him, and which give him that creative power by which he builds and peoples the new worlds of poetry and art. {174}

**56.** Are the brain and the mind identical?

**56.** All these mental acts, and many others, are developed through the action of the brain; not that the brain and the mind are the same, or that the brain secretes memory, imagination, or the ideas of truth and justice, as the stomach secretes the gastric juice. But rather, as the nerve of the eye, stimulated by the subtile waves of light, occasions the notion of color, so the brain, called into action by the mysterious influences of the immaterial soul, gives rise to all the intellectual, emotional, and voluntary activities of mankind.

**57.** What do we know of the cerebrum and its powers?

**57.** The cerebrum, according to our present knowledge of it, must be regarded as a single organ, which produces different results, according as it is acted upon by the immaterial mind in different ways. Recent investigations, however, seem to prove that the faculty of language is dependent upon a small part of the left hemisphere of the cerebrum, near the temple. At least, in almost every instance where this part is diseased, the patient can no longer express himself in speech and writing.

**58.** The reflex function of the organs within the skull? The reflex power of the medulla? Respiration?

**58. The Reflex Action of the Brain.**—The reflex function of the organs within the skull is very active and important. Like that of the cord, it protects the body by involuntary movements, it regulates the so-called vegetative acts, and it takes the place of the will in controlling the voluntary muscles, when the attention is turned in other directions. The reflex power of the medulla governs the acts of respiration, which are absolutely and continuously essential to life. Respiration is, as we have seen, partly under the influence of the will; but this is due in part to the fact that respiration is indirectly concerned in one of the animal functions, that of speech.

**59.** What else does reflex action occasion? Winking? Other examples?

**59.** Reflex action also occasions coughing and sneezing, whenever improper {175}
substances enter the air-passages. Winking is an act of the same sort, and serves both to shield the eyes from too great glare of light, and to preserve them by keeping the cornea moist. Looking at the sun or other strong light, causes sneezing by reflex action. Laughing, whether caused by tickling the feet or by some happy thought, and also sobbing, are reflex acts, taking place by means of the respiratory muscles.

**60.** Muscles called into play by certain reflex movements? The somnambulist?

**60.** Certain of the protective reflex movements call into play a large number of muscles, as in the balancing of the body when walking along a narrow ledge, or on a slippery pavement. The dodging motion of the recruit, when the first cannon ball passes over his head, is reflex and involuntary. The fact that these involuntary, reflex acts are performed with great precision, will explain why it is that accidents seldom befall the somnambulist, or sleep-walker, although he often ventures in most perilous places.

**61.** What is said of walking and other acts in connection with the office performed by the medulla and spinal cord?

**61.** Walking, sitting, and other acts of daily life, become automatic, or reflex, from habit: the mind is seldom directed to them, but delegates their control to the medulla and spinal cord. Thus a person in walking, may traverse several miles while absorbed in thought, or in argument with a companion, and yet be conscious of scarcely one in a thousand of the acts that have been necessary to carry his body from one point to another. By this admirable and beautiful provision, the mind is released from the charge of the ordinary mechanical acts of life, and may devote itself to the exercise of its nobler faculties. And it is worthy of notice, that the greater the use of these faculties, the more work does the reflex function assume and perform; and thus the employment of the one insures the improvement of the other. {176}

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## CHAPTER X. {177}

## THE SPECIAL SENSES.

*The Production of Sensations—Variety of Sensations—General Sensibility—Pain and its Function—Special Sensation, Touch, Taste, Smell, Sight, and Hearing—The Hand, the Organ of Touch—The Sense of Touch—Delicacy of Touch—Sensation of Temperature and Weight—The Tongue the Organ of Taste—The Nerves of Taste—The Sense of Taste and its Relations with the other Senses—The Influence of Education on the Taste—The Nasal Cavities, or the organs of Smell—The Olfactory Nerve—The Uses of the Sense of Smell—The Sense of Sight—Light—The Optic Nerve—The Eyeball and its Coverings—The Function of the Iris—The Sclerotic, Choroid, and Retina—The Tears and their Function—The*

*Movements of the Eyeball—The Function of Accommodation—The Sense of Hearing and Sound—The Ear, or the organ of Hearing—The External, Middle, and Internal Ear.*

**1.** True centre of sensation? Place of the mind's impressions? What is it convenient to say? What further is stated?

**1. Production of Sensations.**—We have already seen that the true centre of sensation is some organ within the skull, probably among the gray masses at the base of the brain; but the mind never perceives impressions at that point; but, on the contrary, always refers them to the external organs of sensation. Hence, it is convenient to say, that those outer parts possess the property of sensibility. For instance, we say that we hear with the ear, taste with the tongue, and feel with the fingers. That this is not the exact truth is proven by the fact, that whenever the nerve connecting one of these organs with the brain is severed, it at once loses its capacity for sensation.

**2.** Consciousness? During sleep? In profound insensibility?

**2.** Consciousness, another faculty of the brain, is necessary to complete a sensation. During sleep, and in other unconscious states, the usual impressions are presented to the ear, the nose, and the skin, but they fail to excite sensations, because the nerve- {178}
centres are inactive. In profound insensibility, from chloroform or ether, a limb may be removed without occasioning the least feeling.

**3.** Sensibility in animals? In the earth-worm? In man?

**3. Variety of Sensations.**—All animals have some degree of sensibility. It is of course feeble and indistinct in the lower forms of life, but increases in power and variety as we ascend the scale. In the earth-worm, the nervous system is very simple, the sensibility being moderate and alike in all parts: hence, if its body be cut into two pieces, each piece will have the same degree of feeling as before. As we approach man, however, the sensations multiply and become more acute; the organs are more complex, and special parts are endowed with special gifts. These special organs cannot be separated from the rest of the body without the loss of the functions they are designed to exercise.

**4.** The lowest form of sensation? The highest? Sensations, how modified? What further can you state as to habitual impressions?

**4.** The lowest form of sensation, that of simple contact, is possessed by the lowest of the animal creation. The highest forms are those by which we are enabled to know the properties of external objects, such as shape, size, sound, and color. A variety of means of communicating with the outer world is the necessary possession of a high intelligence. Sensations are modified by use. They become more acute and powerful by moderate exercise; or, they are dulled by undue excitement. The former is shown by the acute hearing of the Indian, by the sharp sight of the sailor, and by the delicate touch of the blind. The latter is exemplified by the impaired hearing of the boiler-maker, and the depraved taste of him who uses pungent condiments with his food. Again, impressions habitually presented may not be consciously felt; as is the case with the rumbling of carriages in a neighboring street, or the regular ticking of a {179}
clock. All sensations become less vivid with the advance of age, especially hearing and vision.

**5.** General sensibility? What have we seen as regards the brain? Of what other structures is the same true?

**5. General Sensibility.**—There is a property possessed by nearly all parts of the human body which we call general sensibility. We have recently seen that the brain is wholly insensitive, and may be cut or pinched without pain. The same is true of the nails, hair, the scarf-skin or external covering of the body, and a few other structures. In these parts no nerves are found. On the other hand, the sensibility of the true skin, and of mucous membranes, as of the eye and nose, is exquisite, these organs having a large supply of sensory nerve-fibres. The bones and tendons have less of these fibres, and are only moderately sensitive.

**6.** The cause of sensibility? Painful part in a surgical operation? Benumbing the surface? How done by ether?

**6.** The sensibility of any part of the body, then, depends upon the number of nerves present; and, as a rule, the nervous supply is proportional to the importance of the part, and to its liability to injury. When, therefore, a surgical operation is performed, the most painful part of it is the incision through the skin; the muscles, cartilage, and bone being comparatively without sensation. Hence, if we could benumb the surface, certain of the lesser operations might be undergone without great inconvenience. This is, in fact, very successfully accomplished by means of the cold produced by throwing a spray of ether, or of some other rapidly evaporating liquid, upon the part to be cut.

**7.** Tickling? Internal sensations? The nerves of general sensibility?

**7.** Tickling is a modification of general sensibility. At first, it excites a pleasurable sensation, but this soon passes into pain. It is only present in those parts where the sense of touch is feeble. But all impressions are not received from without: there are, also, certain internal sensations, as they are called, which depend upon the condition {180}
of the internal organs, such as appetite, hunger, thirst, the sense of satisfaction after taking food, dizziness when looking down from some lofty position, lassitude, drowsiness, fatigue, and other feelings of comfort or discomfort. General sensibility, whether of the internal or external organs of the body, chiefly depends upon the sensory fibres of the spinal nerve. The face, however, is supplied by the sensory cranial nerves. The sympathetic system has a low grade of feeling in health; but disease in the parts served by it arouses an intense degree of pain.

**8.** Connection between pain and

**8. The Sensation of Pain.**—What then is *pain*? Is it identical with ordinary sensibility? There seems to be some necessary connection between the two feelings, sensibility?

for they take place through the same channels, and they are alike intense in the same situations. But sensibility habitually contributes to our sources of pleasure, the very opposite of pain; hence, these feelings cannot be identical.

**9.** Explain the difference between pain and sensibility.

**9.** Pain must, therefore, be a modification of the general sensibility, which follows an excessive degree of excitement of the nerves; there being a natural limit to the amount of stimulation which they will sustain. So long as this limit is observed, the part excited may be said to be simply sensitive; but when it is exceeded, the impression becomes painful. This difference between sensibility and pain is well shown by the effects of sunlight upon the eye. The indirect illumination of the sun arouses only the former feeling, and is indispensable to our comfort and existence; while the direct ray received into the eye occasions great pain.

**10.** Dread of pain? How may its value be appreciated? Example.

**10. The Uses of Pain.**—The dread of pain is a valuable monitor to the body. It puts us on our guard in the presence of danger; teaches moderation in the use of our powers; indicates the approach of disease; and calls attention to it when present. The {181}
word disease, in fact, according to its original use, had reference simply to the pain, or want of ease, which commonly attends disordered health. When we observe the serious mishaps which occur when sensibility and pain are absent, we cannot fail to appreciate its value. For example, a paralytic in taking a foot-bath, forgets to test its temperature, and putting his limbs into water while it is too hot, is severely scalded without knowing it.

**11.** The case of the traveller? Grain of sand? The sun and child?

**11.** A traveller, overcome by cold and fatigue, lies down and falls asleep near a large fire, and when he is aroused in the morning, it is discovered that one of his feet has been insensibly destroyed. A grain of sand, lodging in an insensitive eye, may cause inflammation and even the loss of sight. If intense light were not painful to the eye, many a child would innocently gaze upon the glories of the sun to the ruin of his sight.

**12.** Mission of pain? Painful impressions compared with those of pleasure?

**12.** Pain is, indeed, a present evil, but its relations with the future prove its mission merciful. Painful impressions cannot be recollected from past experience; and they cannot be called into existence by the fancy. Considered in the light of results, pain has a use above that of pleasure; for while the immoderate pursuit of the latter leads to harm, the tendency of pain is to restrict the hurtful courses of life, and in this manner to protect the body.

**13.** What does Magendie say of the relation of pain to pleasure?

**13.** The relations of pain to pleasure are thus described by the eminent physiologist, Magendie:—"By these sensations Nature induces us to concur in the order which she has established among organized beings. Though it may appear like sophistry to say that pain is the shadow of pleasure, yet it is certain that those who have exhausted the ordinary sources of pleasure have recourse to the causes of pain, and gratify {182}
themselves by their effects. Do we not see in all large cities, that men who are debauched and depraved find agreeable sensations, where others experience only intolerable pain?"

**14.** The law of Nature as regards painful sensations among animals?

**14.** As to painful sensation among the inferior animals, the plan of Nature seems to be, that the higher the intelligence of the creature, and the more complete its power of defence, the more acute is its sensibility. We infer, therefore, that animals low in the scale of existence, and helpless, are not very liable to suffer pain.

**15.** The sensation of contact and pain? Special sensations of man? How regarded?

**15. Special Sensation.**—The sensations of simple contact and pain are felt by nearly all parts of the system, whether external or internal, and are the necessary consequence of the general sensibility; but, so far as the objects which surround us are concerned, these impressions are vague and passive in character, and inform the mind of none of the properties or powers of these objects. Besides these feelings, therefore, man is endowed with certain special sensations, which are positive and distinct in character, and which he can call into exercise at will, and employ in the pursuit of knowledge. For reasons relating to the original constitution of the body, these sensations are to be regarded as modifications of the general sensibility already alluded to, constructed with special reference to the different forces of Nature, of which we have any knowledge, such as heat, motion, gravity, sunlight, and the like.

**16.** What are the special senses? Special organs for them?

**16.** These distinct and active faculties are termed the special senses, and are five in number, viz., Touch, Taste, Smell, Sight, and Hearing. For the exercise of these senses, special organs are furnished, such as the hand, the tongue, the nose, the eye, and the ear. The manner in which the nerves of special sense terminate, varies in the case of each organ, so that each is adapted to one set of sensations alone, and is {183}
incapable of perceiving any other. Thus the nerve of hearing is excited by the undulations of sound, and not by those of light, while the reverse is true of the nerve of sight; and the nerve of smell can appreciate neither of them, being capable only of taking cognizance of the odorous properties of bodies.

**17.** What is said in relation to one more than the five senses?

**17.** By some writers six senses are accorded to man; the additional one being either the sense of temperature, for as we shall presently see this is not the same as touch; or according to others, the muscular sense by which we are enabled to estimate the weights of bodies. The latter also differs in some respects from the sense of touch.

**18.** The sense of touch, how prevalent? What is said of the hand?

**18. Organs of Touch.**—The sense of touch is possessed by nearly all portions of the general surface of the body, but it finds its highest development in the hands. The human hand is properly regarded as the model organ of touch. The minute structure of the skin fits it admirably for this form of sensation: the cuticle, or scarf-skin, is fine and flexible, while the cutis, or true skin, contains multitudes of nerve-filaments, arranged in rows of *papillæ*, or cone-like projections, about one-hundredth of an inch in length. It is estimated that there are 20,000 of these papillæ in a square inch of the palmar surface of the hand. Now, although the nerves of the cutis are the instruments by which impressions are received and transmitted to the brain, yet the cuticle is essential to the sensation of touch. This is shown by the fact that whenever the true skin is laid bare, as by a burn or blister, the only feeling that it experiences from contact is one of pain, not that of touch.

**19.** Office of the cuticle? Tips of the fingers? The fingers with thumb?

**19.** The office of the cuticle is thus made evident: it is to shield the nerve filaments from direct contact with external objects. At the tips of the fingers, where touch is {184}
most delicate, the skin rests upon a cushion of elastic material, and receives firmness and permanence of shape by means of the nail placed upon the less sensitive side. Besides these favorable conditions, the form of the arm is such, and its motions are so easy and varied, that we are able to apply the test of touch in a great number of directions. The slender, tapering fingers, with their pliant joints, together with the strong opposable thumb, enable the hand to mold itself upon and grasp a great variety of objects; so that great as are the delicacy and grace of the hand, it is not wanting in the elements of power.

**20.** What special importance is attributed to the hand?

**20.** Its beauty and adaptation to the wants of man have made the hand an attractive theme for philosophers. They do not, however, always agree in their conclusions. One has the opinion that man has acquired his intelligence and achieved his place as "lord of creation," because he has this organ. Buffon, in effect, declares that with fingers twice as numerous and twice as long, we would become proportionally wiser; but Galen long ago took a more reasonable view, when he taught that "man is the wisest of animals, not because he possesses the hand; but because he is the wisest and understands its use, the hand has been given to him; for his mind, not his hand has taught him the arts." Another has well said, that "no one can study carefully the human hand and fail to be convinced of the existence of the Deity."

**21.** The simplicity of touch? What does it teach us?

**21. The Sense of Touch.**—Touch is the simplest of the senses. It is that which the child first calls into exercise in solving the early problems of existence; and it is that which is in the most constant use throughout life. We are brought by the touch into the most intimate relations with external objects, and by it we learn the greater number, if not the most important, of the properties of these objects; such as size, {185}
figure, solidity, motion, and smoothness or roughness of surface.

**22.** Importance of the sense of touch to the development of the other senses?

**22.** The sense of touch assists the other senses, especially that of sight, giving foundation and reality to their perceptions. Without it, the impressions received by the eye would be as vague and unreal as the figures that float through our dreams. A boy who had been blind from birth, at the age of twelve years received sight by means of a surgical operation: at first, he was unable to distinguish between a globe and a circular card, of the same color, before he had touched them. After that, he at once recognized the difference in their form. He knew the peculiarities of a dog and a cat by feeling, but not by sight, until one day, happening to take up the cat, he recognized the connection of the two sorts of impressions, those of touch and sight; and then, putting the cat down, he said: "So, puss, I shall know you next time."

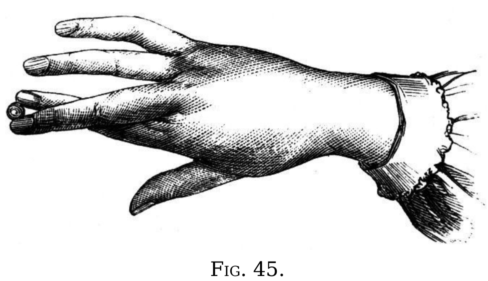

Fig. 45.

**23.** Liability of touch to err? Describe the illustration.

**23.** Touch is considered the least liable to error of all the senses; yet, if that part of the skin by which the sense is exercised is removed from its customary position, a false impression may be created in the mind. This is well illustrated by an experiment, which dates from the time of Aristotle. If we cross the middle finger behind the forefinger, and then roll a marble, or some small object, upon the tips of {186}
the fingers (see Fig. 45), the impression will be that two marbles are felt. If the fingers, thus transposed, be applied to the end of the tongue, two tongues will be felt. When the nose is accidentally destroyed, the surgeon sometimes performs an operation for the purpose of forming a new one, by transplanting a partially removed piece of the skin of the forehead upon the injured part: then, if the new nose be touched or pinched, the feeling is referred to the forehead. This fact illustrates one important truth, that the nerves will re-unite after they have been cut, and feeling will

be restored: if it were otherwise, a succession of slight cuts upon the fingers would seriously impair their tactile sensibility.

**24.** The delicacy of touch? Experiments with a pair of compasses?

**24. The Delicacy of Touch.**—Although the hand is the proper organ of this sense, yet it is exercised by various parts of the body, their degree of sensibility being proportional to the number of papillæ they contain. The varying degrees of tactile delicacy of the different parts of the surface have been measured, in an ingenious manner, by means of a pair of compasses, tipped with small pieces of cork. The two points of the compasses are touched at the same moment to the skin, the eyes being closed, and it is found that, in sensitive parts, the distance between the points may be quite slight, and yet each be plainly felt; while, in less sensitive parts, the points of the compasses are felt as a single point, although they are separated one or two inches.

**25.** Further experiments and results?

**25.** At the tips of the fingers, the distance between the points being one-twentieth of an inch, a double impression is felt. The distance must be twice as great, for the palm; four times as great, for the lips; and, on the forehead, it must be twenty times greater. At the middle of the back, where the touch is least acute, the points must be separated more than two inches before they can be separately felt. Therefore, the {187} sense of touch in the fingers is said to be fifty times more delicate than upon the posterior surface of the body.

**26.** Exquisite delicacy of touch? The same among the blind?

**26.** Exquisite delicacy of touch is attained by practice. This is shown in many of the lighter and more graceful employments of daily life. Without it, the skill of the painter, sculptor, and musician would be rude indeed. By training, also, the physician acquires the *tactus eruditus*, or discriminating touch; but among the blind, delicacy of touch is most remarkable, and it here finds its highest value; for its possession, in a measure, compensates the loss of sight by enabling them to read, by means of raised letters, to work with certain tools, and even to play upon musical instruments. A person born without sight, and without hearing or voice, may, by the education of the touch, be rescued from apparent imbecility, and be taught not only to read and write, but even to perform household and other useful labors.

**27.** Rival candidates for the sixth sense? Give the two reasons on the subject.

**27. Sensations of Temperature and Weight.**—Each of these sensations has been described by the physiologists as a special sense, and they are rival candidates, so to speak, for the position and title of the sixth sense. In the sensation of temperature, or the thermal sense, touch bears a part, but the two feelings appear to be distinct. In proof of this, we observe, firstly, that they are not alike intense in the same situations; as, for example, the skin of the face and elbow, where the sense of touch is feeble, is very sensitive to impressions of heat and cold. Secondly, the ability to recognize temperature may be lost by paralysis, while the sensibility of touch remains unaffected. When the skin comes in contact with a very hot substance, the sensation felt is that of pain, not of touch. In like manner, a very cold substance causes pain, {188} not the feeling of cold. So that a red-hot iron, and solid carbonic acid (the temperature of which is 108° below zero), feel alike; and each, if pressed slightly, will produce a blister.

**28.** The muscular sense? State what is said to illustrate the subject.

**28.** The *muscular sense*, by some considered distinct from touch, gives rise to the sensations of weight, and other forms of external resistance. That this feeling exists, is shown by the following simple experiment. If the hand be placed flat upon a table, and a somewhat heavy weight be put into it, touch alone is exercised and a feeling of pressure results; but if the hand be raised, a certain amount of muscular effort must be put forth, and thus the sensation of weight is recognized. Through the muscular sense, precision of effort is rendered possible; for by it we learn to adjust the force exerted to the weight of the object to be lifted, moved, or carried. Without it, all our movements would necessarily become ill-regulated and spasmodic. In cases of disease, where the sensibility of the lower limbs is lost, while power of motion remains, the patient is able to stand erect so long as he can see his limbs; but just as soon as his eyes are closed, he begins to waver, and will fall unless supported.

**29.** The organ of taste? The tongue? Its powers of motion?

**29. The Organ of Taste.**—The *tongue* is the special organ of the sense of taste; but the back part of the mouth also possesses this faculty. The tongue is a muscular organ, the muscles composing it being so numerous and interwoven as to give it the freedom and variety of motion which it possesses. It can curve itself upward or downward; it can extend or contract itself; and, with its point, can sweep the cavity of the mouth, in all directions, in the search for scattered particles of food.

**30.** Peculiarities of the tongue? Uses of the papillæ?

**30.** The upper surface of the tongue is peculiar, being marked by the presence of innumerable *papillæ*, some of which are of microscopic size, resembling those that {189} abound in the fingers, and in other parts of the body that have the sense of touch. Others are much larger, and give to the tongue its roughness of feeling and appearance. Through the medium of these papillæ, the tongue receives impressions of touch and temperature, as well as taste: indeed, its extremity is fully as delicate, in respect to tactile sensations, as the tips of the fingers themselves. It can recognize the two points of the compasses when separated not more than one-twenty-fourth of an inch; the back of it is much less sensitive to touch, while at the same time it is more highly sensitive to impressions of taste.

**31.** Resemblance to the parts of the tongue? Powers and functions of the parts?

**31.** Each lateral half of the tongue resembles the other in structure, and each receives the same number of nerves—three. One of these regulates motion, the other two are nerves of special sense. One of the latter supplies the front half of the tongue, and is called the *gustatory* nerve. This is a branch of the great cranial nerve, called the "fifth pair," which ramifies in all parts of the face. The back of the tongue is endowed with the power of taste through a nerve known as the *glosso-pharyngeal*, because it is distributed both to the tongue and throat. This difference in the nervous supply of the tongue becomes significant, when we learn, as we shall presently, that each part of it perceives a different class of flavors.

**32.** Taste? What are the requisites to taste?

**32. The Sense of Taste.**—Taste is the special sense by means of which we discover the savors, or flavoring properties of the substances, which come in contact with the tongue. Mere contact with the surface of the tongue, however, is not sufficient, but contact with the extremities of the nerves of taste within the papillæ is required. In order that the substance to be tasted may penetrate the cells covering the nerves, it {190}
must either be liquid in form, or readily soluble in the watery secretion of the mouth, the saliva. The tongue must be moist also. If the substance be insoluble, as glass or sand, or the tongue dry, the sense of taste is not awakened. In sickness, when the tongue is heavily coated, the taste is very defective, or, as is frequently expressed, "nothing tastes aright."

**33.** Portions of the tongue endowed with taste? Where else does the sense lodge? What is stated in respect to sweet and bitter flavors? Reflex effects mentioned?

**33.** All portions of the tongue are not alike endowed with the sense of taste, that function being limited to the posterior third, and to the margin and tip of this organ. The soft palate, also, possesses the sense of taste; hence, an article that has an agreeable flavor may very properly be spoken of as palatable, as is often done. All parts of the tongue do not perceive equally well the same flavors. Thus, the front extremity and margin, which is the portion supplied by the "fifth pair" of nerves, perceives more acutely sweet and sour tastes; but the base of the tongue, supplied by the *glosso-pharyngeal* nerve, is especially sensitive to salt and bitter substances. The nerve of the front part of the tongue, as before stated, is in active sympathy with those of the face, while the relations of the other nerve are chiefly with the throat and stomach; so that when an intensely sour taste is perceived, the countenance is involuntarily distorted, and is said to wear an acid expression. On the other hand, a very bitter taste affects certain internal organs, and occasions a sensation of nausea, or sickness of the stomach.

**34.** What is stated of the relations of taste with other senses?

**34. Relations of Taste with other Senses.**—Taste is not a simple sense. Certain other sensations, as those of touch, temperature, smell, and pain, are blended and confused with it; and certain so-called tastes are really sensations of another kind. Thus an astringent taste, like that of alum, is more properly an astringent feeling, and results from an impression made upon the nerves of touch, that ramify in the tongue. {191}
In like manner, the qualities known as smooth, oily, watery, and mealy tastes, are dependent upon these same nerves of touch. A burning or pungent taste is a sensation of pain, having its seat in the tongue and throat. A cooling taste, like that of mint, pertains to that modification of touch called the sense of temperature.

**35.** Its dependence on smell? on sight?

**35.** Taste is largely dependent upon the sense of smell. A considerable number of substances, like vanilla, coffee, and garlic, which appear to possess a strong and distinct flavor, have in reality a powerful odor, but only a feeble taste. When the sense of smell is interfered with by holding the nose, it becomes difficult to distinguish between substances of this class. The same effect is frequently observed when smell is blunted during an ordinary cold in the head. Sight also contributes to taste. With the eyes closed, food appears comparatively insipid; and a person smoking tobacco in the dark is unable to determine by the taste whether his cigar is lighted or not. Accordingly, it is not a bad plan to close the nose and shut the eyes when about to swallow some disagreeable medicine.

**36.** The chief use of the sense of taste? The position of its organs? The rule as regards wholesome and unwholesome food? Remarks respecting the rule?

**36. Influence of Education on the Taste.**—The chief use of the sense of taste appears to be to act as a guide in the selection of proper food. Hence its organs are properly placed at the entrance of the digestive canal. As a general rule, those articles which gratify the taste are wholesome; while the opposite is true of those which impress it disagreeably. This statement is more exact in reference to the early years of life than to later years, when, by reason of mischievous habits, the sense of taste has become dulled or perverted. The desires of a child are simple; he is fully satisfied with plain and wholesome articles of diet, and must usually "learn to like" those which have a strongly marked flavor. Accordingly, it is far easier at this age to {192}
encourage the preference for plain food, and thus establish healthful habits, than later in life to uproot habits of indulgence in stimulating substances, after their ill effects begin to manifest themselves.

**37.** Diversity in tastes of men? How shown? The education of the sense of taste?

**37.** The tastes of men present the most singular diversities, partly the result of necessity and partly of habit or education. The Esquimaux like the rank smell of whale oil, which is a kind of food admirably suited to the requirements of their icy climate; and travellers who go from our climate to theirs are not slow to develop a liking for the same articles that the natives themselves enjoy. The sense of taste is rendered very acute by education, as is shown in an especial manner by those who become professional "tasters" of tea and wine.

**38.** Location of the sense of smell? The nose? "Roof of the mouth?"

**38. The Sense of Smell—the Nasal Cavities.**—The sense of smell is located in the delicate mucous membrane which lines the interior of the nose. That prominent feature of the face, the nose, which is merely the front boundary of the true nasal organ, is composed partly of bone and partly of cartilage. The upper part of it is united with the skull by means of a few small bones; to which circumstance is due its permanence of shape. The lower portion, or tip of the nose, contains several thin pieces of cartilage, which render it flexible and better able to resist the effects of blows and pressure. Behind the nose we find quite a spacious chamber, separated from the mouth by the hard palate, forming the "roof of the mouth," and by the soft palate (see Fig. 46); and divided into two cavities by a central partition running from before backward.

**39.** Cavities of the nose? Obstruction of the passage of air through them?

**39.** These nasal cavities, constituting the true beginning of the air-passages, extend from the nose backward to the upper opening of the throat, and rise as high as the {193}
junction of the nose with the forehead. The inner wall of each cavity is straight and smooth; but from the outer wall there jut into each cavity three small scroll-like bones. The structure of these bones is very light, and hence they have been called the "spongy" bones of the nose. In this manner, while the extent of surface is greatly increased by the formation of these winding passages, the cavities are rendered extremely narrow; so much so, in fact, that a moderate swelling of the mucous membrane which lines them, as from a cold, is sufficient to obstruct the passage of air through them.

**40.** The special nerve of smell? Its location?

**40. The Nerve of Smell.**—The internal surface of the nasal passages is covered by a delicate and sensitive mucous membrane. Its surface is quite extensive, following as it does, all the inequalities produced by the curved spongy bones of the nose. The upper portion of it alone is the seat of smell, since that part alone receives branches from the "first pair" of cranial nerves, or the olfactory nerve, which is the special nerve of smell (see Fig. 43). In Fig. 46 is shown the distribution of this nerve, in the form of an intricate network upon the two upper spongy bones. The nerve itself (1) does not issue from the skull, but rests upon a thin bone which separates it from the cavity of the nose; and the branches which proceed from it pass through this bone by means of numerous small openings. The engraving represents the outer surface of the right nasal cavity; {194}
the three wave-like inequalities, upon which the nervous network is spread out, are due to the spongy bones. The left cavity is supplied in the same manner.

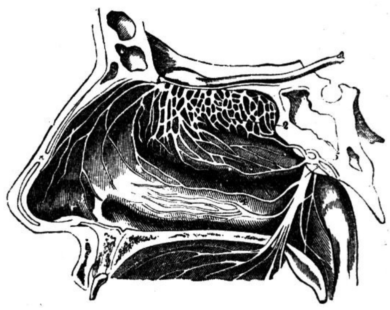

Fig. 46.—Section of the Right Nasal Cavity.

**41.** Branches of the "fifth pair" of nerves? Nasal mucus? Birds?

**41.** The nerves which ramify over the lower part of the membrane, and which endow it with sensibility to touch and pain, are branches of the "fifth pair" of nerves. An irritation applied to the parts where this nerve is distributed occasions sneezing, that is, a spasmodic contraction of the diaphragm; the object of which is the expulsion of the irritating cause. The manner in which the olfactory nerve-fibres terminate is peculiar. Unlike the extremities of other nerves, which are covered in by a greater or less thickness of tissue, these come directly to the surface of the mucous membrane, and thus come into very close contact with the odorous particles that are carried along by the respired air. The surface is at all times kept in a moist condition by an abundant flow of nasal mucus; otherwise it would become dry, hard, and insensitive from the continual passage of air to and fro in breathing. Birds, which respire more actively than men, have a special gland, for secreting a lubricating fluid, located in the air-passages of the head.

**42.** Smell? Touch? Taste? Design of smell? Invisible and gaseous particles? The extreme fineness of the particles? Musk? In other cases?

**42. The Uses of the Sense of Smell.**—Smell is the special sense which enables us to appreciate odors. Touch, as we have seen, is largely concerned with solid bodies; and taste, with fluids, or with solids in solution. Smell, on the other hand, is designed to afford us information in reference to substances in a volatile or gaseous form. Invisible and subtile particles emanate from odorous bodies, and are brought by the respired air in contact with the terminal filaments of the olfactory nerve, upon which an agreeable or disagreeable impression is produced. The fineness of the particles {195}
that constitute odors is often so extreme, that they elude all attempts to measure or weigh them. A piece of musk, for instance, may be kept for several years, constantly emitting perfume, without any appreciable loss of weight. In other cases, a loss of substance is perceptible, such as the essential oils, which enter into the composition of the ordinary perfumes.

**43.** Aid given by smell? The highest use of the sense? Explain the manner.

**43.** Smell, like taste, aids us in the choice of proper food, leading us to reject such articles as have a rank or putrid odor, and which are, as a rule, unfit to be eaten. The highest usefulness of this sense, however, consists in the protection it affords to the organs of respiration. Stationed at the gateways of the air-passages, it examines the current of air as it enters, and warns us of the presence of noxious gases, and of other and generally invisible enemies to health. Not all dangerous vapors are offensive, but almost all offensive vapors are unfit to be breathed. A number of small stiff hairs grow from the margin of the nostrils to prevent the entrance of dust and other atmospheric impurities, which would be alike injurious to the olfactory mucous membrane and to the lungs. The benevolent design of the Maker of our bodies may be observed in all parts of their mechanism; but, probably, in none is it more clearly displayed than in connection with the sense of smell.

**44.** Sense of smell in the inferior animals? How, and in what cases, illustrated?

**44.** The sense of smell is developed in a remarkable degree in certain of the inferior animals, and is especially acute in reference to the peculiar emanations that appear to characterize the different animals. The lion and other carnivorous beasts scent their prey from a great distance; and the fox-hound is able to track the fox through thickets and over open country for many miles; while the timid, helpless herbivora, such as the deer and sheep, find in the sense of smell a means of protection against {196}
their natural enemies, of whose approach they are in this manner warned. By training this sense in the dog, and making it subservient to his use, man is able to hunt with success certain shy and very fleet animals, which otherwise he could but seldom approach. Among men, individuals differ greatly in respect to the development of this sense; and especially in certain savage tribes it is found to be extremely delicate. Humboldt states that the natives of Peru can, by this sense, distinguish in the dark between persons of different races.

**45.** What is sight? What information does it furnish? Composite visual sensations?

**45. The Sense of Sight.**—Sight, or Vision, is the special sense by means of which we appreciate the color, form, size, distance, and other physical properties of the objects of external nature. Primarily, this sense furnishes us with information concerning the different shades of color and the different degrees of brightness: these are the simple sensations of sight, such as the yellowness and glitter of a gold coin. In addition to these, there are composite visual sensations, produced by the joint action of the other senses and by the use of the memory and judgment; such as, in the case of the coin, its roundness, solidity, size, its distance and direction from us. So that many of our sensations, commonly considered as due to sight, are in reality the results of intellectual processes which take place instantaneously and unconsciously.

**46.** Comparison between sight and hearing? Relative capacity of deaf and blind?

**46.** This faculty not only has value in the practical every-day affairs of life, but it contributes so largely to the culture of the intellect and to our higher forms of pleasure, that some writers are disposed to rate it as the first and most valuable of the senses. Others, however, maintain that the sense of hearing does not yield in importance to that of sight; and they cite in support of their position the fact that the {197}
blind are commonly cheerful and gay, while the deaf are inclined to be morose and melancholy. In respect to the relative capacity for receiving education in the deaf and blind, it is found that the former learn more quickly, but their attainments are not profound; while the blind acquire more slowly, but are able to study more thoroughly.

**47.** Sight, unlike the other senses? In the case of the stars?

**47. Light.—The Optic Nerve.**—Unlike the senses previously considered—touch, taste, and smell—sight does not bring us into immediate contact with the bodies that are examined; but, by it, we perceive the existence and qualities of objects that are at a greater or less distance from us. In the case of the stars, the distance is incalculable, while the book we read is removed but a few inches. Light is the agent which gives to this sense its wide range. The nature of this mysterious force is not known, and it is not here to be discussed; since its study belongs more properly to the province of natural philosophy.

**48.** The undulatory theory of light? What does the theory suppose?

**48.** It is sufficient, in this connection, to state that the theory of light now generally accepted, and which best explains the facts of optics, is that known as the undulatory theory. This theory supposes that there exists an intangible, elastic medium, which fills all space, and penetrates all transparent substances, and which is thrown into exceedingly rapid undulations or waves, by the sun and every other luminous body; the undulations being propagated with extreme rapidity, and moving not less than 186,000 miles in a second.

**49.** The sensation of light? Optic nerve?

**49.** These waves are thought to produce in the eye the sensation of light, in the same manner as the sonorous vibrations of the air produce in the ear the sensation of sound. That part of the eye which is sensitive to these waves is the expansion of the *optic nerve*. It is sensitive to no other impression than that of light, and it is the only {198}
nerve which is acted upon by this agent. The optic nerve, also called the "second pair" of cranial nerves, is the means of communication between the eye and the brain.

**50.** The two nerves constituting the pair of nerves?

**50.** The two nerves constituting the pair, arise from ganglia lying at the base of the cerebrum, one of them on each side; from which points they advance to the eyes, being united together in the middle of their course in the form of the letter X (Fig. 43—2). By this union the two eyes are enabled to act harmoniously, and in some respects to serve as a double organ. And by reason of this same intimate nervous communication, when serious disease affects one eye, the fellow-eye is extremely liable to become the seat of *sympathetic* inflammation; and this, if neglected, almost certainly results in hopeless blindness.

**51.** Why is the eye

**51. The Organ of Sight.—The Eye.**—The proximity of the eye to the brain, and the called the "window of the soul?" Why, the subject of enthusiastic study?

important part it performs in giving expression to the emotions, have given it the name of "the window of the soul." The exceeding beauty of its external parts, and the high value of its function, have long made this organ the subject of enthusiastic study. It is chiefly within the last twenty years, however, that this study has been successful and fruitful of practical results. Several ingenious instruments have been invented for the examination of the eye in health and disease, and new operations have been devised for the relief of blindness and of impaired vision. As a result, it is now a well-marked fact that, in civilized lands, the number of those who suffer from loss of sight is proportionally much less than in countries where science is less known and cultivated.

**52.** The most obvious fact? The consequence? The next thing noticed? Its range of view? Of what does the organ of vision consist?

**52.** The most obvious fact in respect to the apparatus of sight is that there are two {199}
eyes, which may either act together as one, and be fixed upon one object, or one eye may be used independently of the other. In consequence of this arrangement the loss of one eye does not necessitate blindness, and, in fact, it not infrequently happens that the sight of one eye may be long impaired or lost before the fact is discovered. We next notice that it is placed at the most elevated part of the body, in front, and near the brain. It also commands a wide range of view, being itself moved with great rapidity, and being further aided by the free motion of the head and neck. The organ of vision consists essentially of two parts: the optical instrument itself—the eyeball—and its enveloping parts, or the case in which the instrument is kept free from harm. The latter, which are external, and which we shall first consider, are chiefly the *Orbits*, the *Eyelids*, and the apparatus for the *Tears*.

**53.** The protection of the eyeball against injury? The overhanging brow? The opening for the optic nerve?

**53. The Orbits.**—The eyeball, which is a delicate organ, is well defended against external injury within the orbits or bony sockets of the head. These are deep conical hollows, bounded in part by the bones of the skull, and in part by those of the nose and cheek. The orbit juts out beyond the most exposed portion of the eyeball, as may be seen by laying a book over the eye, when it will be found that no part of the eyeball, unless it be very prominent, will be touched by the book; so that the only direction in which an injury is liable to be received is immediately in front of the eye. The overhanging brow is itself covered by a layer of thick skin, studded with short, stout hairs, which are so bent as to prevent the perspiration from running into the eye and obscuring vision. Through a hole in the bottom of the orbit, the nerve of sight passes outward from the brain. The orbit also contains a considerable amount of a
fatty tissue, upon which, as upon an elastic cushion, the eye rests. {200}

**54.** What are the eyelids? The upper lid? The lower one? The mucous membrane of the eye?

**54. The Eyelids.**—The eyelids are two movable curtains, or folds, which, when shut, cover the front part of the orbit, and hide the eye from view. The upper lid is the larger, has a curved margin, and moves freely, while the lower lid is comparatively short and straight, and has but a slight degree of motion (Fig. 47). Skin covers the exterior of the lids, while a fine mucous membrane lines their inner surface, and is likewise spread out over the entire front of the eyeball. This membrane, which is called the *Conjunctiva*, is highly sensitive, and thus plays an important part in protecting the eye against the lodgment of sand, ashes, chaff, and other foreign particles that are blown about in the air. This sensitive membrane will not endure the presence of these particles. If any find access, it causes a constant winking, a flow of tears, and other signs of irritation, until it is removed.

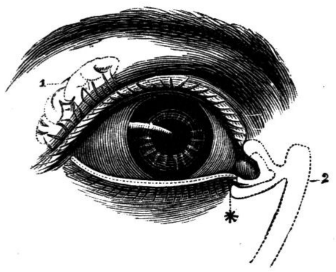


FIG. 47.—FRONT VIEW OF RIGHT EYE. (Natural Size.)

1. The Lachrymal, or tear gland, lying beneath the upper eyelid.

2. The Nasal Duct is shown by the dotted line. The * marks the orifice in the lower lid.

The central black spot is the *pupil*; surrounding it is the *iris*; and the triangular white spaces are the visible portion of the *sclerotic*.

**55.** The eyelashes? The little points within the line of the lashes? Of what use are these glands?

**55.** The long, silky eyelashes, which garnish the edges of the lids, act like a sieve to prevent the entry of dust and the like; and together with the lids, they regulate the amount of light which is permitted to enter the eye, so that it is shielded from a sudden flood or glare of light. The little points seen in the figure just within the line of the lashes, especially on the lower lid, represent the mouths of numerous little sebaceous glands (Fig. 48,
D,D), such as are always found in the neighborhood of hairs. These glands supply a {201}
thick, oily material which greases the edges of the lids and prevents their adhering together, and likewise prevents the overflow of the tears upon the cheek.

**56.** The location of the lachrymal gland? The use of the gland?

**56. The Lachrymal Fluid, or the Tears.**—Just within the outer part of the bony arch of the brow, where the bone may be felt to be sharper than in other positions, is lodged a little organ called the lachrymal gland, the situation of which is indicated in Fig. 47, 1. This is the gland whence flows the watery secretion, commonly called the *tears*, which is designed to perform an exceedingly important duty in lubricating the lids, and in keeping the exposed surface of the eyeball moist and transparent. For, without this or some similar liquid, the front of the eye would speedily become dry and lustreless, like that of a fish which has been removed from the water: the simple exposure of the eye to the air would then suffice to destroy vision.

**57.** When does the secretion of the tears occur? The secretion not used for the eye? Location of the nasal duct? Its use? The overflow of tears in old people?

**57.** This secretion of the tears takes place at all times, during the night as well as the day; but it is seldom noticed, except when under the influence of some strong mental emotion, whether of sorrow or happiness, it is poured forth in excess, so as to overflow the lids. Strong light or a rapid breeze will, among many other causes, excite the flow of the tears. That portion of this secretion which is not used in moistening the eye is carried off into the nose by a canal situated near the inner angle of the eye, called the *nasal duct*. This duct is shown in Fig. 47, 2, and is connected with each lid by delicate tubes, which are indicated by dotted lines in the figure; the asterisk marks the little opening in the lower lid, by which the tears enter the nasal duct. By gently turning the inner part of that lid downward, and looking in a mirror, this small "lachrymal point" may be seen in your own eye. In old people, these {202}
points become everted, and do not conduct the tears to the nasal cavity, so that they are inconvenienced by an overflow of tears upon the face.

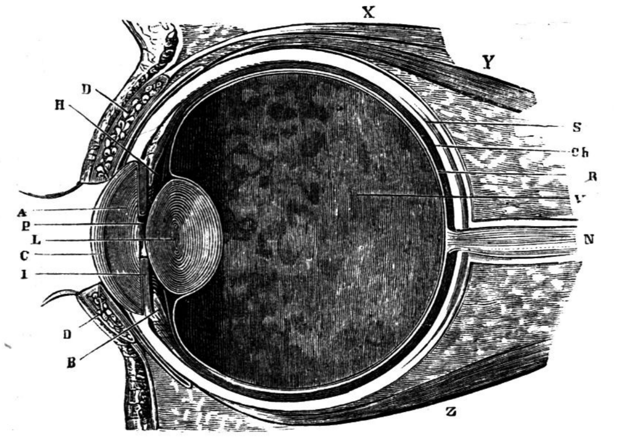


FIG. 48.—VERTICAL SECTION OF THE EYE. (Enlarged.)
C, The Cornea. A, The Aqueous Humor. I, The Iris. P, The Pupil. L, The Crystalline Lens. H, The Ligament of the Lens. B, The Ciliary Process. V, The Cavity containing the Vitreous Humor. S, The Sclerotic. Ch, The Choroid. R, The Retina. N, The Optic Nerve. DD, The Eyelids. X, The Levator Muscle of the Upper Lid. Y, The Upper Straight Muscle of the Eye. Z, The Lower Straight Muscle.

**58.** The watery fluid passing over the eyeball? Design of the arrangement? Winking?

**58.** Thus we observe that the gland which forms the tears is placed at the outer part of the eye, while their means of exit is at the inner angle of the eye; which fact renders it necessary that this watery fluid shall pass over the surface of the eyeball before it can escape. This arrangement cannot be accidental, but evinces design, for it thus secures the perfect lubrication of the surface of the eye, and cleanses it from the smaller particles of dust which may enter it, in spite of the vigilance of the lids {203}
and lashes. The act of winking, which is generally unconsciously performed, and which takes place six or more times in a minute, assists this passage of the tears across the eye, and is especially frequent when the secretion is most abundant.

**59.** Describe the shape of the eyeball. Its structure.

**59. The Eyeball.**—The remarkable optical instrument called the eyeball, or the globe of the eye, upon which sight depends, is, as the name indicates, spherical in shape. It is not a perfect sphere, since the front part projects somewhat beyond the rest, and at the posterior part the optic nerve (Fig. 48, N) is united to it, resembling the junction of the stem with a fruit. In its long diameter, that is, the horizontal or from side to side, it measures a little more than an inch; in other directions it is rather less than an inch. In structure, the ball of the eye is firm, and its tense round contour may in part be felt by pressing the fingers over the closed lids.

**60.** Of what is the eyeball composed? State how.

**60.** The eyeball is composed chiefly of three internal, transparent media, called *humors*; and three investing coats, or *tunics*. The former are the *aqueous humor*, Fig. 48, A, the *crystalline lens* L, and the *vitreous humor* V. Of these the lens alone is solid. The three coats of the eyeball are called the *sclerotic* S, the *choroid* CH, and the *retina* R. This arrangement exists in respect to five-sixths of the globe of the eye, but in the anterior one-sixth, these coats are replaced by the *cornea* C, which is thin and transparent, so that the rays of light pass freely through it, as through a clear window-pane.

**61.** The shape of the cornea? Its structure? The "white of the eye?"

**61.** In shape, the cornea is circular and prominent, resembling a miniature watch-glass, about 1/25 of an inch thick. In structure, it resembles horn (as the name signifies), or the nail of the finger, and is destitute of blood-vessels. The *Sclerotic* {204}
(from *scleros*, hard) is composed of dense, white fibrous tissue, and gives to the eyeball its firmness of figure and its white color; in front, it constitutes the part commonly called "the white of the eye." It is one of the strongest tissues in the body; it possesses very few vessels, and is not very sensitive. It affords protection to the extremely delicate interior parts of the eye; and the little muscles which effect its movements are inserted into the sclerotic a short distance behind the cornea (see Fig.

48, Y, Z). It is perforated posteriorly to admit the optic nerve.

**62.** The second or middle coat of the eyeball? Its dark color?

**62.** The *Choroid* is the second or middle coat of the eyeball, and lies closely attached to the inner surface of the sclerotic. Unlike the latter tunic, its structure is soft and tender, it is dark in color, and possesses a great abundance of blood-vessels. Its dark color is due to a layer of dark brown or chocolate-colored cells spread out over its inner surface. This dark layer serves to absorb the rays of light after they have traversed the transparent structures in front of it; if the rays were reflected from side to side within the eye, instead of being thus absorbed, confused vision would result from the multitude of images which would be impressed upon the optic nerve.

**63.** Similar mechanism in microscopes? The albinos? White rabbits?

**63.** This mechanism has been unconsciously imitated by the opticians, who, when they make a microscope or telescope, take care that the interior of its tube shall be coated with a thick layer of black paint or lamp-black; for without it, a clear delineation of the object to be viewed is impossible. The albinos, in whom these dark cells of the choroid are wanting, have imperfect vision, especially in the daytime and in strong lights. The dark cells are also wanting in white rabbits, and other animals that have red or pink eyes; their vision appears to be imperfect in the presence of a bright light. {205}

**64.** What is the iris? Its construction? How is the size of the pupil regulated?

**64. The Iris.**—Continuous with the choroid, in the front part of the globe of the eye, is a thin, circular curtain, which occasions the brown, blue, or gray color of the eye in different individuals. On account of the varieties of its color, this membrane has received the name *Iris*, which is the Greek word for "rainbow" (see Fig. 48, I). A front view of it is shown in Fig. 47. The iris is pierced in its centre by a round opening, called the *pupil* (P), which is constantly varying in size. In olden times it was spoken of as the "apple of the eye." The hinder surface of the iris, except in albinos, has a layer of dark coloring matter resembling that of the choroid. The iris is a muscular organ, and contains two distinct sets of fibres; one of which is circular, while the other radiates outward from the pupil. The action of these sets of fibres regulates the size of the pupil; for when the circular set acts, the pupil contracts, and when the other set acts, the opening expands. Their action is involuntary, and depends on the reflex system of nerves, which causes the contraction of the pupil when a strong light falls upon the eye, and its expansion when the illumination is feeble.

**65.** The admission of light to the eye? The action of the iris under different circumstances? The lustre of the eye, how affected in youth and old age?

**65.** The iris, accordingly, serves a very useful purpose in regulating the admission of light to the eye. It, however, does not act instantaneously; and hence, when we pass quickly from a dark room into the bright sunlight, the vision is at first confused by the glare of light, but as soon as the pupil contracts, the ability to see becomes perfect. On the other hand, when we enter a dark apartment, such as a cellar, for a short time we can see nothing clearly; but as soon as the pupil expands and admits more light, we are enabled to distinguish the surrounding objects. Animals of the cat species, and others which prowl around after nightfall, are enabled to see in the dark by having {206}
the iris very dilatable. The size of the pupil affects the lustre of the eye. When it is large, as it usually is during youth, the eye appears clear and brilliant; while in old age the pupil is small and the eye is dull. The brilliancy of the eye is in part, at least, dependent upon the reflection of light from the front surface of the crystalline lens.

**66.** Means used to increase the beauty of the eye? The injurious consequences?

**66.** Certain poisonous vegetables have the property of causing the pupil to dilate, and have been used in small doses to increase the beauty of the eye. One of these drugs has been so largely used by the ladies for this purpose, that it has received the name *belladonna*, from the Italian words meaning "beautiful lady." This hazardous practice has resulted more than once in the death of the person desiring thus to increase her personal attraction. The common English name for belladonna is "deadly nightshade." (In the diagram on page 214 the shape and relations of the iris are more accurately shown than in the figure referred to above.)

**67.** What part does the retina constitute? How formed? Its texture? Color? Sensitiveness?

**67. The Retina** constitutes the third and inner coat of the globe of the eye. This, the important part of the eye that is sensitive to light, is a kind of nervous membrane, formed by the expansion of the ultimate filaments of the optic nerve. Its texture is soft, smooth, and very thin; it is translucent and of an opaline, or grayish-white color. It is sensitive to light alone; and if any form of mechanical irritation be applied to it, the sensations of touch and pain are not experienced, but flashes of fire, sparks, and other luminous appearances are perceived. Thus an electric shock given to the eye-ball occasions a flash of light; and a sudden fall, or a blow upon the eye, is often apparently accompanied by the vision of "stars."

**68.** Specific energy of the optic nerve? Trial in Germany?

**68.** These phenomena are due to what is termed the "specific energy" of the optic {207}
nerve, which nerve, in common with the other nerves of special sense, obeys a general law of nature, which requires that, whenever one of these nerves is stimulated, it shall respond with the sensation peculiar to itself. These flashes of retinal light have no power to illuminate external objects, although the opposite of this statement has been maintained. On the occasion of a remarkable trial in Germany, it was claimed by a person who had been severely assaulted on a very dark night, that the flashes of light caused by repeated blows upon the head enabled him to see with sufficient distinctness to recognize his assailant. But the evidence of scientific men entirely refuted this claim, by pronouncing that the eye, under the

circumstances named, was incapacitated for vision. Too intense light occasions a feeling of pain, but it is of a peculiar kind, and is termed "dazzling."

Fig. 49.

**69.** Sensitiveness of all parts of the retina? Experiment to prove the existence of the "blind spot."

**69.** All parts of the retina are not equally sensitive, and singularly enough, the point of entry of the nerve of sight, in the back part of the eyeball, is entirely insensible to light, and is called the "blind spot." The existence of this point may be proven by a simple experiment. Hold the accompanying figure, on page 207, directly in front of and parallel with the eyes. Close the left eye, and fix the sight steadily on the left-hand circle; then, by gradually varying the distance of the figure from the eye, at a certain distance (about six inches), the right-hand circle will disappear, but nearer or {208}
further than that, it will be plainly seen. The other eye may be also tried, with a similar result: if the gaze be directed to the right-hand circle, the left one will seem to disappear. The experiment may be repeated by using two black buttons on the marble top of a bureau, or on some other white surface. The blind spot does not practically interfere with vision, since the eye is seldom fixed immovably on an object, and the insensitive parts of the two eyes can never be directed upon the same object at the same time.

**70.** Duration of impressions upon the retina? How illustrated?

**70.** Impressions made upon the retina are not at once lost, but persist a measurable length of time, and then gradually fade away. Thus, a bright light or color, gazed at intently, cannot be immediately dismissed from sight by closing or turning away the eyes. A stick lighted at one end, if whirled around rapidly in the dark, presents the appearance of an unbroken luminous ring; and the spokes of a rapidly revolving carriage-wheel seem to be merged into a plane surface. If an object move too rapidly to produce this sort of lasting impression, it is invisible, as in the case of a cannon-ball passing through the air in front of us.

**71.** What further illustration? Winking, why it is not noticed. Ease with which the retina is fatigued or deprived of sensibility? How shown?

**71.** If a card, painted with two primary colors—as red and yellow—be made to rotate swiftly, the eye perceives neither of them distinctly; but the card appears painted with their secondary color—orange. The average duration of retinal images is estimated at one-eighth of a second; and it is because they thus endure, that the act of winking, which takes place so frequently, but so quickly, is not noticed and does not interrupt the vision. The retina is easily fatigued or deprived of its sensibility. After looking steadfastly at a bright light, or at a white object on a black ground, a dark spot, corresponding in shape to the bright object, presents itself in whatever {209}
direction we look. This spot passes away as the retina resumes its activity.

**72.** How further shown? How is the result accounted for? "Color-blindness?"

**72.** If a bright color be gazed at intently, and the eyes then be turned to a white surface, a spot will appear; but its color will be the complement of that of the object. Fix the eye upon a red wafer upon a white ground, and on removing the wafer a greenish spot of the same shape takes its place. This result happens because a certain portion of the retina has exhausted its power to perceive the red ray, and perceives only its complementary ray, which is green. The color thus substituted by the exhausted retina is called a physiological or accidental color. In some persons the retina is incapable of distinguishing different colors, when they are said to be affected with "color-blindness." Thus, red and green may appear alike, and then a cherry-tree, full of ripe fruit, will seem of the same color in every part. Railroad accidents have occurred because the engineer of the train, who was color-blind, has mistaken the color of a signal.

**73.** The location of the crystalline lens? How supported? Its color and texture? Shape? Size?

**73. The Crystalline Lens.**—Across the front of the eye, just behind the iris, is situated the *Crystalline lens*, enclosed within its own capsule. It is supported in its place partly by a delicate circular ligament, and partly by the pressure of adjacent structures. It is colorless and perfectly transparent, and has a firm but elastic texture. In shape it is doubly convex, and may be rudely compared to a small lemon-drop. The front face of the lens is flatter than the other, and is in contact with the iris near its pupillary margin, as is represented in the diagram on page 214. It is only one-fourth of an inch thick.

**74.** Cataract? Aqueous humor? Vitreous humor?

**74.** When this little body becomes opaque, and no longer affords free passage to the rays of light, as often happens with the advance of age, an affection termed "cataract" {210}
is produced. Between the crystalline lens and the cornea is a small space which contains the *aqueous humor* (see Fig. 48, A). This humor consists of five or six drops of a clear, colorless liquid very much like water, as its name implies. That part of the globe of the eye lying behind the lens is occupied by the *vitreous humor*, so called from its fancied resemblance to melted glass (Fig. 48, V). This humor is a transparent, jelly-like mass, enclosed within an exceedingly thin membrane. It lies very closely applied to the retina, or nervous membrane of the eye, and constitutes fully two-

thirds of the bulk of the eyeball.

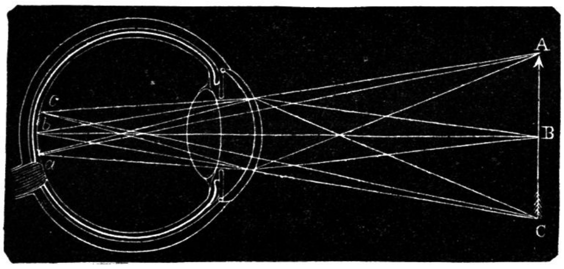


Fig. 50.—The Retinal Image.

75. What is a lens and its focus? The miniature image, how produced?

**75. The Uses of the Crystalline Lens.**—A convex lens has the property of converging the rays of light which pass through it; and the point at which it causes them to meet is termed its focus. If a lens of this description, such as a magnifying or burning-glass, be held in front of an open window, in such a position as to allow its focus to fall upon a piece of paper, it will be found to depict upon the paper a miniature image of the scene outside of the window. It will be further noticed that the image is inverted, or upside down, and that the paper at the place upon which the {211}
image is thrown is much brighter than any other part.

76. How are figures painted upon the retina? How proved?

**76.** Now all the transparent structures of the eye, but especially the crystalline lens, operate upon its posterior part, or retina, as the convex lens acts upon the paper; that is, they paint upon the retina a bright inverted miniature of the objects that appear in front of the eye (Fig. 50). That this actually takes place may be proved by experiment. If the eyeball of a white rabbit, the walls of which are transparent, be examined while a lighted candle is held before the cornea, an image of the candle-flame may be seen upon the retina.

77. What can be said in respect to the form and structure of the crystalline lens?

**77.** The form and structure of the crystalline lens endow it with a remarkable degree of refractive power, and enable it to converge all the rays of light that enter it through the pupil, to a focus exactly at the surface of the retina. When this lens is removed from the eye, as is frequently done for the cure of cataract, it is found that the rays of light then have their focus three-eighths of an inch behind the retina; that the image is four times larger than in the healthy eye, that it is less brilliant, and that its outline is very indistinct. From this we learn that one of the uses of the crystalline lens is to make the retinal image bright and sharply-defined, at the same time that it reduces its size. Indeed, the small size of the image is a great advantage, as it enables the limited surface of the retina to receive, at a glance, impressions from a considerable field of vision.

78. How is the inverted image upon the retina presented in its true position to the mind?

**78.** As the image upon the retina is inverted, how does the mind perceive the object in its true, erect position? Many explanations have been advanced, but the simplest
and most satisfactory appears to be found in the fact that the retina observes no {212}
difference, so to speak, between the right and left or the upper and lower positions of objects. In fact, the mind is never conscious of the formation of a retinal image, and until instructed, has no knowledge that it exists. Consequently, our knowledge of the relative location of external objects must be obtained from some other source than the retina. The probable source of this knowledge is the habitual comparison of those objects with the position of our own bodies: thus, to see an elevated object, we know we must raise the head and eyes; and to see one at our right hand, we must turn the head and eyes to the right.

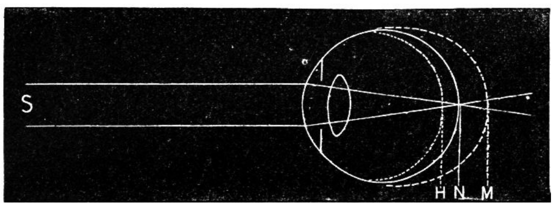


Fig. 51.—The Different Shapes of the Globe of the Eye. N, The Natural Eye. M, The Short-sighted Eye. H, The Long-sighted Eye. S, Parallel Rays from the Sun.

79. The uniform perfection of the eye? Examples? The most common imperfection?

**79. Long-sight or Hyperopia, and Short-sight or Myopia.**—The eye is not in all cases perfectly formed. For example, persons may from birth have the cornea too prominent or too flat, or the lens may be too thick or too thin. In either of these conditions sight will be more or less defective from the first, and the defect will not tend to disappear as life advances. The most common imperfection, however, is in the shape of the globe; which may be short (Fig. 51, H), as compared with the natural eye, N, or it may be too long, M.

80. How is "long-

**80.** When the globe is short, objects can only be clearly seen that are at a distance, {213} sight" explained? "Short-sight?"

and the condition of the vision is known as "long-sight," or hyperopia. It will be observed, by reference to Fig. 51, that the focus of the rays of light would fall behind the retina of this eye. When the globe is too long, objects can only be clearly seen that are very near to the eye; and the condition resulting from this defect is termed "short-sight," or myopia. The focus of the rays of light is, in this case, formed in the interior of the eye in front of the retina.

**81.** Long-sight, how common? With what must it not be confounded? Kind of glasses for short-sight? Why? Squint?

**81.** Long-sight, or hyperopia, is common among schoolchildren, nearly as much so as short-sight, and must not be confounded with the defect known as the "far sight" of old people; although in both affections the sight is improved by the use of convex glasses. Children not infrequently discover that they see much better when they chance to put on the spectacles of old persons. For the relief of short-sight, concave glasses should be employed; as they so scatter the rays of light as to bring the focus to the retina, and thus cause the vision of remote objects to become at once distinct. That form of "squint," in which the eyes are turned inward, is generally dependent upon long-sight, while that rarer form, when they turn outward, is due to short-sight.

**82.** What is stated in connection with the opera-glass? Experiment with pencil and distant object?

**82. The Function of Accommodation.**—If, after looking through an opera-glass at a very distant object, it is desired to view another nearer at hand, it will be found impossible to obtain a clear vision of the second object unless the adjustment of the instrument is altered; which is effected by means of the screw. If an object, like the end of a pencil, be held near the eye, in a line with another object at the other side of the room, or out of the window, and the eye be fixed first upon one and then upon the other, it will be found that when the pencil is clearly seen, the further object is {214}
indistinct; and when the latter is seen clearly, the pencil appears indistinct; and that it is impossible to see both clearly at the same time. Accordingly, the eye must have the capacity of adjusting itself to distances, which is in some manner comparable to the action of the screw of the opera-glass.

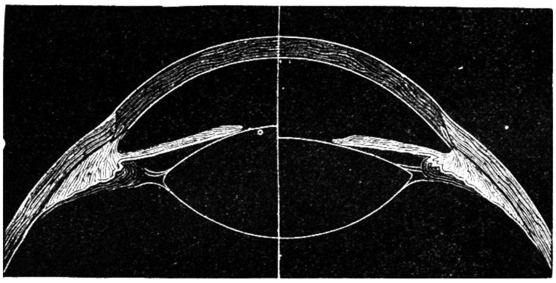

Fig. 52.—The Function of Accommodation.
The right half of the diagram shows the eye at rest. The left half shows the lens accommodated for near vision.

**83.** Function of accommodation? In what does it consist? How is the function explained?

**83.** This, which has been called the function of accommodation, is one of the most admirable of all the powers of the eye, and is exercised by the crystalline lens. It consists essentially in a change in the curvature of the front surface of the lens, partly through its own elasticity, and partly through the action of the ciliary muscle. When the eye is at rest, that is, when accommodated for a distant object, the lens is flatter and its curvature diminished (see Fig. 52); but when strongly accommodated for near vision the lens becomes thicker, its curvature increases, and the image on the retina is made more sharp and distinct. Since a strong light is not required in viewing near objects, the pupil contracts, as is shown in the left-hand half of the diagram. {215}

**84.** Change of sight with the approach of old age? Explain the change?

**84. Old-sight, or Presbyopia.**—But this marvellously beautiful mechanism becomes worn with use; or, more strictly speaking, the lens, like other structures of the body, becomes harder with the approach of old age. The material composing the lens becomes less elastic, the power to increase its curvature is gradually lost, and as a consequence, the person is obliged to hold the book further away when reading, and to seek a stronger light. In a word, the function of accommodation begins to fail, and is about the first evidence that marks the decline of life. By looking at the last preceding diagram, and remembering that the increased curvature of the lens cannot take place, it will be at once understood why old-sight is benefitted in near vision by the convex lens, such as the spectacles of old people contain. It acts as a substitute for the deficiency of the crystalline lens.

**85.** Hearing or audition? What is sound? How propagated commonly? Stone thrown in water?

**85. The Sense of Hearing.—Sound.**—Hearing, or audition, is the special sense by means of which we are made acquainted with *sound*. What is sound? It is an impression made upon the organs of hearing, by the vibrations of elastic bodies. This impression is commonly propagated by means of the air, which is thrown into delicate undulations, in all directions from the vibrating substance. When a stone is thrown into smooth water, a wave of circular form is set in motion, from the point where the stone struck, which constantly increases in size and diminishes in force, as it advances.

**86.** Sound-wave in

**86.** Somewhat resembling this, is the undulation, or sound-wave, which is imparted the atmosphere? Its shape? Rate of motion? Sound, in water, air, and solid bodies?

by a sonorous vibration to the surrounding atmosphere. Its shape, however, is spherical, rather than circular, since it radiates upward, downward, and obliquely as
well as horizontally, like the wave in water. The rate of motion of this spherical wave {216}
of air is about 1050 feet per second, or one mile in five seconds. In water, sound travels four times as fast as in air, and still more rapidly through solid bodies; along an iron rod, its velocity is equal to two miles per second.

**87.** The earth as a conductor of sound? To what has the western Indian been taught? Solid substances as conductors? As regards sound, in what respect is air necessary? Sound in a vacuum?

**87.** The earth, likewise, is a good conductor of sound. It is said that the Indian of our western prairies can, by listening at the surface of the ground, hear the advance of a troop of cavalry, while they are still out of sight, and can even discriminate between their tread and that of a herd of buffaloes. Solid substances also convey sounds with greater power than air. If the ear be pressed against one end of a long beam, the scratching of a pin at the other extremity may be distinctly heard, which will not be at all audible when the ear is removed from the beam. Although air is not the best medium for conveying sound, it is necessary for its production. Sound cannot be produced in a vacuum, as is shown by ringing a bell in the exhausted receiver of an air-pump, for it is then entirely inaudible. But let the air be readmitted gradually, then the tones become more and more distinct, and when the receiver is again full of air, they will be as clear as usual.

**88.** All sonorous bodies do not vibrate with the same degree of rapidity, and upon this fact depends the *pitch* of the sounds that they respectively produce. The more frequent the number of vibrations within a given time, the higher will be the pitch; and the fewer their number, the lower or graver will it be. Now, the rate of the successive vibrations of different notes has been measured, and it has thus been found that if they are less than sixteen in a second, no sound is audible; while if they
exceed 60,000 per second the sound is very faint, and is painful to the ear. The {217}
extreme limit of the capacity of the human ear may be considered as included between these points; but the sounds which we ordinarily hear are embraced between 100 and 3,000 vibrations per second.

**89.** The *ear*, which is the proper organ of hearing, is the most complicated of all the structures that are employed in the reception of external impressions. The parts of which it is composed are numerous, and some of them are extremely small and delicate. Nearly all these parts are located in an irregularly shaped cavity hollowed out in the temporal, or "temple," bone of each side of the head. That part of the bone in which the auditory cavity is placed has the densest structure of all bones of the body, and has therefore been called the "petrous," or rocky part of the temporal bone. In studying the ear, it is necessary to consider it as divided into three portions, which are called, from their relative positions, the *external* ear, the *middle* ear, and the *internal* ear. (In the diagram, Fig. 53, A, the first is not shaded, the second is lightly shaded, and the last has a dark background.)

**90.** Of what does the external portion of the organ of hearing consist? Describe the portal of that organ known as the ear. Its use?

**90. The External Ear.**—The external portion of the organ of hearing, designated in Fig. 53, A, includes, first, that outer part (*a*), which is commonly spoken of as "the ear," but which in fact is only the portal of that organ; and, secondly, the *auditory canal* (*b*). The former consists of a flat flexible piece of cartilage, projecting slightly from the side of the head, attached to it by ligaments, and supplied with a few weak muscles. Its surface is uneven, and curiously curved, and from its resemblance to a shell, it has been called the *concha*. It probably serves to collect sounds, and to give them an inward direction; although its removal is said not to impair the acuteness of
hearing more than a few days. {218}

**91.** The ear in the animals of delicate hearing? Rabbit? Fishes?

**91.** In those animals whose hearing is more delicate than that of man, the corresponding organ is of greater importance, it being larger and supplied with muscles of greater power, so that it serves as a natural kind of ear-trumpet, which is easily movable in the direction of any sound that attracts the attention of the animal. Bold, predaceous animals generally have the concavity of this organ directed forward, while in timorous animals, like the rabbit, it is directed backward. Fishes have no outer ear, but sounds are transmitted directly through the solid bones of the head, to the internal organ of hearing.

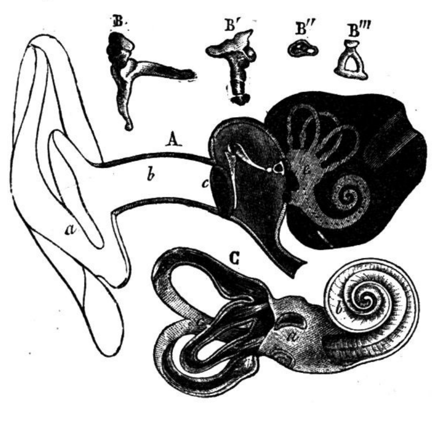

FIG. 53.—THE EAR AND ITS DIFFERENT PARTS.
A, Diagram of the Ear.
*a*, *b*, External Ear. *c*, Membrane tympani.
*d*, Middle Ear. *e*, Internal Ear.
B to B''', Bones of the Middle Ear (magnified).
C, The Labyrinths, or Internal Ear (highly magnified).

**92.** What is the auditory canal? Describe it.

**92.** The *auditory canal* (Fig. 53, A, *b*), which is continuous with the outer opening of the ear, is a blind passage, an inch and a quarter in length, its inner extremity being bounded by a closely-fitting, circular membrane. This canal is of oval form, is directed forward and inward, and is slightly curved; so that the inner end is ordinarily {219} concealed from view. The pouch of the skin which lines this passage is smooth and thin, especially at the lower end, where it covers the membrane just mentioned.

**93.** How is it guarded and protected? Ear-wax?

**93.** As in the case of the nostrils, a number of small, stiff hairs garnish the margin of the auditory canal, and guard it, to some extent, against the entrance of insects and other foreign objects. The skin, too, covering its outer half, is furnished with a belt of little glands which secrete a yellow, viscid, and bitter substance, called "ear-wax," which is especially obnoxious to small insects. As the outer layer of this wax-like material loses its useful properties, it becomes dry, and falls out of the ear in the form of minute, thin scales, a fresh supply being furnished from the little glands beneath. In its form, the auditory canal resembles the tube of an ear-trumpet, and serves to convey the waves of sound to the middle portion of the ear.

**94.** What is the middle ear? Why called tympanum?

**94. The Middle Ear, or Tympanum.**—The middle ear is a small cavity, or chamber, of irregular shape, about one-fourth of an inch across from side to side, and half an inch long (see Fig. 53, A, *d*). From the peculiar arrangement of its various parts it has very properly been called the *tympanum*, or the "drum of the ear." The middle ear, like the external canal, contains air.

**95.** What is the membrana tympani? Describe it.

**95.** The circular membrane, already mentioned as closing the auditory canal, is the partition which separates the middle from the external ear, and is called the *membrana tympani* (*c*), and may be considered as the outer head of the drum of the ear. It is sometimes itself spoken of as the "drum," but this is incorrect; since a drum is not a membrane, but is the hollow space across which the membrane is stretched. This membranous drum-head is very tense and elastic, and so thin as to be almost transparent; its margin is fastened into a circular groove in the adjacent bone. Each {220} wave of sound that impinges against this delicate membrane causes it to vibrate, and it, in turn, excites movements in the parts beyond.

**96.** What are the ossicles? Their number and names? Their arrangement?

**96.** Within the tympanum is arranged a chain of remarkable "little bones," or *ossicles*. They are chiefly three in number, and from their peculiar shapes bear the following names: *malleus*, or the mallet; *incus*, or the anvil; and *stapes*, or the stirrup. A fourth, the smallest bone in the body, in early life intervenes between the incus and stapes, but at a later period it becomes a part of the incus. It is called the *orbicular* bone. Small as are these ossicles—and they, together, weigh only a few grains—they have their little muscles, cartilages, and blood-vessels, as perfectly arranged as the larger bones of the body. One end of the chain of ossicles, the mallet, is attached to the membrane of the tympanum, or outer drum-head, while the other end, the stirrup, is firmly joined by its foot-piece to a membrane in the opposite side of the cavity. The chain, accordingly, hangs suspended across the drum between the two membranes; and when the outer one vibrates under the influence of the sound-wave, the chain swings inward and transmits the vibration to the entrance of the inner ear.

**97.** The Eustachian tube? Describe it, and state its use.

**97.** The musical instrument, the drum, is not complete if the air within be perfectly confined: we therefore find in all instruments of this kind a small opening in the side, through which air may pass freely. By this means the pressure of the air upon the vellum which forms the head of the drum is made equal upon all sides, and the resonance of the drum remains unaffected by the varying density of the atmosphere. It will, therefore, emit its proper sound, whether it be struck in the rarified air of the mountain-top, or in the condensed air of a mine. The tympanum, or drum of the ear, {221} in like manner has an opening by means of which it communicates freely with the external air. This opening is a narrow canal, about an inch and a half long, called the *Eustachian tube*, after the name of its discoverer, Eustachius.

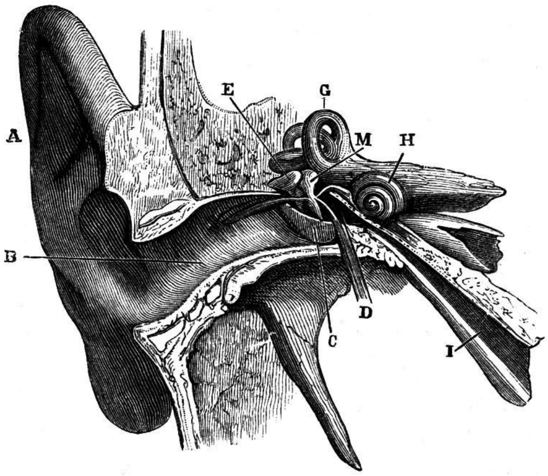


FIG. 54.—SECTION OF THE RIGHT EAR.
A, The Concha. B, Auditory Canal. C, Membrane of the Drum, (the lower half.) D, A small muscle. E, Incus, or Anvil. M, Malleus, or Mallet. I, Eustachian Tube. G, Semicircular Canals. H, Cochlea, or snail's shell.

**98.** What can you state of the action of the Eustachian tube?

**98.** The course of this passage is indicated in Fig. 54, I, directed downward and inward: its other extremity opens into the upper part of the throat. The passage itself is ordinarily closed, but whenever the act of swallowing or gaping takes place, the orifice in the throat is stretched open, and the air of the cavity of the tympanum may then be renewed. Air may at will be made to enter through this tube, by closing the mouth and nose, and then trying to force air through the latter. When this is done, a {222} distinct crackle or clicking sound is perceived, due to the movement of the membranes, and of the little bones of the ear.

**99.** What other purpose does the Eustachian tube serve? How is this shown? "Throat-deafness?" Primary use of the Eustachian tube?

**99.** The Eustachian tube serves, also, as an escape-pipe for the fluids which form within the middle ear; and hence, when its lining membrane becomes thickened, in consequence of a cold, or sore throat, and the passage is thus more or less choked up, the fluids are unable to escape as usual, and therefore accumulate within the ear. When this takes place, the vibrations of the membrane are interfered with; the sounds heard appear muffled and indistinct; and a temporary difficulty of hearing, which is known as "throat-deafness," is the result. This result resembles the effect produced by interrupting the vibrations of a sonorous body, such as all are familiar with; if the finger be placed upon a piano-string or bell when it is struck, the proper sound is no longer fully and clearly emitted. But the primary use of this tube is to afford a free communication between the middle ear and the external atmosphere, and thus secure an equal pressure upon both sides of the membrane of the drum of the ear, however the density of the atmosphere may vary. If, from undue tension of the membranes, pain is experienced in the ears, when ascending into a rare atmosphere, as in a balloon, or descending into a dense one, as in a diving-bell, it may be relieved by repeating the act of swallowing, from time to time, in order that the inner and outer pressure may thus be promptly equalized.

**100.** The essential part of the organ of hearing? Its location? Formation?

**100. The Internal Ear, or Labyrinth.**—The most essential part of the organ of hearing is the distribution of the *auditory nerve*. This is found within the cavity of the internal ear, which, from its exceedingly tortuous shape, has been termed the {223} *labyrinth* (see Fig. 53, C). This cavity is hollowed out in dense bone, and consists of three parts; the *vestibule* (*a*), or ante-chamber, which is connected with the other two; the *cochlea* (*b*), or snail's shell; and the three *semicircular canals* (*c*). The manner in which the nerve of hearing is distributed is remarkable, and is peculiar to this nerve. In the vestibule and the canals its fibres are spread out over the inner surface, not of the bony cavity but of a membranous bag, which conforms to and partially fills that cavity; and which floats in it, being both filled and surrounded with a clear, limpid fluid.

**101.** Where is the "ear-sand" found? Give the theory as to its use.

**101.** A singular addition to the mechanism of hearing is observed within this membranous bag of the labyrinth. This consists of two small oval ear-stones, and a quantity of fine powder of a calcareous nature, which is called "ear-sand." When examined under the microscope, these sandy particles are seen to lie scattered upon and among the delicate filaments of the auditory nerve; and it is probable, that as the tremulous sound-wave traverses the fluid of the vestibule, the sand rises and falls upon the nerve filaments, and thus intensifies the sonorous impression.

**102.** In the cochlea or snail's shell? "Key-board" in the internal ear? The vestibules?

**102.** In the cochlea, or snail's shell, which contains the fluid, but no membrane, the nerve ramifies upon a spiral shelf, which, like the cochlea itself, takes two and a half turns, growing continuously smaller as it winds upward. As many as three thousand nerve fibres of different lengths have been counted therein; which, it has been thought, form the grand, yet minutely small key-board, upon which strike all the

Semicircular canals?

musical tones that are destined to be conveyed to the brain. The vestibule, it is also supposed, takes cognizance of noise as distinguished from musical sounds; while the office of the semicircular canals is, in part at least, to prevent internal echoes, or reverberations. {224}

**103.** With what does the vestibule communicate? What is the theory by which sound is conducted to the brain?

**103.** The vestibule communicates with the chain of bones of the middle ear by means of a small opening, called the "oval window," or *fenestra ovalis*. Across this window is stretched the membrane, which has already been alluded to as being joined to the stirrup-bone of the middle ear. Through this window, then, the sound-wave, which traverses the external and middle ear, arrives at last at the labyrinth. The limpid fluid which the latter contains, and which bathes the terminal fibres of the nerve of hearing, is thus agitated, the nerve-fibres are excited, and a sonorous impression is conducted to the brain, or, as we say, a sound is heard.

**104.** The formation of the organ of hearing with a view to its protection?

**104. Protection of the Sense of Hearing.**—From what has been seen of the complicated parts which compose the organ of hearing, it is evident that while many of them possess an exquisite delicacy of structure, Nature has well and amply provided for their protection. We have observed the concealed situation of the most important parts of the mechanism of the ear, the length of its cavity, its partitions, the hardness of its walls, and its communication with the atmosphere; all these provisions rendering unnecessary any supervision or care on our part in reference to the interior of the ear. But in respect to its external parts, which are under our control and within the reach of harm, it is otherwise. We may both observe the dangers which threaten them, and learn the means necessary to protect them.

**105.** Danger to which the hearing may be subjected? Advice?

**105.** One source of danger to the hearing consists in lowering the temperature of the ear, especially by the introduction of cold water into the auditory canal. Every one is familiar with the unpleasant sensation of distension and the confusion of sounds which accompany the filling of the ear with water when bathing: the weight of the water within it really distends the membrane, and the cold chills the adjacent {225}
sensitive parts. It is not surprising, therefore, that the frequent introduction of cold water and its continued presence in the ear enfeeble the sense of hearing. Care should be taken to remove water from the ear after bathing, by holding the head on one side, and, at the same time, slightly expanding the outer orifice, so that the fluid may run out. For a like reason, the hair about the ears should not be allowed to remain wet, but should be thoroughly dried as soon as possible.

**106.** The general rule as to the use of water for the ear?

**106.** It may be stated as a general rule, to which there are but few exceptions, that no cold liquid should ever be allowed to enter the ear. When a wash or injection is rendered necessary, it should always be warmed before use. The introduction of cold air is likewise hurtful, especially when it pours through a crevice directly into the ear, as it may often do through the broken or partially closed window of a car. The avoidance of this evil gives rise to another almost as great; namely, the introduction of cotton or other soft substances into the ear to prevent it from "catching cold." This kind of protection tends to make the part unnaturally susceptible to changes of temperature, and its security seems to demand the continued presence of the "warm" covering. As a consequence of its presence, sounds are not naturally conveyed, and the sensitiveness of the nerve of hearing is gradually impaired.

**107.** Chief source of injury to the ear? Directions for removing foreign objects from the ear? Of a live insect?

**107.** The chief source of injury, however, to the ear is from the introduction of solid substances into the auditory canal, with the design of removing insects or other foreign objects that have found their way into the ear; or with the design of scraping out the ear-wax. For displacing a foreign object, it is usually sufficient to syringe the ear gently with warm water, the head being so held that the fluid easily escapes. If a {226}
live insect has gained entrance to the ear, it may first be suffocated by pouring a little oil upon it, and afterward removed by syringing the ear as just mentioned.

**108.** The removal of ear-wax is generally unnecessary; for, as we have before seen, Nature provides that the excess of it shall become dry, and then spontaneously fall out in the form of fine scales. The danger from the introduction of solid implements into the outer ear is chiefly found in the fact that the membrane which lies at the bottom of it is very fragile, and that any injury of it is liable to be permanent, and to permanently impair the hearing of the injured ear.

QUESTIONS FOR TOPICAL REVIEW.

*Give as full statements as you can on the following subjects*:

| | |
|---|---|
| 1. Production of sensation | 177, 178 |
| 2. Variety of sensations | 178, 179 |
| 3. General sensibility | 179, 180 |
| 4. The sensation of pain | 180 |
| 5. The uses of pain | 180, 181, 182 |
| 6. Special sensation | 182, 183 |
| 7. Organs of touch | 183, 184 |
| 8. The sense of touch | 184, 185, 186 |

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## CHAPTER XI. {227}

## The Voice.

*Voice and Speech—The Larynx, or the Organ of the Voice—The Vocal Cords—The Laryngoscope—The Production of the Voice—The Use of the Tongue—The different Varieties of Voice—The Change of Voice—Its Compass—Purity of Tone—Ventriloquy.*

**1.** The uttering of sounds by animals? How produced?

**1. Voice and Speech.**—In common with the majority of the nobler animals, man possesses the power of uttering sounds, which are employed as a means of communication and expression. In man, these sounds constitute the voice; in the animals, they are designated as the cry. The song of the bird is a modification of its cry, which is rendered possible from the fact that its respiratory function is remarkably active. The sounds of the animals are generally, but not always, produced by means of their breathing organs. Among the insects, they are sometimes produced by the extremely rapid vibrations of the wings in the act of flight, as in the case of the musquito; or they are produced by the rubbing together of hard portions of the external covering of the body, as in the cricket. Almost all kinds of marine animals are voiceless. The tambour-fish and a few others have, however, the power of making a sort of noise in the water.

**2.** The evidence of man's superior endowment? What is stated of the idiot? Parrot? Raven?

**2.** But man alone possesses the faculty of speech, or the power to use articulate sounds in the expression of ideas, and in the communication of mind with mind. Speech is thus an evidence of the superior endowment of man, and involves the culture of the intellect. An idiot, while he may have complete vocal organs and full {228} power of uttering sounds or cries, is entirely incapable of speech; and, as a rule, the excellence of the language of any people will be found to be proportional to their development of brain. Man, however, is not the only being that has the power to form articulate sounds, for the parrot and the raven may also be taught to speak by rote; but man alone attaches meaning to the words and phrases he employs.

**3.** Speech and hearing? A deaf child? Person having "no ear for music?" Impaired hearing? What do the examples show?

**3.** Speech is intimately related to the sense of hearing. A child born deaf is, of necessity, dumb also; not because the organs of speech are imperfect, for he can utter cries and may be taught to speak, and even to converse in a rude and harsh kind of language; but because he can form no accurate notion of sound. And a person, whose hearing is not delicate, or as it is commonly expressed, who "has no ear for music," cannot sing correctly. A person who has impaired hearing commonly talks in an unnaturally loud and monotonous voice. These examples show the necessary relation of intelligence and the sense of hearing with that form of articulate voice, which is termed speech.

**4.** Organ of the voice? Where situated? Of what is its framework composed?

**4. The Organ of the Voice.**—The essential organ of the voice is the Larynx. This has been previously alluded to in its relation to the function of respiration; and, in the chapter on that subject, are figured the front view of that organ (Fig. 35), and its connection with the trachea, tongue, and other neighboring parts (Fig. 38). It is situated at the upper part of the neck, at the top of the trachea, or tube by which air passes into and out of the lungs. The framework of the larynx is composed of four cartilages, which render it at once very strong and sufficiently flexible to enable it to move according to the requirements of the voice. {229}

**5.** Names, formation, and situation of the cartilages?

**5.** The names of the cartilages are (1) the *thyroid*, which is a broad thin plate, bent in the middle and placed in the central line of the front part of the neck, where it is known as the *pomum Adami*, or Adam's apple (Fig. 55, B), and where it may be felt moving up and down with each act of swallowing; (2) the *cricoid*, which is shaped like a seal ring, with the broad part placed posteriorly (Fig. 55, E). At the top of the cricoid cartilage are situated the two small *arytenoid* cartilages, the right one of which is shown in Fig. 55, C. These latter little organs are much more movable than the other two, and are very important in the production of the voice. They have a true ball and socket joint, and several small muscles which contract and relax with as perfect regularity and accuracy as any of the larger muscles of the body.

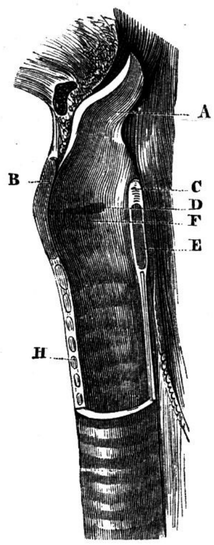


Fig. 55. Section of the Larynx and Trachea. A, The Epiglottis. B, The Thyroid Cartilage. C, Arytenoid Cartilage. D, Ventricle of the Larynx. E, Cricoid Cartilage. F, Right Vocal Cord. H, The Trachea.

**6.** Lining of the interior of the larynx? The epiglottis?

**6.** The interior of the larynx is lined with a very sensitive mucous membrane, which is much more closely adherent to the parts beneath than is usually the case with membranes of this description. The epiglottis (A), consisting of a single leaf-shaped piece of cartilage, is attached to the front part of the larynx. It is elastic, easily moved, and fits accurately over the entrance to the air-passages below it. Its office is to guard these delicate passages and the lungs against the intrusion of food and other foreign articles, when the act of swallowing takes place. It also assists in modifying the voice. {230}

**7.** Where are the vocal cords? The false cords? The true cords?

**7. The Vocal Cords.**—Within the larynx, and stretched across it from the thyroid cartilage in front to the arytenoid cartilages behind, are placed the two sets of folds, called the vocal cords. The upper of these, one on each side, are the false cords, which are comparatively fixed and inflexible. These are not at all essential to the formation of vocal sounds, for they have been injured, in those lower animals whose larynx resembles that of man, without materially affecting their characteristic cries. Below these, one on each side, are the true vocal cords (Fig. 55, F), which pursue a similar direction to the false cords, namely, from before backward. But they are composed of a highly elastic, though strong tissue, and are covered with a thin, tightly-fitting layer of mucous membrane. Their edges are smooth and sharply defined, and when they meet, as they do in the formation of sounds, they exactly match each other.

**8.** Where is the ventricle of the larynx? The essentials to the formation of the tones and modulation of the voice?

**8.** Between the true and false vocal cords is a depression on each side, which is termed the ventricle of the larynx (Fig. 55, D). The integrity of these true cords, and their free vibration, are essential to the formation of the tones and the modulation of the natural voice. This is shown by the fact that, if one or both of these cords are injured or become diseased, voice and speech are compromised; or when the mucous membrane covering them becomes thickened, in consequence of a cold, the vocal sounds are rendered husky and indistinct. When an opening is made in the throat below the cords, as not infrequently happens in consequence of an attempt to commit suicide, voice is impossible except when the opening is closed by external pressure. {231}

**9.** Variation in the interval between the true cords of the voice? Experiment with the mirror?

**9.** The interval or space between the true cords of the voice is constantly varying, not only when their vocal function is in exercise, but also during the act of respiration. Every time the lungs are inflated, the space increases to make wide the entrance for the air; and diminishes slightly during expiration. So that these little cords move gently to and fro in rhythm with the expansion and contraction of the chest in breathing. These movements and others may be seen to take place, if a small mirror attached to a long handle be placed back into the upper part of the throat; the handle near the mirror must be bent at an angle of 45°, so that we may look "around the corner," so to speak, behind the tongue. The position which the mirror must assume will be understood by reference to Fig. 38. A view of

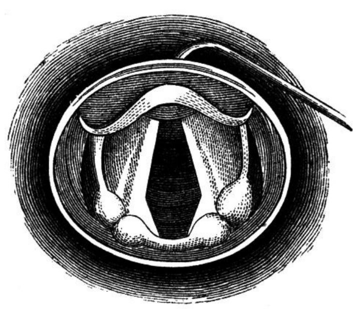

Fig. 56. A View of the Vocal Cords by Means of the Laryngoscope.

what may be seen under favorable circumstances, during tranquil inspiration is represented in Fig. 56. The vocal cords are there shown as narrow, white bands, on each side of the central opening, and since the image is inverted, the epiglottis appears uppermost. The rings partly seen through the opening belong to the trachea.
This little mirror is the essential part of an instrument, which is called the {232}
laryngoscope, and, simple as it may seem, it is accounted one of the most valuable of the recently invented appliances of the medical art.

**10.** The formation of true vocal tones?

**10. The Production of the Voice.**—During ordinary tranquil breathing no sound is produced in the larynx, true vocal tones being formed only during forcible expiration, when, by an effort of the will, the cords are brought close together, and are stretched so as to be very tense. The space between them is then reduced to a narrow slit, at times not more than 1/100 of an inch in width; and the column of expired air being forced through it causes the cords to vibrate rapidly, like the strings of a musical instrument. Thus the voice is produced in its many varieties of tone and pitch; its intensity, or loudness, depending chiefly upon the power exerted in expelling the air from the lungs. When the note is high, the space is diminished both in length and width; but when it is low, the space is wider and longer (Fig. 57, B, C), and the number of vibrations is fewer within the same period of time.

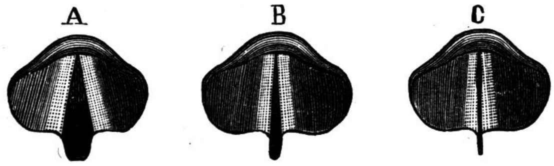


FIG. 57. THE DIFFERENT POSITIONS OF THE VOCAL CORDS. A, The position during inspiration. B, In the formation of low notes. C, In the formation of high notes.

**11.** To what is the personal quality of the voice mainly due? What aids are there?

**11.** The personal quality of the voice, or that which enables us to recognize a person by his speech, is mainly due to the peculiar shape of the throat, nose, and mouth, and
the resonance of the air contained within those cavities. The walls of the chest and {233}
the trachea take part in the resonance of the voice, the air within them vibrating at the same time with the parts above them. This may be tested by touching the throat or breast-bone, when a strong vocal effort is made. The teeth and the lips also are important, as is shown by the unnatural tones emitted by a person who has lost the former, or by one who is affected with the deformity known as "hare-lip." The tongue is useful, but not indispensable to speech; the case of a woman is reported, from whom nearly the whole tongue had been torn out, but who could, nevertheless, speak distinctly and even sing.

**12.** Varieties of voice? The baritone? The voice in early youth?

**12. The varieties** of voice are said to be four in number; two, the bass and tenor, belonging to the male sex; and two, the contralto or alto, and soprano, peculiar to the female. The baritone voice is the name given to a variety intervening between the bass and tenor. In man, the voice is strong and grave; in woman, soft and high. In infancy and early youth, the voice is the same in both sexes, being of the soprano variety: that of boys is both clear and loud, and being susceptible of considerable training, is highly prized in the choral services of the church and cathedral. At about fourteen years of age the voice is said to change; that is, it becomes hoarse and unsteady by reason of the rapid growth of the larynx. In the case of the girl, the change is not very marked, except that the voice becomes stronger and has a wider compass; but in the boy, the larynx nearly doubles its size in a single year, the vocal cords grow thicker, longer, and coarser, and the voice becomes masculine in character. During the progress of this change, the use of the voice in singing is injudicious.

**13.** The range of the voice? Result of careful training of the vocal organs?

**13.** The ordinary range of each of the four varieties of the voice is about two octaves; {234}
but this is exceeded in the case of several celebrated vocalists. Madame Parepa-Rosa has a compass of three full octaves. When the vocal organs have been subjected to careful training, and are brought under complete control of the will, the tension of the cords become exact, and their vibrations become exceedingly precise and true. Under these circumstances the voice is said to possess "purity" of tone, and can be heard at a great distance, and above a multitude of other sounds. The power of a pure voice to make itself heard was recently exemplified in a striking manner: at a musical festival held in an audience-room of extraordinary size, and amid an orchestra of a thousand instruments and a chorus of twelve thousand voices, the artist named above also sang; yet such was the purity and strength of her voice that its notes could be clearly heard rising above the vast waves of sound produced by the full accompaniment of chorus and orchestra.

**14.** The production of the articulate sounds? What experiment is

**14.** In the production of the articulate sounds of speech, the larynx is not directly concerned, but those sounds really depend upon alterations in the shape of the air-passages above that organ. That speech is not necessarily due to the action of the larynx is proven by the following simple experiment. Let an elastic tube be passed mentioned?

through the nostril to the back of the mouth. Then, while the breath is held, cause the tongue, teeth, and lips to go through the form of pronouncing words, and at the same time, let a second person blow through the tube into the mouth. Speech, pure and simple, or, in other words, a whisper is produced. Still further continue the experiment, while permitting vocal sounds to be made, and there will be produced a loud and whispering speech at the same moment; thus showing that voice and speech are the result of two distinct acts. Sighing, in like manner, is produced in the mouth {235} and throat; if, however, a vocal sound be added, the sigh is changed into a groan.

**15.** What is ventriloquism? Indication of the original meaning of the word? How are the ventriloquous sounds produced?

**15. Ventriloquism** is a peculiar modification of natural speech, which consists in so managing the voice that words and sounds appear to issue, not from the person, but from some distant place, as from the chimney, cellar, or the interior of a chest. The original meaning of the word ventriloquism (that is, speaking from the belly), indicates the early belief that this mode of speech was dependent upon the possession and use of some special organ besides the larynx and mouth; but at the present time, it is known that it is produced by these organs alone, and that the sources of deception consist on the part of the performer, in the dexterous management of the voice, together with a talent for mimicry; and, on the part of the auditory, in the liability of the sense of hearing to error in respect to the direction of sounds. The ventriloquist not only seems to "throw his voice," as it is said, or simulates the sound as it usually appears at a distance with but little motion of the lips and face, but he imitates the voices of an infant and of a feeble old man, of a drunken man disputing with an exasperated wife, the broken language of a foreigner, the cry of an animal in distress, demonstrating that the performer must be proficient in the art of mimicry. Ventriloquism was known to the ancient Romans and Greeks; and it is thought that the mysterious responses that were said to issue from the sacred trees and shrines of the oracles at Dodona and Delphi, were really uttered by priests who had the power of producing this form of speech.

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## CHAPTER XII. {236}

## The Use of the Microscope in the Study of Physiology.

**1.** The will of the Creator, by what obeyed? The power of a muscle? Amount of duty performed by the liver?

**1. The Law of the Tissues.**—The will of an infinite Creator is obeyed by atoms as well as by worlds. He has seen fit to commit all the functions of life to structures or tissues so small as to be invisible to the naked eye. A muscle, for example, as we have already learned, is composed of innumerable filaments, visible only by the aid of the microscope; and the power of the muscular mass is but the sum of the contractile power of the filaments which enter into its composition. Again, each cell of the liver, invisible to unassisted sight, is a secreting organ, and the liver performs as much duty as the sum of these minute organs renders possible and no more.

**2.** Necessity for using the microscope? The advantages gained by its use?

**2. The Necessity of the Microscope.**—If, therefore, we would know the real structure of the human body, we must make use of the microscope. We are not at liberty either to use it or not; we *must* have recourse to it in order to obtain a real knowledge of the human body. Our eyes are constructed for the common offices of life, to provide for our wants and guard us from the ordinary sources of danger; but by arming them with *lenses*, the real structure of plants and animals is revealed to our intelligence; and enemies, otherwise invisible, that lie in wait in the air we breathe, and in our daily food and drink, to destroy life, are guarded against.

**3.** What are convex lenses? Kind of lenses used in microscopes? Experiment? Picture thrown upon the eye? Derivation of the word microscope?

**3. Convex lenses**, or magnifying glasses, are disks of glass or other transparent substance, which have the property of picturing upon the retina of the eye an image {237} of an object larger than the image produced there without their aid. The glasses used in microscopes are either double convex lenses (*a*) or plano-convex lenses (*b*). If a double convex lens or a plano-convex one be placed over a hole in the shutter of a darkened room, or over the key-hole of a door, and a piece of paper be held at a proper distance, a picture of all objects in front of the lens will be thrown on the paper, as in the camera-obscura or the magic-lantern. Now, in the same manner, a lens throws a picture of objects to which it is directed on the retina of the eye, and when that picture is larger than the image made in the eye by the object, without the aid of the lens, it is magnified, or the lens has served as a *microscope*, so called, from its use in seeing small objects, from *mikros*, small, and *skopeo*, to see.


**4.** Kinds of microscope? What

**4. Different Kinds of Microscopes.**—Microscopes are either *simple* or *compound*.

are simple microscopes?

The glasses of magnifying spectacles, like those commonly used by aged persons, are simple microscopes. Magnifying glasses, mounted in frames such as are for sale by opticians and others, for the detection of counterfeit money, are simple microscopes, and are useful in studying the coarser structure of plants and animals.

**5.** Construction of the most powerful simple microscopes? In practice? A doublet? Triplet? Why are compound microscopes superior to simple ones?

**5.** The most powerful simple microscopes are made by melting in a flame a thread of spun glass, so as to form a minute globule or bead, which, when set in a piece of {238} metal and used to examine objects on a plate of glass held up to the light, gives a high magnifying power. In practice, however, it is found better to use several magnifying glasses of moderate power, than a simple lens alone of high power. A combination of two lenses is called a *doublet*—of three, a *triplet*. All *simple* microscopes throw an enlarged image of the object upon the retina. *Compound* microscopes are so constructed that the enlarged image of an object is again magnified by a second lens, and hence their magnifying power is vastly superior to that of simple microscopes.

**6.** Explain, by means of the diagram, the action of the compound microscope.

**6.** The accompanying diagrams will explain the action of the compound microscope compared with that of the simple microscope. In Fig. 58, which represents the working of the simple microscope, the rays from the object (*a b*), passing through the lens (L), form an image (*a' b'*) in the retina of the eye (E), and as all images are inverted in the eye, the object is seen as all other objects are, and appears erect. In Fig. 59 is seen the action of the compound microscope. An inverted image (*a' b'*) of the object (*a b*) is magnified by the second lens (L'), and an erect image is thrown upon the retina, which, as all other objects seen erect with the naked eye are inverted, gives to the image a contrary direction, or inverts it to the mind.

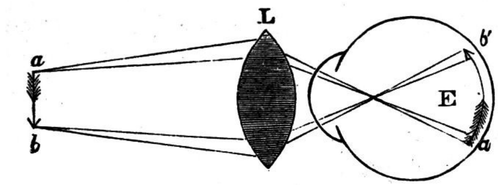


FIG. 58.—SIMPLE MICROSCOPE.

**7.** Portions, in a compound microscope? The glasses?

**7. A Compound Microscope** consists of two portions: the optical portion, or the {239} lenses, and the mechanical portion, or the instrument which bears the lenses. The glasses of a compound microscope are two: the *object-glass* (D), Fig. 60, and the lower lens of Fig. 59, and the *ocular* or *eye-piece* (A), Fig. 60, and the upper piece of Fig. 59. Both the object-glass and the eye-piece may, and usually do, consist of more than one lens, for, as previously mentioned, better results are obtained by a combination of lenses of moderate power than by single lenses of high power and great curvature.

**8.** How to choose a microscope? How to use it?

**8. How to choose and use a Microscope.**—No attractiveness in the mechanical part of a microscope can compensate for inferior lenses; and the very first consideration in the choice of an instrument should be the excellence of the optical part of the instrument. In the use of the instrument, care should be exercised to keep the lenses clean, free from dust, not to press the object-glass upon the object under observation, and not to wet it in the water in which most objects are examined. A good microscope requires its own table; and when not in use should be covered by a bell glass or a clean linen cloth.

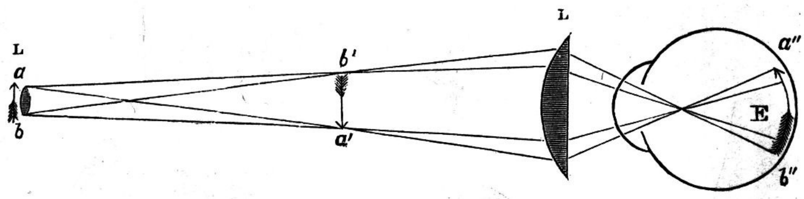


FIG. 59. COMPOUND MICROSCOPE.

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FIG. 60.
A, Eye-piece. B, Body. C, Collar. D, Object-glass. E, Stage. F, Hinge. G, Mirror. H, Stand.

**9.** The characteristics of the best instrument? What special requisites should be insisted upon? Why, as to a horizontal stage?

**9.** The mechanical portion of the instrument varies greatly in different instruments. That one is the best which is simplest, the most solid and easily managed. The stage (E), upon which the object is placed, should not be movable: it should be solid and firm. The screw by which the focal distance is adjusted, and which is in constant use, {241} should be so placed that it can be worked by the hand resting on the table: otherwise fatigue is soon induced. The direction of the tube carrying the glasses should be perpendicular, and the stage therefore horizontal. Most objects in human anatomy are examined in water or in other liquids, or they are themselves liquids; hence an oblique stage is often inconvenient.

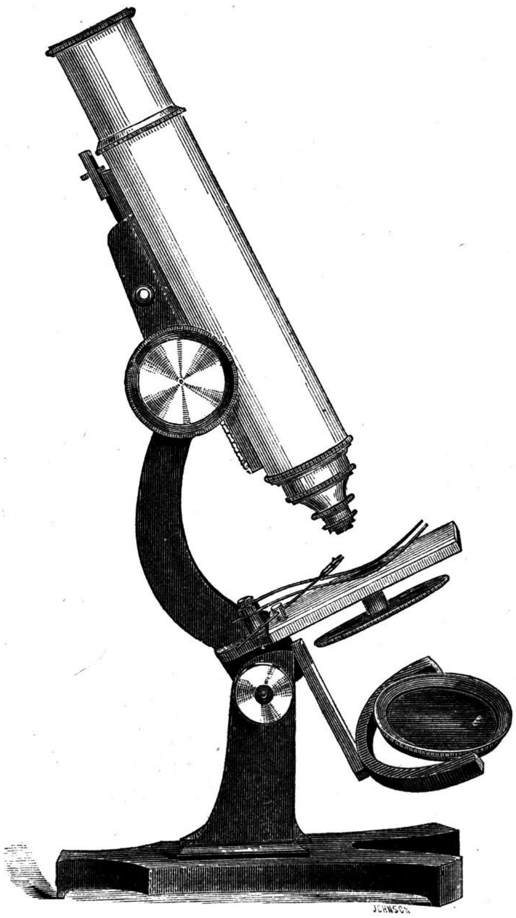

FIG. 61.

10. Slides? Covers, square and circular? How kept?

**10. Additional Apparatus.**—As almost all objects in human anatomy are examined by transmitted light thrown up from the mirror (G, Fig. 60) beneath the stage through the object to the eye, they must be placed upon strips of clear glass about three inches long and one inch wide, commonly called "slides." These should be procured with the microscope. Again, most objects seen with high powers require to be covered with a thin plate of glass, very properly called a "cover," that the moisture of the specimen may not tarnish the object-glass. Square or circular covers of very thin glass are therefore provided; and a good supply of these should be always on hand. These glasses should be kept in a covered dish filled with a mixture of alcohol and water. Simple water will not remove the fatty matter which exists in all animal tissues, and, therefore, the glasses cannot be thoroughly cleaned with it alone. {242}

11. Cleaning the glasses? Knives, scissors, etc.? Various liquids?

**11.** When glasses are required for use, they should be removed from the liquid and wiped clean and dry with a soft linen handkerchief. Delicate knives, scissors, needles mounted in handles, forceps, pipettes or little tubes for taking up water, should be obtained; these are essential to all microscopical study. The table should be supplied with glass-stoppered bottles containing the various liquids ordinarily used in the study of physiology. Thus, tincture of iodine is indispensable in studying vegetable structure, acetic acid in the study of animal tissues; and other articles will have to be added from time to time, as your progress in study demands them. {243}

12. Bodies, in air and water? The examination of starch?

**12. Preliminary Studies.**—In order to prepare the way for the study of any department of science with the aid of the microscope—for the microscope is but an eye, and can be turned in almost any direction for purposes of investigation—it is necessary to become acquainted with the many objects which are liable to complicate the examination of particular structures. Both air and water are full of floating bodies, and the most common of these should first occupy the attention. In the city, particles of starch are always floating in the air. Take a very minute portion of wheat flour, place it in the middle of a clean glass "slide," drop upon it a drop of pure water, cover it with a plate of thin glass, and examine it with a power of from one hundred to six hundred diameters. It will be found to be composed of minute grains or granules, the largest of which are made up of coats or layers, like an onion, arranged around a central spot called the *hilum*.

13. The examination with solution of iodine? Advice respecting other articles?

**13.** Make another preparation in the same manner, and, after adding the water and before covering with the thin glass cover, add a small drop of a solution of iodine. Now, upon examining the specimen, every grain will be seen to be of a beautiful deep blue color. After thus studying wheat starch, the starch of Indian corn, of arrowroot, and of various grains should be examined in like manner, and their resemblances and differences noted. The granules of potato-starch are as distinctly marked as any. (See Fig. 15, page 61.)

14. Directions for examining cotton and other fibres? Vegetable hairs?

**14.** Fibres of cotton, lint, and wool are liable to be found in every specimen prepared for microscopical examination. In order to study these, any cotton, woollen, or linen fabric, or garment, may be scraped, and the scrapings placed on a piece of glass moistened with water, covered with the thin glass plate or cover as before, and examined with the same magnifying power, namely, from one hundred to six hundred {244} diameters. Vegetable hairs or down are constantly floating in air and water. These are of very various forms, are simple or grouped, and form very interesting objects of study. They are readily procured from the epidermis or outer membrane of the leaves or stems of plants, by section with a delicate knife.

15. Directions for examining various tissues? Down of moths, and other structures?

**15.** The tissues of plants, epidermis, ducts, and woody fibres are constantly found in microscopic preparations. They may be studied in delicate sections made with a sharp knife, or by tearing vegetable tissues apart with needles. The down of moths, the hairs of different animals, the fibres of paper, the most common animalcules in water, the dust of shelves, and generally the structures found in all vegetable and animal substances by which we are surrounded, should be studied as a preliminary to any special line of microscopical investigation.

16. Directions for examining a drop of blood?

**16. The Study of Human Tissues.**—When this has been done and familiarity with the use of the instrument has been obtained, proceed to the study of the human body, for human physiology is our subject. If the end of the finger be pricked with a pin, a drop of blood may be procured for examination. Place this on one of the glass slides, cover it with a thin piece of glass, press down the cover so as to make a thin layer, and then examine with the magnifying power just mentioned. Do not add water, for that will cause the blood corpuscles to disappear. If the drop of blood is placed under the microscope at once after being drawn from the finger, most interesting phenomena will be observed. The red corpuscles will be seen to arrange themselves in rows, like piles of coin, while the blood is coagulating. The spherical, white corpuscles will be left out of the rows of red disks, and, if the highest power be used, {245} will be seen to change their shape constantly.

17. Examination of the scales of the

**17.** If you scrape with a dull knife the inside of the cheek, the flattened scales of "pavement epithelium," or of the insensible covering which, analogous to the scarfmouth? Dandruff?

skin on the outer surface of the body, lines the cavities of its interior, may be readily studied. They have the appearance of transparent tiles, each enclosing a round or oval body, called its nucleus. Dandruff and the scrapings from the skin of the body are composed of scales like those of the mouth, but they differ somewhat in being hardened by horny matter, and in having a very faint central body or nucleus.

**18.** In what, as respects the tissues, do the warm blooded animals differ? Statement of Milne Edwards?

**18. The Tissues of the Inferior Animals.**—The warm-blooded animals do not differ in the tissues, or microscopic structures, that compose them, but only in the amount and arrangement of these tissues. Milne Edwards says these tissues "do not differ much in different animals, but their mode of association varies; and it is chiefly by reason of the differences in the combination of these associations in various degrees, that each species possesses the anatomical properties and characters which are peculiar to it."

**19.** How to procure materials for the study of the tissues of man?

**19.** Hence the butcher's stall will furnish all the materials for the study of the microscopic tissues. The structure of the heart, lungs, liver, brain, and muscle may all be studied, and well studied, by using minute pieces of the flesh of the lower animals, especially of the quadrupeds. Such portions of these animals as are not exposed for sale can be readily obtained by order from the slaughter-house. To examine with the powers of which we have been speaking, it is only necessary to cut off exceedingly {246}
small pieces, tear them apart with needles, or make very delicate sections with a sharp knife.

**20. Incentives to Study.**—A complete knowledge of all minute structures is not to be expected at once, for you are here introduced into a new realm of Nature, a world of little things as vast, as wonderful, and as carefully constructed as the starry firmament,—that other realm of grand objects which the astronomer nightly scans with the telescope. It will not appear singular, therefore, if, at first, you feel strange and awkward in this new creation. With a little perseverance, however, and with the attention directed toward simple objects at the outset, it will not be long before an increasing experience will engender confidence.

**21.** If to all this there be added an enthusiastic study of the standard authorities on the subject, the rate of progress will be by so much the more rapid. As compared with similar studies, few possess more interest than microscopy, and to the one who pursues it with fondness, it constantly affords sources of pleasure and agreeable surprises; and in the end, often leads to new and valuable additions to the sum of human knowledge. The depths which the microscope is employed to fathom are no more completely known, than are the heights above us explored and comprehended by the astronomer.

QUESTIONS FOR TOPICAL REVIEW.

*State what you can on the following subjects*:

| | |
|---|---|
| 1. Voice and speech | 227, 228 |
| 2. The organ of the voice | 228, 229 |
| 3. The vocal cords | 230, 231 |
| 4. The production of the voice | 232, 233 |
| 5. The varieties of voice | 233, 234 |
| 6. Ventriloquism | 235 |
| 7. The law of the tissues | 236 |
| 8. Necessity of the microscope | 236 |
| 9. Convex lenses | 236, 237 |
| 10. Kinds of microscope | 237, 238 |
| 11. Choosing a microscope | 239, 242 |
| 12. Preliminary studies | 243, 244 |
| 13. The study of human tissues | 244 |
| 14. The study of the inferior animals | 245 |

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# APPENDIX.

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## POISONS AND THEIR ANTIDOTES.

Accidents from poisoning are of such frequent occurrence, that every one should be able to administer the more common antidotes, until the *services of a physician can be obtained*. As many poisons bear a close resemblance to articles in common use, no dangerous substance should be brought into the household without having the word *poison* plainly written or printed on the label; and any package, box, or vial, without a label, should be at once destroyed, if the contents are not positively known.

When a healthy person is taken severely and *suddenly* ill *soon after some substance has been swallowed*, we may suspect that he has been poisoned. In all cases where poison has been taken into the stomach, it should be quickly and thoroughly evacuated by some active emetic, which can be speedily obtained. This may be accomplished by drinking a tumblerful of warm water, containing either a tablespoonful of powdered mustard or of common salt, or two teaspoonfuls of powdered alum in two tablespoonfuls of syrup. When vomiting has already taken place, it should be maintained by copious draughts of warm water or mucilaginous drinks, such as gum-water or flaxseed tea, and tickling the throat with the finger until there is reason to believe that all the poisonous substance has been expelled from the stomach.

The following list embraces only the more common poisons, together with such antidotes as are usually at hand, to be used until the physician arrives.

## POISONS.

**Acids.**—*Hydrochloric acid*; *muriatic acid* (spirits of salt); *nitric acid* (aqua fortis); *sulphuric acid* (oil of vitriol).

ANTIDOTE.—An antidote should be given at once to neutralize the acid. Strong soapsuds is an efficient remedy, and can always be obtained. It should be followed by copious draughts of warm water or flaxseed tea. Chalk, magnesia, soda or saleratus (with water) or lime-water, are the best {248}
remedies. When sulphuric acid has been taken, water should be given sparingly, because, when water unites with this acid, intense heat is produced.

*Oxalic acid.*

ANTIDOTE.—Oxalic acid resembles Epsom salts in appearance, and may easily be mistaken for it. The antidotes are magnesia, or chalk mixed with water.

**Prussic Acid**; *oil of bitter almonds*; *laurel water*; *cyanide of potassium* (used in electrotyping).

ANTIDOTE.—Cold douche to the spine. Chlorine water, or water of ammonia largely diluted, should be given, and the vapor arising from them may be inhaled.

**Alkalies and their Salts.**—AMMONIA (hartshorn), *liquor or water of ammonia*. POTASSA:—*caustic potash*, *strong ley*, *carbonate of potassa* (pearlash), *nitrate of potassa* (saltpetre).

ANTIDOTE.—Give the vegetable acids diluted, as weak vinegar, acetic, citric, or tartaric acids dissolved in water. Castor oil, linseed oil, and sweet oil may also be used; they form soaps when mixed with the free alkalies, which they thus render harmless. The poisonous effects of saltpetre must be counteracted by taking mucilaginous drinks freely, so as to produce vomiting.

**Alcohol.**—*Brandy*, *wine*; *all spirituous liquors*.

ANTIDOTE.—Give as an emetic ground mustard or tartar emetic. If the patient cannot swallow, introduce a stomach pump; pour cold water on the head.

**Gases.**—*Chlorine*, *carbonic acid gas*, *carbonic oxide*, *fumes of burning charcoal*, *sulphuretted hydrogen*, *illuminating or coal-gas*.

ANTIDOTE.—For poisoning by chlorine, inhale, cautiously, ammonia (hartshorn). For the other gases, cold water should be poured upon the head, and stimulants cautiously administered; artificial respiration. (See *Marshall Hall's Ready Method*, page 250.)

**Metals.**—*Antimony*, *tartar emetic*, *wine of antimony*, etc.

ANTIDOTE.—If vomiting has not occurred, it should be produced by tickling the throat with the finger or a feather, and the abundant use of warm water. Astringent infusions, such as common tea, oak bark, and solution of tannin, act as antidotes.

**Arsenic.**—*White arsenic*, *Fowler's solution*, *fly-powder*, *cobalt*, *Paris green*, etc.

ANTIDOTE.—Produce vomiting at once with a tablespoonful or two of powdered mustard in a glass of warm water, or with ipecac. The antidote is hydrated peroxide of iron. If Fowler's solution has been taken, lime-water must be given. {249}

**Copper.**—*Acetate of copper* (verdigris), *sulphate of copper* (blue vitriol), food cooked in dirty *copper vessels*, or pickles made green by *copper*.

ANTIDOTE.—Milk or white of eggs, with mucilaginous drinks (flaxseed tea, etc.), should be freely given.

**Iron.**—*Sulphate of iron* (copperas), etc.

ANTIDOTE.—Carbonate of soda in some mucilaginous drink, or in water, is an excellent antidote.

**Lead.**—*Acetate of lead* (sugar of lead), *carbonate of lead* (white lead), water kept in *leaden pipes* or *vessels*, food cooked in *vessels* glazed with *lead*.

ANTIDOTE.—Induce vomiting with ground mustard or common salt in warm water. The antidote for soluble preparations of lead is Epsom salts; for the insoluble forms, sulphuric acid largely diluted.

**Mercury.**—*Bichloride of mercury* (corrosive sublimate), *ammoniated mercury* (white precipitate), *red oxide of mercury* (red precipitate), *red sulphuret of mercury* (vermilion).

Antidote.—The white of eggs, or wheat flour beaten up with water and milk, are the best antidotes.

**Silver.**—*Nitrate of silver* (lunar caustic).

Antidote.—Give a teaspoonful of common salt in a tumbler of water. It decomposes the salts of silver and destroys their activity.

**Zinc.**—*Sulphate of zinc*, etc. (white vitriol).

Antidote.—The vomiting may be relieved by copious draughts of warm water. The antidote is carbonate of soda administered in water.

**Narcotic Poisons.**—*Opium* (laudanum, paregoric, salts of morphia, Godfrey's cordial, Dalby's carminative, soothing syrup, cholera mixtures), *aconite*, *belladonna*, *hemlock*, *stramonium*, *digitalis*, *tobacco*, *hyosciamus*, *nux vomica*, *strychnine*.

Antidote.—Evacuate the stomach by the most active emetics, as mustard, alum, or sulphate of zinc. The patient should be kept in motion, and cold water dashed on the head and shoulders. Strong coffee must be given. The physician will use the stomach pump and electricity. In poisoning by nux vomica or strychnine, etc., chloroform or ether should be inhaled to quiet the spasms.

**Irritant Vegetable Poisons.**—*Croton oil*, *oil of savine*, *poke*, *oil of tansy*, etc.

Antidote.—If vomiting has taken place, it may be rendered easier by copious draughts of warm water. But if symptoms of insensibility have come on without vomiting, it ought to be immediately excited by ground mustard mixed with warm water, or some other active emetic and after its {250}
operation an active purgative should be given. After evacuating as much of the poison as possible, strong coffee or vinegar and water may be given with advantage.

**Poisonous Fish.**—*Conger eel*, *mussels*, *crabs*, etc.

Antidote.—Evacuate, as soon as possible, the contents of the stomach and bowels by emetics (ground mustard mixed with warm water or powdered alum), and castor oil, drinking freely at the same time of vinegar and water. Ether, with a few drops of laudanum mixed with sugar and water, may afterward be taken freely.

**Poisonous Serpents.**—Antidote.—A ligature or handkerchief should be applied moderately tight above the bite, and a cupping-glass over the wound. The patient should drink freely of alcoholic stimulants containing a small quantity of ammonia. The physician may inject ammonia into the veins.

**Poisonous Insects.**—*Stings of scorpion*, *hornet*, *wasp*, *bee*, etc.

Antidote.—A piece of rag moistened with a solution of carbolic acid may be kept on the affected part until the pain is relieved; and a few drops of carbolic acid may be given frequently in a little water. The sting may be removed by making strong pressure around it with the barrel of a small watch-key.

## DROWNING.

Marshall Hall's "Ready Method" of treatment in asphyxia from drowning, chloroform, coal gas, etc.

1st. Treat the patient *instantly on the spot*, in the *open air*, freely exposing the face, neck, and chest to the breeze, except in severe weather.

2d. In order *to clear the throat*, place the patient gently on the face, with one wrist under the forehead, that all fluid, and the tongue itself, may fall forward, and leave the entrance into the windpipe free.

3d. *To excite respiration*, turn the patient slightly on his side, and apply some irritating or stimulating agent to the nostrils, as *veratrine*, *dilute ammonia*, etc.

4th. Make the face warm by brisk friction; then dash cold water upon it.

5th. If not successful, lose no time; but, *to imitate respiration*, place the patient on his face, and turn the body gently, but completely *on the side, and a little beyond*; then again on the face, and so on, alternately. Repeat these movements, deliberately and perseveringly, *fifteen times only* in {251}
a minute. (When the patient lies on the thorax, this cavity is *compressed* by the weight of the body, and *ex*piration takes place. When he is turned on the side, this pressure is removed, and *in*spiration occurs.)

6th. When the prone position is resumed, make a uniform and efficient pressure *along the spine*, removing the pressure immediately, before rotation on the side. (The pressure augments the *ex*piration: the rotation commences *in*spiration.) Continue these measures.

7th. Rub the limbs *upward*, with *firm pressure* and with *energy*. (The object being to aid the return of venous blood to the heart.)

8th. Substitute for the patient's wet clothing, if possible, such other covering as can be instantly procured, each bystander supplying a coat or cloak, etc. Meantime, and from time to time, *to excite inspiration*, let the surface of the body be *slapped* briskly with the hand.

9th. Rub the body briskly till it is dry and warm, then dash *cold* water upon it, and repeat the rubbing.

Avoid the immediate removal of the patient, as it involves a *dangerous loss of time*—also, the use of bellows, or any *forcing* instrument; also, the *warm bath*, and *all rough treatment*.

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# GLOSSARY. {252}

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Ab-do´men (Latin *abdo*, to conceal). The largest cavity of the body containing the liver, stomach, intestines, etc.; the belly.

Ab-sor´bents (L. *ab* and *sorbeo*, to suck up). The vessels which take part in the process of absorption.

Ab-sorp´tion. The process of sucking up fluids by means of an animal membrane.

Ac-com-mo-da´tion of the Eye. The alteration in the shape of the crystalline lens, which accommodates or adjusts the eye for near and remote vision.

Ac´id, Lactic (L. *lac*, milk). The acid ingredient of sour milk; the gastric juice also contains it.

Al-bu´men, or Albumin (L. *albus*, white). An animal substance resembling white of egg.

Al-bu´mi-nose (from *albumen*). A soluble animal substance produced in the stomach by the digestion of the albuminoid substances.

Al-bu´min-oid substances. A class of proximate principles resembling albumen; they may be derived from either the animal or vegetable kingdoms.

Al´i-ment (L. *alo*, to nourish). That which affords nourishment; food.

Al-i-ment´a-ry Ca-nal (from *aliment*). A long tube in which the food is digested, or prepared for reception into the system.

An-æs-thet´ics (Greek, αν, *an*, without, αἰσθεσία, *aisthesia*, feeling).—Those medicinal agents which prevent the feeling of pain, such as chloroform, laughing-gas, etc.

An-i-mal´cule (L. *animal´culum*, a small animal). Applied to animals which can only be seen with the aid of the microscope. Animalculum (plural, animalcula) is used with the same meaning.

A-or´ta (Gr. ἀορτέομαι, *aorteomai*, to be lifted up). The largest artery of the body, and main trunk of all the arteries. It arises from the left ventricle of the heart. The name was first applied to the two large branches of the trachea, which appear to be lifted up by the heart.

A´que-ous Humor (L. *aqua*, water). A few drops of watery colorless fluid occupying the space {253}
between the cornea and crystalline lens.

A-rach´noid Mem´brane (Gr. ἀράχνε, *arachne*, a cobweb, and εἶδος, *eidos*, like). An extremely thin covering of the brain and spinal cord. It lies between the *dura mater* and the *pia mater*.

Ar´bor Vi´tæ (L.). Literally, "the tree of life;" a name given to the peculiar appearance presented by a section of the cerebellum.

Ar´ter-y (Gr. ἀέρ, *aer*, air, and τέρειν, *terein*, to contain). A vessel by which blood is conveyed away from the heart. It was supposed by the ancients to contain air; hence the name.

Ar-tic-u-la´tion (L. *articulo*, to form a joint). The more or less movable union of bones, etc.; a joint.

A-ryt´e-noid Car´ti-la-ges (Gr. ἀρύταινα, *arutaina*, a pitcher). Two small cartilages of the larynx, resembling the mouth of a pitcher.

As-sim-i-la´tion (L. *ad*, to, and *similis*, like). The conversion of food into living tissue.

Au-di´tion (L. *audio*, to hear). The act of hearing sounds.

Au´di-to-ry Nerve. One of the cranial nerves; it is the special nerve of hearing.

Au´ri-cle (L. *auris*, the ear). A cavity of the heart.

Bar´i-tone (Gr. βαρύς, *barus*, heavy, and τόνος, *tonos*, tone). A variety of male voice between the bass and tenor.

Bel-la-don´na (It. beautiful lady). A vegetable narcotic poison. It has the property of enlarging the pupil, and thus increasing the brilliancy of the eye; so called from its use by Italian ladies.

Bi-cus´pid (L. *bi*, two, and *cuspis*, prominence). The name of the fourth and fifth teeth on each side of the jaw; possessing two prominences.

Bile. The gall, or peculiar secretion of the liver; a viscid, yellowish fluid, and very bitter to the taste.

Bronch´i (Gr. βρόγκος, *bronkos*, the windpipe). The two first divisions or branches of the trachea; one enters each lung.

Bronch´i-al Tubes. The smaller branches of the trachea within the substance of the lungs, terminating in the air-cells.

Bronch-i´tis (from *bronchia*, and *itis*, a suffix signifying inflammation). An inflammation of the larger bronchial tubes; a "cold" affecting the lungs.

Cal-ca´re-ous (L. *calx*, lime). Containing lime.

Ca-nal´ (L.). In the body, any tube or passage.

Ca-nine´ (L. *canis*, a dog). Name given to the third tooth on each side of the jaw; in the upper jaw {254}
it is also known as the eye-tooth: pointed like the tusks of a dog.

Cap´il-la-ry (L. *capil´lus*, a hair, *capilla´ris* hair-like). The name of the extremely minute blood-vessels which connect the arteries with the veins.

Car´bon Diox-ide ($CO_2$). Chemical name for carbonic acid gas.

Car-bon´ic A-cid. The gas which is present in the air expired from the lungs; a waste product of the animal kingdom, and a food of the vegetable kingdom.

Car´di-ac (Gr. καρδία, *cardia*, the heart). The cardiac orifice of the stomach is the upper one, and is near the heart; hence its name.

Car-niv´o-rous (L. *ca´ro*, flesh, and *vo´ro*, to devour). Subsisting upon flesh.

Ca-rot´id Ar-te-ry. The large artery of the neck, supplying the head and brain.

Car´ti-lage. A solid but flexible material, forming a part of the joints, air-passages, nostrils, etc.; gristle.

Ca´se-ine (L. *ca´seus*, cheese). The albuminoid substance of milk; it forms the basis of cheese.

Cer-e-bel´lum (diminutive for *cer´ebrum*, the brain). The little brain, situated beneath the posterior third of the cerebrum.

Cer´e-brum (L.). The brain proper, occupying the entire upper portion of the skull. It is nearly divided into two equal parts, called "hemispheres," by a cleft extending from before backward.

Cho´roid (Gr. χόριον, *chorion*, a membrane or covering). The middle tunic or coat of the eyeball.

Chyle (Gr. χυλός, chulos, juice). The milk-like fluid formed by the digestion of fatty articles of food in the intestines.

Chyme (Gr. χυμός, *chumos*, juice). The pulpy liquid formed by digestion within the stomach.

Cil´i-a (pl. of *cil´i-um*, an eyelash). Minute, vibratile, hair-like processes found upon the cells of the air-passages, and other parts that are habitually moist.

Cir-cu-la´tion (L. *cir´culus*, a ring). The circuit, or course of the blood through the blood-vessels of the body, from the heart to the arteries, through the capillaries into the veins, and from the veins back to the heart.

Co-ag-u-la´tion (L. *coag´ulo*, to curdle). Applied to the process by which the blood clots or solidifies.

Coch´le-a (L. *coch´lea*, a snail-shell). The spiral cavity of the internal ear.

Conch´a (Gr. κόγχη, *konche*, a mussel-shell). The external shell-shaped portion of the external {255}
ear.

Con-junc-ti´va (L. *con* and *jun´go*, to join together). A thin layer of mucous membrane which lines the eyelids and covers the front of the eyeball; thus joining the latter to the lids.

Con-trac-til´i-ty (L. *con* and *tra´ho*, to draw together). The property of a muscle which enables it to contract, or draw its extremities closer together.

Con-vo-lu´tions (L. *con* and *vol´vo*, to roll together). The tortuous foldings of the external surface of the brain.

Con-vul´sion (L. *convel´lo*, to pull together). A more or less violent agitation of the limbs or body.

Cor´ne-a (L. *cor´nu*, a horn). The transparent, horn-like substance which covers the anterior fifth of the eyeball.

Cor´pus-cles, Blood (L. dim. of *cor´pus*, a body). The small biconcave disks which give to the blood its red color; the *white* corpuscles are globular and larger.

Cos-met´ic (Gr. κοσμέω, *kosmeo*, to adorn). Beautifying; applied to articles which are supposed to increase the beauty of the skin, etc.

Cra´ni-al (L. *cra´nium*, the skull). Pertaining to the skull. The nerves which arise from the brain are called cranial nerves.

Cri´coid (Gr. κρίκος, *kri´kos*, a ring). A cartilage of the larynx, resembling a seal-ring in shape.

Crys´tal-line Lens (L. *crystal´lum*, a crystal). One of the so-called humors of the eye; a double convex body situated in the front part of the eyeball.

Cu´ti-cle (L. dim. of *cu´tis*, the skin). The scarf-skin; also called the *epider´mis*.

Cu´tis (Gr. σκῦτος, *skutos*, a skin or hide). The true skin, lying beneath the cuticle; also called the *der´ma*.

De-cus-sa´tion (L. *decus´sis*, the Roman numeral ten, X). A reciprocal crossing of fibres from side to side.

Di´a-phragm (Gr. διαφράσσω, *diaphrasso*, to divide by a partition). A large, thin muscle which separates the cavity of the chest from the abdomen; a muscle of respiration.

Dif-fus´ion of Gases. The power of gases to become intimately mingled, without reference to the force of gravity.

Duct (L. *du´co*, to lead). A narrow tube; the *thoracic duct* is the main trunk of the absorbent vessels.

Du-o-de´num (L. *duode´ni*, twelve). The first division of the small intestines, about twelve fingers-breadth long.

Du´ra Ma´ter (L.). Literally, the hard mother; the tough membrane which envelops the brain. {256}

Dys-pep´si-a (Gr. δυς, *dus*, difficult, and πέπτω, *pep´to*, to digest). Difficult or painful digestion; a disordered condition of the stomach.

E-mul´sion (L. *emul´geo*, to milk). Oil in a finely divided state suspended in water.

En-am´el (Fr. *email*). The dense material which covers the crown of the tooth.

En´er-gy, Specific, of a Nerve. When a nerve of special sense is excited, whatever be the cause, the sensation experienced is that peculiar to the nerve; this is said to be the law of the specific energy of the nerves.

Ep-i-glot´tis (Gr. ἐπί, *epi*, upon, and γλωττις, *glottis*, the entrance to the windpipe). A leaf-shaped piece of cartilage which covers the top of the larynx during the act of swallowing.

Ex-cre´tion (L. *excer´no*, to separate). The separation from the blood of the waste particles of the body; also the materials excreted.

Ex-pi-ra´tion (L. *expi´ro*, to breathe out). The act of forcing air out of the lungs.

Ex-ten´sion (L. *ex*, out, and *ten´do*, to stretch). The act of restoring a limb, etc., to its natural position after it has been flexed, or bent; the opposite of *Flexion*.

Fe-nes´tra (L.). Literally, a window; the opening between the middle and internal ear.

Fi´brin (L. *fi´bra*, a fibre). An albuminoid substance found in the blood; in coagulating it assumes a fibrous form.

Flex´ion (L. *flec´to*, to bend). The act of bending a limb, etc.

Fol´li-cle (L. dim. of *fol´lis*, a bag). A little pouch or depression in a membrane; it has generally a secretory function.

Fun´gous Growths (L. *fun´gus*, a mushroom). A low grade of vegetable life.

Gan´gli-on (Gr. γαγγλίον, *ganglion*, a knot). A knot-like swelling in the course of a nerve; a smaller nerve-centre.

Gas´tric (Gr. γαστήρ, *gaster*, stomach). Pertaining to the stomach.

Gland (L. *glans*, an acorn). An organ consisting of follicles and ducts, with numerous blood-vessels interwoven; it separates some particular fluid from the blood.

Glos´so-phar-yn-ge´al Nerve (Gr. γλῶσσα, *glossa*, the tongue, and φάρυγξ, *pharunx*, the throat). The nerve of taste supplying the posterior third of the tongue; it also supplies the throat.

Glu´ten (L.). Literally, glue: the glutinous albuminoid ingredient of wheat.

Gran´ule (L. dim. of *gra´num*, a grain). A little grain; a microscopic object. {257}

Gus-ta´tion (L. *gus´to*, to taste) The sense of taste.

Gus´ta-to-ry Nerve. The nerve of taste supplying the front part of the tongue; a branch of the "fifth" pair.

Hæm´or-rhage (Gr. ἅιμα, *hai´ma*, blood, and ῥήγνυμι, *regnumi*, to burst). Bleeding, or the loss of blood.

Hem-i-ple´gia (Gr. ἥμισυς, *hemisus*, half, and πλήσσω, *plesso*, to strike). Paralysis, or loss of power, affecting one side of the body.

Hem´i-spheres (Gr. σφαῖρα, *sphaira*, a sphere). Half a sphere, the lateral halves of the cerebrum, or brain proper.

He-pat´ic (Gr. ἧπαρ, *hepar*, the liver). Pertaining to the liver.

Her-biv´o-rous (L. *her´ba*, an herb, and *vo´ro* to devour). Applied to animals that subsist upon vegetable food.

Hu´mor (L.). Moisture: the humors are transparent contents of the eyeball.

Hy-dro-pho´bi-a (Gr. ὕδορ, *hudor*, water, and φοβέω, *phobeo*, to fear). A disease caused by the bite of a rabid dog or other animal. In a person affected with it, convulsions are occasioned by the sight of a glittering object, like water, by the sound of running water, and by almost any external impression.

Hy´gi-ene (Gr. ὑγίεια, *huygieia*, health). The art of preserving health and preventing disease.

Hy´per-o-pi-a. Abbreviated from Hy´per-met-ro´pi-a (Gr. ὑπέρ, *huper*, beyond, μέτρον, *metron*, the measure, and ὤψ, *ops*, the eye). A defect of vision dependent upon a too short eyeball; so called because the rays of light are brought to a focus at a point behind the retina; the true "far sight."

In-ci´sor (L. *inci´do*, to cut). Applied to the four front teeth of both jaws, which have sharp cutting edges.

In´cus (L). An anvil; the name of one of the bones of the middle ear.

In-sal-i-va´tion (L. *in*, and *sali´va*, the fluid of the mouth). The mingling of the saliva with the food during the act of chewing.

In-spi-ra´tion (L. *in*, and *spi´ro*, *spira´tum*, to breathe). The act of drawing in the breath.

In-teg´u-ment (L. *in*, and *te´go*, to cover). The skin, or outer covering of the body.

In-tes´tine (L. *in´tus*, within). The part of the alimentary canal which is continuous with the lower end of the stomach; also called the intestines, or the bowels.

I´ris (L. *i´ris*, the rainbow). The thin muscular ring which lies between the cornea and crystalline {258}
lens, and which gives the eye its brown, blue, or other color.

Ju´gu-lar (L. *ju´gulum*, the throat). The name of the large veins which run along the front of the neck.

Lab´y-rinth (Gr. λαβύρινθος, *laburin´thos*, a building with many winding passages). The very tortuous cavity of the inner ear, comprising the vestibule, semicircular canals, and the cochlea.

Lach´ry-mal Apparatus (L. *lach´ryma*, a tear). The organs for forming and conveying away the *tears*.

Lac´te-als (L. *lac*, *lac´tis*, milk). The absorbent vessels of the small intestines; during digestion they are filled with chyle, which has a milky appearance.

La-ryn´go-scope (Gr. λάρυγξ, *larunx*, the larynx, and σκοπεω, *skopeo*, to look at). The instrument by which the larynx may be examined in the living subject.

Lar´ynx (Gr.). The cartilaginous tube situated at the top of the windpipe, or trachea; the organ of the voice.

Lens (L.). Literally, a lentil; a piece of transparent glass or other substance so shaped as either to converge or disperse the rays of light.

Lig´a-ment (L. *li´go*, to bind). A strong, fibrous material binding bones or other solid parts together; it is especially necessary to give strength to joints.

Lig´a-ture. A thread of silk or other material used in tying around an artery.

Lymph (L. *lym´pha*, spring-water). The colorless, watery fluid conveyed by the lymphatic vessels.

Lym-phat´ic Vessels. A system of absorbent vessels.

Mal´le-us (L.). Literally, the mallet; one of the small bones of the middle ear.

Mar´row. The soft, fatty substance contained in the central cavities of the bones: the spinal marrow, however, is composed of nervous tissue.

Mas-ti-ca´tion (L. *mas´tico*, to chew). The act of cutting and grinding the food to pieces by means of the teeth.

Me-dul´la Ob-lon-ga´ta. The "oblong marrow," or nervous cord, which is continuous with the spinal cord within the skull.

MEM-BRA´NA TYM´PAN-I (L.). Literally, the membrane of the drum; a delicate partition separating the outer from the middle ear; it is sometimes incorrectly called the drum of the ear.

MEM´BRANE. A thin layer of tissue serving to cover some part of the body.

MI´CRO-SCOPE (Gr. μικρός, *mikros*, small, and σκοπέω, *skopeo*, to look at). An optical instrument which assists in the examination of minute objects. {259}

MO´LAR (L. *mo´la*, a mill). The name applied to the three back teeth of each side of the jaw; the grinders, or mill-like teeth.

MO´TOR (L. *mo´veo*, *mo´tum*, to move). Causing motion; the name of those nerves which conduct to the muscles the stimulus which causes them to contract.

MU´COUS MEMBRANE. The thin layer of tissue which covers those internal cavities or passages which communicate with the external air.

MU´CUS. The glairy fluid which is secreted by mucous membranes, and which serves to keep them in a moist condition.

MY-O´PI-A (Gr. μύω, *muo*, to contract, and ὤψ, *ops*, the eye). A defect of vision dependent upon an eyeball that is too long, rendering distant objects indistinct; near-sight.

NA´SAL (L. *na´sus*, the nose). Pertaining to the nose; the *nasal cavities* contain the distribution of the special nerve of smell.

NERVE (Gr. νεῦρον, *neuron*, a cord or string). A glistening, white cord of cylindrical shape, connecting the brain or spinal cord with some other organ of the body.

NERVE CELL. A minute, round and ashen-gray cell found in the brain and other nervous centres.

NERVE FI´BRE. An exceedingly slender thread of nervous tissue found in the various nervous organs, but especially in the nerves; it is of a white color.

NU-TRI´TION (L. *nu´trio*, to nourish). The processes by which the nourishment of the body is accomplished.

Œ-SOPH´A-GUS (Gr.). Literally, that which carries food. The tube leading from the throat to the stomach; the gullet.

O-LE-AG´I-NOUS (L. *o´leum*, oil). Of the nature of oil: applied to an important group of food-principles—the fats.

OL-FAC´TO-RY (L. *olfa´cio*, to smell). Pertaining to the sense of smell.

OPH-THAL´MO-SCOPE (Gr. ὀφθαλμός, *ophthalmos*, the eye, and σκοπέω, *skopeo*, to look at). An instrument devised for examining the interior of the globe of the eye.

OP´TIC (Gr. ὄπτω, *opto*, to see). Pertaining to the sense of sight.

OR´BIT (L. *or´bis*, the socket). The bony socket or cavity in which the eyeball is situated.

OS´MOSE (Gr. ὠσμός, *osmos*, a thrusting or impulsion). The process by which liquids are impelled through a moist membrane.

OS´SE-OUS (L. *os*, a bone). Consisting of, or resembling bone.

PAL´ATE (L. *pala´tum*, the palate). The roof of the mouth, consisting of the hard and soft palate.

PAL´MAR. Relating to the palm of the hand. {260}

PAN´CRE-AS (Gr. πᾶς, παντός, *pas*, *pantos*, all, and κρέας, *kreas*, flesh). A long, flat gland situated near the stomach; in the lower animals the analogous organ is called the sweet-bread.

PA-PIL´LÆ (L. *papil´la*). The minute prominences in which terminate the ultimate fibres of the nerves of touch and taste.

PA-RAL´Y-SIS. A disease of the nervous system marked by the loss of sensation, or voluntary motion, or both; palsy.

PAR-A-PLE´GI-A (Gr. παραπλήσσω, *paraplesso*, to strike amiss). A form of paralysis affecting the lower half of the body.

PA-TEL´LA (L. dim. of *pat´ina*, a pan). The knee-pan; a small bone.

PEL´VIS (L.). Literally a basin; the bony cavity at the lower part of the trunk.

PEP´SIN (Gr. πέπτω, *pepto*, to digest). The organic principle of the gastric juice.

PER-I-STAL´TIC MOVE´MENTS (Gr. περιστέλλω, *peristello*, to contract). The slow, wave-like movements of the stomach and intestines.

PER-I-TO-NE´UM (Gr. περιτείνω, *periteino*, to stretch around). The investing membrane of the stomach, intestines, and other abdominal organs.

PER-SPI-RA´TION (L. *perspi´ro*, to breathe through). The sweat, or watery exhalation of the skin;

when visible, it is called *sensible* perspiration, when invisible, it is called *insensible* perspiration.

Pe´trous (Gr. πέτρα, *petra*, a rock). The name of the hard portion of the temporal bone, in which is situated the drum of the ear and labyrinth.

Phar´ynx (Gr. φάρυγξ, *pharunx*, the throat). The cavity between the back of the mouth and gullet.

Phys-i-ol´o-gy (Gr. φύσις, *phusis*, nature, and λόγος, *logos*, a discourse). The science of the functions of living, organized beings.

Pi´a Ma´ter (L.). Literally, the tender mother; the innermost of the three coverings of the brain. It is thin and delicate; hence the name.

Pleu´ra (Gr. πλευρά, a rib). A membrane covering the lung and lining the chest. There is one for each lung.

Pleu´ri-sy. An inflammation affecting the pleura.

Pneu-mo-gas´tric (Gr. πνεύμων, *pneumon*, the lungs, and γαστήρ, *gaster*, the stomach). The name of a nerve distributed to the lungs and stomach; it is the principal nerve of respiration.

Pneu-mo´nia (Gr.). An inflammation affecting the air-cells of the lungs.

Pres-by-o´pi-a (Gr. πρέσβυς, *presbus*, old, and ὤψ, *ops*, the eye). A defect of the accommodation of {261}
the eye, caused by the hardening of the crystalline lens; the "far-sight" of adults and aged persons.

Proc´ess (L. *proce´do*, *proces´sus*, to proceed, to go forth). Any projection from a surface. Also, a method of performance; a procedure.

Pty´a-lin (Gr. πτύαλον, *ptualon*, saliva). The peculiar organic ingredient of the saliva.

Pul´mo-na-ry (L. *pul´mo*, *pulmo´nis*, the lungs). Pertaining to the lungs.

Pulse (L. *pel´lo*, *pul´sum*, to beat). The striking of an artery against the finger, occasioned by the contraction of the heart, commonly felt at the wrist.

Pu´pil (L. *pupil´la*). The central, round opening in the iris, through which light passes into the depths of the eye.

Py-lo´rus (Gr. πυλωρός, *puloros*, a gate-keeper). The lower opening of the stomach, at the beginning of the small intestine.

Re´flex Action. An involuntary action of the nervous system, by which an external impression conducted by a sensory nerve is reflected, or converted into a motor impulse.

Res-pi-ra´tion (L. *res´piro*, to breathe frequently). The function of breathing, comprising two acts: *inspiration*, or breathing in, and *expiration*, or breathing out.

Ret´i-na (L. *re´te*, a net). The innermost of the three tunics or coats of the eyeball, being an expansion of the optic nerve.

Sac´cha-rine (L. *sac´charum*, sugar). Of the nature of sugar; applied to the important group of food substances which embraces the different varieties of sugar, starch, and gum.

Sa-li´va (L.). The moisture or fluids of the mouth, secreted by the salivary glands, etc.

Scle-rot´ic (Gr. σκληρός, *skleros*, hard). The tough, fibrous outer tunic of the eyeball.

Se-ba´ceous (L. *sebum*, fat). Resembling fat, the name of the oily secretion by which the skin is kept flexible and soft.

Se-cre´tion (L. *secer´no*, *secre´tum*, to separate). The process of separating from the blood some essential important fluid; which fluid is also called a secretion.

Sem-i-cir´cu-lar Canals. A portion of the internal ear.

Sen-sa´tion. The perception of an external impression by the nervous system; a function of the brain.

Sen-si-bil´i-ty, General. The power possessed by nearly all parts of the human body of recognizing {262}
the presence of foreign objects that come in contact with them.

Se´rum (L.). The watery constituent of the blood, which separates from the clot during the process of coagulation.

Skel´e-ton (Gr.). The bony framework of an animal, the different parts of which are maintained in their proper relative positions.

Spec´tro-scope (from *spec´trum* and σκοπέω, *scopeo*, to examine the spectrum). An instrument employed in the examination of the spectrum of the sun or any other luminous body.

Sphyg´mo-graph (Gr. σφυγμός, *sphugmos*, the pulse, and γράφω, *grapho*, to write). An ingenious instrument by means of which the pulse is delineated upon paper.

Sta´pes (L.). Literally, a stirrup; one of the small bones of the tympanum, or middle ear, resembling somewhat a stirrup in shape.

Sym-pa-thet´ic system of Nerves. A double chain of nervous ganglia, connected together by numerous small nerves, situated chiefly in front of and on each side of the spinal column.

Syn-o´vi-a (Gr. σύν, *sun*, and ᾠόν, *oon*, resembling an egg). The lubricating fluid of joints, so called because it resembles the white of egg.

Sys´to-le (Gr. συστέλλω, *sustello*, to contract). The contraction of the heart, by which the blood is expelled from that organ.

Tac´tile (L. *tac´tus*, touch). Relating to the sense of touch.

Tem´po-ral (L. *tem´pus*, time, and *tem´pora*, the temples). Pertaining to the temples; the name of an artery: so called, because the hair begins to turn white with age in that portion of the scalp.

Ten´don (L. *ten´do*, to stretch). The white, fibrous cord or band by which a muscle is attached to a bone; a sinew.

Tet´a-nus (Gr. τείνω, *teino*, to stretch). A disease marked by persistent contractions of all or some of the voluntary muscles; those of the jaw are sometimes solely affected: the disorder is then termed locked-jaw.

Tho´rax (Gr. θώραξ, *thorax*, a breastplate). The upper cavity of the trunk of the body, containing the lungs, heart, etc.; the chest.

Thy´roid (Gr. θυρεός, *thureos*, a shield). The largest of the cartilages of the larynx; its angular projection in the front of the neck is called "Adam's apple."

Tra´che-a (Gr. τραχύς, *trachus*, rough). The windpipe, or the largest of the air-passages; composed in part of cartilaginous rings, which render its surface rough and uneven.

Trans-fu´sion (L. *transfun´do*, to pour from one vessel to another). The operation of injecting blood taken from one person into the veins of another; other fluids than blood are sometimes used. {263}

Trich-i´na Spi-ra´lis. (L.) A minute species of parasite or worm, which infests the flesh of the hog, and which may be introduced into the human system by eating pork not thoroughly cooked.

Tym´pa-num (Gr. τυμπανον, *tumpanon*, a drum). The cavity of the middle ear, resembling a drum in being closed by two membranes, and in having communication with the atmosphere.

U´vu-la (L. *uva*, a grape). The small pendulous body attached to the back part of the palate.

Vas´cu-lar (L. *vas´culum*, a little vessel). Pertaining to, or containing blood-vessels.

Ve´nous (L. *ve´na*, a vein). Pertaining to, or contained within a vein.

Ven-ti-la´tion. The introduction of fresh air into a room or building, in such a manner as to keep the air within it in a pure condition.

Ven-tril´o-quism (L. *ven´ter*, the belly, and *lo´quor*, to speak). A modification of natural speech by which the voice is made to appear to come from a distance. The ancients supposed that the voice was formed in the belly; hence the name.

Ven´tri-cles of the heart. The two largest cavities of the heart, situated at its apex or point.

Ver´te-bral Column (L. *ver´tebra*, a joint). The back-bone, consisting of twenty-four separate bones, called vertebræ, firmly jointed together; also called the spinal column and spine.

Ves´ti-bule. A portion of the internal ear, communicating with the semicircular canals and the cochlea; so called from its fancied resemblance to the vestibule or porch of a house.

Vil´li (L. *vil´lus*, the nap of cloth). Minute thread-like projections found upon the internal surface of the small intestine, giving it a velvety appearance.

Vit´re-ous (L. *vi´trum*, glass). Having the appearance of glass; applied to the humor occupying the largest part of the cavity of the eyeball.

Viv-i-sec´tion (L. *vi´vus*, alive, and *se´co*, to cut). The practice of operating upon living animals, for the purpose of studying some physiological process.

Vocal Cords. Two elastic bands or ridges situated in the larynx; they are the essential parts of the organs of the voice.

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