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ELEMENTS OF PHYSIOLOGY

COLEMAN

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THE ELEMENTS OF PHYSIOLOGY

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THE ELEMENTS OF PHYSIOLOGY

FOR SCHOOLS

BY

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WITH 248 ILLUSTRATIONS, INCLUDING COLORED PLATES AND MANIKIN

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COLEMAN'S PHYSIOLOGICAL SERIES.

PHYSIOLOGY FOR BEGINNERS. For Intermediate and Lower Grammar Grades. Illustrated with many half-tone engravings and figures. 181 pages.

THE ELEMENTS OF PHYSIOLOGY. For an extended course in Graded Schools and Rural Schools, and for a review course in High Schools, Academies, and Normal Schools. With 248 illustrations, including colored plates and manikin. xi + 358 pages.

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TO THE TEACHER

The human body is made of cells and its life consists in the activities of the cells. Physiology is the study of the cells and tissues in their related activities. Yet the usual school physiology neglects the functions of the cells and tissues and studies organs almost as isolated things, rather than as component parts of the bodily structure. The well organized science of physiology is thus slighted and the result is an unnecessary waste of time. The experience of the author with young students has convinced him that elementary facts in the science are not so difficult of comprehension when given in their real relations as when given as isolated facts.

But due regard solely for logical order would require that the pupil be inducted at once into the study of protoplasm and cells, which are to him mysterious subjects. The interest naturally excited by beginning a new study would be killed before he reached things that he knows something about. The science of teaching requires that we begin with things well known to the pupils and proceed through the known to the unknown. Evidently no subject is so well adapted for the starting point as the skin. The surface of the body is familiar; personal appearance is a subject of interest to young people; for these reasons the skin is a suitable subject for introducing the study. Cell-life being an unknown subject, it is treated at first in the simplest and most elementary manner, but constant return to it is made in the discussions of each organ and function. As the nerves are intimately related to every organ, some authors attempt an exhaustive treatment of the nervous system in the first chapters, but this method has the insuperable objection of treating the most difficult subject first. Recent authors have relegated the simple subject of the skeleton to the last as it is supposed to be the least interesting and of least importance hygienically. In this book it is introduced among the first chapters, because a knowledge of the skeleton furnishes a scheme by reference to which all the organs of the body may be located as studied, thus promoting a definite knowledge of anatomy, without which foundation physiology cannot be learned.

The teacher will notice the incorporation of frequent exercises, thought lessons, applications, and practical questions as a training for the reasoning faculty. These were tested by a number of teachers with hundreds of pupils before being set in type. Where they may seem ambiguous, it is usually because more definite statements would be equivalent to giving the pupil the answers.

That the power of observation may be cultivated, frequent observations of the pupil on his own body and on the life of the community are called for, and after the more important figures and plates quizzes are inserted which can be answered only by studying them.

It is said that there is no impression without expression, and to supplement the work of the recitation in this connection, numerous subjects for compositions and debates are given. It is hoped that the teacher will not allow his classes to lose the interest and enjoyment that the reading of these essays, and debates at regular intervals, always bring. It is suggested that "match reviews" (an adaptation of the old-style spelling match), "competitive drills," written exercises, and other forms of review be used.

It seems to the author that the time has come for a more natural and logical, and therefore a more effective, presentation of the subject of temperance than past methods have furnished. In this book the purpose is to present the blessings of natural incitants, and to show how, if these incitants are taken advantage of by a healthful mode of living, no craving for poisonous stimulants need ever arise. In other words, the temperance teaching is positive rather than negative; it dwells upon happy things more than upon the unhappy. As to amount and arrangement of the space devoted to temperance, the book will be found to comply fully with the laws of the different states on this subject.

The present backward state of methods in teaching physiology is probably to be attributed to the fact that the text-books have been written by physicians, who, by reason of the duties of their noble and arduous profession, have not had time or opportunity to learn much about teaching. The point of view of their profession may also explain why so many physiologies are written from the standpoint of sickness instead of from the optimistic standpoint of health and strength.

Language and mathematics have been taught in the schools for centuries; the majority of the natural sciences have not been taught for more than half a century, which is all too short a time in which to learn to teach them most effectively. The present book is an effort toward raising physiology as a disciplinary study to the plane of grammar and arithmetic, with the idea also that the reasoning required in the many exercises will help to more thorough understanding, and therefore better remembrance, of what is learned. What should we think of an arithmetic or a grammar in which every question was explained, every exercise worked out, and consequently everything a matter of memory and learning by rote? Yet in exactly this way have the school physiologies been written, and with such books the teacher has had small chance to keep the pupils from learning physiology by rote.

It has been the purpose to lead the pupil to approach every question in the scientific spirit. This means careful observation, candor of mind, and patient suspension of judgment until sufficient grounds for a conclusion are forthcoming, and if they do not exist, then to leave the question unsettled.

The recent addition of tropical islands to our territory and the number of our citizens that go thither in military and civil service, together with the semi-tropical climate of our Gulf states, have led the author to deem care of the health in warm climates a topic of sufficient importance to require special references to it.

Those illustrations which are not original are taken from the works of Huxley, Testut (*Anatomie Humaine*), Kellogg, Thornton, Foster, Fabre, and Sappée. The author has taken pleasure in designing the colored plates and manikin, as so many schools lack facilities for instruction and as dissections are seldom advisable. The handsome execution of the numerous line engravings and colored plates testifies to the liberality of the publishers and to their purpose to place this work in the schools in the form most useful and instructive to the pupils.

Sincere thanks are returned to the following persons for valuable aid in reading the proof: W. S. Carter, M.D., Franklin W. Barrows, M.D., Alfred Patton, M.D., J. W. Thomason, M.D., J. Philip Gibbs, M.D., D. W. Lewis, A.M., H. C. Pritchett, A.M., Mrs. Rosa Buchanan, Miss L. W. Elliott, Miss A. Lawrence, and Professor R. B. Halley.

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ELEMENTS OF PHYSIOLOGY

PART I. INTRODUCTORY KNOWLEDGE

CHAPTER I

THE SKIN

1. The skin that covers our bodies is elastic and in this respect is like India rubber. But if they are both examined under the microscope, a marked difference is found. Rubber resembles oil and water in being alike in all its parts, while the skin is composed of an immense number of small objects fitting together. Hence it is said to have a definite structure, while rubber has not. These small objects are called **cells** and **fibers**: fibers are usually thread-like, while cells are of various shapes. In another chapter it will be learned that each cell has life and activity of its own, and that the fibers are believed to be branches from the cells. A number of cells or a number of fibers, or both together, make what is called a **tissue**. The tissues form organs. An **organ** is a part of the body that has special work to perform and this work is called its **function**. The skin is an organ and its chief function is to protect the body. Name the organ of sight. What is the function of the teeth? A number of organs working together for a similar end is called a **system**. Thus the organs which prepare the food constitute the digestive system; those which circulate the fluids, the circulatory system.

2. The skin consists of **two layers** (Fig. 1), the outer layer, or **epidermis**, resting on the inner layer, the **dermis**, or cutis. The dermis is called also the true skin. The epidermis is composed of a mass of cells held together by a cement something like the white of an egg. Those near the surface (Fig. 2) are hard and flattened; those deeper down, near the dermis, are round and soft. The lowest layers contain a pigment consisting of minute grains of coloring matter. The varying amount of this pigment present causes the difference in hue of the blonde and brunette and the light and dark races. Freckles are due to an increase of pigment in patches of neighboring cells. Some persons lack the pigment entirely; their hair and skin are white, the eyes pink. They are called albinos. Albinos are found among various species of animals. Among the specimens in the British Museum there are albino (or pure white) blackbirds, turkeys, etc.

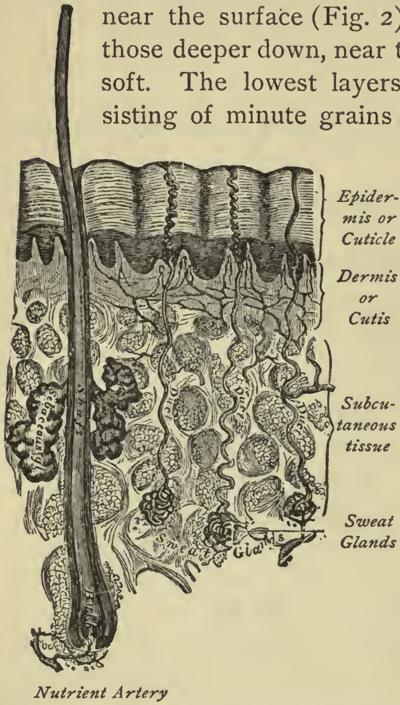


FIG. 1. — Sectional View of the Skin, magnified.
Find: oil (sebaceous) gland, sweat gland, sweat duct, hair bulb. Compare thickness of epidermis, dermis, and subcutaneous tissue. (Thornton.)

3. The main part of the skin is the **dermis**, or cutis (Fig. 1); it is chiefly a network of fibers. This is the part of the skin of animals that is tanned for leather. Did you ever notice the fibrous appearance in the leather of a shoe that has become much worn? Which side of leather is smooth, the side covered by epidermis, or the other side? The human skin when tanned is said to make a leather

resembling the pigskin of which footballs are made. The dermis is connected with the body beneath by a loose tissue consisting of fibers interwoven with cells of fat (Fig. 1). This tissue, together with the skin itself, partly conceals the outlines of the muscles beneath. Yet artists study the muscles carefully, as their shape shows faintly through the skin and gives a key to the human figure.

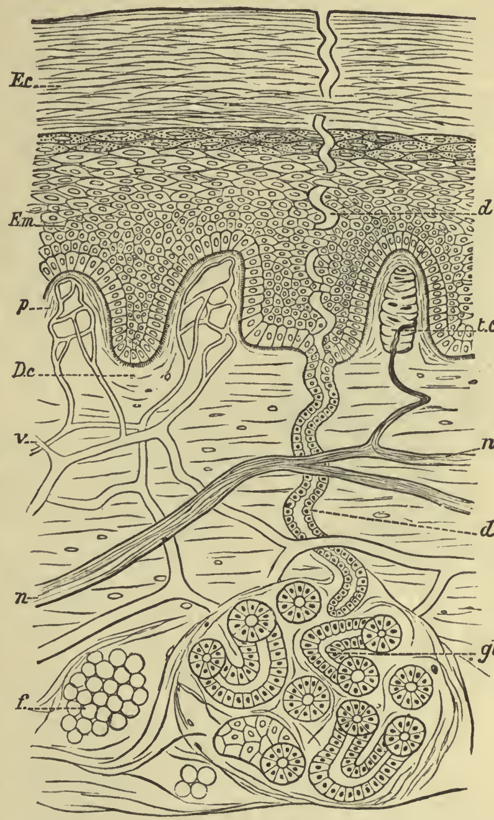


FIG. 2. — Diagram to show the Structure of the Skin.
E.c, epidermis corneous part; *E.m*, epidermis Malpighian part; *D.c*, connective tissue of dermis; *p*, papilla; *gl*, sweat gland, the coils of the tube cut across or lengthwise; *d*, its duct; *f*, fat; *v*, blood vessels; *n*, nerve; *t.c*, tactile corpuscle.

4. The outer surface of the dermis grows into numerous little projections called **papillæ** (Figs. 1 and 2). If its covering of epidermis were taken off, the dermis would appear somewhat like coarse velvet because of its unevenness; for the prominences or papillæ appear under the microscope, in a cross-section of the skin, buried beneath the cells of epidermis, like a tiny mountain range. As the epidermis fills up the valleys between them, the papillæ do not show plainly on the surface of the skin. However, on the palm of the hand and the fingers, where the papillæ are especially numerous, they are crowded into rows, their position being shown by the parallel ridges seen on the epidermis of the palm. Within the papillæ are found the ends of nerves and loops of small blood vessels called capillaries (Figs. 2 and 3).

FIG. 3. — Diagram of Epidermis and Upper Part of Dermis.

Showing nerve, *n*, and tactile corpuscle, *t.c*, or organ of touch; also sweat tube, *d*.

The cells of the **epidermis** which lie next to the dermis are living cells. They are kept alive by nourishment brought by the watery portion of the blood in the blood vessels of the neighboring papillæ. These cells are, therefore, growing cells, and when they grow to a certain size, each cell subdivides into two. (The way in which the cells form new cells will soon be studied in another chapter.) This multiplication of the cells would cause the epidermis to increase greatly in thickness, were not the outer cells constantly worn away by friction. This more easily happens as the outer cells are dead cells. The new cells forming beneath push them so far away from the dermis, that nourishment from the blood no longer reaches them, and they die.

By this constant loss and renewal, the body always has a comparatively new outer skin. Even on the scalp, which is partly protected from friction, the flat dry cells are constantly coming off. If there is much oil on the scalp, the cells stick together and form flakes called *dandruff*.

5. Organs in the Dermis. — The tough, flexible sheet called the dermis is called by what other name? Lodged among its fibers and supported by them (Fig. 2) are (1) a fine network of blood vessels; (2) a fine network of nerves; (3) several million sweat glands; (4) a great number of oil glands. Suppose you were to stick a pin into the true skin. You would find evidence that you had wounded which two of these possessions of the true skin? Are they so numerous that you could penetrate the skin anywhere without striking them? You learned that the dermis is composed chiefly of fibers, and that the epidermis is composed of cells. These cells are very simple and are called epithelial cells.

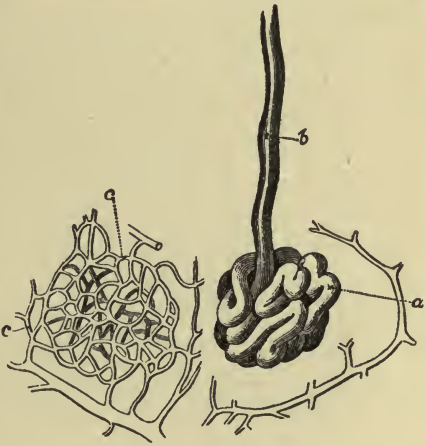


FIG. 4. — Coiled End of a Sweat Gland, Epidermis not shown.

a, the coil; *b*, the duct; *c*, network of capillaries, inside of which the gland lies. Does the sweat gland lie in the skin or beneath the skin? (See Fig. 1.)

6. The Sweat Glands, or perspiratory glands (Figs. 1 and 4), are little tubes, lined with epithelial cells, which pass through the epidermis and down into the dermis. The tube is coiled into a ball in the true skin, where it is surrounded by a network of capillaries. Its course through the epidermis is spiral like the turns of a corkscrew. Its opening on the surface is called a *pore*. The coiled part is supplied with nerves which stimulate the cells to secrete the perspiration. The cells obtain their supply of material from the blood so freely furnished them. This supply is controlled by the nerves which regulate the size of the arteries leading to the skin. The sweat glands take up water and various other substances from the blood and pour them out upon the surface of the true skin. The water evaporates, but the salt and other solids in the perspiration are deposited on the skin; just as salt will not evaporate from the ocean, and as solids form in the bottom of a kettle of boiling water. Usually the amount of perspiration from each gland is so small that it evaporates, or is dried up by the air, as soon as it reaches the surface, and hence does not become visible. On this account it is called insensible perspiration; it becomes sensible perspiration when it is formed rapidly in warm weather or during vigorous exercise. It does not evaporate so quickly in a moist atmosphere; and those who live near the seacoast or in rainy regions show more perspiration than those who live in dry regions, although the former may not perspire so much. The amount of perspiration averages about one and one half pints per day. In the study of physics, we are taught that the evaporation of even a small amount of water, as from a teakettle, uses up a large amount of heat. Hence, perspiration is very effective in cooling the body.

Why is humid weather in summer so oppressive and disagreeable? Is the skin more active in throwing off impurities in winter or in summer? The **mucous membrane** is a kind of inner skin, lining the nose, throat, and all inner passages to which air has access. In case of need, when the skin fails to act and ceases to throw off the usual amount of impurities, the mucous membrane may become swollen with blood and throw off impurities in the form of phlegm and mucus. Such a condition is called a cold.

7. The Number of Sweat Glands. — Count the sweat glands shown in Figure 5. This row is one half inch long.

To get the number in one square inch, multiply by itself the number in a row one inch long. There are about 2,400,000 sweat glands in the entire body. They are most numerous in the palm. If a sweat gland averages one fourth inch in length, how many miles would they extend if placed end to end?

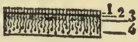


FIG. 5.—Section of the Skin from the Palm of the Hand, natural size.

1, epidermis; 2, papillæ; 3, dermis; 4, subcutaneous tissue and sweat glands.

8. THOUGHT LESSON. **Anatomy and Physiology of the Skin.** — 1. What fraction of an inch in thickness do you judge the skin on the back of the hand to be? (A fold shows double thickness.)

2. Feel and observe the skin, and write five qualities possessed by it.

3. What evidence have you ever had that the skin has two layers?

4. How long will a pair of kid gloves last? What does this suggest about the skin?

5. State a fact which shows that the skin gives out offensive substances.

6. State a fact which shows that the skin is a protection.

FIG. 6.—Surface of the Palm, magnified.

Showing ridges and pores, or openings, of the sweat glands.

7. State a fact which shows that the skin is a regulator of temperature.

8. Are wrinkles a sign that the skin is too tight or too large and loose for what it covers?

9. The loss of what tissue causes wrinkles?

9. **Hair.** — Sometimes a papilla, instead of being on the surface of the dermis on a level with other papillæ, is at the bottom of a pit or bag called a **follicle** (Fig. 7). A column of epithelial cells forming a hair grows from this papilla, and the papilla is sometimes called the root of

the hair. A hair, therefore, grows from the top of a papilla which stands in the bottom of a pit in the true skin. The outside of the hair is formed of colorless, overlapping cells (Fig. 7). The hair is pithy in the center and contains pigment cells. In old people, the pigment is replaced by air, and the hair turns white. The only point at which the cells of the hair, and therefore the hair itself, are *living* and *growing* is at the top of the papilla, deep down in the follicle (Fig. 7). From this it is easy to see that the common notion that cutting off the ends of the hair, either by shaving or trimming with scissors, causes it to grow faster and stronger, is erroneous. It may stop the splitting of hairs and thus prevent the wearing away of the hair. Of course when the hair or beard is short, its growth is more noticeable. Long hair seems by its weight to give exercise to minute muscles in the skin and strengthen the flow of blood, thus adding to the vigor of the hair. The cut end of a hair is nearly round in the straight-haired races, as Indians and Chinese; it is oval in the wavy-haired white race, and flattened still more in the kinky-haired negro race. Which races have black hair? In which races is the color of the hair variable?

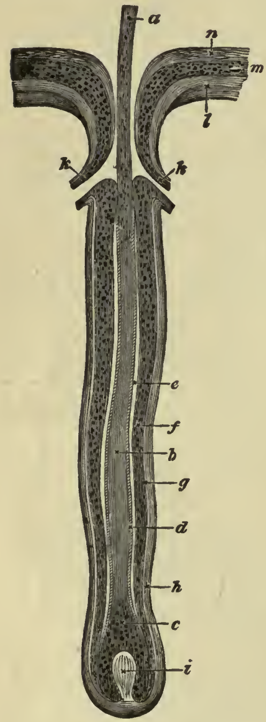


FIG. 7. — A Hair in its Follicle.

a, shaft of hair above the skin; *b*, the hair in its follicle; *c*, newest portion of the hair growing on the papilla *i*; *d*, cuticle of hair; *e*, cavity of hair follicle; *f*, epidermis of follicle corresponding to *m*, the epidermis at the surface; *g*, division between dermis and epidermis; *h*, dermis of follicle corresponding to dermis, *l*, near the surface; *k*, mouths of sebaceous or oil glands; *n*, horny epidermis at surface.

10. Hair is very durable; that found on Egyptian mummies has remained unchanged through several thousand years. It is elastic and is said to stretch one third of its length without breaking. Find out whether this is true by attaching weights to a hair. Hair absorbs moisture readily, and for a time its length is considerably increased thereby. Each hair follicle has fine muscles connected with it. Cold or fear may cause the muscles to contract and the hairs, which are usually in a slanting position, to stand erect. This causes the hair to afford a better protection to the animal from cold or blows. "Goose skin," which occurs if a cold bath is unduly prolonged, is caused in the same way; but the hair on the human skin is so fine that the goose skin avails little against cold.

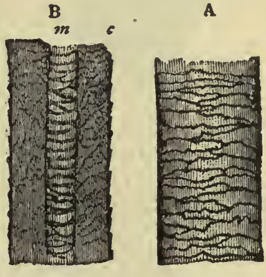


FIG. 8.—Piece of Human Hair, magnified.

A, seen from the surface. B, in section. *c*, cuticle; *m*, pith, the air having been expelled by Canada balsam.

11. The Oil Glands, or sebaceous glands, are small, irregularly shaped cavities which open into the little pits from which the hairs grow (Fig. 1). A few oil glands open directly upon the surface. They are lined with epithelial cells. The cells deposit a kind of oil, which flows out of the mouth of the glands, renders the epidermis flexible and less penetrable by water, and prevents it from drying out by evaporation and cracking open. It is also the natural "hair oil," for softening the hair and keeping it from becoming brittle. The oil glands of the center of the face are especially large and numerous. When their mouths are stopped by dirt, they become distended with oily material and are called blackheads. Oil glands are absent from the soles and palms.

12. The Nails, as well as the hair, are a growth of the epidermis; and like the epidermis, only the lowest cells, near their roots, are alive and receive nourishment. The root of the nail is in a kind of groove or fold of the true skin (Fig. 9) at the bottom of which papillæ are very numerous. The nail may be regarded as a very wide, flat hair. The nail grows not only at its root, but along its bed which is of true skin (Fig. 10). Hence, its thickness increases as it approaches the tip. If the epidermis is pressed back at the root, the nail may not be perfectly nourished, and a white speck or flaw is formed, which travels slowly along with the growth of the nail. It is said that the nail is renewed in three or four months. If you note the date of the appearance of a scar at the base of the nail and note when it has traveled to the tip, you can find whether this is true. Find whether or not a nail is transparent, by looking through the tip of the nail, held up to the light. The nails stiffen the ends of the fingers and aid in handling small objects. Can you pick up a pin without using the nails? Corresponding organs in the lower animals are claws and hoofs. The epidermis forms also the scales, feathers, and horns of the lower animals.

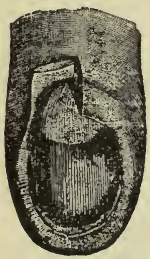


FIG. 9. — End of Finger. The skin covering the base of the nail is cut back.

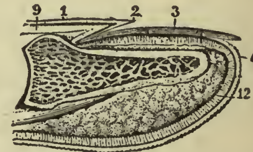


FIG. 10. — Section of Nail and Parts Beneath.

1, 2, 4, horny layer of cuticle, continuous with 3, the nail; 9, 12, dermis.

13. The papillæ over a small area, when the epidermis is weak, sometimes become overgrown, so that they project above the skin, and form a *wart*. If it is burned away with acid, the epidermis will grow over the place. Why is a wart rough? How does it differ from a mole? Which is more likely to increase in size? Which has more pigment? Which contains hairs? When the epidermis is broken so that the true skin is exposed, the epithelial cells at the edge of the break usually produce new cells to cover and heal the opening. But if they do not form new cells, the true skin sprouts through the opening, forming *proud flesh*, which must be scraped off or cauterized before the epidermis can complete the healing. In the case of a *blister*, the lowest cells of the epidermis are not removed; hence the epidermis is readily renewed. Sometimes *superfluous hair* grows on the upper lip of a lady, on moles, or on unusual parts of the face. To remove this hair so that it will not grow again, the papillæ at the bottom of the follicles must be destroyed. This is no easy matter. Numerous "infallible" remedies are advertised, but the only effective way is by means of the electric needle, a needle which transmits an electric current.

14. THOUGHT LESSON. **Hygiene of the Skin.** — 1. What is lacking in the skin when it cracks or chaps? How could chapping be prevented in another way than by using cream, etc.?

2. Why does the skin chap in cold weather more often than in warm weather?

3. How does perspiration cool us?[1]

4. Why do we perspire more freely when we exercise?

5. Why do we perspire more freely when we are warm?

6. Is it more necessary for mental workers to bathe often, or to change their clothes often?

7. Which is more necessary for physical workers?

8. Do you know of persons who burn their hair with hot irons? What is the effect upon the hair of repeated scorching?

[1] Do not try to answer this unless you have studied elementary physics. A knowledge of that subject will enable you to understand why wetting the feet even with *warm* water causes colds more quickly than a draft of cool air upon the feet.

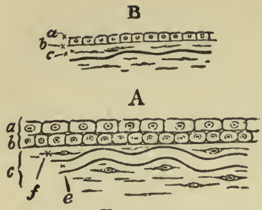


FIG. 11.

A, typical structure of a mucous membrane with two layers of epithelial cells, *a*, *b*; *c*, the connective tissue beneath, with *e*, blood-vessels, and *f*, connective tissue cells.

B, the same with one layer of cells resting on *b*, the so-called basement membrane.

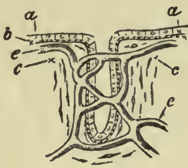


FIG. 12.

A simple tubular gland with blood-vessel.

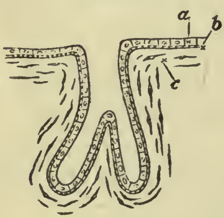


FIG. 13.

A tubular gland dividing.

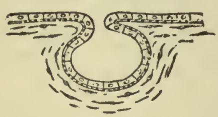


FIG. 14.

A sac-like gland.

Diagrams to illustrate the Structure of Glands.

15. The Mucous Membrane. — Epithelial cells form not only the epidermis to cover the body externally, but they form also a lining for the interior cavities of the body. Any interior cavities to which air has access, as the mouth, stomach, and lungs, are lined with one or more layers of closely packed epithelial cells called mucous membrane. Any cavities from which the air is cut off, as the heart, are called serous cavities, and have a lining of epithelial cells forming what is called a serous membrane. These membranes secrete a lubricating fluid. The fluid formed by the mucous membrane is called mucus. The line where the epidermis and the mucous membrane of the lips join can be plainly seen, as the latter membrane is so thin that the color of the blood shows through it. Mucous membranes are so smooth and their cells are so tightly packed that they are harder to cut than the skin, notwithstanding they are very thin.

16. Glands (Figs. 11 to 17) are always lined with epithelial cells. Glands are cavities in the body, usually bag-shaped or tubular, whose walls secrete fluids which are of various uses in the body. The gland cells make use of the various chemical substances in the blood, so that one gland secretes oil, another perspiration, another saliva, etc. The kidneys are important glands which resemble some of the glands of the skin in that they secrete injurious substances that must be removed from the system. *Secretion* is the name given the various fluids formed by glands. *Excre-*

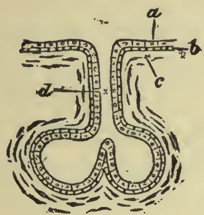


FIG. 15.
A divided saccular gland with duct, *d*.

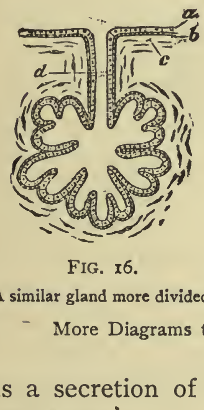


FIG. 16.
A similar gland more divided.

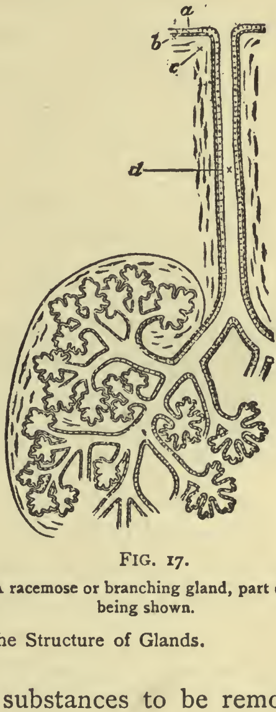


FIG. 17.
A racemose or branching gland, part only being shown.

More Diagrams to illustrate the Structure of Glands.

tion is a secretion of harmful substances to be removed from the body.

17. Secretion is not simply a process of soaking or sifting through. The walls of the glands are made of cells. The cells, those wonderful little bodies which we shall study more carefully in another chapter, obtain from the blood the materials which they secrete. More than this, by the aid of the nerves, they can regulate the amount of secretion independently of the amount of blood circulating around them, although usually the amount of secretion is greatly influenced by the amount of blood in the skin (Fig. 2). Sometimes the skin is hot from the abundance of blood flowing through it, as during a fever, but it is dry as well as hot because the sweat glands are not acting. A dog does not perspire except through the soles of its feet and through its tongue. Once a curious experiment was tried upon a dog in which the nerves supplying one foot had been severed. This dog was placed in a very hot chamber. Three of its feet perspired profusely; but the foot which lacked nerves to control its sweat glands was perfectly dry. This shows that nervous control as well as heat is necessary to make the gland cells perform their functions. Sometimes, under the influence of excitement or fear, a person breaks out in a profuse perspiration, which is, however, cold, for there is little blood in the skin.

18. Stimulants and Narcotics. — A *stimulant* is a substance that is usually an enemy to the welfare of the body; it irritates and excites when first taken. This is because of the effort of the system to expel it. After such effort, the body is weaker and more sluggish than before. This effect is called the reaction. There is no known stimulant that does not cause a reaction. A *narcotic* is a substance that deadens the nerves; this effect does not come as a reaction, but begins as soon as the narcotic is taken. Strychnine is a stimulant; tobacco is a narcotic. How alcohol is apparently a stimulant but really a narcotic will be explained in another chapter. The toper is said to have a "rum blossom" on his nose. This swollen condition of the blood vessels of the nose is caused by the paralyzing action of alcohol upon the walls of the blood vessels. The stagnant circulation allows the blood to become purple with impurities. Coffee-drinking often causes the complexion to be "muddy." Have you ever noticed any difference between the skins of those who use coffee and those who do not? Tobacco has an effect similar to that of coffee. The injury that coffee and tobacco do to the stomach and liver causes the blood to be impure, and the effect of impure blood usually shows in the complexion.

19. The Teeth may be regarded as a part of the skin, since a tooth, like a hair or a nail, is developed from a papilla of the true skin. A tooth extends down into a depression in the jawbone, called a socket, and is held in place largely by the tightness with which the root, or lower part, fits into the socket. The visible part of the tooth is called the crown.

20. Number and Names of the Teeth. — A complete set of teeth in adults consists of sixteen in each jaw or thirty-two in all. They are named according to their form and the uses to which they are adapted. There are eight (Fig. 18) in each quarter of the mouth; and if the names of the eight in one quarter are learned, you know the names of the thirty-two, since they are designated by the same names, in the same order in each quarter of the mouth. Looking, then, at the teeth in one half of one jaw and naming them in order from front to back, there are two incisors, one canine, two bicuspids, and three molars. How many of each kind are found in the whole mouth (Fig. 18)? The eight in front are for cutting off the food, and hence are called *incisors*, or cutters. They have chisel-like edges. Do the edges of the upper and the lower teeth usually meet in the mouth, or do they miss each

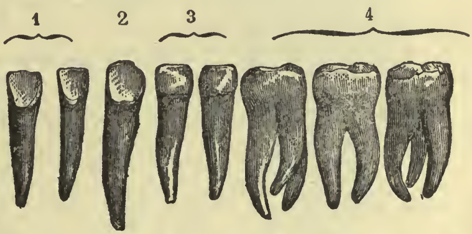


FIG. 18. — Teeth from One Side of the Lower Jaw of Man.

1, incisors; 2, canine; 3, bicuspids; 4, molars.

other like the blades of scissors? The incisors are very long in gnawing animals (rats, squirrels, etc.). Next to the two incisors in each quarter of the jaws, comes one *canine*, so called because the corresponding tooth in the jaws of dogs is well developed; in cats, tigers, dogs, and other flesh-eating animals, it is suited for tearing. It has only one root, but that is a long one. Could you catch hold with your canine teeth so as to use them for tearing? Are they sharper than the incisor teeth? (Use

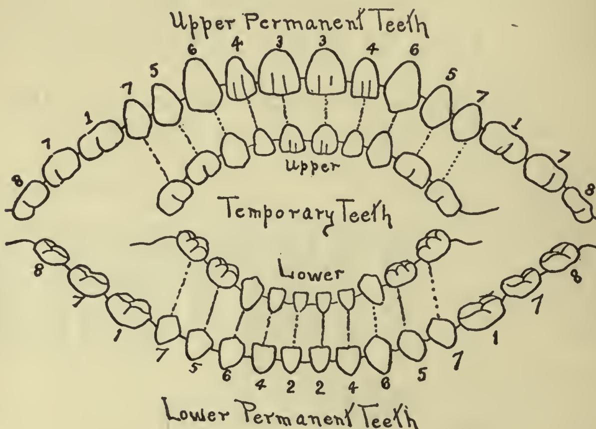


FIG. 19.

a mirror.) The two upper canines are fancifully called the "eye teeth," and the two lower, the "stomach teeth." Next in order behind the canines are the two *bicuspids*, which are grinding teeth. Their crowns are broad and they have two roots. Last of all come the three large grinders, called *molars*. Are the grinding surfaces of the molars smooth or rough? Are they like or unlike the surfaces of the bicuspids? The last molar in each jaw is called the wisdom tooth, because these teeth do not come until the person is supposed to have reached years of discretion. Activity is the law of life, and the wisdom teeth are so far back in the mouth that they are not much used; therefore they do not usually remain so long as the others.

21. Milk Teeth. — The teeth just described are those of the permanent set. The first or temporary set of teeth (Fig. 19) consists of teeth the same in name and number as those of the permanent set except that the three large molars in each half jaw, twelve in all, are lacking; so there are twenty teeth in the temporary set (Fig. 19). The milk teeth come during the first two years of life, and begin during the sixth or seventh year to be pushed out and replaced by the permanent teeth. They are all gone by the twelfth year. The milk teeth have much smaller roots than the permanent teeth. Since a tooth does not enlarge after it develops, the two sets of teeth are a beautiful provision for preserving the regularity of the teeth as the jaws increase in size. If a milk tooth remains so long as to cause the tooth of the second set to grow out of place, the first tooth should be removed.

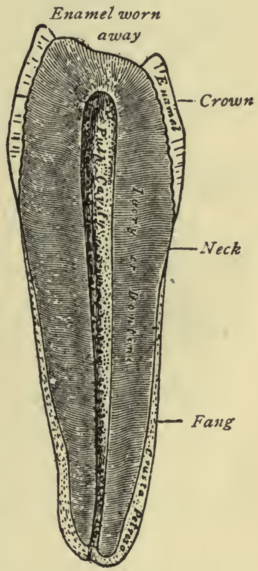


FIG. 20. — Vertical Section of a Bicuspid Tooth, magnified.

22. The main part of the body of a tooth is **dentine** (Fig. 20). The dentine of the teeth of elephants and other large animals is the ivory of commerce. It is commonly used on piano keys, fans, etc. In the central part of the dentine is a space called the pulp cavity. The soft substance called the pulp contains the nerves and blood vessels which enter at the tip of the root. In the socket the dentine is covered by **cement**; above the socket it is covered by

enamel, a substance harder, denser, and more shining than the dentine.

23. The enamel is worn off from the top of the crown between the twentieth and thirtieth years. (If you examine a person's mouth in whose teeth the yellowish dentine shows through the white enamel, you will know that person to be at least how old?) Although the dentine is exposed through the wearing or breaking of the enamel, it will last for years without decaying, but it is more likely to decay than the enamel. We should never run the risk of breaking the enamel by sudden slipping of the teeth, such as often occurs when eating hard candies or cracking nuts. A tooth should never be pulled if it can be saved by being filled; for pulling a tooth means not only the loss of one tooth, but the end of usefulness of the tooth opposite to it, and imperfect chewing in that part of the mouth. Losing a tooth is equivalent to losing part of the life.

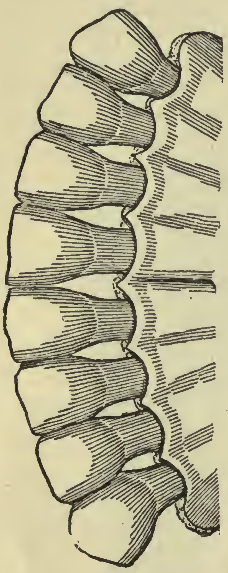


FIG. 21. — Teeth of a Healthy Cow.

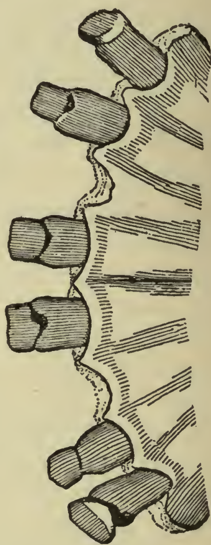


FIG. 22. — Teeth of a Cow fed on Slops.

Showing the need of eating food that requires the use of the teeth.

24. Decay of the teeth is caused (1) by using only soft food (Figs. 21 and 22) which requires no pressure of the teeth while chewing it; (2) by particles of food lodging between the teeth and becoming quickly de-composed in the warm, moist mouth; (3) by the collection of tartar on the teeth (Fig. 23). This is a deposit formed because the secretion of the mouth is in improper condition. It affords an inviting soil in which germs may grow and attack the teeth. (4) Constant nibbling of candy between meals is a bad habit, as the sugar may ferment in the mouth and change to an acid, which injures the teeth.

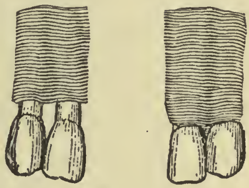


FIG. 23. — Human Teeth; sockets injured by tartar (on left); uninjured (on right).

25. A toothbrush is more effective when it is rubbed up and down as well as across the teeth. A toothpick is as important as a toothbrush. As a tooth powder, fine precipitated chalk is best; it helps to clean the teeth and destroys sourness due to acids. Do you like to leave the table with a sweet taste in the mouth? Why does chalk injure the skin, although good for the teeth?

26. THOUGHT LESSON. **The Complexion.** — 1. Draw lines under the words which name qualities belonging to a healthy skin: hard, soft, dry, moist, flexible, elastic, firm, flabby, smooth, dingy, rough, pink, yellow, pale, velvety.

2. The —— and the —— upon the skin keep it from being dry.

3. These secretions come from the —— and the ——.

4. The organs that furnish these secretions get their material from the ——.

5. What is the best means of improving the circulation in the skin?

6. When a pore is so full of dirt and oil that you can see it, what is it called?

7. You have considered what makes the skin soft; let us think what will make it dry and hard. When our

grandmothers were young, there was no blotting paper. What did they keep in a cup on the writing desk to dry the ink with? Try it.

8. To what similar treatment is the skin sometimes subjected? Why do dry powders, hot winds, and overheated rooms all have a similar effect upon the skin?

9. Think of five girls not over twelve years old. How many of them have healthy skins?

10. Of the first five grown young ladies that you happen to think of, how many have smooth, rosy skins? How many have dingy, bad complexions? Have any of them blotches in the middle of the cheek?[1]

11. The skin does not naturally become dry or dark-colored with age until after middle life. What have the young ladies done to injure their soft, rosy complexions?

12. Why are such young ladies not bright?

13. Who is more apt to be sincere in nature, a person with a clean face and a truthful complexion, or one who paints and powders? (Is a "white lie" more truthful than a pink one?)

A young lady with a very beautiful complexion was once asked the secret of it. She said that when she was a little girl she spent the night with a neighbor's daughter, and they amused themselves dressing in the clothes of an elder sister and powdering their faces. On returning home next morning from her visit, her mother saw some of the rice powder still around her eyes and punished her with "a switching," and told her that she must never do so again. She never did, and grew up with the complexion of her childhood.

[1] The study of physiology cannot be made practical without observing the effects of violating its laws in daily life. In tracing the effects of tobacco, overeating, alcohol, ignorant treatment of the skin, overwork, etc., it would be manifestly improper and ill-mannered to refer to persons by name in a public place such as a school.

27. Review of Functions of the Skin. — Its chief function, one of more importance than all others combined, is **protection** of the body. The dead outer cells well fit it for this, as does its peculiarity of becoming thicker where friction is greater. Savage man's only protection for his head from the heat of the sun and the blows of enemies, is his hair.

28. Physiologists usually mention the **absorbing** power of the skin, but this is very slight; if it were great, the skin would lack part of its ability to protect. As it is, man can handle poisons without harm, provided there is no break in the epidermis. He can suck with safety the poison from a bite made by a rattlesnake if there is no raw place or break in the mucous membrane of the mouth. If the poison should be swallowed, the stomach would destroy it. Some volatile poisons like the poison ivy can penetrate the skin.

29. Some writers mention the **respiratory** or breathing power of the skin and speak of the skin as a third lung, but this is a great exaggeration. The skin probably has about one fiftieth of the breathing capacity of the lungs. The pathetic story told concerning a child who was gilded to represent an angel in a pageant held in honor of one of the popes, may be true. The child is said to have died in a few hours. Death was probably due to some poison absorbed in the process of gilding. A man can live after his body is varnished or covered with a layer of impenetrable substance. But varnishing the skin of an animal covered with fur leads to its death from loss of heat, as the varnish destroys the non-conducting property of the fur.

30. The skin is an organ of **sensation**, the nerve fibers going not only to the papillæ, but some of the finer filaments penetrating even among the deeper epithelial cells.

31. The skin is an organ of **excretion**, the chief substances excreted being water, salt, ammonia, and a slight trace of a crystalline solid called **urea**.

32. The skin is the chief organ for **regulating the temperature.** It accomplishes this by means of the perspiration.

33. Clothing does not give heat to the body, but helps to prevent the escape of bodily heat. Linen and cotton absorb moisture readily and allow it to evaporate rapidly. They thus serve, when worn next to the skin, to keep the body dry; the evaporation, if very rapid, may chill the body. Woolen absorbs moisture quickly, but parts with it slowly, and in the case of those who perspire freely, the damp clothing next to the skin may conduct away the heat. But dry woolen contains much air in the meshes of the cloth; and as this is a non-conductor of heat, such clothing is the warmest of all, silk ranking next. In cold climates woolen should be worn next to the skin, and should not be laid aside until the heat of summer begins. In warm climates, like that of the Gulf States, it should not be worn next to the skin at all, even in winter, unless by the very delicate, and it is a question as to whether woolen does not do more harm than good, even to the delicate, as it relaxes and weakens the skin. If it is worn in such climates, with the warmth of spring it should be changed for less relaxing fabrics. White clothing reflects the heat of the sun; dark clothing absorbs the sun's heat. Rubber clothing prevents moisture from penetrating to the body and also prevents perspiration from escaping.

34. Bathing. — A bath is necessary for cleanliness, once a week in winter and perhaps daily in summer. Frequent bathing, if accompanied by the use of soap and friction, makes the skin too thin and sensitive. A warm bath should be succeeded by a dash of cold water to overcome its relaxing effects. A warm bath is more suitable on retiring than on rising; it is also more suitable than a cold bath for a person that is much fatigued. A cold bath is more invigorating than a warm bath, and should be followed by a reaction or glow caused by the return of the blood to the skin. The cold water stimulates the heart and lungs and causes the bather to breathe deeply and vigorously. A cold bath, if not taken rapidly, may injure a delicate person more by its duration than by its coldness; a delicate person may bear a very cold shower-bath if continued for only a few seconds.

35. Thought Lesson. **The Value of Health.** — 1. Name five blessings in youth or later in life that result from good health.

2. Name five unfortunate results of bad health.

3. Name five things that people apparently value more highly than health.

4. Think of ten grown persons at random. How many of the ten are in sound health?

APPLIED PHYSIOLOGY

EXERCISE I

1. Why does the **palm** of a washerwoman's hand **absorb more water** than the back of the hand? (§ 11.)

2. If a **hair is pulled out,** what determines whether it will **grow again?** (§ 9.)

3. Why is **linen** used for **towels?** (§ 33.)

4. What causes the hair to "**stand on end**" when a person is frightened or when an animal is cold? (§ 10.)

5. Calculate the **length** of the **perspiratory tubes** in one square inch of the palm, if placed end to end. (§ 7.)

6. Why does the skin become roughened and **chapped** in **cold weather?** (See chapter on Circulation.)

7. What **color of clothing** is best adapted to summer? To winter?

8. When is a **scar** incapable of being affected by **freckles** or **tan?**

9. Could a **scar** on a **negro** be white?

10. How may **rubber** shoes make the **feet moist?**

EXERCISE II

11. Why does the heat seem more **oppressive** in **moist weather?**

12. Which should usually wear **warmer clothing,** a farmer or a merchant?

13. Which teeth cut like a pair of **scissors ?**

14. Why is the **outer surface** of leather smoother than the inner ?

15. How long does it take a **spot of indelible ink** on the fingers to wear off ? Of what does this show the rate of change ?

16. How may **indigestion** cause the teeth to decay ?

17. In what respect do patent leather shoes **resemble** rubber shoes ?

18. Why is **baldness** more common among men than among women ?

19. How do you account for the location and **shape** of the **bald spot ?**

20. When their skins contain the same amount of pigment, a **man's complexion is darker** than a woman's, because his blood is darker, since it contains ten per cent more red corpuscles. Why do women desire a fair complexion ?

21. Why is a woman's complexion considered **beautiful** when it is pink and fair, but **ugly** when it is pale or sallow ?

EXERCISE III

22. Did you ever know of a case of loss of health caused by changing the warm clothing of daily wear for the **thin or scanty dress** of a ball or party ?

23. Why should we **remove an overcoat** or a cloak when we go into a warm room ?

24. Why is **cold water** better than warm water for the daily bath?

25. Should a person wait for a warning such as fatigue, depression, or chilly feeling before **leaving a bath** in the sea or an ordinary bath?

26. Why do healthy persons living along the Atlantic, Pacific, or Gulf coasts, have softer skins and **fresher, rosier** complexions than those who live in the interior of the United States? Why, if they live in forest regions such as Louisiana and east Texas, rather than in prairie regions such as west Texas, Kansas, and Nebraska ?

27. Why are the **complexions of English** people fresher and rosier than those of people in the United States ?

28. Glass allows the radiant heat of the sun to pass through ; wood does not. Why are **inside blinds** appropriate in cold climates but very unpleasant and inappropriate in warm climates?

29. Which are healthier, and in **better taste for furniture**, in the Gulf States and the West Indies, willow and rattan, or plush and velvet?

30. Show how the **wearing away** of the outer cells of the epidermis contributes to the **cleanliness** of the body.

CHAPTER II

CELLS AND TISSUES

36. The Place of Physiology among the Natural Sciences. — Natural objects have long been divided for purposes of study into the Mineral, Vegetable, and Animal kingdoms. Are any two of these divisions more closely related to each other than they are to the third? Yes, we find that an animal and a plant resemble each other and differ from a mineral in that they are both alive. In order to carry on the mysterious process called life, animals and plants must have an orderly growth and activity. The parts by means of which they carry on this activity are called organs; and plants and animals together form what is called the *organic kingdom*, while minerals form the *inorganic kingdom*.

37. The science which treats of living things in general is called Biology. Botany is one of the biological sciences and treats of plants. Zoölogy is another branch of biology and treats of animals.

38. We may study the body of an animal in two ways. We may study the structure and forms of its organs; this science is called Anatomy, and it may be studied in the dead body better than in the living animal. Or we may study the actions or the functions of the organs of the living animal; this science is called Physiology. It is divided into Plant Physiology and Animal Physiology. Anatomy is likewise divided into two sciences.

39. The Study of the Human Body. —The study you have undertaken is generally, for convenience, called Physiology; but Anatomy must also form a part of the study, since we cannot understand the functions or the actions of an organ without knowing its form and structure. But if we go no further than these sciences, we may as well be studying the position of the stars in the constellation of Orion so far as practical benefit to our lives is concerned. There is a third science based upon the other two, called Hygiene, or the Science of Health. It treats of the proper surroundings for healthful living, and of the activities of the body necessary for the perfect performance of all its functions. It is in Hygiene that Anatomy and Physiology find their practical application.

40. The study of the human body should give the following results: —

1. It should be a means of intellectual training through the attempt to master its facts, solve its problems, and comprehend the relations of its parts.

2. It should be a source of pleasure in leading us to realize the wonders of our bodily structure and the wonderful adaptations of the body to the surrounding conditions.

3. It should give a thorough knowledge of one vertebrate animal that would greatly aid in studying other animals.

4. It should give knowledge which, rightly applied, would form a basis for intelligent care of the health. It should thus be a training in "common sense," which expression taken in its original meaning denotes "sense about common things." We see why physiology, if studied thoughtfully, affords a better training in common sense than almost any other study, when we remember that health is the commonest of all subjects for observation and conversation, and that every habit and surrounding condition of life affects the health.[1]

41. Cells. — While studying the skin, reference was made a number of times to the cells of which it is chiefly

[1] To a person who is destitute of common sense, or who fails to use his common sense while studying this subject, it may become the occasion of

composed. Before passing to the study of any of the internal organs, it will be necessary to study more thoroughly the nature of cells. The unit of structure of animals and of plants is a minute object called the *cell*, and each of their tissues and organs is composed of many cells. The living substance of which the cell is made is called *protoplasm*[1] and this name is applied to the cell substance of both animals and plants. Workers with the microscope over a century ago found that plant and animal tissues are composed of little chambers, which they called cells. It was found later that the liquid in the little chambers is of more importance than the walls which the protoplasm builds around itself. The wall was first called a cell; now we use the word *cell* for the globule of living protoplasm together with its wall, if it has one.

42. Protoplasm. — We should not think because we use the same name, *protoplasm*, for the substance forming the cellular material of both animals and plants, that its chemical composition is always exactly the same. This varies in different cells, and is indeed so complex that no chemist has ever been able to analyze it. The probability is that it will never be analyzed, as its complexity seems unlimited. Besides, there is no such thing as dead protoplasm. As soon as a chemist begins to analyze protoplasm, it separates into a number of substances. It is transparent and jellylike, yet under a microscope there

many unreasonable and misleading notions. This is especially the case with extremists, or with persons who entertain only one idea at a time. They are unable to assign to each truth its proportionate importance.

These are the persons who chill themselves in order to ventilate, worry themselves about digestion, make themselves nervous while trying to develop their muscles, etc. On the other hand, we all know of cases where a person when young was the weakest member of the family; but who, through an intelligent study of physiology and hygiene, became the soundest and healthiest one in the family, and outlived those who were at first sound and strong.

[1] Greek, *protos*, first; *plasma*, that which is molded.

appears an interlacing series of beads and lines (Fig. 26). But there must be some test for identifying protoplasm, or we should never be able to tell organic from inorganic matter; animal and plant substance from mineral. The only distinguishing feature yet known about protoplasm is that there are *always* found in it certain complex *albuminous* substances that are *never* found in inorganic bodies. The white of an egg, also called albumen, is such a substance. The power that the cells possess of performing the processes of life depends upon the presence of these albuminous substances. The albumin, or nitrogenous substance, in protoplasm makes it, therefore, the life substance, and distinguishes it from the mineral world. Nothing in the world besides animals and plants possesses the power of growth by converting other material into its own kind of substance.

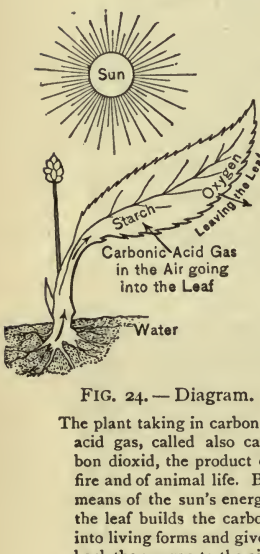


FIG. 24. — Diagram.

The plant taking in carbonic acid gas, called also carbon dioxid, the product of fire and of animal life. By means of the sun's energy the leaf builds the carbon into living forms and gives back the oxygen to the air.

43. Difference between Animals and Plants. — Can you always tell an animal from a plant? You say an animal can move from place to place; the reply is, no, a sponge and many other animals cannot. You say an animal has nerves and feeling, but some simple animals are without nerves; on the other hand, some plants respond to a stimulus or irritation, although they never develop special organs for transmitting the stimulus. It is easy to distinguish the higher animals from plants; but in regard to many of the lowest forms of single-celled organisms, the most learned biologists find it impossible to say whether they are plants or animals. The clearest difference between animals and plants is, that plants get their food directly from mineral substances, while animals must get their food from organic substances, either from plants or from other animals which in turn have eaten plants. The plant builds up complex, unstable substances by means of the sun's light and heat (Fig. 24). The animal eats the plant, and these substances are finally reduced in the body to simple, stable substances, thus setting free the energy stored up in the plant. (What is it, therefore, that indirectly furnishes the energy that sustains all life?)

FIG. 25. — Diagram of the Parts of a Cell.

44. A Living Cell has two essential parts: a small mass or globule of protoplasm, and a still smaller body in its interior, also consisting of protoplasm, called a *nucleus* (Fig. 25). There may be two other parts, for often there is a still smaller body, a dot in the nucleus, called a *nucleolus*, and usually the protoplasm has a wall surrounding it called the *cell wall* (Fig. 26). Cells are of various shapes and constitute the substance of all the organs. The cells are all of the human body that is really alive, the substances in the body outside of cells not being considered living matter. A cell may be defined as a tiny particle of protoplasm containing a nucleus.

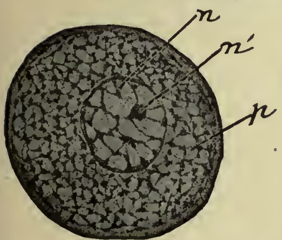


FIG. 26. — Diagram of a Cell.

Showing that protoplasm has an intricate structure; in this case it appears somewhat like honeycomb; *p*, protoplasm; *n*, nucleus; *n'*, nucleolus.

FIG. 27. — A Cell that is Slender and in the Form of a Fiber.

It is from the muscular coat of the intestines; *p*, granular protoplasm around the nucleus, *n*.

45. Fibers. — In some of the tissues the cells are very long and slender, and a single cell forms a fiber. A fiber is stringlike in shape (Fig. 27). Sometimes the fibers consist of rows of cells or of long, fine branches of cells.

46. Membranes. — Sometimes the cells lie side by side, packed closely together, and form a thin skinlike structure, called a *membrane* (Fig. 28).

FIG. 28. — Cells forming a Membrane.

(Mucous membrane of intestines.) A few cells (dark) that secrete mucus are shown.

47. The Varied Life of the Cells. — Some cells, as the red blood cells, move about from place to place, but always keep in a definite channel. There is, however, one kind of cell, called the white blood cell, that can change shape and pass from one tissue into another (Fig. 29).

48. In having a wall, soft contents, and nucleus, the cells of the body resemble minute one-celled animals sometimes found in water. Figure 30 shows the appearance under the microscope of the **ameba**, one of these small animals. The ameba seems to be hardly more than a minute drop of jelly, yet it can move by pushing out a part of its body. It can absorb food from a tiny particle by rolling itself around the particle (Fig. 30). Afterward the ameba pulls itself away and leaves behind the indigestible part.

FIG. 29. — Successive Forms assumed by a Colorless Corpuscle of the Human Blood.

At intervals of one minute.

If the ameba is jarred or struck, it shows that it has feeling. It absorbs oxygen and gives off carbon dioxid. When it attains a certain size, it divides into two parts, which lead independent lives (Fig. 31). The white blood cells are more like independent one-celled animals than any of the other cells. Some animals are larger than others because their bodies contain more cells, not larger cells.

49. An Ordinary Animal is a Community or Colony of Cells. — An animal such as a horse or a man, made up of millions of cells, may be compared to a colony or community of one-celled animals. When a child is born in a community of people, we cannot tell what part in the community it is destined to fill. When a new cell is formed in the body, by the division of an old cell into two cells, it may serve its community as a railroad man serves a community of people, that is, as a red blood cell, and carry food from place to place; or it may be a farmer cell, that is, a digestive cell, and convert crude material into substances ready for use by the other cells. It may be a sentinel and soldier, that is, a white blood cell, and go to any place that is attacked by foreign organisms, such as microbes, or it may help to repair a break in the wall, as when the white blood cells (a kind of "jack at all trades") collect in great numbers and form the white matter seen around a cut in the flesh, or a sore that is healing. It may be a carpenter cell, that is, a bone cell, and help to form the framework or skeleton of the great house which shelters the community; and last of all, it may be a director and guide for the community, that is, one of the nerve cells, which correspond to the

FIG. 30. — The Ameba (as seen under a high power of the microscope) taking food.

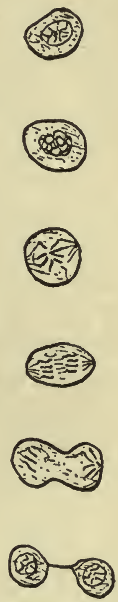


FIG. 31. — A Cell undergoing Division.

Six stages of the process are shown. The nucleus divides as well as the rest of the cell. The mother cell divides into two daughter cells.

officials, teachers, and preachers of any ordinary community of human beings. One man learns to do one kind of work and can do this better than anything else. Often the nature of his work can be judged by his appearance: so it is with the cells. Still, the general structure of all cells is essentially the same, just as all men are alike in their plan of structure. Thus the tissues of the higher animals beautifully exemplify the principle called —

50. Division of Labor. — By this means a community of men working together can accomplish vastly more than the same number working separately. Each, learning to do a few things well, can turn out perfect products of skilled labor, and by a system of interchange can come to possess the products of the skilled labor of others. Without this the human race could have made but very little progress and would have remained in the state of savages, who do not practice the division of labor to any great extent.

51. In the human body, the several groups of cells called tissues have divided among themselves the various physiological processes: the muscle cells are for movement, nerve cells for feeling, gland cells for digestion, etc. They are thus unlike the ameba, whose one cell carries on all the functions, unaided by any other cell. Still, in the body of a higher animal, each cell has many forms of activity common to the ameba and all other living cells; it requires food as much as if it lived alone, and its food is digested and brought to it in a state ready for use; it requires oxygen, and the oxygen is separated by special cells and brought to it purer than that found in air or water. Cells all have at least sometime in their lives the power to increase in size, and to reproduce themselves by dividing just as the ameba does (Fig. 31). In this way, the tissues grow, and thus they may be repaired if injured or broken.

52. The Tissues. — Sets of similar cells are grouped together to form tissues. The cells may develop long branches, called *processes* or *fibers*, and may deposit material between adjoining cells called intercellular substance. A tissue consists of a mass of cells built up together, along with all of their processes and intercellular substance. A part of the body which has a definite work to do is called an *organ*, and each organ consists of several tissues. The tissues are of many kinds. In order to understand them clearly and to remember them distinctly, we must learn them according to their uses in the different organs.

53. What are the chief uses or purposes of our bodies? If we consider our life, we shall at once say that our bodies enable us to perceive, to feel, to think, on the one hand, and to work, to execute, to exert energy, on the other. The powers of thinking and doing have two tissues allotted to them in the animal economy, and these two tissues have been named by physiologists, the *master* tissues, while the remaining tissues, to which are intrusted the protection, support, and renewal of the master tissues, are called the *supporting* tissues. The two master tissues, or those that have to do with controlling and exerting energy, are called, respectively, the *muscular* and the *nervous* tissues. They will be treated in a general way in the next chapter, so that their part in the functional activity of each of the various organs may be understood as they are taken up in turn. Those organs the chief functions of which are nervous or muscular will be studied in later chapters.

54. In studying the definitions of the tissues and the drawings showing microscopic views of them, it will be well to remember that they are all developed from the same elements, namely, nucleated cells. Every tissue in the earlier stages is a mass of such cells packed together. The cells of one tissue, when mature, resemble one another, but are unlike those of other tissues.

CHAPTER III

THE SUPPORTING TISSUES

55. Connective Tissue consists of three elements: white fibers, yellow fibers, and connective tissue cells. The *white fibers* (Fig. 32) are not elastic. They form a meshwork of bundles running in various directions. The bundles consist of still smaller fibers which are fine, long, and wavy; they run parallel in the bundle and never branch. Scattered among the bundles are some branching fibers, forming a network; they are yellow and generally much thicker than the white fibers, and are called *yellow elastic fibers*.

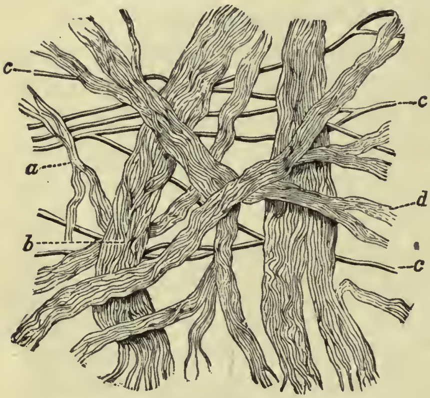


FIG. 32. — Connective Tissue Fibers.
a, small bundles of white fibrous tissue; *b*, larger bundles; *c*, single yellow elastic fibers.

They form the second element in connective tissue (Fig. 32, *c*). The third element is the *connective tissue cells*. They are scattered among the fibers. Each has a nucleus (Fig. 33); many of them are much branched and the fibrous parts of the tissue already described are believed to have been first formed as branches of such cells.

56. This wonderfully strong, though delicate, tissue (Fig. 34) is found in every organ, binding together and holding in place the various tissues and cells, thus preserving delicate tissues like the master tissues from strain and injury. It is said that if every other tissue were removed, the connective tissue would still give a perfect model of all the organs. The tendons and ligaments consist almost wholly of it. Leather, the part of skins that is left after tanning, is made up of connective tissue. You have already learned that the true skin consists of nerves, blood vessels, and glands supported by fibers of connective tissue. In tanning, the more delicate parts are destroyed and only connective tissue is left.

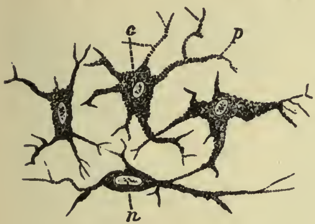


FIG. 33. — Connective Tissue Corpuscles.

c, cell ; *p*, process ; *n*, nucleus.

57. Adipose (Fatty) Tissue. — This soft tissue furnishes cushions for delicate organs like the eye, forms a layer under the skin, thus rounding out the form, and storing up food for the use of nerve, muscle, and other cells. The fat is first deposited in the form of minute globules in the connective tissue corpuscles, or cells; these globules gradually increase in size. That fatty tissue consists of both cells and fibers and is developed from connective tissue can be seen by studying Figure 38. The fat is in the cells, and the cells are lodged in pockets formed by meshes of the fibers of connective tissue.

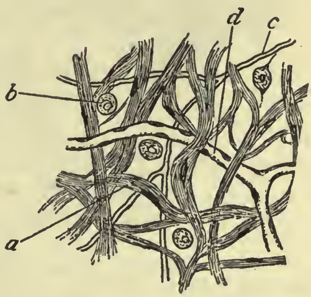


FIG. 34. — Connective Tissue.

a, fibers with cells on them ; *b*, free cells in spaces ; *c*, yellow elastic fiber ; *d*, blood capillary.

58. What part of the tissue of hog fat furnishes lard? What does beef fat contain that is not in the tallow? What is suet?

59. Epithelial Tissue. — Covering the surface of the body and lining every cavity and tube of its interior, is a tissue consisting of one or more layers of distinct cells, forming what is called epithelial tissue. You learned in Chapter I that from it the hair and nails are produced. It is perhaps the simplest of the tissues, consisting merely of cells packed closely together, and united by a very small amount of a cement substance of albuminous nature. The cells may be in a single layer, as in the mucous membrane of the intestine (Fig. 28), or in many layers, as in the epidermis. No blood vessels pass into the epithelial tissue; the cells derive their nourishment by absorbing it from the watery portion of the blood exuded into the adjacent tissues. The epithelial tissue grows by subdivision of the cells of the lowest layer. When the nucleus has disappeared, the cells die and flatten and become mere horny plates, easily detached; and thus the outer cells are constantly wearing away as you learned when studying the skin.

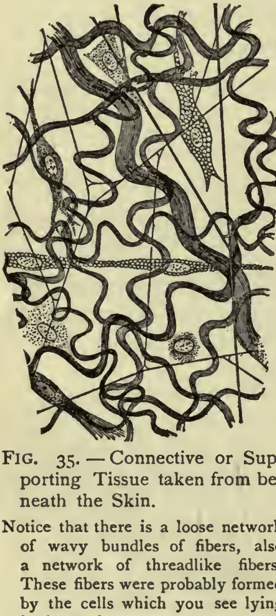


FIG. 35. — Connective or Supporting Tissue taken from beneath the Skin.

Notice that there is a loose network of wavy bundles of fibers, also a network of threadlike fibers. These fibers were probably formed by the cells which you see lying in the meshes.

FIG. 36. — The Skin.

Epithelial tissue at *ep.* and *s*; connective and fatty tissue below.

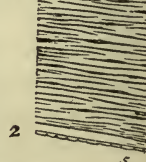


FIG. 37. — Connective Tissue. (*H*), Epithelial. (*I*), in the Wall of the Eyeball.

60. The epithelial structures may be placed according to their functions, in two divisions. One is chiefly protective in character; such as the outer skin, the lining of the mouth and windpipe, the epithelial layers protecting the delicate nerves and blood vessels beneath. The other kind of epithelial tissue consists of cells that contain highly active protoplasm and are actively engaged in forming fluids called *secretions*, from food brought to them by the blood (Figs. 11 to 17). Such are the cells of the salivary glands, which secrete the saliva (Fig. 40); of the gastric glands, which secrete gastric juice (Fig. 41); of the pancreas, sweat glands, kidneys, liver, etc. This class of epithelial tissue is, therefore, of the greatest value in purifying the body and in preparing material to be used in its activities: it is essential to the growth of sound and well-nourished nerve and muscle.

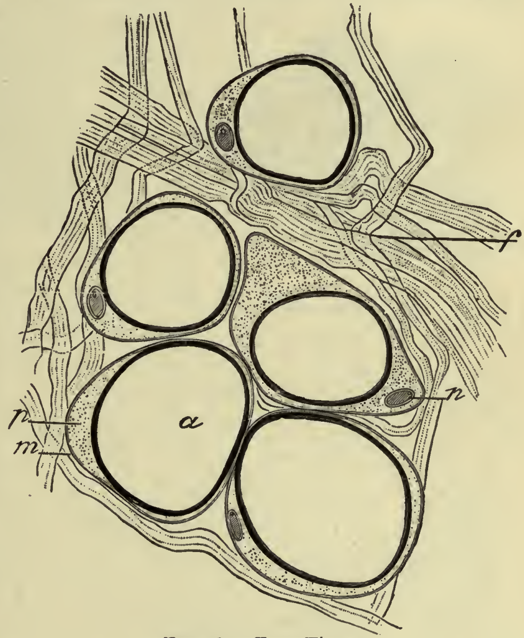


FIG. 38. — Fatty Tissue.

Five fat cells, held together by bundles of connective tissue *f*; *m*, the membrane or envelope of the fat cell; *n*, the nucleus, and *p*, remains of the protoplasm pushed aside by large oil drop *a*. Magnified 200 diameters.

61. Cartilaginous Tissue. — Some parts of the body require tissue having something of the rigidity of bones, yet capable of bending under pressure. This purpose is fulfilled by the elastic tissue called *cartilage*. A piece obtained fresh from the animal is seen to be covered by a thin fibrous membrane, which is reddish because it contains blood vessels. When this membrane is stripped off, the cartilage shows no signs of redness, that is, it contains no blood vessels. A thin section of fresh cartilage appears to the unaided eye as uniform as a piece of glass. Under the microscope we see that it is not so, but that scattered in its general substance are numerous cells. Each cell is rounded and nucleated (Fig. 43). They are often in pairs, and in that case adjacent sides are flat; which at once suggests that they have been formed by the division of one cell. In the growth of cartilage each cell divides into two cells. These new cells later on divide in a similar way, so that a group of four or eight cells that have all sprung from one cell may be seen. The general substance between the cells is deposited by the cells and is called the intercellular substance or the *matrix*.

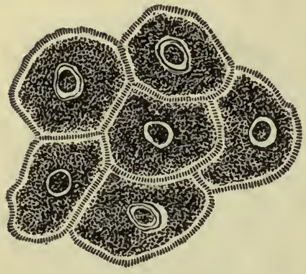


FIG. 39. — Epithelial Cells Lining the Mouth.

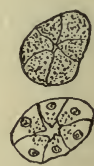


FIG. 40. — Six Gland Cells.

Resting, full of granules, after activity; lower cells shrunk and containing few granules.

FIG. 41. — Two Gastric Glands.

Simple tubular glands such as these may be likened to a well; the cells are like the bricks of the well-curb.

62. Cartilage may be readily felt in the nose (in what portion?), ears, and windpipe. It may contain an abundance of the yellow elastic fibers of connective tissue, in which case it is very elastic, as in the ear; or it may have masses of white fibers, and may be unusually tough, as in the cartilages between the divisions of the vertebral column.

63. Osseous (Bony) Tissue. — Just as ordinary connective tissue supports and holds in place the delicate cells and fibers of the organs, so the bone and cartilage support the various complete organs and hold them in their proper places in relation to one another. Cartilage and bone are closely related as to location and function; they are also closely related in their development. For example, in infancy the flat bones forming the roof and sides of the skull are soft and flexible, being composed of cartilage, except a patch of bone in the middle of each. As growth proceeds, the bones touch and interlock, replacing the cartilage. If a bone is broken, the new bone, as it heals, is first cartilaginous and afterward solid. Late in life some of the ordinary cartilages of the joints change to bone.

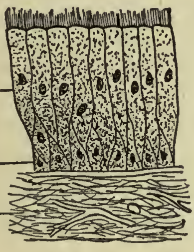


FIG. 42. — Ciliated Epithelial Cells, which line the Air Tubes. (Cilia are hairlike.)

a, large cells; *b*, young cells; *c*, connective tissue cells and blood vessels.

64. Periosteum. — A bone usually has its ends coated by a layer of cartilage. At the margin of the surface that forms the joint the cartilage thins out, and a layer of vascular ("full of vessels") connective tissue begins and, extending over the remaining surface of the bone, forms a covering for it, called the *periosteum*. This contains the blood vessels which pass into the bone to supply

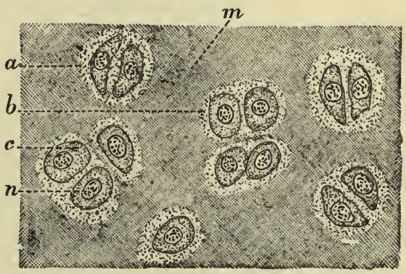


FIG. 43. — Cartilage. A thin Section, highly magnified.

m, matrix; *a*, group of two cartilage cells; *b*, a group of four cells; *c*, a cell; *n*, nucleus.

nourishment. It is closely adherent to the bone and may be removed by scraping. It is sometimes seen as a ragged margin on the sawed end of a bone fresh from the butcher.

65. The hardest and most compact part of a bone seen under the microscope shows the following **system of openings** (Fig. 44): (1) canals, called *Haversian canals*, running lengthwise of the bone and containing blood vessels which extend into them from the periosteum; (2) irregular spaces called *lacunæ* arranged in circular lines around the canals; (3) from the lacunæ numerous minute wavy passages called *canaliculi* pass inward to the Haversian canals, while others pass outward to open into the lacunæ in the outer circles. The canaliculi afford passage to minute blood vessels.

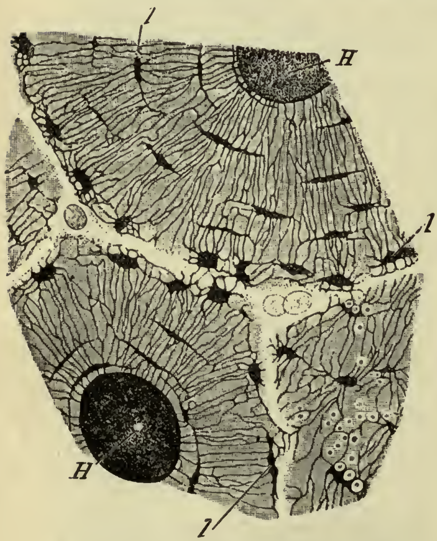


FIG. 44.— Bone cut across, highly magnified.

H, Haversian canals; *l*, lacunæ, connected by canaliculi.

66. The lacunæ contain small cells called **bone cells**, each having a nucleus and sending out fine processes or branches for some distance along the canaliculi. They receive their nourishment from the blood flowing through the Haversian canals, which penetrate to them in their stony prisons, through the canaliculi. They have for their special form of activity the building of walls of phosphate and carbonate of lime about themselves. The walls built by the neighboring cells touch one another, and becoming fused together make the whole bone strong and rigid. Thus the hard, mineral part of the bone is deposited by these bone cells and is nourished by them. The bone corpuscles, we thus see, lie in the intercellular substance or matrix, in much the same way that the cartilage cells lie in the intercellular substance of the cartilage. In bone the matrix consists mostly of lime.

67. Aided by the figures, make a series of **drawings** showing the form of the cell in the several tissues. Can you see that the cell has not only similar parts but also similar functions, in each of the tissues studied? Some cells live only a few hours; others, as the cells of cartilage and bone, may live for years.

68. It should be repeated that each organ of the body consists not of one, but of several tissues. The heart, for example, is composed principally of muscular, nervous, connective, and fatty tissues; the eye is formed of nervous, connective, muscular, and epithelial tissues. The following list shows the several classes of tissues: —

MASTER TISSUES	Nervous Tissues Muscular Tissues
SUPPORTING TISSUES	Connective Tissues Fatty Tissues Cartilaginous Tissues Osseous Tissues Epithelial Tissues

69. Tissue Building. — As you have learned, all of the tissues are built, maintained, and repaired by living cells. Life and health depend upon the proper and continuous activity of these cells, and anything which aids in this activity strengthens the body and prolongs life; anything which injures them or interferes with their activity, impairs the health and shortens life. Growth and repair of tissue are promoted by sunshine, by fresh air, by drinking plenty of pure water, by good food, by active and happy occupation. Weakness and injury of cell and tissue result from depriving the body of these conditions. The only possible way to return to health of the body is to restore these conditions, and adapt the daily life to them. The effect of various substances upon living cells may be watched under a microscope. If bathed with a proper food substance, the cell is seen to expand and grow and move more actively. If bathed in an astringent substance like the tannin of tea, it shrinks and ceases its movements until revived. If bathed in a liquid to which a small quantity of alcohol has been added, its activity ceases, and unless the proportion is very small, such activity cannot be restored. The chemical substances that actually attack delicate living cells, causing them to shrivel, or decomposing and destroying them, are called poisons. Arsenic destroys the red blood cells. Strychnine attacks some of the master cells, namely, the nerve cells, and their activity in attempting to cast off the poison sometimes throws the body into a spasm. The action of some poisons upon cells, especially the nerve cells, is called —

70. Stimulation. — This unnatural and exhausting activity of the cells in their efforts to free themselves from poison, is interpreted by some persons to mean that the poison gives the strength and activity shown in the cells. The poison does not put strength into the cells, but gets it out, and honest food alone puts the strength back. Alcohol hastens the breaking down of cell protoplasm and lessens the activity of the tissue-building cells. This is one reason why a person who has been used to alcoholic drinks recovers less rapidly from an accident or surgical operation than one who uses none. One of the first questions asked by a surgeon before operating, is whether the patient uses alcohol. Tobacco also lessens the activity of the cells that build and repair the tissues. This is the reason why men who begin the use of tobacco when young boys are often poorly developed and stunted in growth.

Opium completely paralyzes certain cells. Those poisons which are used by physicians to regulate the activity of the cells are called —

71. Drugs and Stimulants. — There are some people who are so reckless in regard to that delicate organism, the body, that they are ready to take the place of a physician and to doctor themselves or their friends with virulent drugs and patent medicines, and even to make a habit of using alcohol, tobacco, or opium. The persons who prescribe drugs to their families or friends may say they have often taken calomel, quinine, patent cure-alls, headache medicines, etc., and have not been injured. In the case of some drugs, the most powerful microscope may fail to show any effect upon the cells; nevertheless, we know a change has occurred, for it requires more of the same drug to have a like effect next time. The wisest physician cannot peep into the secrets of the cells and always discern whether they are injured. How presumptuous in those who are not physicians to tamper with drugs! Such persons err through ignorance or presumption and often do injury to themselves or their dear ones which lasts through life. The best physicians give little medicine, especially when practicing in families of intelligent people who have the ability and patience to carry out their hygienic directions. The safe way is to seek the conditions of life named above. How to do this will be considered in the sections of this book devoted to hygiene. Sickness is sometimes unavoidable. When a person is in bed, it is too late for him to cure himself by right living alone; care should be taken to call a good physician, and his directions should be implicitly followed. Self drugging by the public is considered by some the most fruitful cause of disease in the United States. "Mind cure" and kindred ideas often do more by rescuing victims from poisonous drugs than through their calming effect upon the mind.

CHAPTER IV

THE MASTER TISSUES

72. A complete animal (or plant) is called an **organism.** The cells constituting it and working harmoniously together were likened to a human community or town. Such a comparison helps us to realize how complex and mysterious is an animal body, and how wonderful are the processes of life. But the relation between the cells is much closer than that between the individuals of a community. A marked difference is that the human being can move as a whole, can change place in space, can act with all the organs in the organism working in unison. The energy stored in the body enables it to do these things, and the two tissues that chiefly expend the energy and give us the ability to do things, to act, are the nerve tissue and the muscular tissue. How is energy, or the ability to do work, stored in the body?

73. Oxidation. — We know that this energy arises from a kind of combustion or slow burning, thus resembling in its source the energy of the steam engine. That something besides wood or coal is necessary to a fire can be shown by shutting off entirely the draught of the stove. Fire and all other forms of combustion depend upon a process called *oxidation*. This consists in the *uniting of oxygen*, the active element of the air, *with carbon*, *hydrogen*, *and other elements* in wood, coal, etc. Bread, meat, and other foods contain these latter elements. That carbon is in sugar, for instance, can be easily proved by charring sugar upon the stove, the charcoal thus produced being a form of carbon. Compounds containing these elements are taken into the body through *the digestive organs*, carried around by the fluid portion of the blood, and stored up in the cells ready for union with oxygen by the process of slow combustion, or slow oxidation, of which the activity called animal life seems to consist. The oxygen, on the other hand, enters the body through *the lungs* and is carried to the tissues by the red corpuscles of the blood. Thus is energy stored in the body, the oxygen being ready to unite with the other elements, giving rise to heat and motion. The rate and manner of this union are regulated by one of the master tissues, the nerves; while the application of the energy so as to produce motion is the function of the muscular tissue.

74. The "burning" of food substances in the muscle is essentially the same process as the burning of coal in the furnace of the engine, but in the muscle the oxidation takes place under peculiar conditions not at present thoroughly understood, at a temperature of less than 100° Fahrenheit, while for ordinary combustion a temperature of several hundred degrees is required.

75. The body **resembles a locomotive** in having warmth and motion as a result of the union of fuel and oxygen; but it differs from the locomotive, since the intelligent engineer is an organic part of it, and since the oxidation in the body is in the presence of moisture, and so gradual that it is not a true fire accompanied by light. Moreover, the body can repair itself as it wears out, and the engine cannot. The energy stored in the body is used more economically and effectively than any steam engine can use fuel. This we might well expect from the fact that the engineer is a part of the engine.

76. Muscular Tissue. — How does the oxidation of food produce motion? We learn that the ameba and other one-celled animals can change their shapes. Many of the cells in the body have lost this power, but the muscle cells retain it. Figure 27 shows a muscle cell of one form. Figure 45 shows muscle cells of another form. There are other forms of muscle cells, but they are all alike in the fact that under certain conditions they get broader and shorter. Suppose we have a row of cells in a muscular tissue. Think, for instance, of the muscle in the upper arm that causes the elbow to bend when the muscle becomes shorter. It is plain that the shortening of the whole muscle will be equal to the sum of the shortening of all the cells in a line extending along the muscle, and its thickening will be equal to the thickening of the individual cells as they lie side by side. But what makes the muscle cells change shape? We have found that the food brought to the muscle by the blood is stored in the muscle cells in a condition just ready for union with the oxygen which has also been stored in the cells. This union, or combustion, does not occur continually, but is caused when a certain change called a nerve impulse comes to the muscle along a nerve fiber; and when the impulse comes, carbonic acid gas, or carbon dioxid, is formed and the muscle cells become broader and shorter.

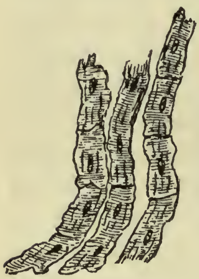


FIG. 45. — Fibers from the Muscular Walls of the Heart.

Showing nucleated cells.

77. Nervous Tissue. — Knowing, as you do, how microscopic the cells are in size, what would you think if you were told that there are cells in the body that have parts which extend several feet in length! There are cells with branches which reach, for instance, from the backbone to the toes (Fig. 193). A mass of nerve tissue called the *brain* occupies almost all of the skull, and forms the spinal cord, or spinal marrow. Nerve tissue forms also the glistening white cords, called *nerves*, going from the brain and spinal cord to all parts of the body (Fig. 46).

FIG. 46.—The General Arrangement of the Nervous System (viewed from behind).

Showing the brain, the spinal cord and the chief nerves that branch from it.

When eating pork, did you ever see the spinal cord of a hog? How large was the cord? Have you seen a hog's brain or the brain of an ox? However complicated nerve tissue may seem to be, it is found to consist of nerve cells and their branches, called *nerve fibers* (Fig. 48). Some cells are arranged in a distinct mass called a *ganglion*.

78. A nerve consists of a great number of cell-branches or nerve fibers, just as a number of telephone wires are sometimes bound together in a cable. Nerve cells grow, become active and die, like other cells, and like other cells they consist of protoplasm with a nucleus and nucleolus. A number of processes branch off from them, some cells giving off only one or two, others many (Fig. 47). One of these processes forms a nerve fiber. The axis, or central part of the fiber, is a continuation of the jellylike protoplasm of the cell; this core is the essential part of the fiber. The axis is surrounded in most fibers by a sheath of fatty material (Fig. 48). This is for nourishment and protection of the axis, and it is this which gives to the fiber its characteristic ivory-white appearance. The whole is strengthened by being inclosed in a thin, delicate sheath of connective tissue. Some of the nerves go to the muscles, and passing between the bundles of fibers, soon divide into branches, for we have seen that the nerves are bundles of separate fibers. They subdivide in the muscles till they ultimately send a single nerve fiber to each individual muscle fiber.

79. How Nerves and Muscles work together. — Suppose you put your hand on a hot stovepipe or poker; it is immediately jerked away. How does this wonderful thing happen? It is found that the heat of the iron causes a disturbance in a nerve fiber ending just under the skin of the finger. This disturbance travels rapidly along the axis, or core, of the nerve, and is called an *impulse*. It is not a visible change, but some influence that travels from particle to particle. It resembles electricity somewhat, but some physiologists think it is like a wave of chemical change, running along the nerve faster than a railway train can run. It reaches a nerve cell in the spinal cord. The disturbance there causes the cell to send out impulses along its other branches or fibers. Some impulses are sent down the arm again to its muscles, causing them to contract, and the arm is jerked away, as we say, by reflex action, or action without will on our part. Other impulses go at the same time to the brain, and we become conscious of what has happened. The nerves which carry impulses to the nerve cells are called *sensory nerves*, or nerves of feeling, and those which carry impulses from the cells to the muscles are called *motor nerves*, or nerves of motion. Nerves transmit impulses, but do not originate them. An impulse in a nerve can be excited by pinching, pricking, electricity, a drop of acid,

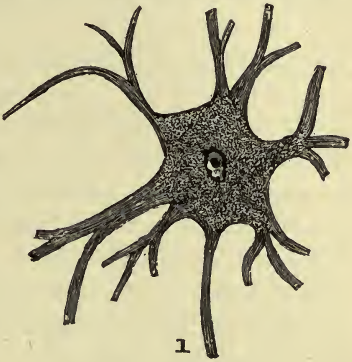


FIG. 47. — A Nerve Cell.
From the gray matter of the spinal cord, magnified.

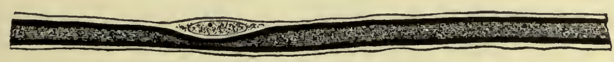


FIG. 48. — Nerve Fiber, highly magnified.
Showing axis (gray), sheath of fatty material (black), sheath of connective tissue (white).

a hot wire, a cold object, or a thought. Reflex action always occurs on account of some influence from the outer world, but voluntary action comes from activity in the brain.

80. Suppose you step out of a warm house into a cold wind. The face immediately blanches or turns white. Let us see how this is accounted for. There are muscle fibers in the walls of the blood vessels. The cold air excites impulses in the sensory nerves of the face, which travel to the enlargement at the top of the spinal cord just at the base of the brain, called the *spinal bulb*, or medulla oblongata (Plate VI). Here it reaches a nerve center which reflects impulses along the nerves that go to the muscle fibers in the walls of the blood vessels, causing them to contract, and the face turns white. Thus we see how closely related are the two master tissues.

81. If we consider that the nerves reach almost everywhere in the body, and that the muscles of the body weigh nearly as much as all other tissues together, we realize how important the master tissues are. Let us count up some of the activities in which the muscles are necessary: swallowing, digesting food, breathing, blushing, writing, walking, talking, looking, tasting, chewing, frowning, smiling, laughing, circulation of the blood. There are only a few things, such as hearing, smelling, and feeling, that can sometimes be accomplished without muscles. It is now taught by those who study psychology, or the science of the mind, that emotions of the mind are always simultaneous with a change in the circulation of the blood, and that emotion cannot be felt without a change in the heart or other blood vessels.

CHAPTER V

SUBSTANCES FORMING THE BODY; OXIDATION

82. Oxidation.—You learned that oxidation is the process of forming a union of oxygen with some other substance. When iron oxidizes, iron-rust is formed. When wood decays, the carbon in it oxidizes and carbonic acid gas is formed. When wood burns, the oxidation is more rapid. When hydrogen is oxidized, water is formed. For instance, kerosene oil contains hydrogen, and, by burning it in a lamp, water is formed which collects on the chimney when the lamp is first lighted, before the glass has become hot. You learned that animal life seems to be based upon a process of slow oxidation taking place in the tissues of the body. Oxygen has great affinity for many substances, and its union with them is accompanied by the production of heat; thus the heat of the body is kept up.

83. Plant and Animal Life. — In plant life there is more of deoxidation than of oxidation. Carbon when alone is a solid like coal, charcoal, or plumbago; oxygen when alone is a gas. When joined together they make a gas called carbonic acid gas, or carbon dioxid. The leaves of a plant absorb the carbon dioxid, and by the aid of the sunlight the green coloring matter of the leaf separates the carbon from the oxygen. The carbon remains as a part of the plant, while the oxygen escapes from the leaves as a gas, and is ready to burn the carbon in wood or sugar or animal tissue, and form carbon dioxid again. Just as much heat, or energy, will be given back in the oxidation as was furnished by the sun to the plant to enable it, in the leaf, to separate the carbon from the oxygen. Thus we see how animals and plants help each other, and how all nature forms one harmonious whole (Fig. 24).

84. List of Substances. — The most important solid and liquid substances of which the body is composed are water, albumin, fat, sugar, salt, lime, soda, potash. Water, salt, and lime do not oxidize, either in or out of the body. Their use in the body is more mechanical than chemical.

One ounce of albumin is completely oxidized by one and one half ounces of oxygen.
One ounce of fat is completely oxidized by three ounces of oxygen.
One ounce of sugar is completely oxidized by one and one fifth ounces of oxygen.

85. Water. — Water does not oxidize. It is composed of two gases firmly united: hydrogen and oxygen; that is, water is hydrogen already oxidized. Water forms three fourths of the body. When a solid substance is dissolved in a liquid so that each remains unchanged in its essential properties, the result is a solution of the solid in the liquid. Sugar in water is sugar still; in fact we can taste sugar only when it is dissolved. Most solutions can go anywhere that water alone can go. In the stomach the food is dissolved and taken into the circulation. The blood containing the food in solution penetrates to the cells, carrying nourishment and washing away the waste material. By means of the perspiration, water takes heat from the body. About three quarts of water are taken into the body each day, either alone or in watery foods.

86. Albumin (Proteid). — We learned that protoplasm, or living matter, differs from inorganic matter in containing an albuminous material, composed partly of nitrogen. The other two oxidizable foods, fat and sugar, do not contain nitrogen. Pure nitrogen is found in the air, but the body cannot use it in that form, for nitrogen is very inactive when pure; when compounded in albumin, however, it gives to the tissues firmness and strength such as sugar and fats containing no nitrogen cannot give. Albumin is a very complex substance which only plants can form. Animals must get it from vegetables, for it is the essential part of all living cells. It is similar to the white or albumen of an egg. Because it turns white when heated, it is called albumen (Latin *albus*, white). Pure albumin is hard and brittle, as the white of an egg is when dried. The albumin of the body is a solution in from five to twenty-five times its own weight of water. In the blood it is liquid, in the flesh it is jellylike, in the connective tissue of the skin it is tough and strong. Albumin may be hardened or coagulated by heat; the albumen of a boiled egg is an example. Coagulation of its albumin destroys the life of a cell. Lean meat, cheese, animal gelatine, glue, and gluten are forms of albumin. About four and one half ounces of pure albumin per day are necessary to supply the body in winter.

87. Fats. — Fats are smooth, greasy substances that become liquid when heated; those that are liquid at ordinary temperature are called oils. Fat is always oil in the living body and is stored in thin-walled cells in connective tissue (Fig. 38). Fat is a simple substance compared to albumin; divided in tiny particles or globules, and floating in water, it forms an emulsion. Milk is an emulsion. No emulsions are permanent; *e.g.* the cream rises in the milk in a few hours. Fat is a living garment to the body lying underneath the skin to retain heat, protect from the cold, and round out the form. It is a cushion for protection and a store of heat-producing food to be used in sickness or at any time when food cannot be eaten. About three ounces of fat should be eaten each day in winter.

88. Starch and Sugar (Carbohydrates). — Starch is abundant in young plants. As the plant grows the starch is changed to wood. Fruit while green is chiefly starch; but as it ripens, the starch is changed to sugar.

Starch and the cellulose of wood are different forms of the same chemical substance. Wood cannot be used in the body, and starch must be changed to sugar before it can become a part of the body. Very little sugar is found in the body at one time, as it is constantly used to produce warmth. About five ounces of sugar or starch should be eaten each day in winter, and less in summer and in warm climates.

89. Other Substances. — There are about six ounces of *salt* in the human body. We do not give salt to a pet cat because it gets salt in the flesh it eats; but we give salt to the cattle because there is not enough in vegetable food to supply their needs. Salt gives an agreeable taste to food and helps to keep the albumin of the body dissolved; when salt is not used, weakness results.

90. There are about ten pounds of *lime* in the human body. The lime is deposited around the cells of the bones to give stiffness to the bones.

91. Soda and potash are called *alkalies*. A substance which corrodes metals, is sour to the taste and unites with soda or potash, is called an *acid*. Vinegar is an acid substance; when soda is added to it, both are changed, and the liquid resulting has a flat, bitter taste. Thus acids and alkalies neutralize each other. Saliva is formed in the mouth and is alkaline. The gastric juice of the stomach is acid. The blood is alkaline and performs the function of destroying irritating acids in the body by neutralizing them.

92. The human body is **built up of 13** of the 70 or more elements. **The 13 elements are compounded** into substances which make up the body of a man weighing 150 pounds, in the following proportions: —

92 pounds of water.
21 pounds of fat.
18 pounds of dry proteid.
9 pounds of gelatin.
8¼ pounds of phosphate of lime.
1 pound of carbonate of lime.
6 ounces of phosphate of magnesium.
2-3 ounces of common salt and chlorid of potassium.
3 ounces of sugar and animal starch.
As much iron as there is in four carpet tacks.

93. THOUGHT LESSON.[1] **The Tissues.** — 1. Which tissue has the largest amount of intercellular material?

2. Which tissue has no fibers and very little intercellular material, but is composed almost wholly of cells?

3. The walls of the arteries contain more of the yellow fibers of connective tissue than the veins. Which have more elastic walls?

4. Which tissues have cells without branches? Which tissues have cells with branches? Which tissue has two kinds of cell-branches or fibers?

5. Does fat accumulate in the body within the cells or outside of them (Fig. 38)?

6. Which cell has the greatest variety of functions? Which cells are the seat of great activity and change? Which are moderately active? Which are very inactive?

7. Which tissue gives the least evidence under the microscope of having been formed by cells?

8. Do adjoining cells have a common wall separating them, or does each cell have its own wall? Are instances of both kinds of cells to be found?

9. Choose a cell and write its "biography."

10. How does a tissue grow? Does a scar on a child, or a "brand" on a calf or other young animal, enlarge as its body grows?

11. State the difference between albumen and albumin.

[1] The teacher may require the answers to the questions in this Thought Lesson to be prepared in writing. In class the pupils should change (but not exchange) papers, and criticise and correct the answers as they are read aloud from different papers. The same plan is applicable to the other Thought Lessons.

PART II. HOW THE BODY IS MOVED

CHAPTER VI

THE SKELETON

94. Animals and their Skeletons. — There are some animals, such as the slug (a kind of snail without a shell, Fig. 50) and the jellyfish, that do not possess any hard part corresponding to a skeleton. Such an animal, if it lives on land, lies flat on the ground and moves slowly and with difficulty. Some animals, as the crawfish and the beetle, have the skeleton on the outside in the form of a crust.

95. Three Functions of the Skeleton and the Three Shapes of Bones. — Even in man, so capable of self-protection, it is necessary to have the skeleton, or hard part, to protect some of the most delicate organs. The bones for this purpose are *flat*, as the breastbone and shoulder blade, the ribs, which protect the heart and lungs, and the skull bones, which protect the soft and delicate brain. The muscles by their shortening accomplish very simple and imperfect motions; by using the bones for support and as levers, this motion is changed in rate, direction, and place of application.

The *long bones* of the arms and legs, with the fingers and toes, have motion as their chief function. The ribs are flat but are the longest bones in the body in proportion to their size, and enable us to perform the important motions of breathing. Yet they are classed as flat bones, for they lack the round shaft and enlarged ends or heads, which typical long bones have. Even the bones of the

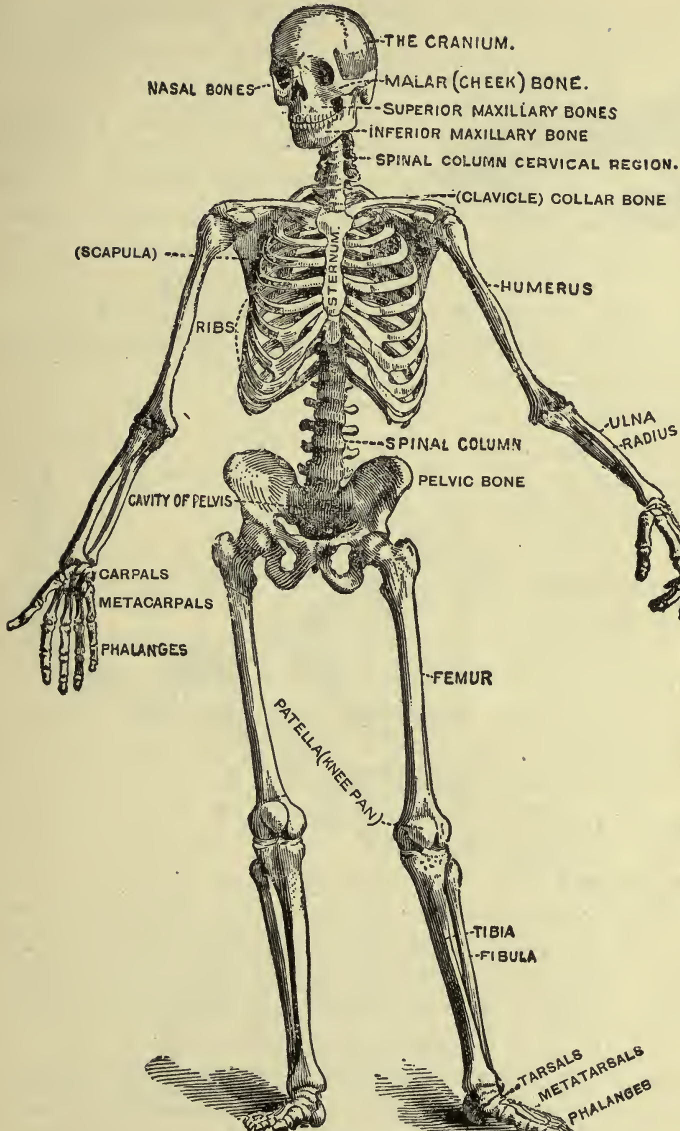


FIG. 49.—The Skeleton.

instep, palm, fingers, and toes, which are the smallest of the long bones, have the shaft and heads.

FIG. 50. — The Slug.

The many small short bones are stronger than the long slender bones, or the flat thin ones. These bones are called *irregular bones.* They are not easily broken and their chief function is support. They are found in the spine, the ankle, the wrist, the knee, and the face. We should remember that the irregular bones also assist in the two other functions of protection and motion; also that the long bones and the flat bones are not confined to one function but participate in all three functions (Fig. 49).

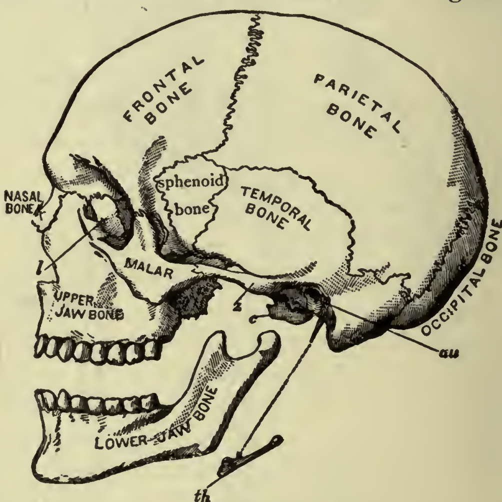


FIG. 51. — Side View of Skull.

The larger bones are named in the figure. The lower jaw is dropped down. Its socket in the skull is shown in front of the opening of the ear, *au*; *z*, process of temporal passing to malar, or cheek bone; *c*, one of the condyles or projections which rest in sockets on the highest vertebra; *th*, hyoid bone, not joined to any other bone, except by muscles; *au*, opening of ear; *l*, lachrymal bone. A small part of sphenoid bone is shown; the main part is at base of skull.

The eight cranial bones are: —

One Frontal (forehead).	One Occipital (back and floor).
Two Parietal (sides and roof).	One Sphenoid (central floor).
Two Temporal (sides).	One Ethmoid (front floor).

96. Another Use of Bones. — Recent discoveries have shown that the red marrow in the small cavities of spongy bones, is active in producing the red corpuscles found in the blood.

97. Number of Bones. — There are 206 bones in the adult human body. The number of bones is greatest in childhood and diminishes in old age by the obliteration of joints. The head has 22 bones in adult life, more in infancy, and fewer in old age.

98. General Arrangement of the Skeleton (Fig. 49). — The central part of the skeleton, called the vertebral or spinal column, forms a firm, but flexible axis. The head rests upon the top of this column. The ribs are attached at its sides to make the walls of the chest. The shoulder girdle rests upon the chest, and the hip girdle is attached to the base of the spinal column. These girdles connect the upper and lower limbs with the trunk. The bones of the head and trunk form the *axial skeleton*. The bones of the girdles and limbs are called the *appended skeleton*, since they are appended to the axial skeleton.

99. The Skull (Figs. 51 and 52) is the cranium, or casket which contains the brain, and the facial bones. The arched form of the skull is the best shape for resisting blows and pressure. Its bones are so firm and hard that bullets sometimes glance from it. The occipital bone curves under at the back of the neck to aid in forming the floor of the skull. It has two projections called *condyles* ("knuckles") situated just behind its junction with the sphenoid ("wedgelike") bone. The condyles fit into depressions (Fig. 53) in the uppermost vertebra; thus the head rests and rocks upon the spinal column. Grasp the neck with both hands so as to hold it motionless and stiff, and find whether the head rocks forward and backward, or sidewise. Between the condyles is a large opening through which the spinal cord goes from the brain.

Of the eight cranial bones, how many are in pairs, and how many are not? Those in pairs are located at the sides of the cranium. The hair over the temples first turns white, thus reminding us of the temporary nature of life. What bones receive their name because of this?

100. The Bones of the Face are fourteen in number, twelve being in symmetrical pairs, and two unpaired: the two malar bones forming the prominences of the cheeks; two nasal bones, small and slender, forming the bridge of the nose; two upper maxillary bones, forming the upper jaw; one inferior maxillary, the lower jaw; one vomer, the bony partition between the nostrils; two lachrymal bones in the eye sockets; two palate bones in the roof of the mouth; two turbinated bones in the interior of the nose (Plate VII). Is any bone of the head movable upon the others?

FIG. 52.— Bones of the Head.

1, Frontal bone; 2, parietal bone; 3, temporal bone; 4, occipital bone; 5, nasal bone; 6, malar bone; 7, upper jaw; 8, lachrymal bone; 9, lower jaw (maxilla).

101. The Hyoid Bone, called also the tongue bone, is U-shaped (this is the meaning of its name in Greek) and lies in the front of the neck, where it may be felt above the Adam's apple. Can you move it from side to side with your hand (Figs. 51 and 129)? Does it feel rough or smooth? It forms points of attachment for numerous muscles, the muscular tongue being attached to it above.

102. The Vertebral Column. — The spinal column consists in the adult of twenty-six bones (Fig. 53). Twenty-four of these bones have a similar shape, and each is called a vertebra (Latin, "that which turns"). The other two have the names of sacrum and coccyx. The first seven vertebræ are in the neck and are called cervical ("of the neck"). The next twelve are those to which the ribs are attached and are called thoracic or dorsal ("of the back") (see Fig. 49). The next five vertebræ are in the loins or lumbar region and are called *lumbar* ("of the loins"). They are the largest of the vertebræ. The lowest lumbar vertebra rests upon the sacrum ("sacred," because this bone of lower animals was once used in sacrifice). In infancy the sacrum consists of five vertebræ; these begin uniting at two years of age and complete the union at twenty years. The coccyx ("cuckoo," from resemblance to bill of cuckoo), or last bone of the column, is that part of the skeleton which in the lower animals forms the tail. In infancy it consists of four small bones which later unite into one. The coccyx is of little use, but the sacrum is a highly important bone, since to its sides are attached the bones of the pelvic arch, by which the weight of the body is transmitted to the legs.

FIG. 53. — Spinal Column (seen from behind).

sp, spinous process; *tr*, transverse process. Find the 7 cervical, 12 thoracic, 5 lumbar, vertebræ. Do the sacrum and coccyx show evidence of having been divided in early growth?

103. A Single Vertebra consists of a thick disk called the body of the vertebra (Fig. 54); behind the disk is an arch, and upon the arch are several projections called *processes*. The projection at the rear is called the *spinous* process, those at the sides are called *transverse* processes. All three serve for the attachment of muscles which prevent the body from bending forward under its own weight. The holes under the arches of the vertebræ form a passage for the spinal cord.

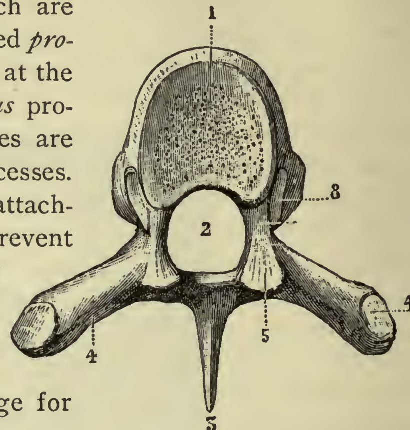


FIG. 54. — Thoracic Vertebra (top view).

1, body; 2, hole which forms part of vertebral canal; 3, spinous process; 4, transverse process; 5, surface which articulates with next vertebra above; 8 and 4, surfaces which articulate with a rib.

104. The first cervical vertebra, or *atlas* (Fig. 55), has no body; it has two depressions into which the occipital condyles fit. The head rocks back and forth (nods) by the condyles slipping in the two depressions, or sockets, of the atlas. The second vertebra (Fig. 56) is called the *axis*. It has a peg in place of a body; this peg projects into the hole in the atlas, making a pivot joint upon which the atlas and head turn (Fig. 57). When the head moves around, the atlas moves with it, rotating upon the peg of the axis. Can you find out why the atlas received its name?

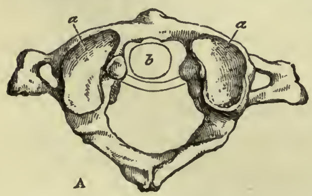


FIG. 55. — The Atlas (from above).

a, sockets for articulation with skull; *b*, peg of axis, with ligament behind it.

105. Between the vertebræ are elastic cushions of cartilage, which give flexibility to the spinal column and prevent injurious jarring of the brain and spinal cord. Otherwise, the head would receive a great shock whenever one alighted upon the feet in jumping from a height. The spinal column is so constructed as to furnish strength to support the body, to facilitate the attachment of the organs to it, to furnish a safe passage for the spinal cord, — yet while accomplishing these several purposes, to allow the body to bend without displacing any of the numerous organs of the trunk.

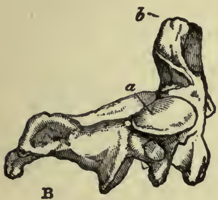


FIG. 56. — The Axis (side view).

a, one of the areas for articulation with atlas; *b*, pivot or peg.

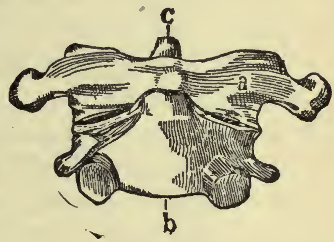


FIG. 57.

a, atlas; *b*, axis; *c*, pivot of the axis.

106. **The Thorax**, or chest, is formed in the rear by the twelve thoracic vertebræ; in front, somewhat parallel to the spinal column, but approaching it above, is the sternum, or breastbone (Fig. 58). Twelve ribs curve around each side. Each rib joins one of the thoracic vertebræ behind. The first seven pairs directly join the sternum in front by means of short cartilages, and are called *true ribs*. The next three pairs, called *false ribs*, do not reach the sternum, but each rib unites to the rib

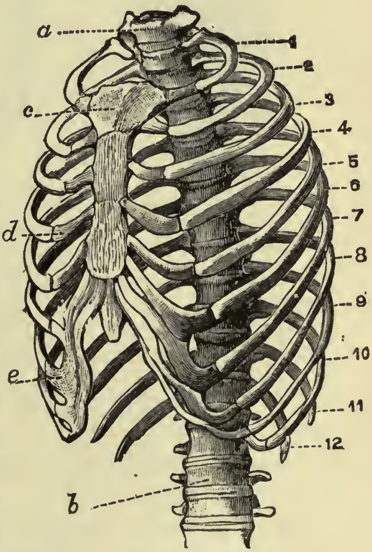


FIG. 58. — Bony Walls of Thorax.

a, *b*, vertebral column; *c*, sternum; *d*, costal cartilages; *e*, united cartilages of 8th, 9th, and 10th ribs; 11, 12, floating ribs.

above by a long cartilage. The last two pairs are called *floating ribs*, since the front ends are not attached to a bone either directly, like the true ribs, or indirectly, like the false ribs, but rest in the muscular walls of the waist. (Describe the microscopic structure of cartilage as shown in Fig. 43.)

107. The Appended Skeleton. — This part of the skeleton consists of the four limbs and the bones which serve to attach them to the trunk or axial skeleton.

108. Shoulder Girdle. — The arms are attached to the trunk by the shoulder girdle. This consists (Fig. 49) of four bones, two on each side, the scapulæ, or shoulder blades, and the clavicles, or collar bones. Each shoulder is composed of a *clavicle* ("key," from its resemblance to the ancient form of that article) and a scapula (Fig. 59). The *scapula* (a "trowel") occupies the rear part of the shoulder. It is a large flat bone, of triangular shape, and bears in the end at the angle of the shoulder a shallow socket into which is fitted the end of the upper bone of the arm. The clavicle is a slender bone, round and slightly curved, which occupies the front of the shoulder, and is joined at one end to the scapula and at the other to the sternum. The clavicles can be felt at the right and left of the base of the neck.

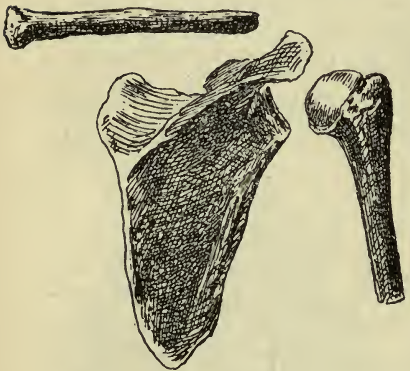


FIG. 59. — Clavicle, Scapula, and Head of Humerus.

Disjointed and seen from behind.

109. The Arm consists of the upper arm, forearm, wrist, and hand (Fig. 60). The upper arm extends to the elbow and has only one bone, the *humerus*. From the elbow to the wrist is the forearm, formed of two bones, arranged parallel to each other; the *ulna* is on the outside, the side corresponding to the little finger; the *radius* occupies the inner side, the same side as the thumb. At the lower end of each, a bump may be felt, the bump on the ulna being larger. The wrist is called the *carpus*, and is composed of eight small bones arranged parallel in two rows, four in each row, running across the wrist. Next follows the *metacarpus* ("beyond the carpus") (Fig. 60), or the bones in the palm of the hand. The palm is composed of five long bones, each serving to support a finger or thumb. Each finger is composed of three small bones called *phalanges*, ("rows of soldiers"); the thumb has only two. The thumb is more movable than the fingers, and can be opposed to each of them. The arm therefore consists of thirty bones; the upper arm has one; forearm, two; wrist, eight; palm, five; fingers, fourteen.

FIG. 60.—The Arm and Shoulder.

Seen from the front. Why do the fingers seem so long?

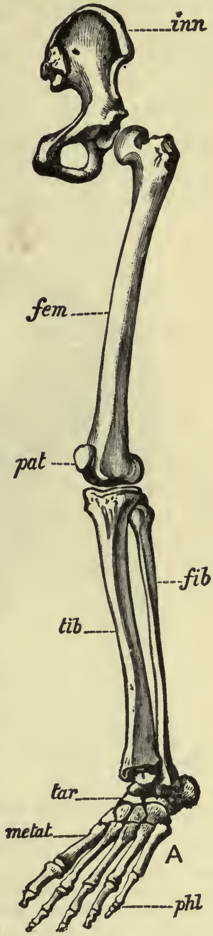


FIG. 61.— Bones of the Hip and Leg.

Front view.

110. The Leg. — The skeleton of a lower limb has a striking resemblance to that of an upper limb (Fig. 61). The hip girdle, corresponding to the shoulder girdle, forms the hip. The hip bones, or *innominate* ("nameless," because they do not resemble anything) bones, are large, flat, and somewhat semicircular in shape. They meet in front (Fig. 62), but behind they join the portion of the spinal column called the *sacrum*, which separates

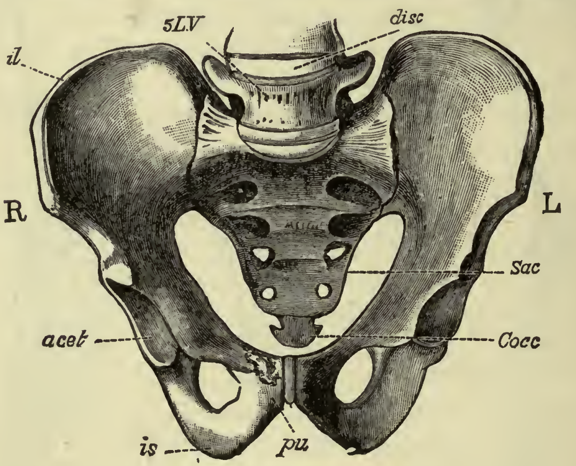


FIG. 62. — The Pelvis.

Sac, Sacrum, *cocc*, coccyx; *acet* (acetabulum), cup for head of femur; *5LV*, fifth lumbar vertebra.

them and forms, as it were, the keystone of the arch (Fig. 62). Thus is formed a large band of bone inclosing a basin-shaped space, called the *pelvis* ("basin"), which contains the bladder and other organs. There is a deep socket at the side in each innominate bone. This socket is occupied by the round head found on the upper end of the thigh bone, or *femur*. The femur is the largest and longest bone in the body (Figs. 63, 64).

111. The leg below the knee, like the forearm, is composed of two parallel bones. They are not equal in size, like the radius and ulna, however, one, called the *tibia*, being much larger than the other, the *fibula* (Fig. 61). The latter bone is merely a brace to the large tibia, which forms the joints with the femur above and the foot below. There is a bony disk embedded in the great tendon over the knee, forming a protection to the knee joint; this is called the *patella*, or knee-pan. In which direction can you move the patella to and fro with the hand, when the leg is straight and the heel resting upon the floor?

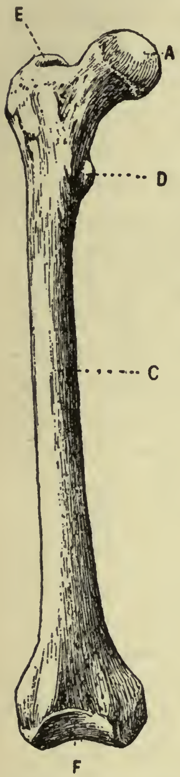


FIG. 63.— Front View of Femur.

A, smooth head of bone for articulating with hip bone; *C*, shaft; *D* and *E*, rough processes to which muscles are attached; *F*, smooth surface which articulates with tibia.

FIG. 64. — Femur (seen from behind).

In case of a fall, the femur would be likely to break at the turn or angle near the hip, if there were not a brace there which prevents this.

112. Like the hand, the foot consists of three parts. The *tarsus*, or ankle, is formed of seven bones, although the carpus has eight. The *metatarsus*, like the metacarpus, is composed of five bones, arranged parallel to one another, which serve for the base of the toes. The toes have the same number of bones as the fingers, and have the same name, the *phalanges*. How many phalanges are there in the great toe? The leg, like the arm, contains thirty bones. How can this be true since the ankle has only seven bones as compared with eight in the wrist?

113. Thought Lesson. **Classification of the Bones.** — Copy and fill out the following table. Place after each name in the first column the number of the bones of that name. This number should be repeated in the column to which the shape assigns the bone. For instance, there are two femur bones, "2" is therefore placed in the first column; they are long, therefore "2" is placed also in the second column. (See Fig. 49.)

Names	No. of Bones	No. of Long Bones	No. of Flat Bones	No. of Irregular Bones
Face . . .				
Cranium . .				
Vertebra . .				
Sacrum . .				
Coccyx . .				
Innominate .				
Rib				
Sternum . .				
Clavicle . .				
Scapula . .				
Humerus . .				
Ulna . . .				
Radius . . .				
Femur . . .				
Tibia . . .				
Fibula . . .				
Carpus . . .				
Metacarpus .				
Tarsus . . .				
Metatarsus .				
Phalanges .				
Patella . . .				
Hyoid . . .				
Ear				
Totals . .	206	74	59	73

114. Joints. — The meeting of two bones is called a *joint.* Joints are of two general kinds, fixed (or immovable) and movable. The hip bones join the sacrum by fixed joints. The most remarkable fixed joints are those in the skull, the bones of which fit into one another by means of toothed edges, forming irregular lines known as *sutures*. A crayon box is so joined, but the teeth in the wood are much more regular than in the joints of the skull.

115. A Movable Joint. — Let us take the knee joint, for example. The two bones which join are the femur and the tibia. They present to each other an enlargement, or head, which serves to increase the strength of the joint and increase the surfaces applied to each other. The two heads instead of being formed altogether of rigid bone are covered by cartilage, which by its elasticity and smoothness provides for the gliding of one bone upon the other. Strong fibrous bands called *ligaments* bind together the ends of the two bones. Surrounding the ends of the bones, like a collar, is found a ligament (the capsular ligament) inclosing the space of the joint in a closed sac. This closed sac is called the *capsule*. A thin membranous sac, called the *synovial membrane*, lines the capsule. It secretes a slimy fluid which resembles the white of an egg and is called the *synovial fluid*. This lubricates the joint, and is deposited continually, but only so fast as used up in exercise. As the sac has no opening, air is excluded, and atmospheric pressure aids in holding the bones in place. The hip joint (Fig. 65) and other joints

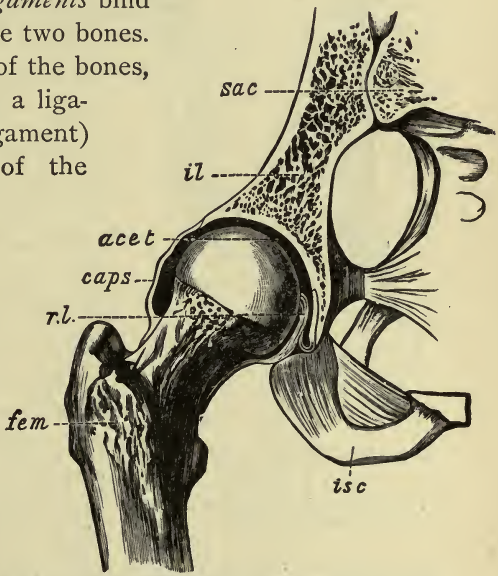


FIG. 65.—The Right Hip Joint. The Hip Bone sawed through so as to show the Cup of the Joint. *fem*, femur; *acet*, cup, or acetabulum; *caps*, capsule; *r. l.*, round ligament.

have the same parts as the knee joint. It is rarely that two bones put together so perfectly are forced from their natural places. When this happens it is called a *dislocation.*

116. The Kinds of Movable Joints are: the ball-and-socket joint, which allows motion in any direction, as the shoulder joint; the hinge joint, which allows free motion back and forth in one plane, as the knee joint; the pivot joint, in which one bone rotates around another, as the atlas around the axis, the radius around the ulna (Fig. 66); the gliding joints, in which the flat surface of one bone glides over the other, as in the bones of the wrist; elastic joints (also called mixed joints), in which there is one flexible cartilage growing to both bones, and motion is allowed by the compression or bending of the cartilage, as where the ribs join the sternum. Elastic joints are sometimes called mixed joints, because they resemble both movable and immovable joints. There are about 91 hinge joints, 4 ball-and-socket joints, only 3 pivot joints, and 43 elastic joints in the body. The gliding joints cannot be distinctly divided and numbered.

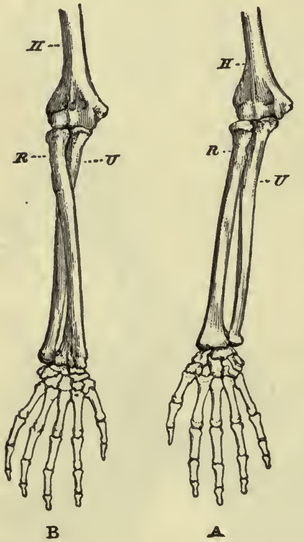


FIG. 66. — The Bones of the Right Forearm.

When the hand is supine *A*, and prone *B*; *H*, humerus; *R*, radius; *U*, ulna.

117. Structure of a Long Bone. — If a long bone is sawed through lengthwise (Fig. 67), it will be observed that there is a central cavity containing yellow marrow. (What kind of steak has a marrow bone?) We should observe also that the portions inclosing this cavity are of a dense solid structure, but that the bone is spongy near the ends, — enlarged for forming the joints. The cavities in this spongy portion contain red marrow. A long bone is hollow, because a given weight of material has more strength in the form of a hollow cylinder than in the form of a solid rod. (Does this imply that a hollow cylinder is as strong as a solid one of the same size?)

118. Thought Lesson. **Classification of the Movable Joints.** — The table below is to be filled out by the same plan as in the Thought Lesson on page 68.

Names of Bones Connected	No. of Joints	Ball-and-Socket Joints	Hinge Joints	Gliding Joints	Pivot Joints	Elastic or Mixed Joints
Head–atlas . . .	1					
Atlas–axis . . .	1					
Rest of spine . .	23					
Ribs–vertebræ .						
Ribs–sternum . .						
Ribs–ribs . . .						
Clavicle–sternum .						
Scapula–clavicle .						
Scapula–humerus .						
Humerus–ulna. .						
Humerus–radius .						
Wrist joints . .	x					
Fingers						
Innominate–femur						
Femur–tibia . .						
Ankle	x					
Toes						
Head–jaw . . .						
Total number .	141	4	91	indefinite	3	43

119. Composition of Bone. — Bone is covered with *periosteum*. This is the name given to the close-clinging fibrous covering of the bone, composed of connective tissue and blood vessels. If we remove the periosteum from the surface, the red marrow from the pores, and the yellow marrow from the larger cavity, we have remaining the true bony substance. Yet even this is not one substance, but consists of animal matter and mineral matter in the proportion of two parts of the former to one of the latter. The animal matter is gelatin, like the substance composing the white fibrous part of connective tissue. The mineral matter is chiefly phosphate of lime and carbonate of lime. Can you describe the microscopic structure of bony tissue as shown in Fig. 70? The mineral matter may be removed by soaking the bones for several days in strong vinegar or in dilute muriatic acid. The bone is then flexible but tough. If a slender bone, as a hog's rib, has been used, it can be tied in a knot; after the acid has been washed off, it may be preserved in dilute alcohol as a curiosity. The animal matter may be removed by holding the bone on a shovel in the fire for a sufficient length of time. The mineral part remaining is very light and brittle, and weighs only one third as much as the original bone, the form of which it still preserves.

FIG. 67. — Shin-bone (tibia) sawed in two along its Length.

2, struts and stays of spongy bone supporting 7, the upper and lower articular surfaces; 3, compact bone forming the shaft; 4, marrow cavity; 6, periosteum.

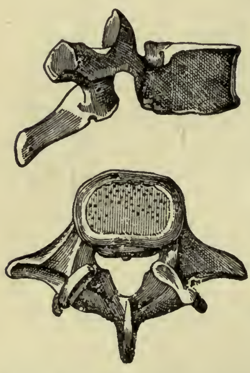


FIG. 68. — Side and Under View of a Vertebra.

Is it a cervical, a thoracic, or a lumbar vertebra? (See Fig. 69.)

120. THOUGHT LESSON. **The Spinal Column.** —

1. Observe a single vertebra (Fig. 68). What is the use of the "body" of a vertebra? the arch? the processes?

2. How is the spinal column constructed so as to allow movement (Fig. 69), without seriously displacing any organ supported by it?

3. In the general form of the spinal column what shows that its strength is proportional to the weight to be supported (Fig. 69)?

4. Do the spinous (or rear processes) project at the same angle in all parts of the spinal column (Fig. 69)?

5. Find, by bending your own body, or by studying Figure 69, what part allows least motion. Why?

6. Why are the spinous processes a source of danger to the spinal cord, instead of a protection? (Suggestion: a blow from the rear, or a fall upon a process, would cause what part of a vertebra to break?)

7. In what region might a blow from the rear, or a fall, cause the process to snap off and leave the cord uninjured?

8. If the processes inclined in the neck and the lumbar regions, as in the thoracic region, what disadvantage would there be?

9. Which part of the spinal column is most easily sprained? Which next?

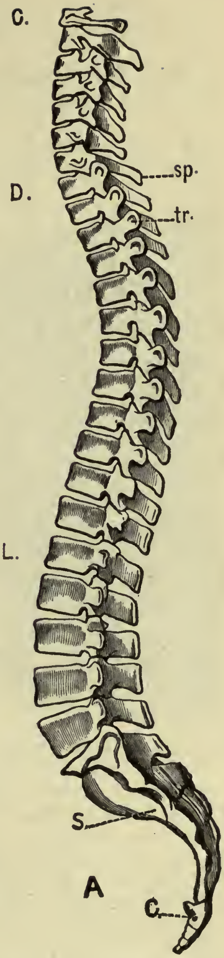


FIG. 69. — The Vertebral Column.

Side view, left side; C, first cervical vertebra; D, first dorsal, or thoracic; L, first lumbar vertebra; S, sacrum; C, Coccyx; sp, spinous processes; tr, transverse processes.

HYGIENE OF SKELETON

121. Nourishment of Bones. — If a limb be disused because of paralysis or long sickness, the bones, as well as the soft parts, lose in strength and weight. This shows that the more vigorous circulation which comes with exercise helps to repair the osseous tissue (Fig. 70). The blood vessels that supply the bones enter from the inner side of the periosteum. We thus see why the bone shrinks away if the periosteum is removed, and why the surgeon is careful to leave as much of the periosteum as possible in the case of bones splintered by accidents.

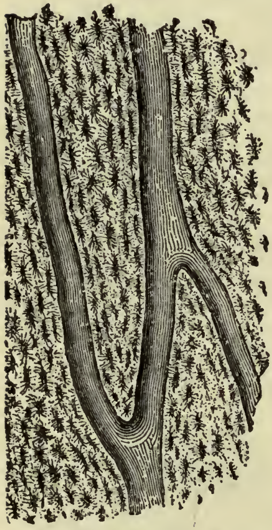


FIG. 70. — Haversian Canals in Compact Tissue of Bones, with their Connecting Canaliculi and the Lacunæ. Magnified 200 Diameters.

The bone is cut lengthwise. Compare with Fig. 44 where the bone is shown cut across; why are fewer canaliculi cut apart in Fig. 44 than in Fig. 70?

The animal matter of bones is most abundant in childhood, and a child's bones will bend before they break. If broken, they heal rapidly. The animal matter is less abundant in the aged, therefore the bones are brittle, more easily broken, and take longer to heal.

122. Broken Bones. — The two ends of a broken bone should be brought together in their correct position as soon as possible, before inflammation and swelling render this difficult. Of course a surgeon should be called to set a broken bone. If the patient has to be carried some distance, care should be taken to prevent injury to the fleshy parts by the ends of the fractured bone; the limb should be bound with handkerchiefs to a strip of board, or even to umbrellas or walking sticks, as temporary splints.

123. Dislocation of a joint stretches and sometimes breaks the ligaments surrounding it, producing inflammation. This makes examination of it difficult, hence there should be no delay in procuring the necessary skill and restoring it to place.

124. A Sprain is an injury due to a sudden wrenching or straining of the ligaments, as a result of which a ligament is lacerated or torn from its fastenings to the bone. A bad sprain may be more serious than a fracture, and result in stiffness or in permanent weakness. Immediate rest is necessary. A hot footbath immediately after spraining the ankle is sometimes beneficial; careful rubbing, very light at first and gradually increasing in vigor from day to day, may shorten the period of recovery.

FIG. 71.—Sitting with Head and Shoulders drooped forward at Work.

A position conducive to round shoulders.

125. Acquired Deformities.—The bones are flexible in childhood, and, in the case of children at school, seated so that the feet hang, instead of resting upon the floor, the thigh bones may become bent by the weight of the legs below. Bowlegs are caused by encouraging children to walk while too young. The bones of the feet are deformed by tight shoes, "flat foot" sometimes resulting; but most often the toes only are deformed, the joint at the base of the big toe becoming enlarged into an unsightly bump. Tight shoes by influencing the gait may hinder the development of the body.

126. Deformities of the Spinal Column come chiefly on account of the yielding nature of the cartilage. The extent of the compressibility of cartilage may be realized if one's height is measured upon rising in the morning and again at night, when the loss in height sometimes amounts to nearly half an inch. The cartilages between the vertebræ are very thick, so as to give flexibility to the spinal column. This blessing also brings with it a danger of deformity. If the head is bent forward continuously in study or work instead of being held up (Fig. 71), the upper cartilages are compressed in front, the ligaments stretch, and a deformity of the neck may result, causing the head to project forward. Working with the desk low in front, or working upon the ground, may cause round shoulders.

FIG. 72.

Writing at a desk that is too high causes one shoulder to be higher than the other, and curves the spine.

127. Tight clothing deforms the ribs, which are readily movable because of the long cartilages. The binding down of the front ends of the ribs causes posterior curvature of the spine, with flat chest and round shoulders. *Lateral*, or sidewise, *curvature* of the spine is caused by constantly carrying the book, satchel, or other weight in the same hand; by overindulgence in the valuable habit of horseback riding (in the case of ladies); by writing at a desk that is too high (Fig. 72); by hanging the head to one side.

128. *Posterior curvature* is caused by habitually bending over the work, and by slipping down in the seat or desk (Fig. 73). (It has been called "trying to sit upon the small of the back.") It is caused also by weakness of muscles, by wearing shoes with high heels, and by writing at a desk that is too low. In curvature of the spine, the cartilages become V-shaped, and the ligaments stretched. If shoulder braces are so uncomfortable as to serve as a reminder every time the wearer drops back into the old position, can they do good? If they comfortably support the trunk so as to take the weight off the muscles, do they do good or harm? If it takes some months to compress the cartilages

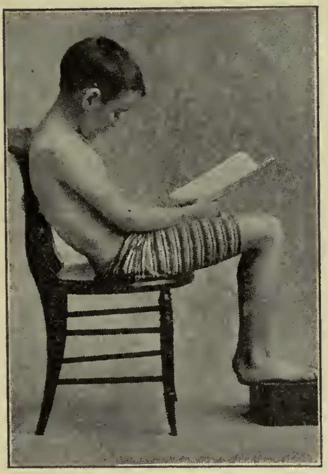


FIG. 73.

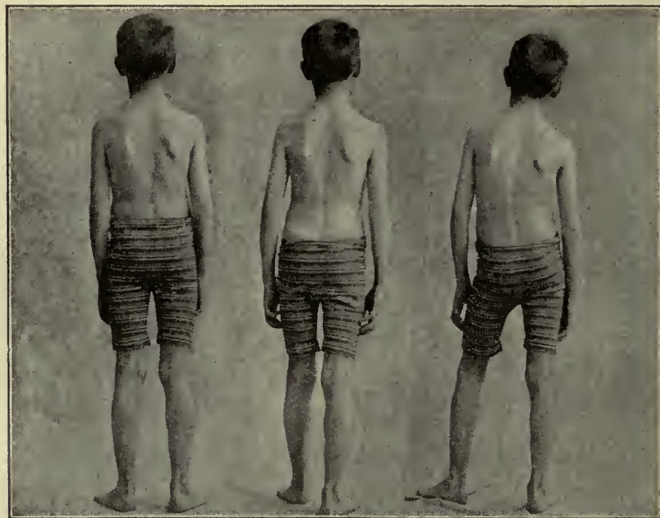
Flat chest, protruding chin, and round shoulders are produced by slipping forward on the seat.

FIG. 74.—The Proper Position in Sitting.

This position is also the easiest because the weight is poised.

and stretch the ligaments, thus deforming the spinal column, should one expect to recover natural grace of form in a few days? Exercise of the neglected muscles, that is, opposite muscles, instead of those that were used excessively while acquiring the deformity, is a great aid. Posterior curvature has been overcome by sleeping on the back on the floor, or on a hard mattress.

129. The Rule for Correct Position in sitting is to sit back in the chair with body and head erect (Fig. 74). The correct position in standing or walking is: chest forward, chin in, hips back. By keeping this attitude in mind and practicing it faithfully for a few weeks, one can train the muscular sense to become so accustomed to it that a stoop-



FIGS. 75, 76, 77.— Positions in Standing. (After Mosher.)

In Fig. 75 the weight rests equally upon both legs. This position does not cause deformity, but soon becomes tiresome, as the legs demand the privilege of working by turns.

In Fig. 76 is shown the best position and the one that should be assumed habitually. One foot is slightly advanced, and the weight of the trunk can be transferred with ease from one leg to another. The chest is free to expand.

In Fig. 77, one leg supports the trunk and the other is thrown to one side as a brace. It is very harmful if the weight is not often shifted. One who has acquired the habit of dropping upon one and the same leg while at work soon shows the following variations from the normal : —

If it is the right leg, for instance, that supports the body, the right thigh becomes greater in circumference, the right hip higher, the spinal column curved laterally with concave side to the right. The right shoulder is lower than the left, the ribs are crowded together on the right side, the face becomes slightly unsymmetrical.

ing or crooked position will be uncomfortable (Figs. 75, 76, 77, 78, 79).

130. Nutrition of Bones. — Good food and pure air brought by a vigorous circulation are necessary to the health of the bones. Poor or indigestible food, stimulants, and poisons affect the health and strength of the bones. Surgeons report cases of fracture of the bones occurring in persons having the alcohol habit, where the bones would not unite by bony material, but remained flexible and useless. Indulgence in alcoholic liquors, especially wine, is a very prominent feature in the causation of gout, a disease of the joints. Tendency to gout may be inherited. Smoking in boyhood often results in low and stunted stature. Rheumatism of the joints, a diseased condition in which acids accumulate, affecting the nerves very painfully, is sometimes caused by chronic indigestion, which in turn may have been brought on by frequent taking of drugs, by want of exercise, or by other causes.

FIG. 78. — Incorrect Position in Standing.

FIG. 79.

This would be correct if the body were not apparently too strained and stiff. Compare positions of head, chest, and hips in Figs. 78 and 79.

131. THOUGHT LESSON. **The Joints of the Arms** (Figs. 61 and 66). — The arm is for grasping and for moving things. In order to perform this function, the joints are so located and arranged as to give to the movements of the arm the utmost possible accuracy, range, firmness, and delicacy.

1. Determine which of the above four qualities predominates in different joints, as follows: The ball-and-socket joint gives —— to the arm movements. The hinge joint gives —— to the arm movements. The pivot and gliding joints give —— and —— to the movements.

2. Why is it better to have a ball-and-socket joint at the shoulder and a hinge joint at the elbow, rather than *vice versa* (Fig. 49)?

3. What economy of motion is there in having the pivot joint in the forearm rather than at the shoulder?

APPLIED ANATOMY

EXERCISE I

1. What in the composition of a bone gives it stiffness? hardness? toughness? flexibility?

2. Should chairs and benches have straight backs?

3. Why is a chair back that is very **slanting** often injurious? Why is a **very deep chair** injurious, if deep enough for the front edge to strike the occupant behind the knee?

4. Why does a young child usually crawl before it walks?

5. Which girdle is attached **directly** to the spinal column? Which girdle is attached indirectly?

6. Why is the arm so often dislocated at the shoulder?

7. **High pillows** may cause what deformity?

8. Which three bones in the body are **not attached** to other bones? Find twenty-seven bones in the skeleton which are attached to other bones at one end, but have the **one end free** (Fig. 49).

9. Why does a fall not hurt a child as much as it does an adult?

10. Should a **young child** be urged to stand or walk?

11. **What part** of a long bone is composed of compact tissue? Of very porous tissue?

EXERCISE II

12. Could the neck be broken and death result without breaking a bone?

13. What would be the result if the ligaments were composed of the **yellow fibers** of connective tissue instead of the white fibers (Fig. 32)?

14. If a **child's feet** be allowed to dangle from a high seat, what will be the effect? (See § 125; also Chapter VIII, on Circulation.)

15. Is the "straight front" a healthful position?

16. The pivot joint formed by the peg of the axis projecting into the atlas allows the head to rotate through a large part (about half) of a circle. Can it **nod in any position** in that half-circle?

17. When the palm is turned upward is the radius parallel or crossed with the ulna? When the back of the hand is up?

18. Why should one always sit and walk erect?

19. What are the **only two vertebræ** whose surfaces move upon each other? How is motion between the other vertebræ accomplished?

20. In a long bone what is chiefly a **storage tissue**, saving food for future use? (§ 117.)

21. Ligaments are **of very slow growth.** This accounts for the tedious nature of the recovery from what kind of accidents?

22. Observe how many of your classmates **sit "slid forward"** in the seat, and report in recitation the result of your count.

23. When the school is marching out, count those who walk with **the head protruded.**

24. A **bone felon** is often caused by a bruise on the bone beneath the periosteum. Why should it be lanced?

CHAPTER VII

THE CIRCULATION

132. Function and Composition of Blood. — It will be recalled that the tissues composing the body are made up of cells; that these cells are active and must have food; that there are several substances necessary to feed the cells (albumin, fat, sugar, water, salt, lime); that some of these substances undergo slow combustion in the tissues; that this combustion or uniting with oxygen gives rise to carbon dioxid and other waste substances. How is the food taken to the cells, how does the oxygen reach them, and how are the products of combustion removed before they accumulate and do injury to the delicate cells? These three things are done by the circulation of the blood. We can thus readily see how important the blood is and how, if the circulation is free and strong and reaches every part of the body, it is almost impossible for disease and weakness to occur in the body.

133. Assist, in imagination, in an experiment of great interest. The artery of a hog or other animal is opened. As the blood escapes the animal weakens; at last it succumbs, and lies motionless, insensible, without breathing, without any external sign of life. It is only a carcass in appearance; and in a few seconds, it will be only a carcass in reality. Its life is arrested and will soon be finished for want of combustion in the body excited by oxygenated blood. Without delay, the extracted blood is injected again into the veins of the animal. If the experiment is conducted by skillful hands, you will now assist, as it were, at a resurrection. The body seems to move, little by little strength returns, and finally the animal rises. The life has returned because the vital combustion, not totally extinguished, was resumed when the blood reëntered the vessels.

134. It is found that the heart stops beating, or beats very faintly, just before a person faints. What does this show to be constantly needed that the mind may work?

Give a proof that blood is present almost everywhere in the body.

Explain why blushing is a proof of this fact? What two kinds of tissue are destitute of blood vessels (Chapter II)?

135. The Problems, the answers to which we are to study in this chapter, are: the composition of blood, the reasons for this composition, and how the blood is distributed to the different cells and tissues.

136. Composition of the Blood. — When seen under the microscope blood no longer appears of a uniform red color. It is found to consist of a clear, colorless liquid called *plasma*, in which floats a multitude of small bodies called *corpuscles*. The corpuscles themselves are seen to be of two kinds. By far the greater number are round, yellow, and flattened, but a few, perhaps one in four hundred, are round, white, and globular, and larger than the yellow ones (Fig. 80). The yellow ones are called the red corpuscles, because the light shining through a great number of them gives the blood a red color.

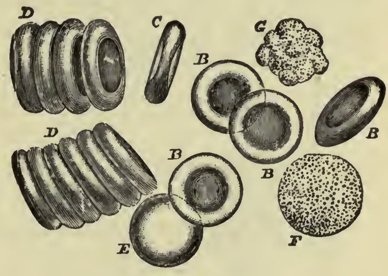


FIG. 80.

B, red corpuscles seen from the side; *D*, red corpuscles, seen on edge, are run together in rows; *G*, *F*, colorless corpuscles.

137. Reasons for the Composition of the Blood. — That the blood may *flow readily* through every little tube, it must be liquid, hence a large part of it is water. It is the plasma or watery portion of the blood which *transports the food* to the tissues. The plasma is not, then, a simple but a very complex liquid. The tissues require albumin, fat, sugar, and mineral food. We should expect the plasma to contain all of them, and so it does. As we should likewise expect, it gets this nourishment from the alimentary canal. The sugar is in the form of grape sugar, and because of this, blood or meat containing it is slightly sweetish in taste. The fat is in the form of minute globules, and the albumin is similar to egg albumen, but very much diluted with water.

138. Let us take up another function of the blood. How does it **carry the oxygen?** This gas enters the red corpuscles while the blood is in the lungs, and makes them a brighter red. It is given up to the tissues; and at the same time the tissues give up carbon dioxid, which is carried to the lungs by the corpuscles and the plasma. The liquid impurities in the tissues are carried by the plasma to the skin and kidneys. We see, then, that the red corpuscles transport the greater part of gaseous material, while the plasma transports the liquids and the solid materials dissolved in the liquids.

FIG. 81.
1, human blood corpuscles, side and front view; 2, frog's blood corpuscles, side and front view. Both are drawn to the same scale.

139. What are the White Corpuscles for? — This brings us to a fourth function or use of the blood, a function that has been discovered only within the last few years. The blood of healthy persons possesses a certain power of destroying germs of disease which may enter the body; this is called its germicidal or germ-killing power. The germs are minute one-celled organisms to be seen only through a powerful microscope. Some float in air; others are found in liquids or solids. Most kinds of germs are not harmful to man. For instance, there is a germ which gets into milk and causes it to turn sour. The yeast germ, used in bread making, is a microscopic one-celled plant which obtains its nourishment from sugar.

140. The germicidal power of the blood is believed by many physiologists to rest, in part at least, in the white corpuscles. When the flesh is cut, or when bacteria lodge in the tissues, these little scavengers may be seen collecting at the danger point in great numbers: some of the germs are devoured bodily by the white corpuscles: others are killed probably by substances in the plasma which were formed by these little guardians. In no way is the provision for our welfare better shown than by the existence of these corpuscles (Fig. 82).

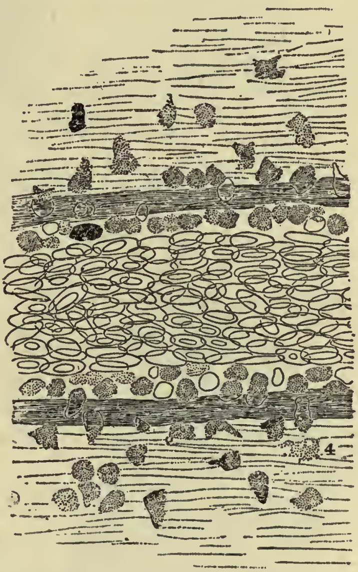


FIG. 82.— Migration of White Corpuscles through the Walls of a Vein.

They are shown in different stages of migration. The red corpuscles remain in the stream.

141. Experiment on the Parts of the Blood. — If some blood from an animal is allowed to stand in a vessel, it soon becomes a red, jellylike mass. This change is called *coagulation*. If we let the coagulated blood stand, it gradually separates into two parts, — a light yellow liquid called *serum*, which is colored by a few blood cells, and a semi-solid mass called the *clot*, which contains most of the cells together with some threadlike fibers (Fig. 83). A substance called animal fibrin was in solution in the plasma or liquid portion of the blood. It has solidified into fibers which by entangling the corpuscles caused the formation of the clot. The serum, or the portion of the blood that remains liquid, is composed of water and albumin, with traces of sugar, fat, and certain salts. If the

FIG. 83.— Diagram to Illustrate the Process of Coagulation.

I. Fresh. (Corpuscles and plasma.) II. Coagulating. (Birth of fibrin.) III. Coagulated. (Clot and serum.)

Plasma minus fibrinogen equals serum. Corpuscles plus fibrin equal clot.

water is boiled away, the albumin is left as a white jelly. The composition of the clot, serum, and plasma may be shown as follows:—

COAGULATED BLOOD	Clot	Blood corpuscles		LIQUID BLOOD
		Fibrin	Plasma	
	Serum	Water		
		Albumin		

CIRCULATION OF THE BLOOD

142. The organ which gives the push or impulse to the blood and causes it to circulate in the tubes or vessels is the heart (Fig. 84). The tubes that conduct the blood away from the heart to the organs and tissues are called *arteries*. The tubes through which it returns to the heart are called *veins*. The very small tubes that take the blood from the arteries to the veins where it begins its return journey are called *capillaries*. The blood must circulate in order that it may go to the digestive organs to get food, to the lungs to get oxygen, and to all the tissues in order to distribute these things, and to carry away waste materials to the organs that will free the body of them. Can you see in your mind the dark color of a piece of beef and the lighter color where a fresh cut is made? Blood going from the lungs to the tissues is bright red, about the color of a piece of new beef when the knife cuts into it. The blood going from the tissues to the lungs is darker, about the color of the outside of the piece of raw beef some time after it is cut.

143. The heart is situated in the chest, between the two lungs. It is a hollow muscle, and has the remarkable power of contracting and relaxing itself with periodical regularity. The movement of contraction is called the *systole;* the relaxation is called the *diastole.*

144. The heart is divided by a vertical partition into halves (Fig. 84). The right half receives the dark blood

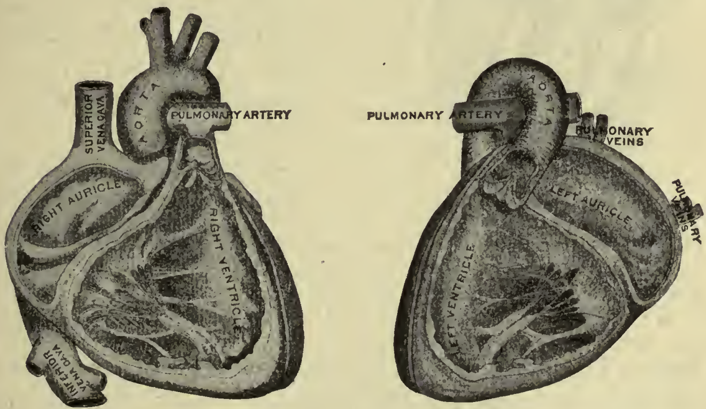


FIG. 84. — Diagrammatic Section of Heart.

from the body and sends it to the lungs. The left half receives the bright blood from the lungs and sends it to every part of the body. Each half is also divided by a horizontal partition, but unlike the vertical ones, these partitions are pierced with openings for communication. The heart therefore contains four chambers; the two upper ones are called *auricles*, the two lower ones *ventricles.* The right auricle communicates with the right ventricle just below it, and the left auricle communicates with the left ventricle.

145. Circulation of the Blood. — From all parts of the body (except the lungs) the blood arrives at the right auricle, dark red in color, and charged with carbon dioxid, a gas that is unfit for supporting life. The blood has come through two large veins, the superior vena cava, from the head, arms, etc. (Fig. 85), and the inferior vena cava, from the lower parts of the body. The first chamber of the heart that it enters is the right auricle. The auricle contracts and presses the blood into the right ventricle (Fig. 86). It begins to squeeze together just around the openings of the veins, so that it closes their openings. The blood, owing to this, cannot go back into the veins, but is forced into the ventricle. The right ventricle thus filled with blood at once begins to contract. The first effect of the pressure thus produced is to force blood behind the flaps of the *tricuspid* valve, the valve between the auricle and ventricle, consisting of three flaps made of white fibrous tissue. The blood behind the flaps brings the flaps together and so blocks the way to the auricle (Fig. 87). The contraction of the ventricle goes on, and soon the blood presses hard enough upon the *semilunar* valve to open it and go on into the pulmonary artery (Fig. 85);

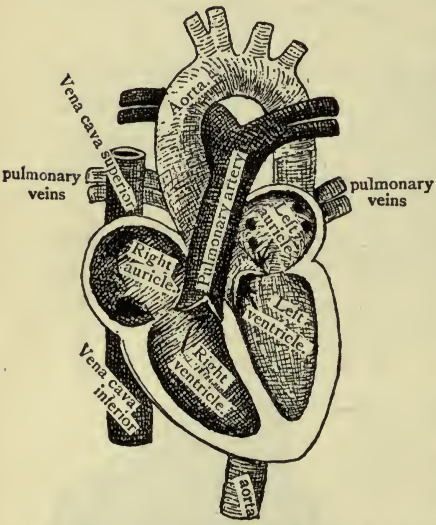


FIG. 85. — Diagram to show the Course of the Blood through the Heart.

The vessels containing impure blood are drawn darker than the others.

the pressure from the ventricle soon sends it through the swollen artery into the lungs (Plates IV and VIII).

FIG. 86.—The Right Side of the Heart.
The blood flowing through the tricuspid valve into the ventricle.

146. When the ventricle has emptied itself, it relaxes. The semilunar valve is composed of three pockets, which the swollen pulmonary artery fills with blood as soon as the ventricle begins to relax. The pockets of the valve are thus pressed together, and no blood flows back into the ventricle. The auricle was relaxing while the ventricle was contracting, and it is already filled with blood that has flowed in from the veins. After a short pause, it again contracts; and the same action is repeated. More and more blood is thus driven by the right ventricle through the semilunar valve into the pulmonary artery, so that the blood which is already in the artery is sent on through the numerous small branches and through the multitude of fine tubes called *capillaries*, which go through every part of the lungs.

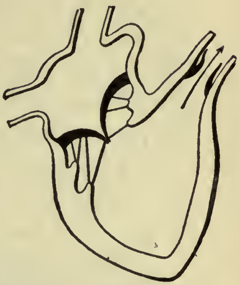


FIG. 87.—The Blood going through the Pulmonary Artery to the Lungs.
Tricuspid valve closed, semilunar valves open.

147. In the lungs the carbon dioxid passes into the air passages, and the oxygen brought by the breath goes into the blood of the capillaries, which changes in color to bright red. The capillaries unite again to form the pulmonary veins, which lead back to the heart. We thus see how the blood is sent from the heart through the lungs and back to the heart. How is the blood sent through the body and back to the heart? We shall find that this is done by the left side of the heart; that the two pumps work in unison; that, in fact, a wave of muscular contraction starting at the top of the heart passes downward over both sides of the heart at once, both auricles contracting at the same time and then relaxing as the contraction passes to the ventricles.

148. As we learned, the pressure from the right ventricle keeps the blood moving through the pulmonary artery, the capillaries of the lungs, and the pulmonary vein; it returns to the heart again, and this time it enters the left auricle.

149. When the left auricle is full, it contracts and drives

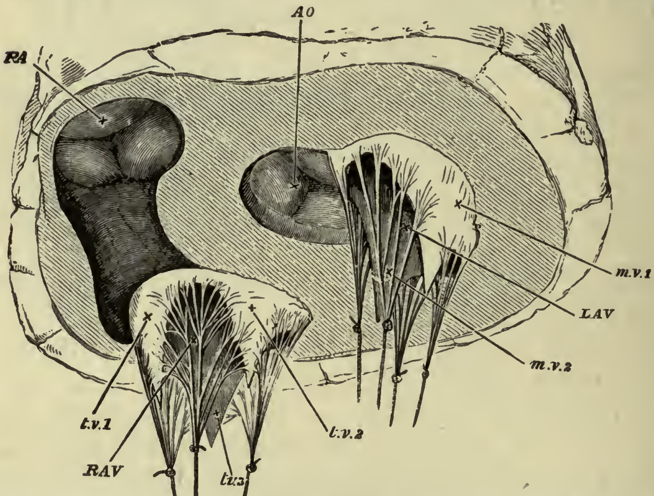


FIG. 88. — View of the Orifices and Valves of the Heart from below, the whole of the two Ventricles being cut away.

Ao, aorta; *PA*, pulmonary artery, each with its three cups of the closed semilunar valves seen convex from below; *RAV*, opening between right auricle and right ventricle, surrounded by the three flaps, *t.v.*1, *t.v.*2, *t v.*3, of the tricuspid valve with chordæ tendineæ between them, to which three cords are tied, taking the place of the papillary muscles; *LAV*, opening between left auricle and left ventricle, with the two flaps, *m.v.* 1, *m.v.* 2 of the mitral valves and chordæ tendinæ, to which cords are tied.

This figure may be said to show the roof of the two ventricles, with the two great valves by which the blood enters the ventricles and the two great valves by which it leaves them. All the openings of the ventricles are upward.

the blood through a valve called the *bicuspid* (Fig. 88), or *mitral, valve*, into the left ventricle. [Mnemonic: the t(r)i cuspid is on the (r)ight side, the bicuspid on the left.] The left ventricle (at the same time with its mate, the right ventricle) then contracts, forcing the blood behind the flaps of the bicuspid valve, closing the way back to the left auricle. The pressure of the ventricle opens the semilunar valve in the mouth of the great aorta, which is the large artery carrying the blood from the left ventricle. The aorta takes the blood to every part of the body except the lungs. It gives off smaller arteries, and the division is repeated until arteries are supplied to every organ and tissue. In the tissues the arteries empty into smaller tubes called *capillaries*. The aorta, with its branches, becomes distended with blood, and as more and more is forced into it by the left ventricle at each heart beat, the distention is kept up, and some of the blood already in the aorta is forced along its branches, and the same pressure forces it through the capillaries and into the veins (Plates V and VIII).

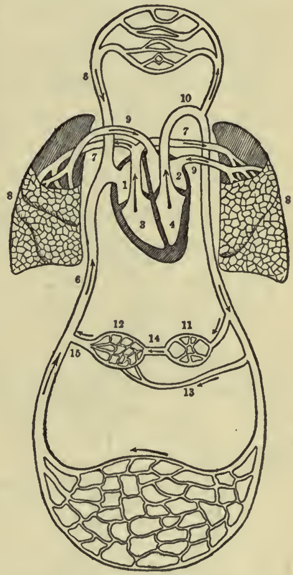


FIG. 89. — Diagram illustrating the Circulation.

1, right auricle; 2, left auricle; 3, right ventricle; 4, left ventricle; 5, vena cava superior; 6, vena cava inferior; 7, pulmonary arteries; 8, lungs; 9, pulmonary veins; 10, aorta; 11, alimentary canal; 12, liver; 13, hepatic artery; 14, portal vein; 15, hepatic vein. Follow the arrows and see whether you come around to the starting point again.

150. The blood flows slowly through the capillaries and performs its function of exchanging substances needed for those used up. It next goes into the veins on the return journey to the heart where it enters the right auricle again, which was our starting place in this description (Fig. 89).

151. Review of Circulation. — The blood comes from the tissues through the veins and enters the right auricle, goes through the tricuspid valve into the ventricle, then through the semilunar valve it enters the pulmonary artery. Traversing the capillaries of the lungs, it goes by the pulmonary veins, to the left auricle, then through the bicuspid, or mitral, valve to the left ventricle, thence into the aorta by the semilunar valve, thence to the capillaries of the system, thence to the veins, and through them it returns to the heart, completing the circulation.

152. Structure of Blood Vessels. — In order to understand how the arteries, veins, and capillaries are adapted to their work, we will study their anatomy. We shall find three kinds of tissue (Fig. 90) used in their construction, — epithelial tissue to prevent friction, connective tissue to give both strength and elasticity, and muscular tissue to enable the vessels to change in size.

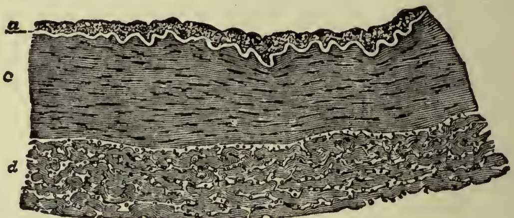


FIG. 90. — Transverse Section of Part of the Wall of an Artery, highly magnified.

a, epithelial (endothelial) layer, or inner coat; *c*, muscular layer or middle coat; *d*, outer coat, consisting of connective tissue.

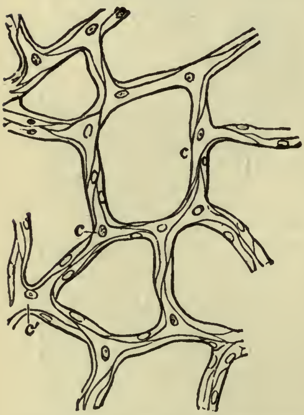


FIG. 91. — Epithelial Cells forming the Walls of Capillaries.

The nuclei and the outlines of the cells may be seen. The forming of the thin tubular walls of the capillaries is one of the most curious among the many wonderful feats accomplished by the cells

153. The epithelial tissue forms the innermost layer of the vessels. The endocardium or inner lining of the heart is formed of this membranous layer, and is continued throughout the arteries, capillaries, and veins. In these vessels it is called the *endothelium*. The epithelial cells forming this smooth layer are thin and flat, and serve to diminish friction. The walls of the capillaries, the smallest vessels, consist simply of this epithelial membrane (Fig. 91). In the small arteries a layer of muscular tissue is placed outside the endothelium. Outside of this muscular tissue, and forming the outer surface of the artery, is a layer of connective tissue containing both white fibers and yellow elastic fibers (Fig. 90, also Fig. 32). In fact, some of the yellow elastic fibers (Fig. 32) are found also in the other coats. The muscular and connective tissue layers become still thicker in the larger arteries. So the wall of an artery consists of three layers: (1) the endothelium; (2) the muscular coat; (3) the connective tissue coat on the outside (Figs. 90 and 92). The arteries are therefore very firm and elastic, and do not collapse when they are cut, but stand open, and the

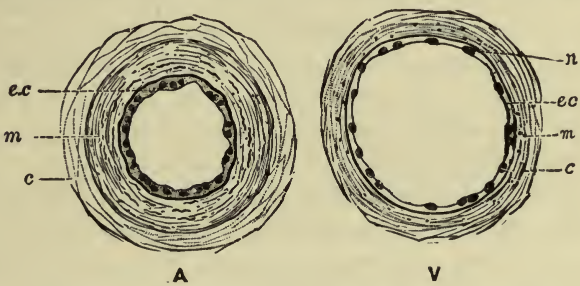


FIG. 92. — An Artery and Corresponding Vein cut across.

A, artery; V, vein; *e.c*, endothelial cells; *m*, muscular coat; *c*, connective tissue; *n*, nuclei of endothelial cells.

flow of blood through them is unobstructed. The walls of the veins consist of the same three layers. Their walls are not so thick as those of the arteries, for the muscular and connective tissue layers are much thinner (Fig. 92). When a vein is cut it collapses, that is, the thin walls fall together, and the bleeding is stopped unless the vein is large.

154. The Use of the Three Coats. — The white fibers of the connective tissue coat (see Fig. 90) give strength and firmness to the vessel, and the yellow elastic fibers give elasticity. The muscular, or middle, coat enables the arteries and veins to change in size, and the inner, or endothelial, layer gives smoothness and prevents friction. Why are these three properties necessary to blood vessels?

155. Why the Blood Vessels must be Elastic. — The aorta and its branches are full of blood all the time. When the left ventricle with its great muscular walls contracts, the blood cannot move forward into the narrow arteries and capillaries fast enough to make room for the new supply so suddenly sent out of the ventricle. Therefore the aorta becomes more than full. If a cup is full, it cannot become "fuller"; not so with an artery. The yellow elastic fibers of its connective tissue allow it to expand as a rubber hose does under pressure. The first part of the aorta having expanded to receive the incoming blood, the portion of the aorta just ahead of the expanded portion is less tense, or tight, so the stretched elastic fibers contract and force blood into it, expanding it in turn. Thus a wave of expansion travels along the blood vessel. It is called the *pulse*, and may be most easily felt in the wrists and neck. The distended elastic walls exert pressure on the blood in the arteries, and this presses some of the extra blood out of them into the capillaries. As much blood as is being pressed on into the capillaries is being thrown into the aorta by the beat of the heart; so that during life a distension is always kept up, and the blood in the vessels is always under pressure. Although the arteries may get rid of the additional distension following each heart beat, there is a normal distension that always remains. It has existed ever since life began, and will remain until the heart ceases to beat. The pulse, therefore, is only an additional distension following the contraction of the ventricle.

You should not think that the muscular layer actively contracts and helps to send along the pulse; for the pulse is simply the passive stretching and contracting of the elastic tissue; as a wave travels across a pond when a stone is dropped into the water. The force of the pulse is furnished by the heart. What, then, is the purpose of the muscular layer in the arterial wall?

156. Use of the Muscular Coat. — The body of an adult contains about five quarts of blood. We have learned that the blood supplies the substances needed for the activity of each organ. If an organ is working, it needs more blood than usual, which is supplied by the other organs that are at rest; they get along with less blood for the time. The muscular coat of the blood vessels makes this possible. This coat is usually in a condition of slight contraction, but the nerves controlling the muscular coat in the blood tubes of the active organs may cease to act, thus allowing the muscular coat to relax and the blood tubes to enlarge under the pressure from the heart, so that the active organs may obtain the additional supply of blood needed. While this is happening, part of the pressure in the blood tubes of the inactive organs is relieved and they become smaller. If cold air strikes the face, the nerves stimulate the muscular coat of the blood tubes in the face to contract more strongly than usual, and the face turns white. This driving of the warm blood from the face saves heat to the body, which would be lost if the warm blood remained in the skin. Thus the amount of blood circulating in any organ is regulated by means of the muscular coat of the blood vessels and of the action of the nerves upon this coat.

157. The Use of the Inner Coat. — We learned that the inner coat of the heart and blood vessels is made of epithelial tissue, like that which forms the outer layer of the skin, and the smooth lining of the mouth and other organs. This lining membrane is very smooth and thus friction is lessened. The friction, however, is inconsiderable in the large vessels; but in the smaller vessels it is greater; and in the minute capillaries it becomes of very great importance. We see, therefore, why it is necessary to have this smooth coat in the capillaries, although the muscular and connective coats are not prolonged into them. It should be stated here that although the extremely minute size of the capillary tubes increases the friction and the pressure which the heart must expend in sending the blood through them, yet their resistance to the blood flow is lessened by their great capacity. The united capacity of the capillaries is six hundred times that of the blood arteries that supply them. In the capillaries the blood flows slowly like a river which flows into and out of a lake.

158. Rate of Flow and Differences of Pressure. — The velocity of flow is 15 inches per second in the aorta, $\frac{1}{30}$ of an inch per second in the capillaries, and about $7\frac{1}{2}$ inches per second in the inferior vena cava. When an artery is cut, the blood is thrown out by jerks corresponding to the pulse, and flows slowly between the jerks because the arteries are kept over-full and the blood is pressed out by their elastic walls. The pressure that results from the arteries being always over-full, likewise explains why the blood flows constantly from the arteries into the capillaries. Hence, although the blood is thrown into the aorta at intervals by the beat of the heart, it flows from the arteries to the capillaries continuously, being only quickened in its flow by each beat. In the capillaries, owing to the great friction in the minute passages, there is strong resistance to the flow of blood, and the great pressure in the arteries is necessary to send the blood through the capillaries; a great deal of this pressure is used up in doing so, hence the pressure beyond the capillaries (that is to say, in the veins) is much less than the pressure in the arteries. Enough is left to force the blood part of the way through the veins; but it is not sufficient to carry the blood back to the heart, for it gives out entirely before the heart is reached. We shall learn later how the contraction of the muscles and their squeezing effect upon the veins passing through or beneath them, aids the heart to move the blood;

also how the expansion and contraction of the lungs act as a great pump; and how these aids, together with changes of posture, enable the blood to reach the heart again. If one stands perfectly still for some time, the blood, owing to its weight and the lack of pressure on the veins, slowly congests in the veins in the lower part of the body, and the consequences may be serious.

159. Hence the pressure is greatest in the arteries, less in the capillaries, and least of all in the veins.

160. How the Amount of Blood flowing through any Organ may be modified. — We learned that the ability to do this lies in the muscular or middle coat of the vessels, and that the muscular coat in turn is controlled by the nerves. This very important power, therefore, is intrusted to the two master tissues. The nerves that control the sizes of the blood vessels are called *vasomotor nerves* and are of two kinds. One kind, the *constrictor nerves*, stimulates the walls of the blood vessels to contract, while the other kind of vasomotor nerves, called the *dilator nerves*, neutralizes or inhibits the effect of the constrictors, and thus allows the blood tubes to enlarge. The regulation is involuntary, or beyond the control of the will; for instance, the blood vessels of the brain may become enlarged and the great pressure there cause a headache, but the will cannot drive it away. We sit before a fire, and the face becomes red as the warmth soothes the constrictor nerves into inactivity; or the constrictors leading to the face may become paralyzed by mental confusion and we blush.

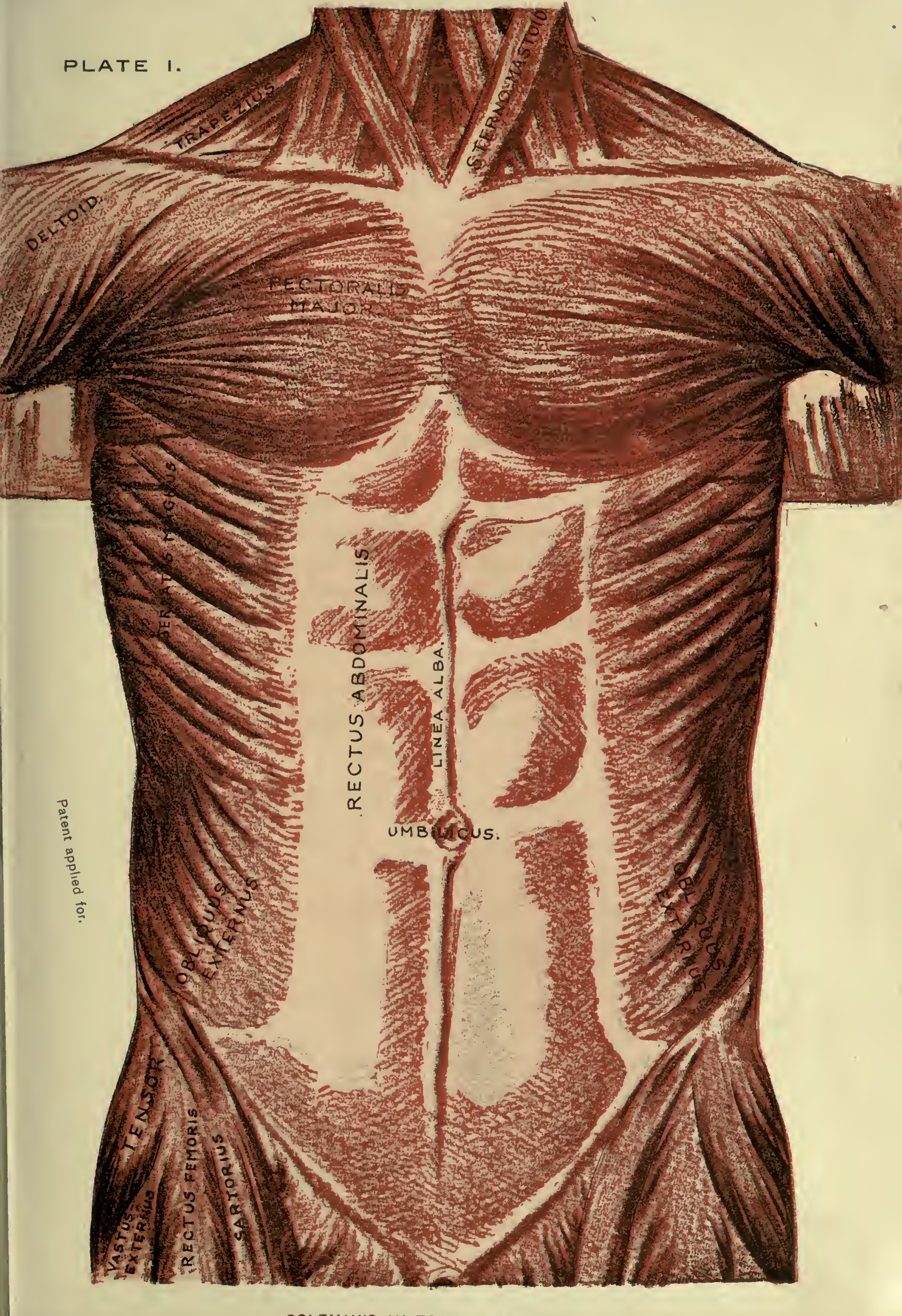
161. Why must the Relative Amount of Blood in the Different Organs continually change? — The necessity for this comes from the fact that if the one and one fourth gallons of blood were evenly distributed, none of the organs would be capable of any powerful and effective action. A person weighing 157 pounds has only 12 pounds of blood, for the blood is $\frac{1}{13}$ of the total weight of the body. There is not enough blood in the body to distend all of the blood vessels at once. The skin alone with all of its blood vessels distended could contain two thirds of all the blood in the body. The veins have twice the capacity of the arteries; they could contain every drop of blood in the body. When the brain works, it requires more blood. When digestion is in progress, the lining of the digestive organs blushes a rosy red and the digestive fluids are poured out. During the digestion of a hearty meal, one will not do his best thinking. When a muscle is used, the dilator nerves act, the blood tubes in the muscle become enlarged, and its supply of blood increases to serve it during its action. The impulses that run along the vasomotor nerves arise in the enlargement at the top of the spinal cord called the *spinal bulb*. The part of the spinal bulb that in this way regulates the caliber of the arteries is called the *vasomotor center*. It is constantly sending impulses along the constrictor fibers so as to keep the muscles of the arteries slightly contracted. The vasomotor center thus keeps a rein upon the arteries, holding them in a condition of *tone*, as this slight contraction is called. Sudden paleness, due to fear, is brought about by extra strong impulses from the vasomotor center, causing the muscular walls of the small arteries of the face to grip the vessels tight and drive the blood from the face. Alcohol destroys the tone of the blood tubes. From temporary drinking the face becomes red; from habitual drinking the "rum blossom," the purple swollen blood tubes in the nose, results.

162. How the Flow of Blood through the Whole Body is regulated. — The amount of blood passing through one organ may be increased by the vasomotor nerves, but it is only because the amount going through the enlarged vessels of that organ has been withdrawn from other organs whose blood tubes, not being enlarged just then, afford greater resistance to the passage of the blood than the dilated vessels afford. But can the total amount of blood reaching, in a given time, not a single organ only, but all the organs in the body, be increased? Yes, for if the one and one fourth gallons of blood flow faster all over the body, more fresh blood will reach each organ. This is accomplished by faster or stronger beating of the heart. During rapid general exercise, as running, when the demands of the body are increased, the heart beats faster, as you have doubtless observed. When the body in general is at rest, as during sleep, the heart beats more slowly. Thus the general blood supply is regulated. But how is the heart itself regulated? For these facts show two things: first, that we cannot directly control it by the will; and second, that there is something in the body that does control the heart, and perhaps our wills may influence the beating of the heart indirectly. The heart, like the blood vessels and the muscles in general, is supplied with nerves; but there is this difference, namely, that the heart can go on beating without receiving impulses along its nerves. The heart of a frog, after being cut out of the body, will go on beating for several hours if it is kept moist; if it is cut into several pieces, the pieces will go on beating. It is the property of the heart muscle to contract, and it will do so as long as its protoplasm is alive.

163. The nerves going to the heart do indeed carry impulses to the heart, but this is to regulate the beat of the heart and not to originate it. A nerve called the *vagus nerve*, extending from the spinal bulb to several organs, goes to the heart; and gentle impulses which are almost always passing down the vagus nerve from the spinal bulb, restrain the heart from too great activity, and are the chief means of regulating the strength and frequency of its beats. When an animal requires a greater supply of blood, as in running, these impulses for a time cease, and the heart beat is quicker and stronger (Fig. 202).

164. There are other nerves, called *sympathetic nerves*, connected with the spinal cord below the point at which the vagus branches, that bring impulses to the heart which are opposite in effect to those brought by the vagus. These impulses also start in the spinal bulb; they cause a quickening and strengthening of the beats (Fig. 200). Do the vagus nerve fibers or the sympathetic nerve fibers resemble the whip which a driver uses in driving a horse? Which kind corresponds to the reins? Thus the need of the body for a greater or less active blood supply is regulated by controlling the rate and strength of the heart beats. If the nerves are all in order, the heart beats more slowly when the tissues of the body need little blood, and more rapidly when the tissues need more food or more oxygen. But quickening of the heart beat cannot send more blood through one organ without sending more blood through all the organs, hence it is not so delicate a means of regulating the blood supply as the vasomotor system.

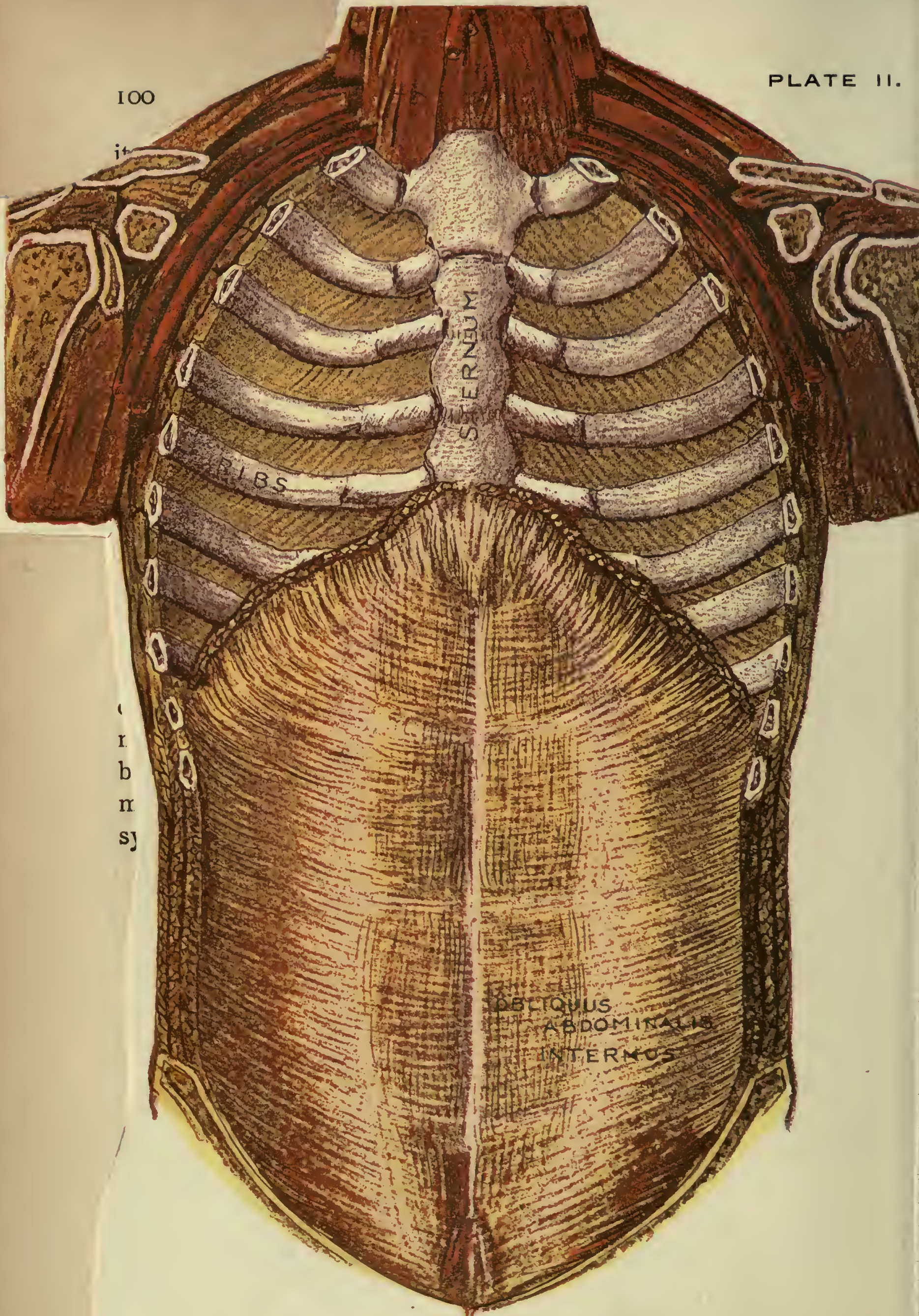
PLATE I.



Patent applied for.

COLEMAN'S ANATOMICAL MANIKIN.

PLATE II.



it

r
b
m
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PLATE III.

Viscera (front view). For rear view, see next plate.

it

r
b
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PLATE IV.

Viscera (rear view). Student will find ducts from the liver and pancreas entering duodenum together; also, mesenteric artery leading to intestines and portal vein leading from them to liver.

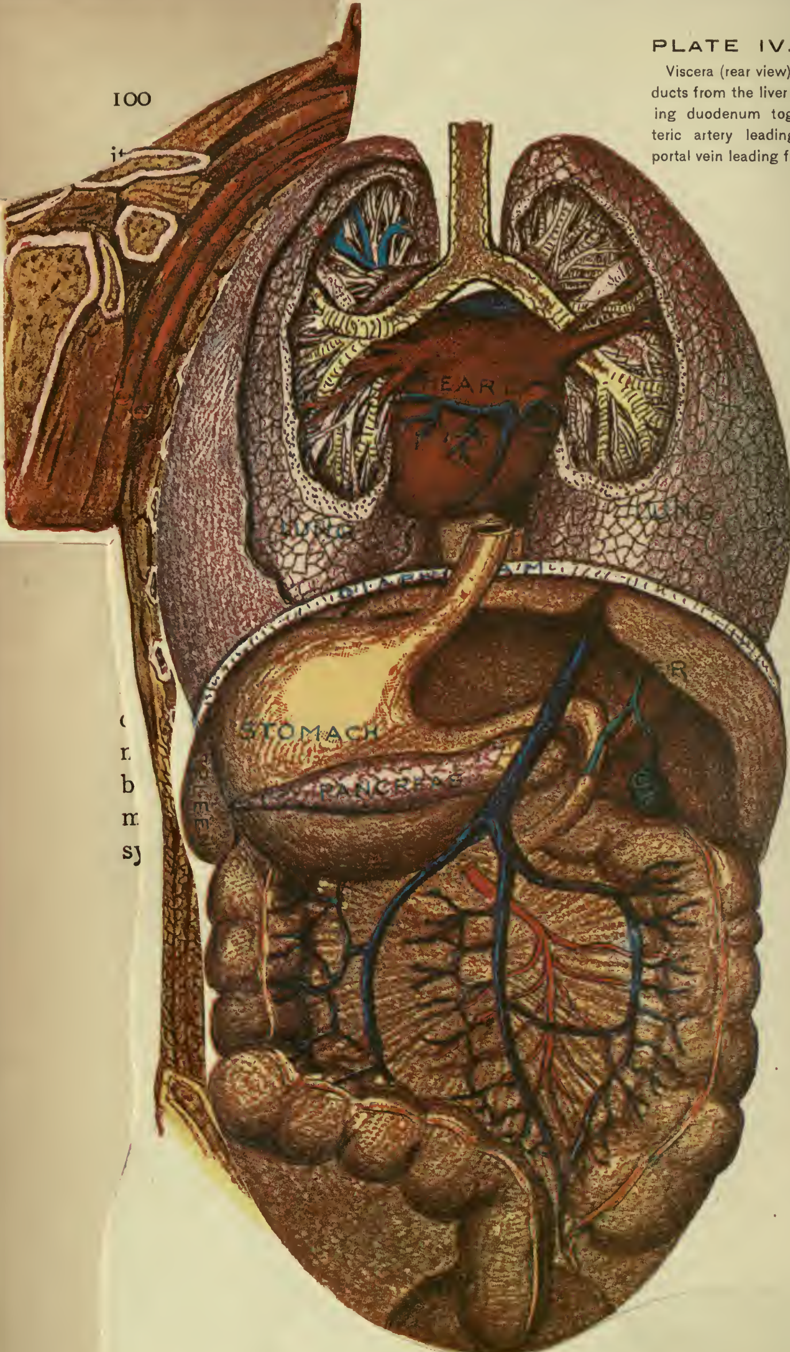


PLATE V.

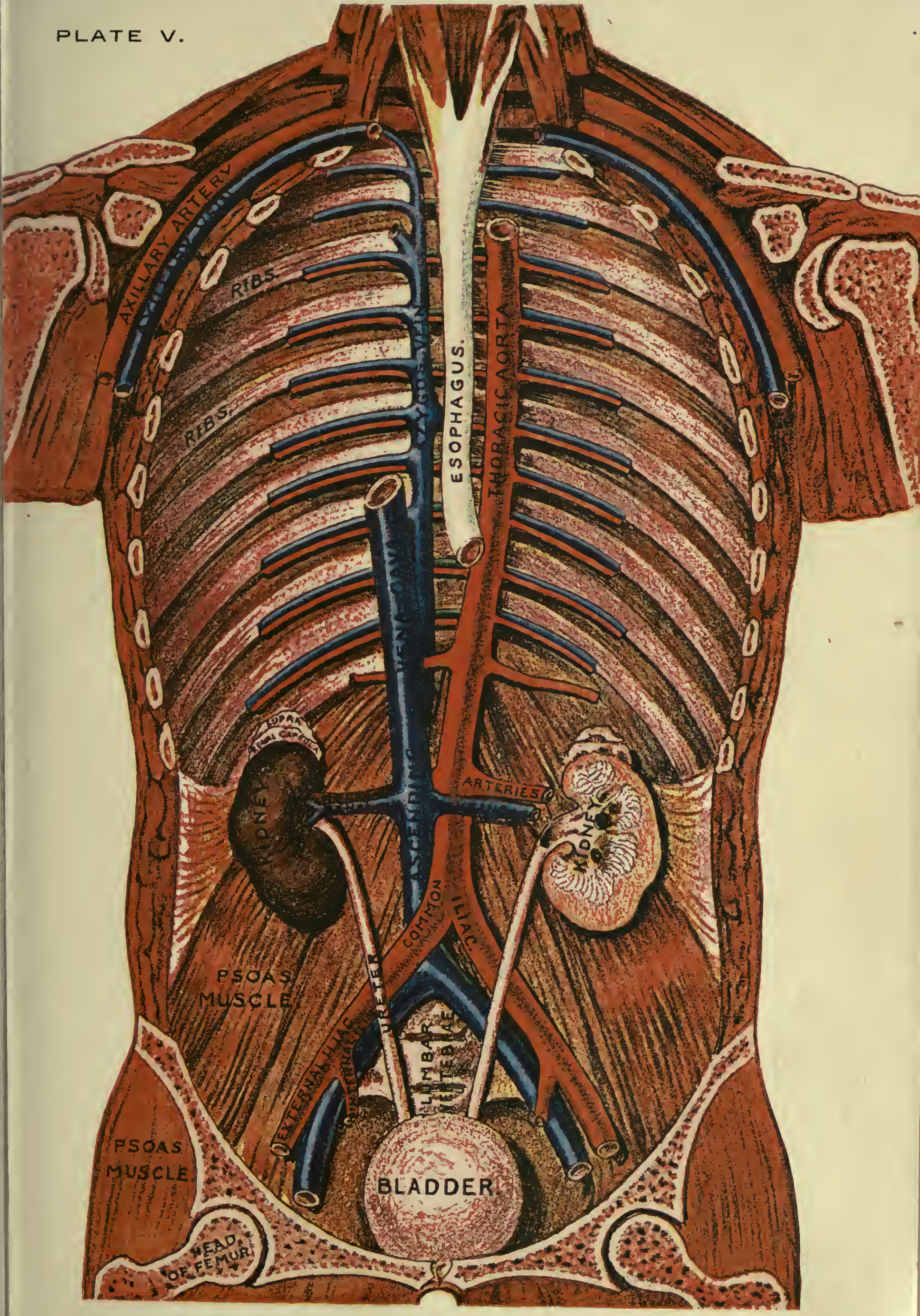

AXILLARY ARTERY
RIBS
RIBS
ESOPHAGUS.
THORACIC AORTA
VENA CAVA
ARTERIES
ASCENDING
KIDNEY
KIDNEY
COMMON
ILIAC
URETER
PSOAS
MUSCLE
EXTERNAL ILIAC
LUMBAR VERTEBRAE
PSOAS
MUSCLE
BLADDER
HEAD OF FEMUR

PLATE VI.

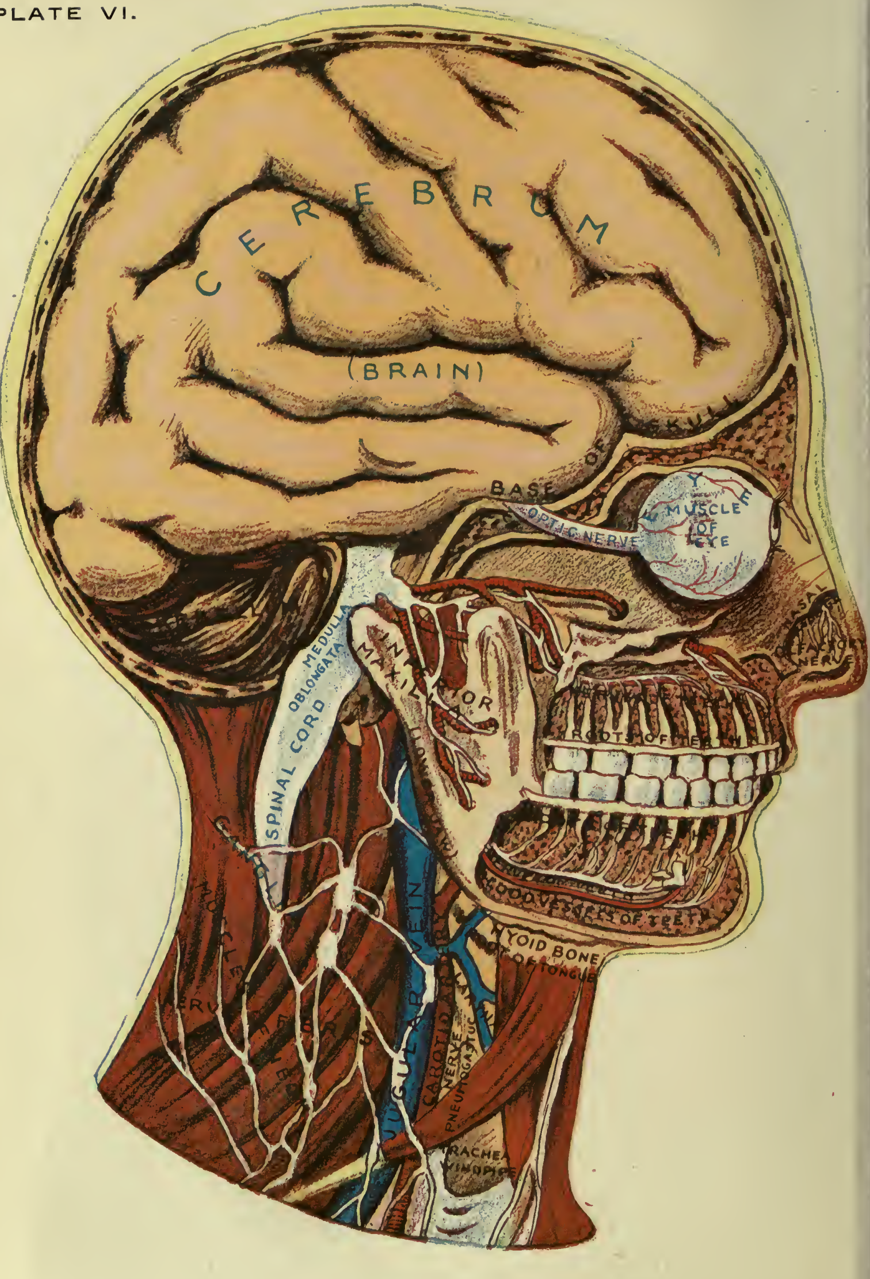

CEREBRUM
(BRAIN)
BASE
OPTIC NERVE
MUSCLE OF EYE
MEDULLA OBLONGATA
SPINAL CORD
HYOID BONE
JUGULAR VEIN
NERVE
PNEUMOGASTRIC
TRACHEA

PLATE VII.

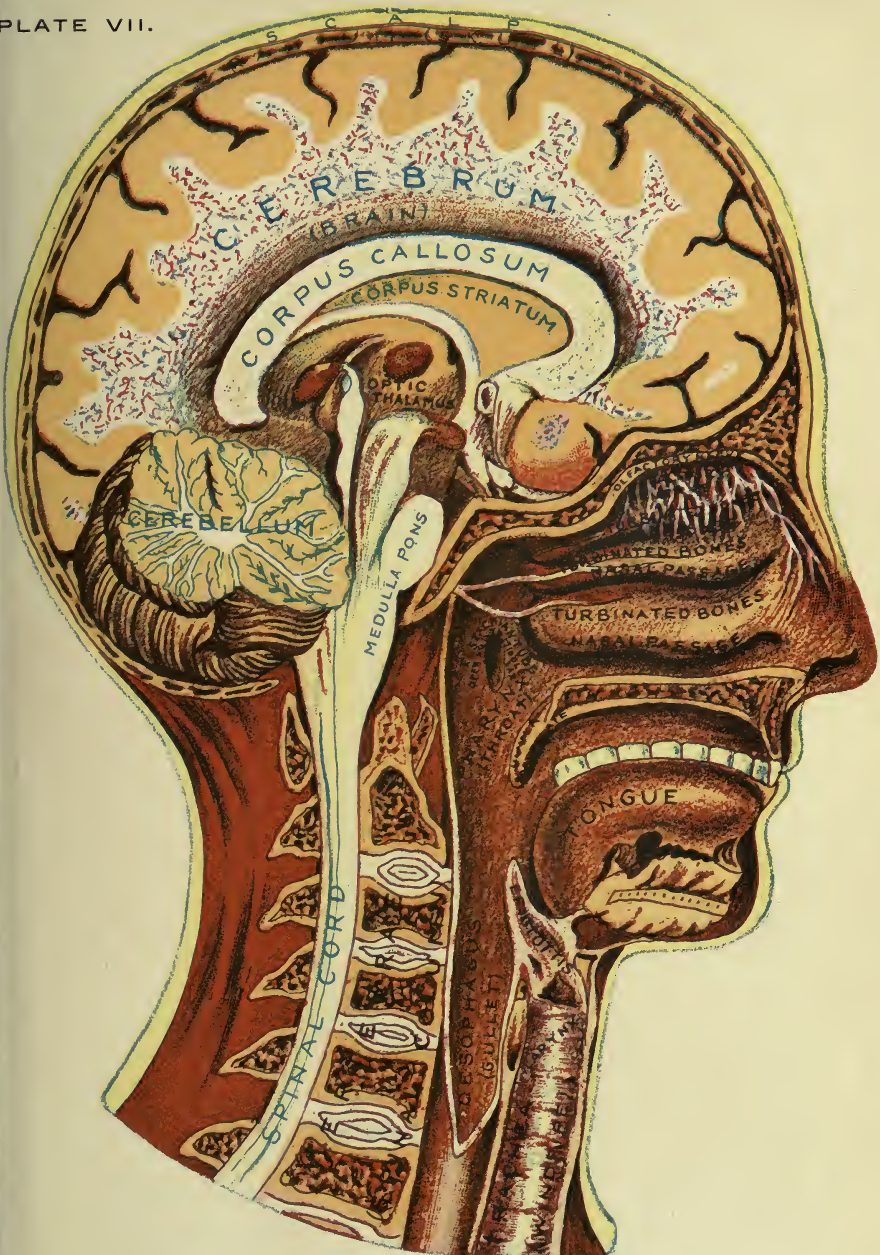
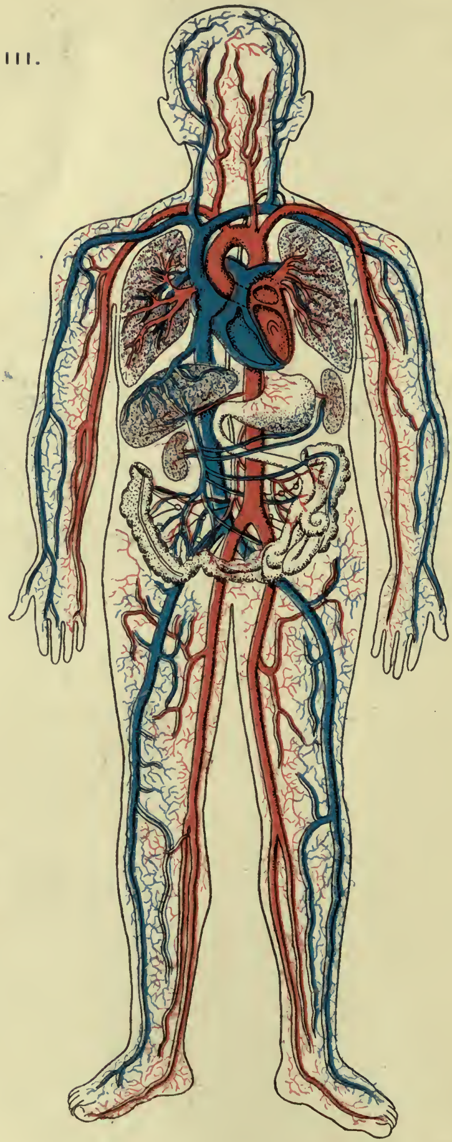

SCALP
CEREBRUM
(BRAIN)
CORPUS CALLOSUM
CORPUS STRIATUM
OPTIC THALAMUS
CEREBELLUM
MEDULLA PONS
TURBINATED BONES
NASAL PASSAGE
TONGUE
SPINAL CORD
OESOPHAGUS
(GULLET)

PLATE VIII.



The pupil will trace the circulation of the blood from the body through the right side of the heart to the lungs; and from the lungs through the left side of the heart to the body; also trace the portal circulation, from the digestive organs through the liver to the heart.

CHAPTER VIII

THE CIRCULATION (continued)

165. How the Heart is aided in its Work. — The heart seems to be constantly at work, but such is not the case. As a matter of fact, the heart occupies nearly as much time in resting as in working. It works for about half a second and rests for about half a second. Yet it does work in a day equivalent to raising a ton of coal nearly two hundred feet.

166. Increase the circulation in the arm by **exercising** it for a few minutes. The veins in the front of the wrist will then be plainly visible. The skin and walls of the veins make the blood in the veins appear blue, but it is dark purplish red. (Did you ever see "blue" blood?) Place the tip of the forefinger on one of the large veins; with the middle finger then stroke the vein toward the hand so as to push the blood from a portion of it, keeping the two fingers in place. The vein remains empty between the fingers. Lift the finger nearer the heart and no blood enters the vein; there is a valve above which holds it back. Lift the other finger, and the vein fills instantly. Stroke a vein toward the hand, and see the blood cause the veins to swell up into little knots where the valves are. (Experiments upon veins are plainest with adults whose veins are large.) The veins have valves placed frequently along their course. The valves are pockets made by a fold in the inner coat of the wall of the vein (Fig. 93). When you place your hand in your pocket, the latter swells out; but if you rub your hand on the outside of the pocket from the bottom toward the top, it flattens down. So with the action of the blood upon the valves in the veins (Figs. 94, 95). They all open toward the heart.

167. Suppose a muscle hardens as it contracts and **presses upon a vein** which goes through the muscle; the blood is pressed out of the vein. The blood cannot go toward the capillaries, for the valves fill and close when it starts that way; so it is all pressed out toward the heart. When the muscle relaxes, the blood that has been pressed forward cannot come back because of the valves, but the valves nearer the capillaries open, and the veins are filled. When the muscle contracts again, the same effect on the blood movement is repeated. We see, therefore, that every contracting muscle converts into a pump the vein running through it, and when a person works or exercises, many little pumps are working all over the body, aiding the heart in its function.

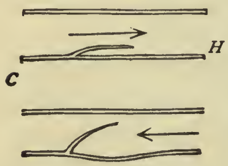


FIG. 93. — Diagram of the Valves of Veins.

H, heart side; *C*, capillary side. The arrow shows the direction of flow.

168. This aid makes the blood flow faster and relieves the heart of part of its work, so that it beats faster, just as a horse might trot faster if half the load were removed. All of the body gets fresher blood than it got when the muscles were still and the blood flowed more slowly. This help comes during active work, just when the body is demanding more blood and the heart needs help.

169. Suppose a person engages in vigorous muscular exertion just after eating. The stomach and the muscles both demand an increased supply of blood. The muscles will get it because the valves in the veins will increase the flow through the muscles, and the muscles are so extensive and use so much blood that the digestion may suffer because of the vigorous exercise.

170. Massage. — So effective and necessary is exercise in aiding the circulation, that some people employ others who are skilled in the art called *massage*, to come regularly and squeeze and knead every muscle like dough. Thus fresh blood is brought and the removal of waste material from the tissues is aided. If a boy has so-called "growing pains" which may come from over-fatigue, or which may be a light form of rheumatism from exposure to wet and cold, his pains can be relieved by thoroughly rubbing the aching part.

FIG. 94. — Vein laid open to show Two Valves.

FIG. 95. — Valve in Vein distended with Blood.

171. The arteries lie deep under the muscles near the bones, and are likewise pressed upon by muscles, but their walls are much stiffer than the walls of the veins. In fact, many of them in passing through the muscles have tough, fibrous sheaths. It is well that the arteries are not so much affected by exercise, for if they were squeezed by the contracting muscles, the blood would be pressed backward as well as forward since they are destitute of valves, and this would not be favorable to the circulation.

172. The Lungs aid the Heart to circulate the blood since when they expand and the air rushes into them, the blood as well is drawn toward the cavity of the chest, and when they contract, the blood tends to leave this region.

173. Does the elasticity of the arterial wall furnish any force to aid the heart? No. When the arteries contract as the pulse passes, it is the force of the heart that is doing it. When you open a door or gate that is closed by an elastic spring, it is the force furnished by you to the spring that shuts the door after you release your hold.

THE LYMPHATIC SYSTEM

174. How the Nourishment gets from the Blood into the Tissues. — We left the food and oxygen in the capillaries. How does it get out of them into the tissues? We found that the blood flows very slowly in the capillaries ($\frac{1}{30}$ of an inch per second), and that the capillary walls are very thin, being made of only the inner of the three coats that make the veins and arteries. Here, then, are two favorable conditions for giving up the nutrition (Fig. 96). We learned that the albumin, sugar, and fats were dissolved in the plasma, or liquid portion of the blood. The plasma passes through the thin capillary walls, carrying the food with it. When it gets outside the capillaries, it is next to the walls of the cells that make up the tissues. These spaces are called *lymph spaces*. Thus the lymph bathes the cells in the nutritious fluid, and the hungry cells absorb what they need.

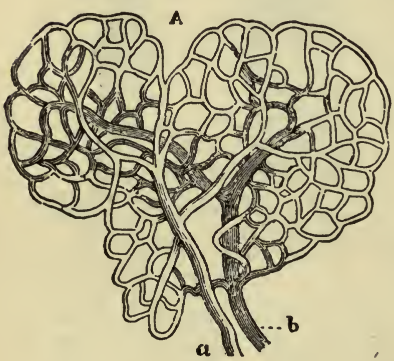


FIG. 96.

Capillaries connecting a small artery, *a*, with a small vein, *b*.

175. The red corpuscles bearing the oxygen cannot get through the capillary walls. Oxygen is a gas, however, and the walls of the capillaries are so thin that they offer no hindrance to the passage of the oxygen into the cells in the tissues. Carbon dioxid, which is one of the products of the combination of oxygen with the food material in the tissues, is also a gas, and it passes back through the capillary walls into the blood, which takes it back to the heart, and thence to the lungs to be sent out of the body.

176. Why cannot the capillaries themselves carry the food into the tissues? Because they are tubes, and as long as the food is in the blood it cannot reach the cells; the capillary walls prevent. The lymph spaces and the lymphatics act as middlemen between the blood and the cells (Fig. 97).

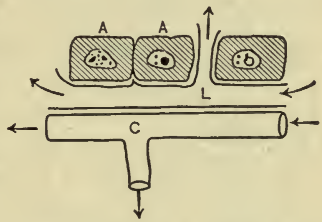


FIG. 97.— Diagram to show Function of Lymph.
A, tissue cells; C, capillary; L, lymphatic.

177. Necessity for the Lymphatic System.— If the plasma kept coming into the tissues without any way of getting back into the blood vessels, the blood would soon be lacking in plasma and the tissues would be oppressed with it. We see, then, the absolute necessity for some provision to get this liquid back into the blood vessels, from which it is constantly overflowing. This is done by a system of tubes called the *lymphatics* (Fig. 98).

178. What is lymph? The blood plasma is called lymph after it gets out of the capillaries. But it soon becomes changed by the addition of substances thrown out by the cells, and by giving up to the cells the digested food brought by the blood. We should have said also that the white blood corpuscles may pass out into the lymph, especially if there is some condition in the tissues that they can correct (Fig. 82).

179. We may say, then, that lymph is nearly the same as the blood without the red corpuscles. Did you ever see any lymph? Certainly you have seen it, many times. Whenever there is a blister in the skin from friction, or from a burn, the lymph collects. Sometimes when the skin is grazed, but no blood vessel touched, the lymph may exude.

180. The Origin and Course of the Lymphatics.—Unlike the blood vessels, the lymphatics, or the tubes which carry the lymph. have a beginning. The blood vessels do not begin, but make a never-ending circle. The lymphatics begin in open ends between the capillaries and the cells, or among the cells themselves (Fig. 97). It will be interesting to learn how they lead the lymph back to the circulation, and what makes it flow, for surely there is no heart for the lymph as there is for the blood. When the lymph once enters the open end of the lymphatic, it does not return to the blood, but continues to move slowly or at intervals through the lymphatics on its return to the blood system (Fig. 98). Small lymphatics come together and form larger ones. They continue to unite and form larger ones, until finally the lymphatics from nearly the entire body unite into one large tube, which passes up through the abdomen and thorax, and pours the lymph into the venous system beneath the collar bone near the neck. This largest of all lymphatics is called the *thoracic duct.*

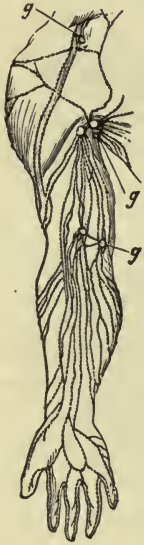


FIG. 98.—The larger Lymphatics of the Front of the Right Arm. *g*, lymphatic glands.

181. The Thoracic Duct is about the size of a goose quill, and empties into the venous system just where the large vein from the left side of the head (the left jugular vein) joins the large vein from the left arm (left subclavian vein) (Fig. 99). We said the lymphatics from nearly all over the body form the thoracic duct; but the lymphatics from the right arm and right side of the trunk and head form what is called the right lymphatic duct, which empties into the right subclavian vein just where the right jugular vein joins the latter (see Plates).

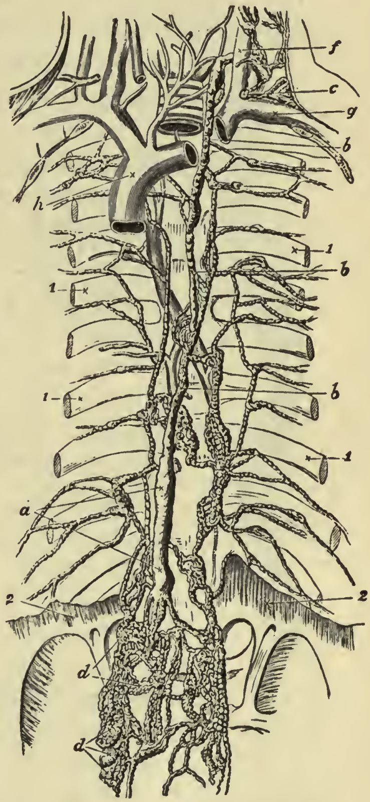


FIG. 99. — The Thoracic Duct.

1, part of ribs; *a*, receptaculum chyli; *b*, trunk of thoracic duct, opening at *c* into junction of left jugular (*f*) and left subclavian (*g*) veins. The connection of these veins with the superior vena cava (*h*) has been cut across to show the thoracic duct behind it; *d*, lymphatic glands in the lumbar regions.

182. What makes the Lymph flow? — Did we not learn that something besides the heart makes the blood flow? It is the contraction of the muscles and their consequent pressure upon the veins. The valves in the veins make this pressure effective by allowing the blood to be forced in only one direction. It is likewise found that the lymphatics have valves, and that they are more abundant than those of the veins. Whenever the muscles contract, the lymph is forced along, and the valves provide that no progress made shall be lost by any backward movement. Every pressure leaves a part of the lymphatic empty and ready to fill from behind (Fig. 100). Also, if the body is pressed upon or shaken, as when riding a trotting horse, or in a jolting vehicle, the lymph is moved beyond the valves at every jolt, and its circulation aided.

183. The secret of the powerful effect of muscular work upon the health lies chiefly in the great aid that it gives the lymphatic and venous circulations. The importance of an active lymphatic circulation is seen when we remember that the blood does not make its exchange directly with the cells of the tissues, but with the lymph, and the lymph makes the exchanges with the tissue cells.

FIG. 100. — A Full Lymphatic with its Valves distended.

184. The Lymphatic Glands. — Along the course of the lymphatics, numerous enlargements occur called lymph nodes or lymph glands (Fig. 101). They consist of a connective tissue framework, the meshes of which are crowded with lymph cells. The lymph in its course must filter through these clusters of cells, and, in doing so, is purified; for the node cells take up impurities in the lymph, and work over and change their nature. The cells in these nodes multiply, and some of them are taken up by the lymph and carried into the blood to become those remarkable little bodies, the white blood corpuscles. It is a curious fact that the older white corpuscles are broken up in the lymph nodes, and their remains are absorbed by the newly formed white corpuscles, just as the latter absorb germs and other foreign particles that may

FIG. 101. — Lymphatic Gland.

Showing valved lymphatics entering and leaving it.

enter the blood. The lymphatics penetrate and help in the nourishment of every tissue, even in that of the bony tissue (Fig. 102).

185. The Spleen.—This organ resembles the lymph nodes. It is purplish red, about five inches in length, and is situated just inside of the lower ribs on the left side of the abdomen. White corpuscles are formed in it as well as in the smaller lymph nodes. In it also the red corpuscles that have finished their service in the blood are probably broken up and destroyed.

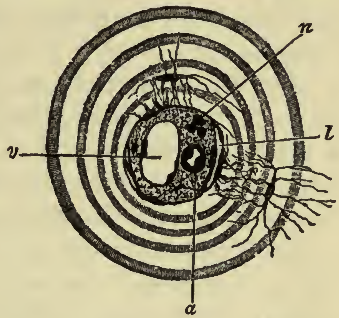


FIG. 102.—Section of a Haversian Canal, showing its Contents, highly magnified.

a, small arterial capillary vessel; *v*, large venous capillary; *n*, pale nerve fibers cut across; *l*, cleftlike lymphatic vessel; one of the cells forming its wall communicates by fine branches with the branches of a bone corpuscle.

HYGIENE OF THE CIRCULATION

186. Have you learned yet the curious fact that **all of the living cells of the body live under water**, just as the ameba does? The lymph and the blood are chiefly water and the cells are all bathed continually in one or the other. The blood bathes the cells in the walls of its vessels, and the lymph, or the blood without the red corpuscles, is found filling the interstices or spaces between the cells, like water in a sponge. From the spaces, as we learned, it is taken by the lymphatics in order to make room for fresh lymph, free from waste material and bringing fresh nourishment. The only exception to the rule that the cells live a watery existence, is found on the surface of the body; the cells of the outer skin, hair, and nails, however, may be called dying cells, for they are not alive in the same sense that the other cells are: they do not contain nuclei and cannot repair themselves or grow.

187. The supreme, the transcendent importance to the health of the tissues, of pure blood and **good circulation**, now becomes apparent. All that the cells need, in order to be sound and vigorous, is to have good food and oxygen brought within their reach, and to have the waste material, or products of combustion, removed; the circulation meets these needs.

188. When **unsoundness** occurs in any part of the body, there is a strong probability that the circulation there is defective. The hair is lost by cutting off the circulation from the scalp. The eyes may become inflamed, or the lids diseased, because of obstructing in the neck the return of the blood from the head; improper neck clothing or stiffened muscles may cause this obstruction. A corn grows on the toe because of the interruption of the circulation there, resulting from intermittent pressure of the upper leather of a tight shoe upon the toe as the foot lengthens and shortens at every step. Indigestion may result if vigorous mental or physical activity, just after eating, draws the blood away and prevents the secretion of the digestive fluids. Gout may occur from the deposit of waste materials in the spaces around the joints where the pressure from the circulation is least. Colds occur when the blood vessels in the walls of the air passages become congested or swollen with blood, and the vessels lose their tone so that they cannot contract and keep the blood moving onward.

189. **Pure Blood** is just as necessary as free and unimpeded circulation. We shall learn later how the digestive organs serve to furnish the nutrition, how the lungs furnish the oxygen, and how the skin, kidneys, and lungs remove from the blood the impurities and waste materials.

190. **Taking Cold.** — Sudden or prolonged exposure to cold while the muscles are inactive, so stimulates the surface blood vessels through the vasomotor nerves that they become tightly contracted and send the blood to the interior of the body. It accumulates there and may cause such congestion of the mucous membrane of the nose, throat, windpipe, or lungs, that inflammation ensues. A cold is an inflammation of the mucous membrane of part of the air passages. Rapid cooling off from a heated condition, especially if one is in a profuse perspiration, may cause the same results; or, exposure to moderate but continuous cold without exercising may bring on a cold. Sitting on the damp ground, sitting with damp feet, sitting for a long time in a cool draught, or going thinly clad in cool weather, may cause a cold; only foolish persons think they are so hardened as to withstand such risks without injury. Persons who pay attention to their feelings and instincts can detect the beginning of any such derangement of the circulation, and prevent trouble by timely prudence.

191. A person may be in **the habit of coddling** himself by living in overheated rooms, or by wearing too warm clothing and by constant use of mufflers on going out; his surface nerves thus become so delicate and the blood vessels of the surface so relaxed, as to insure taking cold on every accidental or unavoidable exposure. A better plan is to keep the house cool, the thermometer standing at 65° or 70°, sleep with open windows, take cool baths, and keep warm when out of doors by walking or exercising briskly. Thus the blood vessels are toned up, the circulation is made vigorous and steady, and the person is better fitted to withstand the ordinary conditions of life without disease continually recurring owing to deranged or weak circulation. Any process of "hardening to cold" that is not accompanied by vigorous exercise, is a risk to the health.

192. The **reciprocal action** of the blood vessels of the skin and the internal organs is sometimes illustrated when a person drinks freely of cold water. There is a sudden breaking out of perspiration. Why is this? Certainly the water does not reach the skin so quickly. The cold in the interior stimulates the internal vessels to contraction and the blood is diverted to the unstimulated vessels of the skin, surrounding the sweat glands.

193. Effects of Unusual Exercise. — If a person has sedentary habits and has neglected active exercise for some time, the heart, as well as the other muscles, becomes weak. If such a person hurries to catch a train, or takes very rapid and trying exercise of any kind, he may bring on an unpleasant palpitation of the heart, which is a warning to desist at once. Violent exercise should not be taken until one has gradually led up to it.

194. Sleep and the Blood. — A person who loses much sleep becomes pale; the paleness is evidence of a diminution in the number of red corpuscles. It is during sleep that the corpuscles that have been worn out during the day are replaced, but loss of sleep causes a greater loss to the blood than usual, with less than the usual opportunity for repair.

195. Mental Influences. — Rage excites and strains the heart. The unexpected receipt of joyful news sometimes so acts upon the heart through the emotions as to cause death. Thinking intently of an organ may cause an increase of the circulation in it.

196. Clothing. — The blood cannot circulate with perfect freedom unless the entire body is so loosely clothed that there is no pressure upon any of the blood vessels, no interference with the lungs as they expand, no pressure upon the stomach, liver, and intestines. Many of the largest veins, particularly those of the arms and legs, lie so near the surface that any tightness of the clothing is certain to diminish the flow of blood through them. Sleeve supporters and garters, if used at all, should be of weak elastic with adjustable buckle, and no tighter than is absolutely necessary. It is especially necessary to keep the extremities warmly clad and dry.

197. Effects of Alcohol upon the White Corpuscles. — Dr. Woodhead, of the University of Cambridge, says that the white corpuscles are injured by alcohol in the blood, and that they lose to some extent their activity in attacking poisons and germs of disease. This gives an explanation of the susceptibility of drinking men to germ diseases. Persons accustomed to use alcohol are usually the first victims of cholera and of yellow fever; while some abstainers, under constant exposure, remain untouched. The white corpuscles repair cuts and broken bones; hence intemperate persons do not recover from accidents and surgical operations as quickly as do total abstainers.

198. Effect of Alcohol upon the Red Corpuscles. — The red corpuscles carry the oxygen. When alcohol is freely taken, the red corpuscles are injured so that the blood loses in part its power to carry oxygen. The injury is to the red coloring matter of the corpuscles.

199. How the Heart may beat faster without expending More Strength. — Prof. Destreé says that increased action of the heart only appears to be a stimulation, and that alcohol is a narcotic (from the Greek *narkoun*, to benumb). Its effect on the heart is thus explained: The benumbing effect of the alcohol upon the constrictor nerves (§ 160) of the arterial walls, paralyzes these walls, allowing them and the capillaries to dilate, thus lessening the friction and reducing the blood pressure in the vessels. The heart keeps on exerting the same force from habit; and since it is pumping against less resistance, the same exertions of the heart suffice to make it pump faster for a time and send the blood over the body faster. When a dam is broken down, the water flows faster for a time; the force of the flow, however, is not supplied by the weakness of the dam in breaking down.

200. But Alcohol affects the Heart itself. — "The valves, which consist of folds of membrane, lose their suppleness and become diseased and weakened. The muscular fiber of the heart is replaced by fatty cells, so that the power of contraction is greatly reduced. These derangements are likely to cause death from sudden failure of the heart itself, or from rupture of the weakened blood vessels, and oozing of the blood in the brain, producing apoplexy" (G. H. McMichael, M.D.). The condition of the heart mentioned above is called fatty degeneration of the heart.

201. Hemorrhage is a flow of blood from an injured blood vessel. When the wound is slight, the clotting of the blood stops the flow. Clotting is rapid in the blood of healthy persons and slow in the blood of poorly nourished persons. Blood does not spurt from a cut vein but flows in a slow stream. When an artery is cut, the blood comes forth in a jet, with stronger spurts at each throb of the heart. In a large artery the pressure is so strong that it forces away the clot as fast as it is formed, so that death may result from loss of blood.

202. Tobacco Heart, or Trotting Heart. — Tobacco, unlike alcohol, does not dilate the blood vessels of the skin; tobacco users are often pale from want of blood in the skin. We thus see why tobacco users develop a stronger craving for drink than non-users, because the alcohol has, in some respects, an effect opposite to that of tobacco. However, heart action is temporarily increased when tobacco is used. In the present chapter you learned that the sympathetic nerves increase the heart action and the vagus nerves hold it in check. The vagus is partially paralyzed by tobacco, and the heart beats with more force, thus exhausting itself. The pulse of the habitual user shows unmistakably the injury done to the heart. It loses the firm steady beat of health and becomes irregular. Most of the time its beat is feeble, but for a short period its beat may be rapid and palpitating. This condition is known to physicians as the "tobacco heart." The short period of palpitation has caused it to be named in England, the "trotting heart." Physicians who have made a special study of the subject, claim that one out of every four tobacco users has the tobacco heart. It prevents success in athletic contests and feats of strength. It prevented a large proportion of the young men who applied for enlistment, during the recent war with Spain, from entering the army. Knowing the paramount importance to sound health of rich blood and perfect circulation, we are not surprised to know that the whole body is enfeebled by tobacco, and that mental as well as physical vigor is impaired. Observant teachers can often tell which of the boys in school are addicted to the use of tobacco from the comparative inferiority of their appearance and from their indolence of body and mind.

203. THOUGHT LESSON. **Comparison of Arteries and Veins.** — (If this is made a written exercise, underline the words which you supply.)

Walls. — The walls of the —— are very elastic, while the walls of the —— are slightly elastic. The walls of the —— are thicker and stiffer than the walls of the ——. It is necessary that they should be so, because they must sustain the —— of the ——.

Work of each. — The arteries take pure blood from the —— to the ——, and impure blood from the —— to the ——. The veins take pure blood from the —— to the ——, and impure blood from the —— to the ——.

Connections at heart. — The —— are connected with the auricles. The —— are connected with the ventricles.

Rate of flow. — The blood flows more rapidly in the ——.

Manner of flow. — The blood in the —— flows uniformly. The blood in the —— flows ——.

Control of flow. — The —— are abundantly supplied with ——. The —— have none.

Location. — The arteries as a general rule are located ——. The veins are generally located ——. This adds to the —— of the body.

Definitions. — The arteries are tubes that carry blood (both pure and impure) to the ——.

The veins are tubes that carry blood (both pure and impure) from the ——.

Accidents. — If an artery is cut, the pressure is to be applied —— the cut and the ——. If a vein is cut, the pressure is to be applied —— the cut. A cut vein may be told from a cut artery in the three following ways: —

204. Activity is the most necessary condition for the health of a cell. In every cell is found matter in three conditions: that which is actually living, that which was recently living, and that which is about to live by being transformed in the cell. The transformation from lifeless to living, and from living to dead, and the removal of dead matter must go on promptly. Anything which interferes with this activity interferes with the health of the cells. When life is natural and complete, all the organs are given work to do and are healthy, active, and strong; there is a feeling of buoyant happiness, the mind is clear, the will is firm, and the man truly lives.

APPLIED PHYSIOLOGY

EXERCISE I

1. The main arteries run down the middle of each limb close to the bone on the side toward which the limb bends. Why do they have this position?

2. Where is the thickest wall of the heart? (See Fig. 85.) Why? The thinnest walls? Why?

3. Why do we need warmer covering when asleep than awake?

4. When would it be pleasant to throw off a coat or cloak, but imprudent to do so?

5. If the clothing has been accidentally wet and the wet garments cannot be changed for dry ones at once, how can one **keep up a good circulation** to prevent taking cold?

6. Why does the toper have a **red nose?**

7. When cold air strikes it, why does the face first **blanch** and then **flush** (§§ 156, 160)?

8. When a person is **warm-hearted** in the usual sense of the term, is it also true physiologically?

9. What is the origin of the term "**blue-blooded aristocracy**"? When do dark veins in the wrist show most plainly? Of what is dark blood in the body in general a sign?

10. Why does a hot foot-bath sometimes **relieve a headache?** Why should it relieve a cold in the head?

EXERCISE II

11. **Tight clothing** at the waist may cause too much blood in what parts? Does it tend to make the circulation sluggish or active?

12. Which is more compressible, a vein or an artery? Does **a tight garter** interfere more with the flow of blood to the feet or from the feet?

13. Why are **varicose veins** so often found in the lower leg?

14. Why may a sluggish circulation through full veins in the feet as well as want of blood in the feet cause them **to be cold**?

15. Why are **students** very likely to have cold feet?

16. Why does the body of a person dying by drowning or strangulation **turn blue?**

17. What would you do in the case **of a severe wound** in the absence of a surgeon?

18. What is the object of **a collar?** Why is it therefore not necessary to have the collar as high in front as behind? Why is it unhealthful to have it so? What is the **purpose of a cuff?**

19. What is the most serious injury of **alcohol** to the **blood?**

20. In what part of the circulation does the so-called venous **blood** flow through arteries?

EXERCISE III

21. Show how life comes by death (§ 204).

22. Can any physiological basis be given for the claims **of patent medicine** venders that their nostrums "purify the blood"?

23. What vein **begins and ends** with capillaries (Fig. 89)?

24. What artery takes arterial blood to an organ where it is **still further purified,** yet is called venous blood when it leaves the organ?

(As it leaves that organ the blood is the purest in the body.) (See Plate V.)

25. How does **alcohol interfere** with the process of oxidation?

26. What keeps the blood in circulation **between the beats** of the heart?

27. What are the functions of the **capillaries?**

28. Why does a cool draft **in the house** cause a cold quicker than a cool wind out of doors?

29. Why do we perspire freely after drinking freely of **cold** water?

30. How can an extensive burn cause death by **congestion** of the lungs?

31. What causes the difference between the **hard hand** of the blacksmith and the soft hand of the clerk?

32. Why does rubbing **wear out the leather** of the shoe, but the friction of the shoe upon the toe cause the skin to grow thicker and to form **a corn**(§ 188)?

33. What is the effect upon the circulation of traveling upon the cars or in a vehicle?

CHAPTER IX

THE MUSCLES

205. It has been learned that motion is one of the physiological properties of protoplasm, along with sensibility and the power of assimilating food. The white blood cells have a distinct motion, and certain cells that line the windpipe and other air passages are able to contract and wave their cilia, or hairlike appendages, to and fro. With these two exceptions, the muscle cells are the only cells of the body that have a marked power of contracting and producing motion. As feeling or perceiving through the nerves, and moving or exerting energy through the muscles, seem to be the two chief purposes of the organism, we see how important the muscles are for the purposes of life. The body has been compared to a steam engine but the only object of an engine is to set free energy.

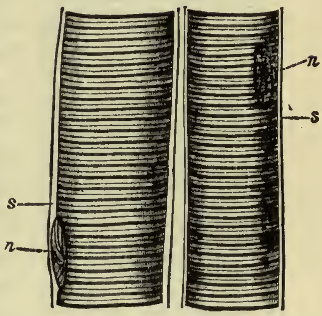


FIG. 103. — A Portion of Two Striated Muscle Fibers, highly magnified.

n, nucleus.

206. Kinds of Muscles. — Muscular tissue occurs in nearly every organ. We found that it helps to form the walls of the blood vessels, and assists in the circulation of the blood; the eyeballs are moved by six sets of muscles; the act of swallowing is performed by muscular contraction in the gullet; the contraction of the muscles in the walls of the stomach produces the motion by which the food is mixed; in the intestines the muscles keep the partly digested food in motion; the muscles in the limbs enable us to move and work; the heart is chiefly muscle; the muscles in the chest and trunk enable us to breathe; those in the larynx are used in talking. Muscles have been divided into two classes, *voluntary* and *involuntary*. The first class is under the control of the will, either at all times or part of the time: the second is never under the control of the will; their work goes on quite independently of the will and even during sleep. Can you assign to their proper classes the muscles that have been named in this paragraph?

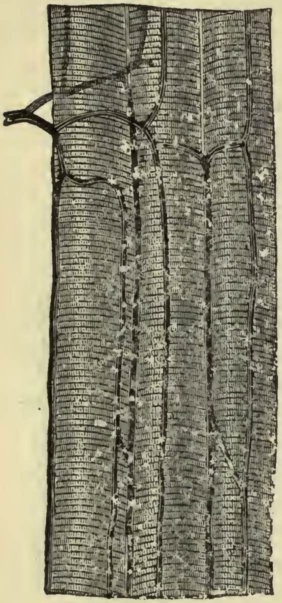


FIG. 104.—A Portion of Three Striated Muscle Fibers, moderately magnified.

Showing the capillary vessels (dark).

207. Structure of Muscles.—In studying the master tissues we studied muscular tissue in general, and learned how a muscle is able to shorten. The contraction of a muscle is caused by the contraction of the individual fiber-cells which compose it. Each fiber shortens in length and becomes proportionally thicker; the sum total of the contractions of these fiber-cells taking place at the same time, makes up the contraction of the whole muscle. The number of fibers lying side by side determines the thickness of the muscle, and the amount of strength with which it can contract; while the number of fibers lying end to end determines the amount of shortening or contraction of which the muscle is capable. When a muscle is habitually used, it becomes larger, firmer, darker, and stronger.

208. Voluntary and involuntary muscles are not constructed exactly alike. Examined under the microscope, each fiber of a **voluntary muscle** shows bright bands alternating with dark bands, running across it (Fig. 103). These bands give the whole muscle a striated or striped appearance under the microscope, hence this kind of muscle is called *striated muscle* (Fig. 104). The fibers are bound together by connective tissue into bundles called *fascicles* and these again into larger bundles. The connective tissue surrounding the bundles can be plainly seen in chipped beef, also in fresh beef and boiled beef. The voluntary muscles are darker red than the involuntary. Lean meat is made up of these muscles. They are near the surface, but their outlines under the skin are obscured to a greater or less degree in different persons, according to the thickness of the layer of fat between the muscles and the skin. These muscles are usually attached to bones. They contract quickly, while the involuntary muscles contract slowly.

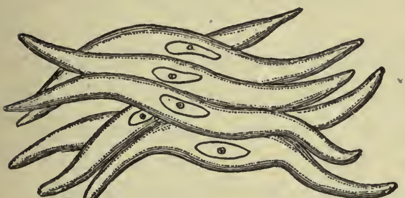


FIG. 105. — Fibers of Non-striated Muscles, or Involuntary Muscles.

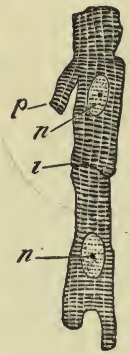


FIG. 106. — Two Cardiac Muscle Fibers.

n, nucleus; *l*, line of junction between the two cells; *p*, process joining a similar process of another cell. (Magnified 400 diameters.)

209. Involuntary Muscles are found in the walls of the alimentary canal, the bladder, the gullet and several other organs; all such muscles are composed of fibers which are not striated, and are, therefore, called plain muscle fibers. A striated fiber is about one inch in length and $\frac{1}{500}$ of an inch in thickness and is shaped somewhat like a cylinder; it possesses several nuclei. A plain muscle fiber is not more than $\frac{1}{400}$ of an inch in length, has the form of a very slender spindle, and contains one nucleus (Figs. 27, 105). The fibers interlace and are held together by fine connective tissue to make the hollow, slow, involuntary muscles.

210. Cardiac Muscular Tissue, of which the heart consists, differs from both striated and plain muscular tissue (Fig. 106). Its fibers possess one nucleus, like plain fibers; they are not spindle-shaped and narrow, however, but broader and cylindrical. They are, moreover, faintly cross-striated by light and dark bands. We may say, therefore, that although the heart is in every respect an involuntary muscle, it has more resemblance to striated than to plain muscle. The many muscles used in breathing are at times voluntary, and at other times involuntary; but they are all striated muscles with the usual structure.

211. Thought Lesson. **Effects of Unhygienic Shoes.** —

Fig. 107. — A Natural Foot.

1. What the faults of shoes may be (in shape, size, sole, heel, toe, and instep).

2. Deformities resulting to foot (skin of foot, nails, joints, arch, instep, and ankle).

3. Effects of improper shoes on habits of life.

4. Effect on particular organs or functions.

5. Gain and loss to personal appearance from wearing improper shoes.

6. Effect on mind and disposition.

7. If a shoe is too loose, it slips up and down at the heel and chafes the skin there. If too tight, there is pressure on the toes, which causes a corn or ingrowing nail. Have your shoes been correct or have they been too loose or too tight? What proportion of people wear shoes that are too tight?

FIG. 108. — A Deformed Foot in an Unhygienic Shoe.

FIG. 109. — The Natural Shape of the Sole.

FIG. 110. — Showing the Toes unduly crowded, with Corns, caused by Tight Shoes.

FIG. 111.— The Track made by a Natural Foot. Make a test by wetting your bare foot and noticing the track made upon the floor.

FIG. 112. — The Track made by a Foot in which the Natural Arch has been partly broken down by Tight Shoes.

If the arch breaks down entirely the foot is called "flat foot."

FIG. 113. — Sole of Foot.

Showing some of the muscles and tendons that bend the toes.

8. How many sprained ankles have you known of? Were the sufferers mostly boys or girls? Why?

Most people assume the following rule in selecting a shoe: If you can just draw on a shoe without much effort and sit with it on the foot for ten minutes, it will be comfortable to walk in and wear all day. Yet such a shoe is one size too small for walking. Many makers no longer number their shoes plainly because of the vanity of some purchasers. A new shoe should be as comfortable as an old one.

FIG. 114. — Skeleton of Foot. If the child never goes barefooted, the arch is likely to become flattened instead of high.

9. What is the general arrangement of the bones of the foot? Does the weight of the body come upon the middle of the arch? How can this arch be injured and what is such a deformity called?

10. Why is it that people who grow up in warm climates are more likely to have high arched insteps and elastic feet than those who pass their childhood in cold climates?

Persons who, because of silly jokes about big feet or for other reasons, have the idea that the shoe should leave no extra room, but should fit as if it were covering a wooden foot, will always get uncomfortable shoes.

212. THOUGHT LESSON. **Compare the voluntary and involuntary muscles** by writing in two columns headed, Voluntary Muscles and Involuntary Muscles, the facts concerning their Control, Structure, Color, Position in Body, Attachment, Rate of Contraction, Number of Nuclei, Length of Fibers, Breadth of Fibers, Shape of Fibers. (Place these titles in a third column.)

213. The Attachment of Muscles. — The involuntary muscles are usually tubular or hollow, and surround the internal organs. They are sometimes called the *visceral* *muscles* because the internal organs are called the *viscera.* The quicker, stronger-acting voluntary muscles are sometimes called the *skeletal muscles* because nearly all of them are attached to bones. Exceptions to this are the sphincter muscles or circular muscles that surround orifices, as the muscles that pucker the mouth and squint the eye. There are about five hundred voluntary muscles. By studying the figures you will notice that the middle portion of these muscles is usually large and full, and that the muscles taper to small cords at the ends (Fig. 113, etc.). The muscles of the calf move the foot, and the muscles of the forearm move the hand. If the full round muscles extended down over the wrists and ankles, it would make these as large around as the forearm or calf, and the wrists and ankles would be very clumsy and awkward. It is found that the connective tissue which binds the fibers of a muscle into bundles and forms sheaths for the bundles, extends beyond the muscular tissue and unites to form a dense, inelastic, glistening white cord called a *tendon* (Fig. 115). The fibers are very closely packed together and make a very strong cord. One no thicker than a lead pencil is strong enough to support twice the weight of the body. A tendon contains

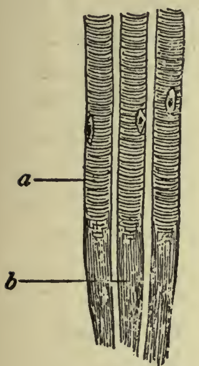


FIG. 115.—Striated Muscular Fibers (*a*), terminating in Tendon (*b*).

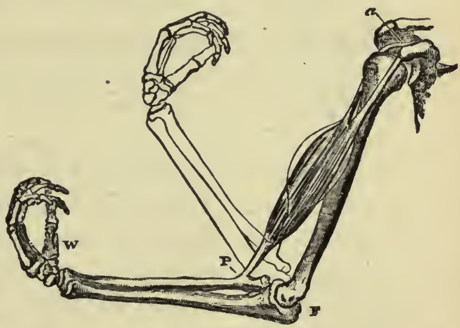


FIG. 116.—Diagram to show the Action of the Biceps Muscle of the Arm.

The two tendons by which the muscle is attached to the scapula are seen at *a*; *P*, the point of attachment of the muscle to the radius; *F*, the elbow joint; *W*, the weight of the hand.

no nerves and very few blood vessels. Some muscles have a tendon at only one end; some have no tendon but are attached directly to bones. Find muscles without tendons by studying the figures. The cordlike nature of tendons can be ascertained by feeling the tendons under the knees, called *hamstrings*, or the tendons in the angle of the elbow.

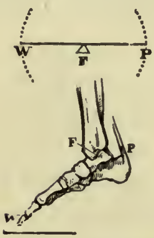


FIG. 117.— Tapping Floor with Toe.

Lever of first order.

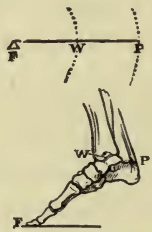


FIG. 118.— Raising Weight of Body upon Ankle.

Lever of second order.

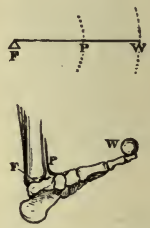


FIG. 119.— Raising a Weight upon Toes.

Lever of third order.

214. How Muscles and Bones Coöperate. — When you grasp a heavy weight in the hand and lift it by bending the elbow, where is the muscle that does the work? You will easily find it in the upper arm; this muscle is called the *biceps* because it is attached to the shoulder blade above by two tendons. The lower arm acts as a lever with the fulcrum, or fixed point of the lever, at the elbow (Fig. 116). It is easy to see that a slight contraction of the biceps muscle will move the weight a greater distance than is accounted for by the shortening caused by the actual contraction of the muscle. This is what the bones usually accomplish for the muscles; they change a slow, short, inadequate movement into a long, swift movement. While the muscle contracts an inch, the bone may move a foot. The bones thus add greatly to the range and rate of motion.

215. Figures 117, 118, and 119 show the three orders of levers. In the lever of the first order, the fulcrum (F) is between the power (P) and the weight (W). In the lever of the second order the weight is between the other two, and in the lever of the third order the power is between the others. In Fig. 116 the biceps muscle acts on the radius and ulna fastened together as one, turning at the elbow as a fulcrum; the weight to be lifted is in the hand. This is evidently a lever of the third order with the power between the other points. In this case it takes a force in the muscle equal to about six pounds to raise one pound in the hand.

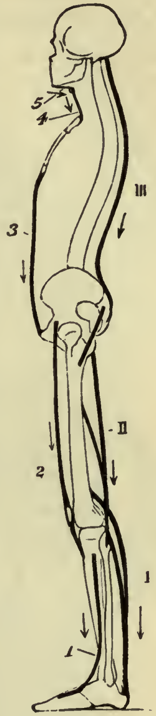


FIG. 120.—Diagram of the Muscles that keep the Body erect.

216. Figure 120 shows how the muscles may act as levers upon the bones to prevent the bones from turning upon the joints as fulcrums; thus the body is held erect. Where are the muscles located that keep the body from falling or bending forward (Fig. 120)? From falling backward? (Which of the two sets is in front?) What kind of lever is illustrated by the head tilted upon the atlas (Fig. 121)?

217. Names and Positions of Muscles.— A few of the important muscles are here mentioned: The *scalp muscle* (Fig. 122) passes over the top of the head; it raises the skin over the eyes, and (in some persons) moves the scalp. The two pairs of chewing muscles are the *temporal* and *masseter* (Fig. 122). You can feel the temporal muscle swell and harden if you place your finger on the temple and close your mouth forcibly. In the same manner you may feel the contraction of the masseter by placing the fingers just below the cheek bone. The muscle used in *bowing* passes obliquely down on the side of the neck to the collar bone (Fig. 124). It can be felt as a thick band; when the head is turned to one side, it stands out as a ridge. When one of the two acts alone, it turns the face so as to look to the other side. When both act they bow the head. The *deltoid* (Figs. 123, 124), or shoulder cap muscle, raises the whole arm outward and upward from the side. Can you locate it by the feeling of fatigue after raising the arm twenty times? The *biceps* can be seen and felt contracting on the front of the arm when bent at the elbow. The *triceps* is on the opposite side of the arm and straightens the elbow

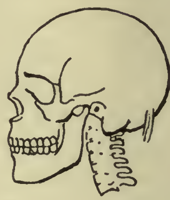


FIG. 121. — Head tilted upon Atlas.

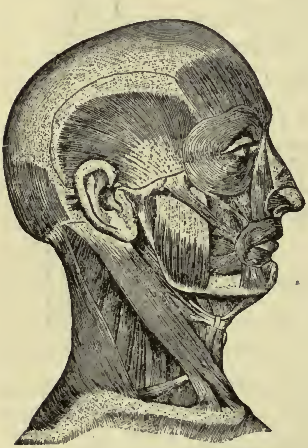


FIG. 122. — Muscles of Head and Neck. Find the following muscles: —

Chewing muscles; scalp muscles; bowing muscle of one side; muscle that holds head erect (upper part of trapezius at back of neck); muscle that squints the eye; muscle that pouts the lips; muscle that broadens the mouth in smiling; muscle that raises corners of mouth; muscle that draws down corner of mouth.

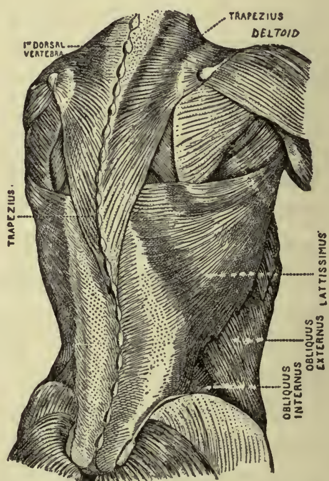


FIG. 123. — Principal Muscles of the Back.

Trapezius draws shoulder and head back; deltoid raises whole arm; latissimus, climbing muscle. Obliquus internus and obliquus externus draw abdominal wall in and force abdominal contents against the diaphragm, thus expelling air from lungs.

(Figs. 124, 125). Which is used in striking a blow, the biceps or the triceps?

218. The *sartorius* ("tailor") *muscle* (Fig. 126) is nearly two feet long and is the longest muscle in the body; it passes from the outer side of the hip bone to the inner side of the leg below the knee, and is used in crossing the leg; because of the position assumed by a tailor at work it is named the *tailor's muscle*. The *gastrocnemius* is a thick muscle in the calf of the leg, and raises the heel (Fig. 125). When is it used? It is attached to the heel by the largest tendon in the body, called the "tendon of Achilles." Ask the teacher why it is so called; or read the story of Achilles.

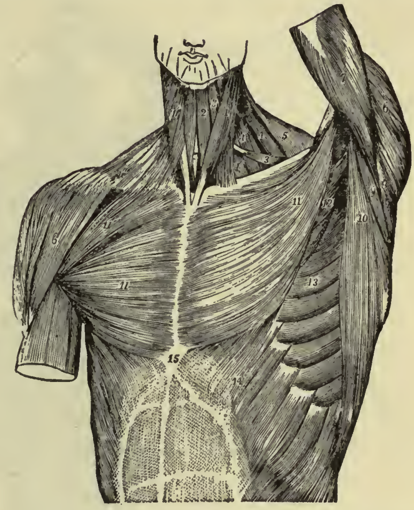


FIG. 124.—Superficial View of Muscles of Upper Part of Trunk, from the front. (Allen Thomson.)

1, sterno-mastoid of the left side; 5, trapezius; 6, deltoid; 7, upper part of triceps in the left arm; 10, latissimus dorsi; 11, pectoralis major; 11′, on the right side, its clavicular portion; 12, part of pectoralis minor; 13, serratus magnus; 14, external oblique muscle of the abdomen; 15, placed on the tip of the sternum.

219. The *trapezius* ("four-sided") (Figs. 123, 125) is a large muscle covering the back between the shoulders. It draws the shoulders back and holds up the head. Can you find the climbing muscle (Figs. 123, 124), or the muscle that draws the arm backward and downward (*latissimus* or "broadest")? When a person hangs by the hands, it helps to raise the body. It is a large spread-out muscle extending from the humerus to the vertebral column.

220. Each muscle has another muscle or other muscles that can undo the work done by it. Two muscles with opposite action or function are said to be antagonists. There is a great fan-shaped muscle called the *pectoralis* (11, Fig. 124)

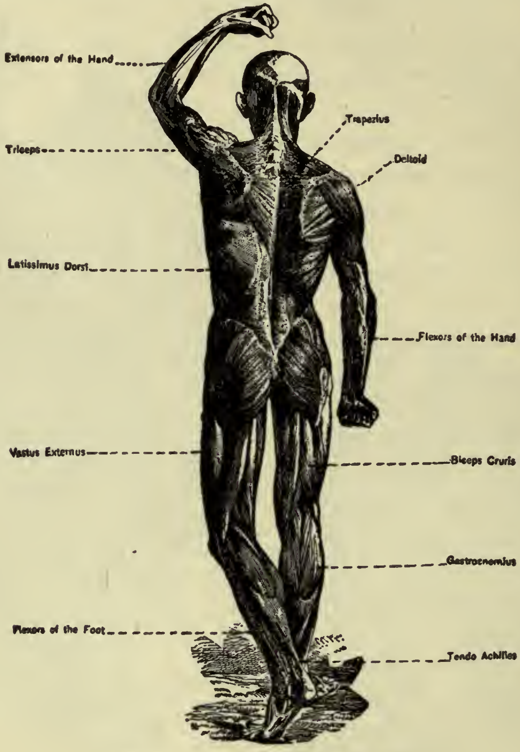


FIG. 125. — Full Figure Muscles (rear).

on the chest, extending from the sternum to the arm. It draws the arm downward and inward. This muscle is very large in birds and is used in flying. To what muscle is it an antagonist? Muscles that bend joints are called *flexors*. Those that straighten joints are called *extensors*. To which kind does the biceps belong? Which extensor muscle is its antagonist?

221. Muscles are named from: their *shape*, as deltoid (like the Greek letter delta, Δ; their *location*, as tibialis (near the tibia); their *action*, as flexors; their *manner of attachment*, as triceps (three-headed).

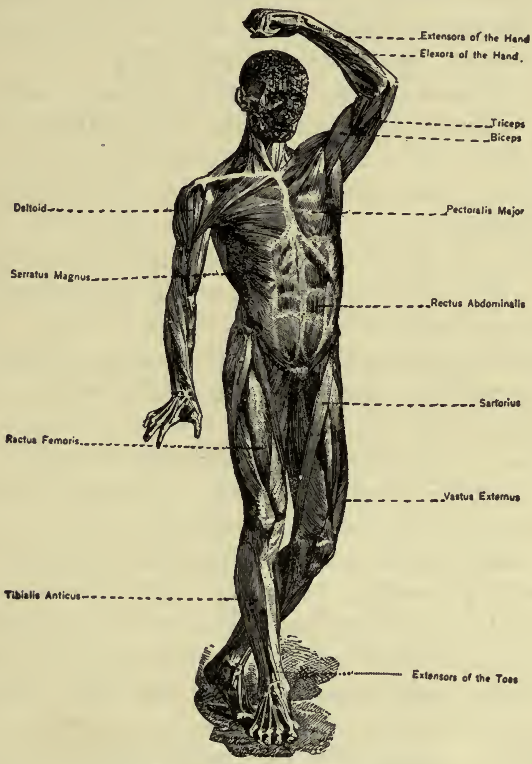


FIG. 126. — Full-figure Muscles (front).

222. THOUGHT LESSON. **Anatomy and Physiology of Muscles.** — By studying the figures, apply these four pairs of adjectives in their proper places in the lines below: long and round; thin and flat; short and narrow; broad and flat: —

1. The muscles of the face are —— and ——.
   The muscles of the cranium are —— and ——.

The muscles of the trunk are —— and ——.

The muscles of the limbs are —— and ——.

2. Grasp your arm above the elbow and bend it. What changes do you feel?

3. Span the biceps, holding tip of finger in elbow and thumb farther up the arm. About how many inches of its length does the biceps lose by contracting?

4. What muscles are attached to the bones without tendons? (Examine figures in book; also think of meat you have eaten.)

5. Why is round steak usually the toughest steak? the most nutritious?

6. Why is a fowl's leg dark meat although its breast is white? Why is a fowl's breast white and a dove's breast dark (§§ 207, 220)?

7. Why does practicing looking cross-eyed have a tendency to make one so? (Give effect on both nerve and muscle.)

8. Where are the muscles that bend the fingers?

9. Name the places in the body where the tendons can be most easily felt while the muscles are working.

223. How the Nerves and Muscles coöperate. — How many ways of exciting the contractility of a muscle have you learned? When the food enters the stomach, the mechanical stimulus starts impulses along the nerve to the ganglion, and reflex impulses cause the involuntary muscles in the walls of the stomach to contract. When we desire to make a certain movement, an impulse is sent from the brain along a nerve to the muscle which performs this movement. This impulse sets the muscle engine going somewhat as an electric current sent by pressing a button starts a bell to ringing or a machine to running.

224. The muscular tissue is composed chiefly of albuminous material. It has been found that increased muscular action, such as mountain climbing, hardly increases the amount of albuminous material (urea) excreted as waste. Such activity, however, does largely increase the amount of carbon dioxid given off. It is believed, therefore, that our energy is largely derived from starches and sugars (carbohydrates) and fats. The fact that beasts of burden depend chiefly upon carbohydrate foods strengthens this view. That muscles use sugar in their action is indicated by the fact that the arteries take more sugar to the muscles than is carried away from them by the veins.

225. The nerve impulse reaching the muscle causes it to contract. This takes about $\frac{1}{20}$ of a second. It would relax in $\frac{1}{20}$ of a second also, and it can be kept in a state of contraction only by successive impulses, usually about 10 per second. Thus it remains in a tremulous state of contraction. The vibrations may become apparent during excitement, or when a great effort is being made. If a muscle contracts continuously for a long time, a time comes when it can no longer be made to contract, not even by an electric stimulus, but it becomes soft and relaxed. What is the cause of this? Are the oxygen and sugar and fat all combined and changed into carbon dioxid? Or, as we say, is the strength all used up? No, it is found that if the carbon dioxid is allowed to escape but no fresh blood allowed to come, the muscle can be made to contract again. This shows that the accumulation of the carbon dioxid gas and perhaps some acids besides, prevent the nerve stimulus from having effect. The paralysis and aching of extreme fatigue are thus caused. It is a very beneficent thing that a healthy person undisturbed by poisonous drugs or stimulants can never use up all his strength. A man may have been ill for weeks, yet when delirious, and stimulated by the poisons formed in the course of the disease, he proves that he still has strength enough to overpower several strong men.

226. Coördination of Several Muscles. — Would you like to see two persons try to thread a needle, one holding the thread and the other the needle? Would they succeed well? Or in so simple a matter as the use of the knife and fork in eating, could it be easily done if one holds the piece of meat with the fork while the other tries to cut it? Why is it that the right hands of two persons cannot work so well together as the right and left hands of one person? It is because of the nervous connection between the hands of the same person, so that one hand knows just what the other is doing. Let us think of what takes place in our bodies when we throw a stone at a mark. At the same time we see the mark, hold the stone in the hand and throw it. In throwing a stone, at least a dozen muscles are used. Each one of these must contract at the right time and in the right way, or the stone will miss the mark. Each muscle shortens under the influence of a nerve impulse brought from the brain by a motor nerve. If one muscle shortens an instant too soon, or a little too much, the stone goes to one side. This working together of the muscles by the aid of the nerves is called *coördination*. Coördination is necessary, even in standing erect.

227. Nerve Expenditure. — It is found that the use of many small muscles is much more exhausting than the use of a few larger ones. This is on account of the nerve energy consumed. A drummer beating a big bass drum may do more muscular work than one who plays a tune softly on the piano, but the piano playing exhausts the performer much sooner. This is because the movements of the wrist and fingers employ thirty muscles and a great number of nerves. The striking of the keys with the ends of the fingers where some of the most sensitive nerves of the body terminate, may have some effect also, and may help to explain why so many persons, especially young ladies, who take little other exercise, have become nervous wrecks from piano playing. The typewriter has one of the objections named above, but it has the advantage over the pen of giving some variety of motion compared to the monotonous use of the same muscles in penmanship.

228. Habitual Over-expenditure of Nervous and Muscular Energy. — The fact that the muscles are arranged in pairs as antagonists of each other may have a calamitous effect in the case of persons with ill-regulated nervous systems. Such persons, on account of anxiety or worry, doubt, or overactive desire, keep their muscles drawn tense, the antagonists pulling against each other, and after awhile they lose the power of relaxing their muscles. They wear anxious expressions, because the muscles of the face are never relaxed or in repose. Their movements are nervous and jerky instead of graceful and easy. Their breathing is not deep and natural, because the breathing muscles pull against each other, and their voices, therefore, are not even and steady. They cannot be perfectly still, but chew gum or a pencil, rock the chair, pull the mustache, etc. Do you know of any of your friends who are handicapped by this condition of over-tension? When such people listen to a sermon their backs get tired because they cannot relax comfortably to the seat and use their ears only while listening. When they lie down, they try to hold the body on the bed, and they keep the muscles of the neck tense as if trying to hold the head on the shoulders. Such persons should lie down for ten minutes twice a day and have an assistant make a test to ascertain whether they are thoroughly relaxed; let the assistant lift one arm and see whether it will drop as if lifeless when released, or fall like a rope when flung to one side; let him find out also whether the head is relaxed on the shoulders.

229. Over-tension is common to adults in cold climates, but is also known in warm climates. A graceful person, like a child, uses just the muscles necessary for any act, and no more. Ease of manner, as well as health, make important the correction of conditions to which all hurrying, ambitious persons are liable in an age of keen competition and of ambition for learning and distinction. Above all, repose of spirit and contentment of mind bring grace and ease of body.

230. Muscular Tone. — That the muscles may be always ready for use, they must not be entirely soft and flabby, but under a condition of very slight contraction called *tone*. We find that the muscular walls of the blood vessels possess tone. It is this condition of slight contraction which causes a wound in the flesh to gape open. If a tendon is cut, the muscle shortens on account of its tone. If the nerve going to the muscle is cut, the muscle lengthens a little, that is, it relaxes, showing that there must be faint but constant impulses coming through the nerve to keep the muscle in tone. When one is asleep the body does not lie perfectly straight, but the joints are slightly bent to allow relaxation.

231. THOUGHT LESSON. **Physiology of the Circulation.** — 1. What do you notice after muscular exercise that leads you to think that it makes the blood flow faster?

2. What must be the effect in a vein when a contracting muscle presses upon it? Why does this aid the blood-flow in only one direction?

3. What shows that exercise lessens the work of the heart?

4. Why is standing still more tiresome than walking?

5. Why is there need for valves in the veins (§ 167)?

6. Why is the activity of the kidneys greater in winter than in summer, while with the skin the reverse is true (§ 417)?

232. Physiological Effects of Muscular Activity. — It has been explained how, during exercise, each muscle becomes, as it were, a throbbing heart, squeezing the blood tubes empty while contracting, and then relaxing and allowing them to fill up anew. This pumping is done by the pressure of the thickened muscle fibers on the veins, the flow being controlled by the valves. It has been actually observed that the quantity of blood flowing through one of a horse's muscles used in eating, was three times as great when the animal was engaged in chewing oats as when the muscle was at rest. This powerful effect upon the circulation causes renewed nutriment to reach every neighboring organ and tissue, and the waste material to be removed. Through the effects of exercise upon the circulation, the body is thus purified and made sound and strong (Fig. 128).

233. An Aid to the Memory. — In tracing the effect of muscular work upon the different organs, let us take them in the order in which the organs are located in the body. Let us go in order from the outer organs to the deeper ones, viz: skin, fat, muscles, skeleton, viscera. The viscera will then be taken in order, beginning with the highest, viz: brain, lungs, heart, digestive organs, and lastly, general effects. By using this fixed order, all can be called to mind without omission. It is recommended to the pupil that he group other series of topics in his memory in the same way, thus keeping the mental eye upon the body instead of upon the pages of the book.

234. The Nine Effects of Muscular Exercise enumerated in order are as follows: —

1. *The Skin.* — It opens the pores of the skin with perspiration, fills the capillaries with fresh blood, and improves the complexion by making the skin fresh, pink, and smooth.

2. *The Fat.* — In cases of undue accumulation of fat, the fat is burned up, and in cases of too great leanness, muscular exercise, by means of improved digestion and circulation causes the fat to increase to the proper amount.

3. *The Muscles.* — Muscles affect themselves through the improved circulation, and even the weakest and

thinnest muscles will grow large and strong, and the flabbiest muscles will acquire a healthy tone, through regular use. The condition of an arm carried in a sling is an illustration of the effects of disuse.

4. *The Skeleton.* — The bones are better nourished, but the chief benefit of exercise to them comes through the improved strength and tone of the muscles by which the bones are held in proper position. Thus deformed cartilages and stretched ligaments, with the accompanying round shoulders, flat chest, and spinal curvature are prevented. A person with good muscles sits, stands, and carries himself erect. One with weak muscles is apt to slouch down.

5. *The Brain.* — The aid given to the heart by the contraction of the muscles makes the blood bound forward in the vessels, and the pure fresh blood enables the brain to work with greater ease and pleasure. This fresh blood is still purer because of the increased expansion of the lungs.

6. *The Lungs.* — Gentle and slow exercise has little effect upon the lungs, but rapid and vigorous exercise expands them till every nook and cell is filled, and the chest is developed and enlarged. A good-sized chest is very necessary to good health.

7. *The Heart.* —The heart is aided in its work, as already pointed out. Long-continued exercise puts more demands upon the heart, which becomes strong with the rest of the muscles. With people who take no exercise, the heart cannot be said to become flabby, but it may become weak, just as any other muscle.

8. *The Digestive Organs.* — Exercise gives a good appetite and prevents trouble in the stomach and clogging of the intestines from which lazy people are apt to suffer.

9. *General Effects.* — It promotes good humor, prevents vice and dissipation, gives one the agreeable look of health and vigor. It is not the pitcher in the baseball team, or

the industrious son, that is most often found loafing in a back alley smoking cigarettes; and it is not the industrious, helpful daughter who is most often found with the "blues," or nursing a headache.

235. Heredity. — The disastrous effect upon the heart of a life of habitual muscular inactivity is apparent in the lives of many people. The disappearance of dyspepsia and many other diseases, with the remarkable restoration to health that follows judicious muscular exercise or physical labor, is likewise often seen. We have received our bodies as an inheritance from an ancestry which dates back at least to a time when the human race lived an active life in the open air. The human body is adapted to such conditions, and an attempt to change these conditions too rapidly, as in the case of city dwellers, causes extinction. The health and continuance of the race under conditions of city life are aided by the continual influx of healthy individuals from the country. In a human body weighing one hundred and fifty pounds, there are about sixty pounds of muscle, and we cannot neglect sixty pounds of tissue with impunity and allow it to become unsound from disuse (Fig. 126).

236. THOUGHT LESSON. **Position of the Voluntary Muscles.** — On Figs. 125 and 126 mark the location of the muscles having the functions named in the following list. Locate them first in your body by performing the action and feeling the muscle with your hand; then mark lightly with pencil. For instance, take question 4: locate the muscle that bends the elbow. This is found to be in the front of the upper arm, and the figure "4" placed on the dotted line drawn from that muscle.

Locate the muscle (or muscles) that —

1. Lifts the whole arm outward and upward.
2. Draws it downward and forward.
3. Draws it downward and backward.

4. Bends the elbow.
5. Straightens the elbow.
6. Bends the fingers.
7. Straightens the fingers.
8. Turns the head (Fig. 124).
9. Draws the shoulders back.
10. Bends the knee.
11. Straightens the knee.
12. Raises the toes.
13. Raises the body on the toes.
14. Crosses the legs.

237. Effect of Stimulants and Narcotics. —You learned that true fatty tissue is formed by the accumulation of oily material within the connective tissue cells (Fig. 38).

238. The weaker forms of alcohol, such as ale and beer, cause a change into fat of much of the albumin in muscle cells, thus bringing about a bloated and flabby condition, called *fatty degeneration.* It may even reach the heart, causing a dangerous disease called *fatty degeneration of the heart.* (There are other causes of fatty degeneration. If an athlete who has developed enormous muscles, suddenly ceases to train, his muscles may undergo fatty degeneration.) Through the narcotic or deadening effect of alcohol upon the nerves, they become less sensitive, and fatigue is not so readily perceived, so the drinker has a deceptive feeling of strength and power. It was found that two hours after taking two ounces of whisky mixed with eight ounces of water, the muscular strength of the man experimented on was reduced one third. This means that a lifting power of three hundred pounds was reduced to two hundred pounds. An old drunkard usually has a dragging gait and trembling hands. Coffee sometimes causes a twitching of the eyelids; this is a sign that the body is being poisoned.

239. Forms of Exercise. — It is best to choose a form of exercise or labor which you thoroughly enjoy. Most games are excellent kinds of exercise. **Baseball** and **football**, played in a sensible way, are admirable. Such games not only strengthen the muscles but also develop presence of mind, coolness, fearlessness, self-control, and other manly qualities. Men trained in such sports may often stop panics and save lives in cases of accidents, or in other emergencies. **Walking**, if not done too leisurely, is fine exercise. Americans probably make too much use of street cars. English women are noted as walkers, going many miles at a time, and in the cooler parts of the United States, and in cold weather in the Gulf states, this custom would be equally beneficial in preventing nervousness and weakness. **Running** is a still better exercise, but it should be begun gradually and with caution, so as to give heart and lungs opportunity to become strong enough to sustain the increased effort required of them. One should never run with the mouth open (§ *272*).

240. Boxing is fine exercise but should never be indulged in with the bare hands. Two pairs of boxing gloves may be said to contain a whole gymnasium. Boxing makes one sure and quick on his feet, trains the eye, keeps the body in an erect position, develops the arms, legs, and back, and teaches control of temper. **Wrestling** is equally beneficial, developing the "wind" and the muscles of the whole body. It should never be practiced in the house, unless in a gymnasium, and where there is ample space and no injurious objects to fall upon. Training in these manly arts will make one "less likely to pay serious attention to idle bluster, and less likely to quarrel; and it may prove valuable to know how to defend oneself from the attack of a ruffian, or bully, or drunken brute, or other infuriated animal."

241. Cycling when properly done is excellent exercise, but the cycler that gets a foolish notion of trying for speed (and most of them do) usually brings on the deformity of round shoulders.

242. Dancing, in itself, is said to be exhilarating exercise. As usually conducted, indoors instead of outdoors, prolonged to late hours, with overheating, and (in the case of ladies) sudden chilling from insufficient clothing in the region of the chest, this exercise has serious drawbacks, and often wrecks the health of the participants.

FIG. 127. — The Veins near the Surface on the Arm.

Nerves may be seen accompanying the veins. The fibrous sheaths covering most of the muscles have not been removed.

243. Curative Effects of Exercise. — "He who does not find time for exercise must find time for sickness" (Lord Derby). Many persons in declining health have insisted on doing nothing but taking the nauseous doses of patent medicines, or the drugs of physicians, but not their advice, and have died. But a little change in the habits of life, such as adding to their usually sedentary work a little gardening, or wood-cutting, or raising flowers, or horseback riding, or woodworking, or pedestrian excursions, would have restored them to health and enabled them to live to a happy old age.

244. Exercise and Mental Ability. — Most men who have been great workers with their minds have also been zealous in using their muscles. There is a flexibility of mind and disposition that results from a mixed occupation which is in great contrast with the machine-like dullness and narrowness of mind produced by a monotonous, one-sided occupation, whether mental or physical. Gladstone chopped down trees; Li Hung Chang walked three miles daily, around the courtyards of his palace, when eighty years old; Napoleon rode horseback; William Cullen Bryant, upon rising in the morning, swung a chair around his head, took wand exercise with a cane, and practiced other gymnastics. He walked five miles to his work. Talmage, when out for a walk in the park, would often run if there was no one in sight. Philip D. Armour, many times a millionaire, walked to his office while his clerks took the street car.

245. Over-development of Muscles. — As important as muscular exercise is for sending the blood bounding through the veins and renewing the health of every part, exercise can be overdone. Some athletes develop great, heavy muscles which are a burden to the vital organs to support. They do not take care to develop their lungs and breathing powers in proportion. Such athletes die young. Among those who have succumbed to consumption may be mentioned Kehoe, the famous club swinger; Dowd, the teacher of physical culture; "Jap," the wrestler; Winship, the inventor of the health lift; Kennedy, the strong man; and Peter Jackson, the pugilist (§ 238). Complete living with conditions of health and activity for all the organs, without extreme use of any of them, is most conducive to a long and healthful life.

PROBLEMS AND QUESTIONS FOR REVIEW

1. In what part of the body are most of the involuntary muscles situated?

2. Name a muscle which is wholly involuntary.

3. Can you name any muscle which is wholly voluntary under all circumstances? To which class do the muscles that lift the eyelids belong?

4. Which muscle, anatomically, belongs strictly to neither class?

5. If a man had absolute control over his muscles of respiration, what might he do that he cannot now do?

6. Can the muscles act independently of the will in walking?

7. Do we shiver with the voluntary or involuntary muscles? Is trembling usually involuntary?

8. How many movable bones are there in the face? Name muscles attached to a movable bone of the face.

9. What purpose do most of the muscles of the face serve?

10. Why is one who uses alcoholic drinks not likely to be a good marksman?

11. Why should a youth who wishes to excel in athletic contests abstain from the use of tobacco?

12. What order of lever is the foot when a weight is lifted on the toes (Fig. 119)? What order of lever do we use when we lift the leg while sitting down?

13. Locate the three points of a lever when swinging the arm from the shoulder; when bending a finger; when tapping the ground with the toes (Fig. 117); when using the foot in walking (Fig. 118).

14. Why can we raise a heavier weight with the hand when lifting from the elbow than from the shoulder? (See Elementary Physics.)

15. Which bone is chiefly in motion when we are using a gimlet?

16. Why does using a muscle cause fatigue?

17. Why can we chew harder with the back teeth than the front ones? (See Physics.)

18. Why is it an advantage that the heel bone projects? That the bones of the limbs are enlarged at the joints?

APPLIED PHYSIOLOGY

EXERCISE I

1. Does **a few minutes' practice** in a gymnasium suffice for a day's exercise?

2. Is there **any relation** between the amount of bodily exertion necessary for a person's health and the amount of wealth he possesses?

3. It is said that an Indian often runs or trots **sixty miles per day,** and that he **rests his muscles without stopping** by running for a while chiefly with the hip joint and muscles of the thigh, then with the knee joint and muscles of the upper leg. Can you rest some of the running muscles while running?

4. Can you relax the chewing muscles so that the lower **jaw will swing loosely** when the head is shaken?

5. Can you **relax the muscles** of the forearm so that the hand will shake loosely on the wrist and the fingers in their sockets?

6. Can you **relax the whole arm** so that another person can move it as a flexible rope?

7. Which joints of the limbs **lock** and refuse to bend further when the limb is straightened?

8. Which muscles have become **useless** with most persons, although some can still use them (Fig. 122)?

9. The average man has **60 lbs. of muscle and 2 lbs. of brain**: one half of the blood goes through the muscles and one fifth goes through

the brain. What inference may you draw as to the kind of life we should lead?

10. What are the beneficial effects of **exercise** upon the functions of the **skin?**

11. Is a **slow formal walk** suitable exercise?

EXERCISE II

12. How can we best **prove** that we have admiration and respect for our wonderful bodies?

13. What part of the body has the least bone in proportion to the other organs? In what part of the skeleton is it most important to keep the muscular walls firm and strong in order to hold the internal organs in position?

14. Which of your legs do you use more than the other in walking? (The foot on that side is larger, as shown by the fit of the shoe.) If you were lost on a prairie, to which side would you turn while trying to go straight?

15. How does the fact that if the nerves on one side of the face are paralyzed the face will be drawn toward the other, illustrate muscular tone?

16. Why does a game of baseball on Saturday afternoon actually rest a tired plow boy?

17. What movements did you ever see **a cat** go through for **the sake of exercise?**

18. What animals have you ever seen **play? Stretch** themselves for exercise?

19. Why do you feel so **exhausted after a fright?**

20. How do you account for the origin of the mental state, which holds in practice if not in theory, that all physical labor is an unmitigated evil?

21. Do you know persons who seem to be possessed by what is called "the spirit of jerkiness"? How could they overcome it (§ 227)?

NOTES

1. **Thought, Exercise, and the Blood.** — Professor Angelo Mosso of Italy devised a large balance on which the human body can be so poised that a change in the distribution of blood can be detected at once. If the body lies perfectly balanced on the apparatus, it is evident that an additional supply of blood will cause the head to sink if the blood goes to the head, or the feet to go down if the flow is in the opposite direction. It is found that during study or mental work, the head

sinks in a very short time. Students balanced before and after written examinations, showed that the center of gravity had risen from $\frac{1}{16}$ inch to $2\frac{1}{2}$ inches. W. G. Anderson, director of the Yale Gymnasium, found that mere thought will send a supply of blood to parts of the body. A man perfectly balanced will find his feet sinking if he goes through leg gymnastics mentally but does not make the movements. The flow of blood to an exercised part is affected by the attitude of mind of the person exercising. If a man exercises in a listless, mechanical manner, the center of gravity is not changed to any extent; but when a man takes a series of movements in a conscious and highly volitional manner, the increase in the supply of blood to the arms or legs, according to the movements taken, is very noticeable. If two men exercise the arms and thorax, one standing before a looking-glass, the other not, the former will show a greater rise of the center of gravity than the other, or a richer supply of blood to the parts. The looking-glass aids him in concentrating his mind on the parts exercised. Dr. Anderson also finds that movements in which men take pleasure send blood more abundantly to parts than do movements which are not to their liking. These experiments furnish important conclusions as to the manner of taking exercise, and the kind of exercise to be taken in order to obtain the greatest benefit therefrom.

2. Unfortunately, the majority of human beings regard the necessity of sweating as a calamity; and to dodge sweating, to earn one's livelihood in some other way, seems to be the special aim of a growing multitude in all civilized lands. But sweating is a blessing in disguise. The Scripture maxim teaches us that if any will not work, neither shall he eat, — either from poverty or indigestion. Nature tells us, "They who will not earn an appetite, cannot digest," and further she says with equal emphasis, "He that will not work shall not sleep" (J. H. Kellogg).

3. **Effect of Exercise on Growth.** — Henry G. Beyer, M.D., reported observations on the growth of 188 naval cadets who took special systematic exercise, and compared it with the usual growth of cadets of the same age.

There was an increase in height of more than one inch above that which took place without the special exercise.

The increase in strength was five times as much as the normal increase.

There was an increase in weight of 77 pounds in the four years during which the observations were made.

There was an increase in lung capacity of 1.72 liters.

PART III. HOW THE BODY IS NOURISHED

CHAPTER X

THE RESPIRATION

246. Why Breathing Organs are needed. — Every cell in the body requires oxygen to enable it to do its appointed work. When the supply of oxygen stops, the activity of the cell ceases at once. If it is a muscle cell, motion can be generated in the muscle only by the union of oxygen with the contents of the cell. If it is a gland cell, it cannot do its work of secreting useful fluids without the help of oxygen, for the substances which the gland cell takes from the blood must be changed to form the secretion. If the cell is a brain cell, although it may not use as much as a muscle cell uses, oxygen is still indispensable. The oxidation that takes place in the various cells results in the formation of carbon dioxid and other waste products which would destroy the life of the cell if allowed to remain; these are removed from the body by the same organs that supply the oxygen.

247. What must be the Nature and Structure of a Breathing Organ? — It is obvious that in animals of large size with many tissues, the great majority of the living cells of the tissues must be buried deep away from the external surface. But even if deep-seated and away from the air, the living cells have the same need of oxygen as though near the surface. If oxygen is supplied to the blood, the latter conveys the oxygen to the cells; but it is seen that a very efficient organ is needed to supply the blood with oxygen sufficient for so many cells. The breathing apparatus varies in different animals; it usually consists of a device for exposing to the air a great amount of thin tissue, which is a specialized form of the outer skin of the animal (if the animal is not a land animal, the tissue is exposed to the water); the animal is further provided with means to keep up a current of air (or water) on the outside of this modified skin and a current of blood on the inside. In some small animals, as the ameba and the earthworm, the simple external body surface is sufficient for the purpose of breathing. But large animals with many deep-seated and inaccessible cells require an increase of surface, which is supplied by having the oxygen-absorbing surface inside of the body and by having it folded or provided with tubes or branches of the greatest degree of complexity. In man, it has been estimated that by the finer and finer division of the air sac, a pair of human lungs presents to the air a surface of at least one hundred square feet (or ten feet square). The remainder of the breathing apparatus consists of muscles for changing the air that is in contact with this great surface.

248. Definitions. — The passing of the air into the lungs is called *inspiration*, and the passing of the air out from the lungs is called *expiration.* The two together constitute *respiration*, or breathing.

249. Anatomy of the Respiratory Organs. — The air usually passes in at the nose and returns by the same way, except during talking or singing. If you look in your mouth with a mirror, you will see at the back part an arch which is the rear boundary line of the mouth. Just above the arch is likewise the limit for the back part of the nasal passages. The funnel-shaped cavity beyond, into which both the mouth and nasal passages open, is called the *pharynx* (*far′inks*), or throat. Below, two tubes open from the pharynx, one into the trachea (*trāk′e-a*) or windpipe, the other into the esophagus, or gullet. At the top of the trachea (Fig. 129) is the cartilaginous larynx, or voice box, and the opening from the throat is provided with a lid, the epiglottis, also consisting of cartilage. The larynx will be described more fully in treating of the voice; it may be felt as the Adam's apple. Just below it comes the trachea proper which is a tube about three fourths of an inch in diameter, and about four inches long (Fig. 129). It consists of hoops of cartilage which are not complete circles but are shaped somewhat like the letter C, being completed behind by nonstriated (involuntary) muscular tissue (Fig. 130), whose function is to draw the ends of the rings together at times, *e.g.* during coughing, and reduce the caliber of the tube. The function of the hoops of cartilage is to keep the windpipe open at all times. If it should collapse under pressure, life might be lost. These rings of cartilage may be felt in the neck.

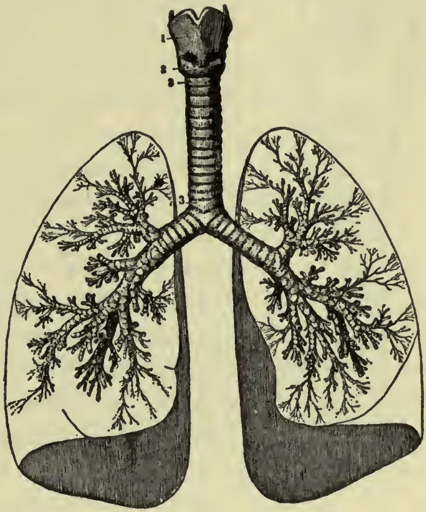


FIG. 128.

1, largest cartilage of larynx; 2, lowest cartilage of larynx; 3, 3, trachea; the divisions and subdivisions are the bronchi.

250. The lower end of the trachea is just behind the upper end of the sternum; and there it divides into two bronchi, called the *right bronchus* and the *left bronchus* (plural, *bronchi*) (Fig. 129). The bronchi subdivide into a great number of smaller branches, called *bronchial tubes.* Cartilage is found in the walls of all but the smallest of the tubes. The subdivision continues until the whole lung is penetrated by branches, all having the general name of bronchial tubes (Fig. 128). The smallest are only about $\frac{1}{75}$ of an inch in diameter. They ramify through the lungs, somewhat like the branching of a tree, each tiny tube finally ending in a wider funnel-shaped chamber called a *lobule* (Fig. 131), into which so many dilated sacs, called *air cells*, open that the walls of the terminal chamber, or lobule, may be said to consist of tiny cups, or air cells, placed side by side. (The word "cell" is here used in its original sense to denote a cavity or chamber, and not in the sense of a protoplasmic cell.)

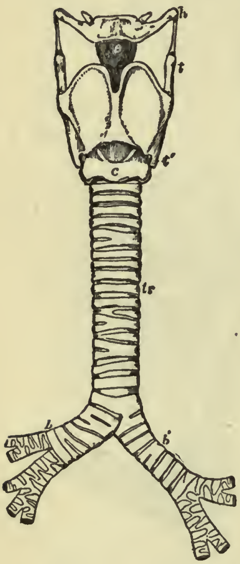


FIG. 129. — The Trachea (front).

h, hyoid bone; *t*, *t′*, thyroid cartilage; *c*, cricoid; *e*, epiglottis; *tr*, trachea; *b* and *b′*, bronchi.

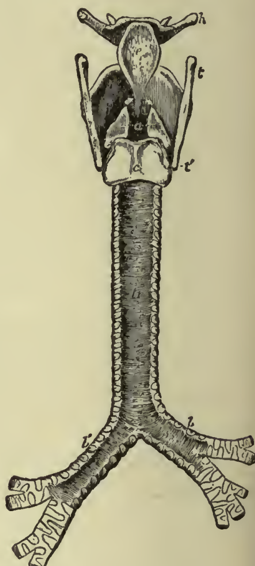


FIG. 130. — The Trachea (back).

a, arytenoid cartilages; *h*, hyoid bone; *t*, *t′*, thyroid cartilage; *c*, cricoid, *e*, epiglottis; *tr*, trachea; *b* and *b′*, bronchi.

251. The wall of an air cell consists of elastic connective tissue lined with a layer of very flat and thin epithelial cells (Fig. 132). This lining is continuous with the epithelial lining of the bronchial tubes. It is so thin as to offer almost no obstruction to the passage of oxygen out of the cell and the entrance of the carbon dioxid from the blood vessel (Fig. 133).

FIG. 131.—Two Lobules at the End of a Bronchial Tube.

252. Ciliated Cells.— It must be remembered that mucous membrane lines all cavities in the body accessible to the air. Almost all of the nose and pharynx, and all of the air passages as far as the lobules, are lined with a mucous membrane the cells of which are furnished with cilia (Fig. 134). These are minute hairlike filaments which are in constant motion. When a few of the cells are examined under a microscope, we may see the cilia in motion, even for a time after the removal of the cells from the body. They make a quick stroke upward, and move back more slowly, and this is found to give them the power of moving particles of dust which enter the lungs upward toward the larynx. Upon reaching the larynx, the dust brings about irritation which causes it to be coughed up. In the nasal passages, they serve a similar purpose. At the opening of the nostrils are also placed ordinary hairs (hundreds of times larger than cilia), which aid in cleaning the air of dust as it enters the nose.

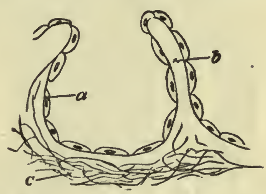


FIG. 132.—The Wall of an Air Cell.

a, the epithelium; *b*, partition between two air cells, in which the capillaries lie; *c*, fibers of elastic tissue.

253. The Blood Tubes in the Lungs. — Near where the trachea divides into the two bronchi, the pulmonary artery, bringing the dark blood to the lungs, divides into two branches, and the subdivision continues, until, finally, a network of capillaries is formed around each lobule, or cluster of air cells. These capillaries are the termination of the branches of the pulmonary artery, and the beginning of the pulmonary veins. It is here that the blood changes from a purplish red to a rosy red. A fine connective tissue holds together all these air cells and tubes.

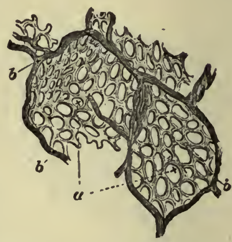


FIG. 133. — The Blood Vessels around Two Air Cells.

a, network of capillaries; *b*, small arteries and veins.

254. The Lungs Entire. — The entire cavity of the chest except the space occupied by the heart and a few of its blood vessels and the esophagus, is filled by the lungs and their coverings. The lungs are light pink in early life but become grayish and darker as age advances. This change is more marked in persons who dwell in large cities or where the atmosphere is smoky and dusty. The lungs, or a part of one, will float if thrown upon water. The right lung has three lobes, or divisions, and the left, two lobes. The lower end, or apex, of the heart hangs somewhat to the left, diminishing the space for the left lung. The general substance of the lungs consists of bronchial tubes, blood vessels, lymphatics, and air cells, as above described, the air cells being chiefly near the surface.

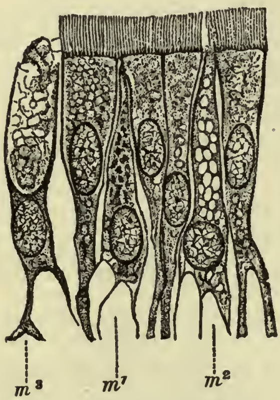


FIG. 134. — Ciliated Cells from the Trachea of a Rabbit, highly magnified.

m, m, m, mucous cells in various stages of secreting mucus.

255. The Pleuras. — The surface of the lungs is not in contact with the chest wall. Imagine a closed bag or sac made of thin membrane lining the whole of the chest. Now imagine another closed sac a little smaller, that is inside of, and lining, the first one. Next imagine the lungs to be found inside the inner sac. Here we have the lungs within the two membranes, called the *pleuras*. The heart is in the chest, but is not inclosed by the pleuras. It is in a deep indentation in the lower surface, such as you might make in a paper bag by pressing your fist up into the bottom without breaking the bag.

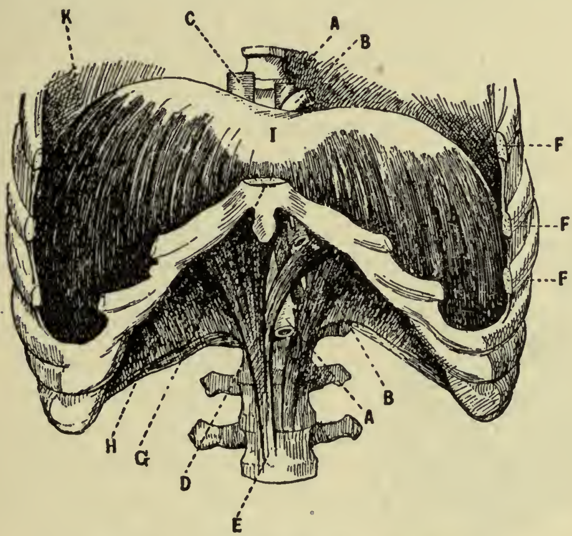


FIG. 135. — The Dome-shaped Diaphragm.

A, aorta; *B*, esophagus; *C*, vena cava inferior; *D*, muscular pillars of the diaphragm arising from the spinal column *E*; *F*, ribs, and *G*, sternum, sawed through so as to allow removal of the front of the thorax; *H*, hind, and *K*, front, muscular sheet, and *I*, central tendinous part of diaphragm.

256. Use of the Pleuras. — The outer pleura lines the chest wall, the inner pleura covers the lungs. The two membranes form between them a closed sac, a serous cavity which is air-tight and aids the lungs in following the chest wall without friction when the chest expands. The two pleural surfaces are in contact, and secrete just enough fluid to enable them to glide smoothly upon each other.

But for the pleura there would be friction between the lungs and the chest walls.

257. The Diaphragm (Fig. 135). — The floor of the chest cavity is formed by a muscle that is the broadest in the body, and also the thinnest in proportion to its width. It is called the *diaphragm*. It rounds up under the concave base of the lungs somewhat like a dome and separates the thoracic and abdominal cavities. It is attached to the lowest ribs at the sides and to the lumbar vertebræ behind (Fig. 135). Its rounded side is turned toward the chest, and its hollow side toward the abdomen. It is the most important muscle of the respiratory system. When it contracts, it flattens and descends, and the lungs descend with it, thus lengthening and enlarging the cavity of the chest from top to bottom.

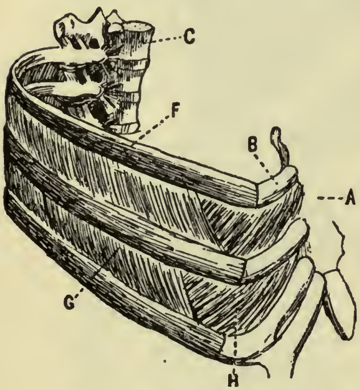
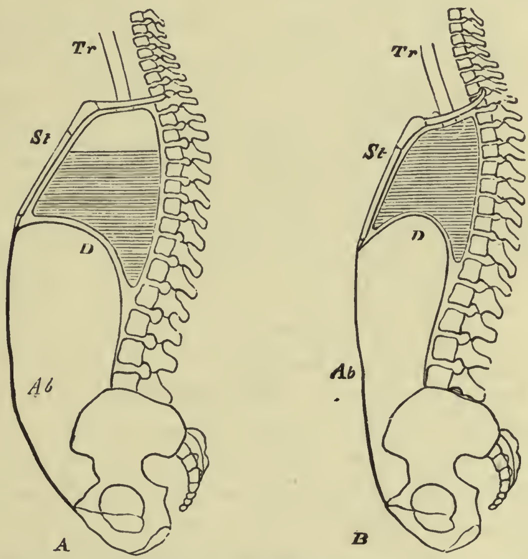


FIG. 136.— Figure showing Three Ribs, their Attachment to Spine and Sternum, and the Muscles completing the Thoracic Wall.

A, sternum; *B*, rib cartilage; *C*, vertebral column; *F*, rib; *G*, outer intercostal muscles; *H*, inner intercostal muscles.

When the diaphragm descends, it acts as a piston or a tight-fitting round board would act if pressed down into a barrel of water. If there were two holes in the board (corresponding to the vena cava and the thoracic duct), the water would be pressed up. Thus the circulation is aided by breathing. When the diaphragm relaxes, its thinness and flexibility would allow it to drop downward, instead of springing upward as pupils sometimes suppose; but the abdominal walls contract as the diaphragm relaxes and force the liver, stomach, etc., against the diaphragm, thus pressing it against the lungs (Figs. 137 and 138).

258. Other Muscles that expand the Chest. — The chest walls can also be lifted out at the sides and in front. This is accomplished by muscles leading from the shoulders and spinal column to the outer surface of the ribs (Fig. 124), and by the intercostal muscles, or the muscles that connect each rib with the rib above (Figs. 136, 140). Thus the chest may be made deeper from front to back and from side to side, and if the diaphragm acts at the same time, the chest is elongated from top to bottom, and thus is enlarged in all directions.



FIGS. 137 and 138. — Diagrams to show the Positions in Respiration of the Sternum, Diaphragm, and Abdominal Wall.

A, inspiration; *B*, expiration; *Tr*, trachea; *St*, sternum; *D*, diaphragm; *Ab*, abdominal wall. The shaded part is to indicate the stationary air. The unshaded part shows the increased air space during inspiration.

259. Inspiration. — The lungs themselves contain no muscular tissue; therefore they cannot expand by any force of their own. Yet they expand when the chest expands. How does the enlargement of the chest cause the lungs to expand, and the air to rush in? The air cannot be pulled in, for it has no cohesion, its parts do not stick together. It is found that the air has considerable weight, for the height of the atmosphere is at least forty miles, and the air above is pressing down on that below. When the chest walls are moved outward against the weight of the outer air, the space in the chest is increased, and the air already in the chest expands to fill the greater space. The air, when expanded, is lighter, and exerts less pressure than before, and the denser air outside, having greater pressure, presses inward until the air in the lungs is as dense as it was before the lungs were enlarged. Thus do we allow the air to come into our lungs; we do not draw it in, but make space for it, and the atmosphere outside presses it in.

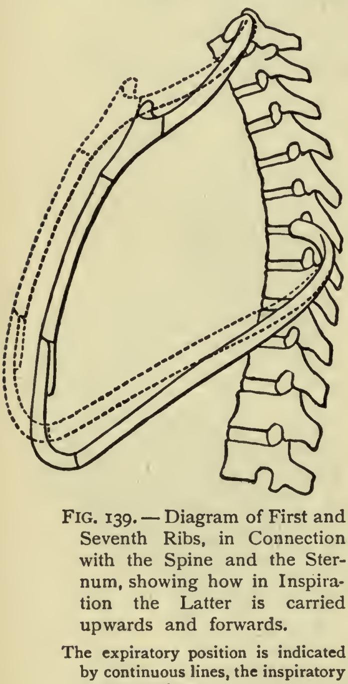


FIG. 139. — Diagram of First and Seventh Ribs, in Connection with the Spine and the Sternum, showing how in Inspiration the Latter is carried upwards and forwards.

The expiratory position is indicated by continuous lines, the inspiratory by broken lines.

260. Expiration. — This is the reverse of inspiration. The space within the chest is diminished, and the air in the lungs is compressed and becomes denser than the air outside. This denser air has greater pressure than the outside air, and presses out through the air passages until enough has passed out to restore the equilibrium, making the pressure equal without and within (Figs. 137, 139).

261. But how are the Lungs made Smaller? In ordinary quiet breathing, the lungs become smaller, owing chiefly to the elasticity of the parts involved. When the air rushes in during inspiration, it enlarges the air cells by stretching their walls, and the walls being made partly of elastic tissue, the cells contract again when the muscles of inspiration cease to act. When the ribs are lifted up during inspiration, the costal cartilages that connect them with the sternum are slightly bent, and the elasticity of these cartilages, as well as the weight of the chest wall, causes the ribs to become lower when the muscles of inspiration cease to act. Many pupils get the erroneous idea that the diaphragm is also elastic and pushes upward when it relaxes, thus aiding expiration. When relaxed, it has no more elasticity than a piece of cloth, and no more power to push itself upward. However, the abdomen has been somewhat compressed, and its walls somewhat stretched during the inspiration. When the diaphragm relaxes, the elasticity of the muscular walls of the abdomen presses the organs against the under side of the diaphragm, pressing that in turn against the base of the lungs, and aiding expiration.

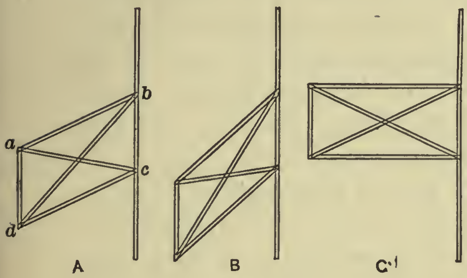


FIG. 140.

Diagram to show action of intercostal muscles. At *A* two ribs are represented in passive position. If line *ac* shortens, the ribs will go down as in *B*. If line *bd* shortens, the ribs will rise as in *C*. One line represents an inner, and the other an outer, intercostal muscle. A frame made with jointed corners (with strings to represent the muscles) will readily demonstrate the action of the two layers of intercostal muscles.

262. Quiet or Passive Expiration is, therefore, a rebound brought about by the elasticity of the air cells, costal cartilages, and abdomen, and by the weight of the chest wall. Active expiration adds muscular contraction to the above forces. The two layers of intercostal muscles are among those used in inspiration and active expiration (Figs. 136, 140). The outer muscles diminish the spaces between the ribs when they contract, and thus move the ribs upward and outward (Fig. 140). (Place the hands at the sides of the waist while inspiring, and this will be noticed.) The inner muscles increase these spaces when they contract, and thus depress the ribs and aid in expiration (Fig. 137). In active expiration the abdominal walls contract and press the abdominal organs against the diaphragm. By feeling the body, find the location of the muscles that contract during strong expiration. Feel the same muscles during the act of coughing.

263. Thought Lesson. **Ease in Breathing.** — By studying the skeleton of the chest (Figs. 59, 141), carefully observing the bones and cartilages, and by experimenting upon his or her own breathing, the pupil is to fill out the following reasons why expansion and contraction of the lower chest ("waist breathing") is easier than breathing with the upper chest ("collar-bone breathing").

1. There are two pairs of —— ribs below, while there are none above.

2. There are three pairs of —— ribs below, while there are none above, but all the ribs of the upper chest are —— ribs.

3. The joints between the seven pairs of true ribs and the sternum are more flexible below because ——. (Observe carefully Figure 141.)

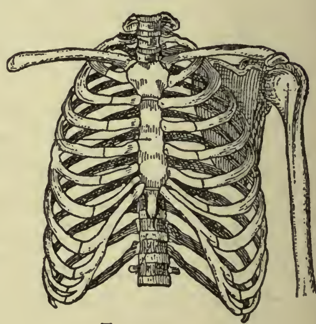


Fig. 141.

4. In waist breathing the breaths will not have to be so frequent to supply the same amount of air, because the lower chest, besides being more flexible, is —— than the upper chest.

5. The walls of the waist swing —— and —— while the walls of the upper chest must move —— and ——.

6. The bones of the —— rest upon the upper chest. In upper chest breathing their weight, and the weight of

both of the ——, must, therefore, be lifted. (Test by experiment.)

264. Modifications of the Breath. — After studying the following list and experimenting with your own breathing, write after each word, I or E, according as inspiration or expiration is chiefly involved in the action. Study each action in other respects also: —

Sighing	Coughing	Sneezing
Sobbing	Laughing	Hiccoughing
Crying (of a child)	Yawning	Snoring

265. Air is composed of a mixture made up chiefly of oxygen, nitrogen and a very small quantity of carbon dioxid. Nitrogen is colorless, tasteless, and odorless; it does not support combustion, and is one of the most inactive gases known to chemists. The oxygen of the air is also colorless, tasteless, and odorless, but is one of the most active gases known to chemists. The air exhaled contains about the same amount of nitrogen as that inhaled, but it contains much less of oxygen, the latter having been replaced by an almost equal quantity of carbon dioxid.

266. One Hundred Parts of Pure Air contain about 20 parts of oxygen, nearly 80 parts of nitrogen (and other gases), and .004 of a part of carbon dioxid. Air coming from the lungs contains 16 parts of oxygen, nearly 80 parts of nitrogen, and over 4 parts of carbon dioxid. The air while in the lungs has lost four parts of its oxygen, there has been no change in the quantity of nitrogen, and it has gained four parts of carbon dioxid. The oxygen is in the air in order to supply an element to animals essential to their activity. The nitrogen in the air is not used in the body. The small amount of carbon dioxid in the air supplies the plants with carbon. Its quantity is being constantly added to by fires and by the breath of animals. The leaves of plants, aided by the sunlight, are constantly removing it, so that it is kept at .004 of one per cent in the air. If it increases in the blood greatly beyond the usual amount, dullness of mind and finally unconsciousness result.

267. Foul Air. — Besides the carbon dioxid, the air coming from the lungs contains a small and variable quantity of water and of foul-smelling vapors. In the air of a closed room in which several persons have been for some time, there is a characteristic odor which belongs to man, just as there are odors peculiar to each of the lower animals. The odors are caused by fine organic particles from the skin and lungs of the persons. When a number of human beings are together, and the ventilation is imperfect, the air becomes very oppressive and is called "crowd poison." Although it is given off by the cleanliest and healthiest persons, the "crowd poison" accumulates faster if individuals in the room (whether it be church, school, parlor, or theater) have catarrh, decayed teeth, or some other diseased condition. The necessity for breathing and ventilation is just as great, because of these organic particles, as it is for the purpose of preserving the proper proportion of inorganic elements in the air. Headaches and other symptoms of distress, caused by ill-ventilated rooms, are to be attributed chiefly to the effects of the "crowd poison" upon the nerves.

268. THOUGHT LESSON. **Protective Instincts: Effects of Tobacco on Lungs and Habits of Life.** — 1. Chemical analysis shows that there is enough nicotine in one cigar if taken into the system, to kill two men. Does the experience of tobacco users disprove this?

2. Name, in four words, four disagreeable effects that soon follow smoking a pipe or strong cigar for the first time.

3. Name two qualities belonging to tobacco that God has given it in order to teach us through the senses that

it is not good for us and that we should not try to use it.

4. What change does God cause to come over our instinct to avoid harmful things if we disregard the warnings as if they were from an unwise source?

5. What means have shrewd manufacturers provided so that even children now learn to smoke so gradually as not to awaken the instinctive repugnance to the poison in tobacco? What aids in learning to chew tobacco?

6. What injury results from chewing tobacco that does not result from smoking? What injury results from smoking that does not result from chewing (§ 284)?

7. Where has the smoke been that a boy blows out of his nose? What does such a boy usually smoke?

8. Give several reasons why weak tobacco smoke in the lungs does a far greater amount of injury than strong tobacco smoke in the mouth.

9. Why do cigarette smokers usually inhale, or draw the smoke into the lungs, while cigar smokers do not?

10. Think of three boys (without writing their names) whom you know that do not use tobacco, and of three that smoke cigarettes habitually. Fill out the following table, placing the boys in two classes, and showing how many of the three tobacco users are fleshy, and how many are thin, etc.; how many of the three abstainers are fleshy, how many of the three are thin, etc.

	Fleshy.	Thin.	Rosy.	Pale or sallow.	Studious.	Idle.	Obedient.	Unruly.	Full sized.	Stunted.
3 tobacco users,										
3 abstainers,										

269. Subjects for Compositions. — The Benefits and Disadvantages of Bicycling. Natural and Artificial Beauty. My Personal Observations and Experiences in the Light of Physiology. Natural Cures and Medicines. The Breath. Tobacco. Alcohol and Crime. Tight Shoes. Sketch of the Life of a Friend. Exercise. The Lungs. The Cigarette Habit. Health and Happiness.

CHAPTER XI

HYGIENE OF RESPIRATION

270. Dust. — The cilia of the air passages stop most of the dust before it reaches the lungs, but not all. If the dust is excessive, millions of particles enter the lungs. If a housekeeper would examine the air of the room with a beam of light reflected by a mirror during the time of sweeping, she would often be horrified, and would heed the caution of those who say that every **door and window should be opened** before beginning to sweep, and **allowed to stay open** for two hours afterward. If there is a breeze, so much the better; it blows the dust out, especially if she sweeps in the direction of the breeze. It is the presence of dust floating in the air, more than fragments of trash upon the floor, that makes a dirty home.

271. When a carpet is swept, dust comes from the carpet itself, especially if it is old. Curtains and hangings also hold dust. Hardwood floors, with rugs instead of carpets, are recommended, and oilcloth and linoleum are also excellent substitutes for carpets. Rugs can be conveniently cleaned at any time, and the floor can be cleansed with a moist cloth. Statistics indicate that among civilized races a large proportion of the deaths is due to lung diseases. This proportion is frequently estimated as high as one seventh of the entire number.

272. Reasons for breathing through the Nose. — (1) On account of the projections of the turbinated bones and processes into each nasal passage and the round-about way the air takes in passing through the nose instead of the mouth, nasal breathing brings the air in contact with a much larger extent of moist and warm mucous membrane than does mouth breathing. The air becomes warm and does not, like cold air, irritate the trachea and bronchial tubes. (2) The air becomes purified, because the hairs just within the nostrils and the mucous lining of the latter serve to catch particles of dust, and the mucus has the power of destroying germs. (3) While a mouth breather is eating, sufficient time is not taken for chewing the food, but it is swallowed too soon, so urgent is the necessity for breathing.

FIG. 142. — The Facial Expression when breathing through the Nose and when breathing through the Mouth.

(4) In the habitual mouth breather, the nasal mucous membrane, from lack of stimulus of the cold air, dries and shrinks, causing discomfort; and since, in its dry condition, the circulation easily becomes obstructed, there is a predisposition to congestion and catarrhal nasal affections and injury to hearing. (5) An unpleasant expression of the face results from mouth breathing (Fig. 142), the lower jaw recedes, the upper teeth project, the nostrils are not developed and in a grown man may be no larger than during childhood. (6) A person has greater endurance in muscular exertion if he breathes strictly through the nose. He can hold out much longer, his lungs are kept more expanded, and the heart is not oppressed; and, after a while, a "second wind" comes to him, — for instance, during running. (7) The voice has more resonance if the nasal passages are open.

A Scotch physician, fully appreciating the importance of proper breathing, has written a valuable medical paper, entitled, "Shut your Mouth and Save your Life." Sometimes the cause of stopping up the nose in children is enlargement through glandlike growth of a structure in the upper part of the pharynx called the *third* tonsil. It is just behind the posterior openings of the nasal passages, and can be easily removed if it becomes enlarged. Persons who sleep with the mouth open are likely to snore, and the mouth and throat are always dry in the morning.

273. Do the Breathing Muscles rest? — Expand your lungs, and see whether they will contract of themselves. Contract your lungs and see whether they will expand of themselves. See whether you can make waist, chest, and abdomen expand at the same time. You learned that the periods of rest taken by the heart muscles amount to how many hours daily? The breathing muscles also rest a considerable portion of the time; with calm and happy people they rest more than with people of anxious, unquiet dispositions. We can breathe by means of *the expiratory muscles alone* or by means of *the inspiratory muscles alone*, or by *using each set alternately*. When all the breathing muscles are relaxed, the lungs are at rest in what may be called the *neutral position*, since there is neither voluntary contraction nor expansion. In this position they are of about average size. If now we use the expiratory muscles and contract the lungs, the muscles may relax during inspiration which follows, for it will be accomplished by the elasticity of the abdominal walls and organs, and of the cartilages of the thoracic cage; for these were bent when the cage was pulled from the neutral position. Try this method of breathing for a few minutes.

274. Or, on the other hand, when the lungs are at rest we may breathe by using the inspiratory muscles (Fig. 139) (diaphragm, external intercostals, etc.), thus *expanding the lungs from the neutral position*, and allowing the muscles to rest, while the elasticity of the parts forces out the air. Try breathing in this way.

275. This *expanded breathing* has the advantage over *contracted breathing*, of removing pressure from the heart and large blood vessels in the chest, and allowing the heart to work with greater freedom. It also keeps the lungs more expanded. You learned in another paragraph that it is the usual method of quiet breathing; but strong, contracted breathing sends out fouler air from deep in the lungs.

276. In both of these ways of using the breathing muscles, there is a pause in the neutral position before the next breath. But in a time of great exertion, as when running, or during a time of excitement and in some forms of illness, there is no pause between breaths, and we use what may be called *continuous breathing*. Both when expiring and inspiring, the ribs are pulled on beyond the position at which they rest. Thus the use of the breathing muscles is continuous, and it is no wonder that they may get so tired that they almost refuse to work for a moment, and we are "out of breath," as we say. The heart is thumping so fast and strong that the corpuscles are shot through the lungs with unnecessary speed and do not get even as much oxygen as they would if going more slowly. Continuous breathing is a wasteful method; haste makes waste of strength, although it may seem to be necessary in an emergency. You can really accomplish more by quiet, steady work. Anxiety and worry, as well as great physical exertion, cause this hurried, wasteful breathing; hence we should cultivate the easy way of breathing.

277. Reasons for Strong Expiration and Inspiration.— Purifying the air in the lungs may be illustrated by dipping dirty water out of a barrel and replacing it with clear water. If a dipperful of clean water is poured into the barrel and the same amount of water is dipped out, this will cause the cleanest water to be at the top, whence it will always be dipped out and the dirtiest water will be left. It is the same way with the lungs; the purest air in the lungs is always removed by breathing, but if the lungs are contracted by strong and long expirations, more air from deep down in the lungs, and therefore fouler air, is removed. When the lungs expand fully, their surface is increased and every little air cell is opened, helping the exchange of carbon dioxid and oxygen through the thin walls.

278. You have just been studying about the three methods of breathing according as you use (1) the inspira-

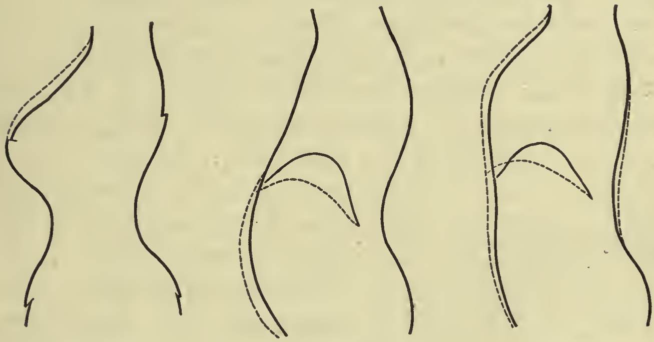


FIG. 143. FIG. 144. FIG. 145.

Diagrams illustrating Proper and Improper Methods of Breathing.

Dotted lines show area of expansion.

Fig. 143. — Female figure encased in corset. Expansion at the waist is here impossible and the breathing is called "collar bone breathing."

Fig. 144. — Male figure. Here, owing to pressure of clothing and faulty position, expansion of chest is impeded and breath is taken by the "diaphragmatic method."

Fig. 145. — Figure properly poised and free from constriction. Here the entire thorax can move freely and normal breathing is the result.

tory muscles, (2) the expiratory muscles, (3) both. The breathing may be varied also by the activity of the muscles prominent in (1) the abdomen, (2) the chest, (3) both. This gives rise to —

279. Abdominal Breathing, Chest Breathing, and Full Breathing. — See whether you can make waist, chest, and abdomen expand at the same time. See whether you can make waist, chest, and abdomen contract at the same time.

There has been much discussion among physicians, voice trainers, and elocutionists as to the proper way to breathe, some advocating chest breathing (Fig. 143), and some advocating abdominal or diaphragmatic breathing (Fig. 144). The fact that so elementary a process as breathing is still a subject of discussion illustrates how imperfect is the state of our physiological knowledge, especially when an attempt is made to apply it to practical purposes. The author believes that pure chest breathing and diaphragmatic breathing are both wrong, and that what may be termed full breathing is the natural and best way (Fig. 145).

280. Full breathing employs movement of both chest and diaphragm, the greatest expansion being in neither chest nor abdomen, but at the waist, and diminishing in amount both upward and downward. The objection to *pure chest breathing* is that the marked movement of the upper part of the bony cage requires exhausting effort; such movement can be employed without waste of strength for only a short period, as in gasping for breath or during great muscular exertion (§ 263). Yet some women with waists confined by tight clothing breathe in this way for hours at a time; thus their strength wears out, and they are old before their time (Fig. 146).

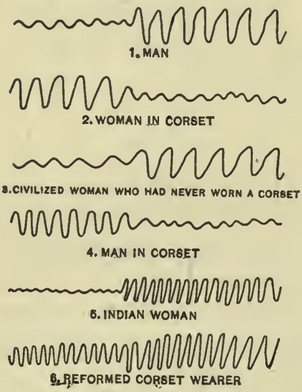


FIG. 146.—Breathing Tracings (Kellogg).

Motion of chest recorded at left and of waist at right.

281. *In full breathing*, the diaphragm contracts but at the same time the ribs are lifted upward and outward, and the points of attachment of the diaphragm are thus raised and separated so that the diaphragm flattens without any great descent. But in *pure abdominal breathing*, the movement is confined to the diaphragm and abdomen, and lateral action of the chest is suppressed. The effect of this is to cause too great a displacement downward of the liver, stomach, kidneys, colon, and other organs. But in normal or full breathing, any great degree of downward movement is prevented by expansion of the trunk at the waist. In abdominal breathing, the abdominal walls are entirely relaxed as the diaphragm descends, and the liver and other organs are moved but not compressed. In full breathing they are compressed and slightly moved, and the compression squeezes the blood out of them toward the heart and presses the lymph upward through the thoracic duct; the expansion of the chest at the same time helps to draw the blood upward. During expiration fresh blood is sent back to the abdominal organs, and so they are kept fresh and strong. Ladies who wear skirts with bands tight enough to support them at the waist, and men who support their trousers by buckling them around the waist, gradually lose the power of lifting the ribs outward at the waist. This expansion is most important for good breathing, because the lungs are largest there.

282. Effect of Alcohol upon the Lungs. — It was learned that alcohol paralyzes the vasomotor nerves, or those that control the size of the blood vessels. This allows the smaller arteries in the lungs to swell and the capillaries to become congested, crowding upon the air cells and diminishing the breathing power of the lungs, as is readily shown by the use of the spirometer, a simple instrument which, when the breath is blown into it, measures the number of cubic inches the lungs expand. The continual congestion of the lung tissue results in an abnormal growth of connective tissue fibers in the walls of the cells; the walls thus become thickened and hardened and obstruct the absorption of the oxygen and the escape of the carbon dioxid. Besides this, alcohol injures the red corpuscles, causing them to shrink and impairing their power to receive and carry oxygen. All these changes diminish the oxygen in the blood. This state of blood is plainly shown in the purplish face of the drunkard, crowded with enlarged veins. The weakened power of breathing explains why a man given to drunkenness cannot endure vigorous muscular exertion so long as can a healthy person.

283. The injurious effects described readily explain why the consumption that attacks inebriates is a very rapid and fatal form of the disease.

284. Effect of Tobacco upon the Respiratory Organs. — The hot smoke irritates and dries the mucous membrane of the mouth and throat, producing an unnatural thirst that may readily lead to the use of alcoholic drinks. Inhaling the poisonous smoke, which occurs to the greatest degree in cigarette smoking, inflames the delicate mucous lining of the bronchial tubes and air cells. There may result from this an irritating cough, short breath, and chronic bronchial catarrh.

285. Ventilation. — The evil effects of re-breathing air can hardly be exaggerated. The blood stagnates, the heart acts slowly, the brain is clogged, the head aches, and either a dull or a feverish feeling arises. The body becomes sensitive to cold. The skin becomes pale, the blood is loaded with impurities, and the whole body is obstructed with refuse material. In such a human body, colds, catarrh, consumption, and other diseases readily develop. The constant breathing of even the slightly impure air of most private houses cannot but tend to undermine the health and prevent that perfect soundness of body which thorough ventilation or life in the open air insures.

286. Judgment with regard to ventilation is rare. In many **churches and assembly rooms** the windows are tightly closed except in warm weather. If, during the meeting, the room becomes too warm (not if it becomes foul with impure air), some one will open one or more windows *to their full height;* the strong draught soon cools the room and chills some one, whereupon he goes to the window and *shuts it tight.* One absurd extreme thus follows another. All that was necessary, if there was no scientific provision for ventilation, was for all of the windows to have been opened, for an inch or less, when the assembly began, and allowed to remain so; then no one would have been too hot or too cold, or would have suffered from foul air.

287. What is the probable cause of persons fainting or going to sleep in church? With the foul air was combined what other disadvantage to breathing, as shown by one of the measures often taken to restore a person in a faint, especially if a woman?

288. The ventilation of **the schoolroom** is often deplorable. A visitor, upon entering a schoolroom, especially if the school has been in session for an hour or more, may notice a stifling, foul-smelling atmosphere. The children have rushed in from their active games with their clothing saturated with perspiration. Their healthy skins perspire more freely than do those of adults. Some of them may have coughs or colds, and sometimes come from sick rooms.

289. Carbon monoxid forms in the stove if the draught is closed too much, and escapes through cracks and seams in the stove, and, if the stove is red-hot, through the iron itself. Carbon monoxid is different from the dioxid in being imperfectly oxidized, and its attraction for oxygen causes it, when breathed, to attack the red corpuscles of the blood causing headache and dizziness, for the monoxid is an active poison, not merely negative like the dioxid. The ashes from the stove, the dust from the pattering of many feet, the clouds of chalk dust, accumulate until they become almost unbearable, and all that gets out leaves the room on the clothes of the pupils, or on the mucous membrane of their nasal passages, windpipes, and lungs; for the janitor is more ignorant than the housekeeper, and he likewise will not open the windows before sweeping because of the trouble; or, if persuaded to open them, he must be compelled by the principal to allow them to remain open for the dust to blow out, otherwise he will close them on leaving each room to avoid the annoyance of returning.

290. These are the conditions of many, many schoolrooms and houses, for, unfortunately, some persons' knowledge of physiology consists largely of a knowledge of big names. It is not strange that lung troubles are rife, and that people wonder whence they come, and take medicated gases instead of pure air. Many of the Indians of Patagonia died of consumption within nine months after being taught by the missionaries to live in houses.

291. It is necessary to give children knowledge of the geography of Africa and other remote lands, but it is at least as necessary to train them to sit and to stand correctly. Interruptions to study every half hour by calisthenic exercises so selected as to give vigor to those muscles that counteract the evil, deforming effects of prolonged sitting, would help them to grow up well-formed men and women, and would aid in learning the geography as well.

292. The health of children at school often suffers, and parents usually think it is because of the number of studies. This idea is no doubt largely erroneous. The breathing of the bad air, both at home and at school, the close confinement in the schoolroom, sitting in a cramped position, and studying by improper light, are the true causes in a majority of cases.

293. Some persons in their anxiety for pure air become extremists, and forget that the body may likewise be injured by cold. In ventilating a room, not one but two purposes must be kept in view: to furnish air that is pure, and air at the proper temperature.

294. Methods of Ventilation depend upon the principle that hot air is lighter than cold air and is pushed up by it. If you have two openings for ventilation, one higher than the other, at which opening does the warm air go out? If the higher opening is near the ceiling, do the persons in the room get the coldest or the warmest air? Does such a method economize the fuel? If the inlet is near the floor, why should the stove be near the inlet? Why should the outlet be on the side of the room farthest from the stove?

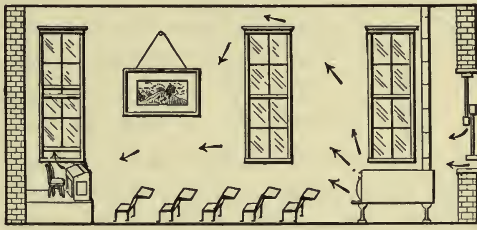


FIG. 147. — The Proper Method of ventilating a Room.

The stove is on the side toward the cold winds. The inlet is near the stove, the outlet farthest away. If the window near the stove were lowered from the top, what would probably happen? If another window near the stove were opened, what might happen? If the prevailing cold winds came from the opposite direction, what changes should be made in the room? How do you ascertain whether the outlet fails to serve its purpose and becomes an inlet?

295. Good ventilation is arranged so that the fresh air shall be heated before or just after it enters the room, and that it shall pass across the room in order that the inmates may get the benefit of both its warmth and its purity before it passes out (Fig. 147). Test the direction of the air currents in your bedroom and in your schoolroom by means of a spider web hanging from the end of a stick. Why is it best not to have the outlet on the side of the house toward the prevailing wind in winter? If the inlet is so situated that the cold air does not pass over the stove, a board or a screen may be placed before the window to deflect the current upward and prevent its chilling those seated nearest the window (Fig. 148). If you find by holding your hand near the inlet that there is a good inward current, you may be sure there is sufficient outlet; although if it is not far enough from the stove, heat will be wasted. If you know there is a strong outward current, for instance, when a fire is burning in an open fireplace, you may be sure that the same amount of air is entering somewhere, if only through minute cracks (Fig. 150).

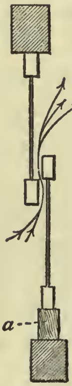


FIG. 148.

To deflect the air upward, place a wooden strip at *a*.

296. When over-enthusiastic people become interested in ventilation, they sometimes injure themselves by chilling draughts and low temperatures. The temperature of the room should be kept between 65 and 70 degrees. The foregoing directions for ventilation apply to cold weather. For warm weather no special directions are necessary, for most people are more unwilling to bear unpleasant heat or to soil their collars with perspiration, than to breathe foul air.

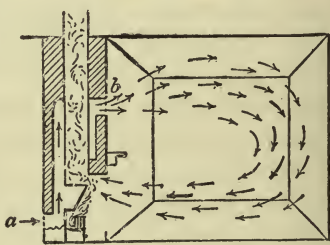


FIG. 149. — Galton's Fire Grate.

With a passage behind the grate that the air may be heated as it enters.

297. The Five Degrees in Cleanliness. — Nearly all people are very careful to wear clothes that are perfectly neat and clean. Dust or mud upon their clothes is considered the highest degree of uncleanliness. Many think it of the highest importance to health and refinement to keep the skin clean by regular baths. But there are a few that think it of still greater importance to keep the air clean that goes into the lungs. A few also think it necessary to keep the alimentary canal pure throughout by reasonable eating and living. We also meet with those who believe not only that the clothes, the skin, the lungs, the digestive organs, must be kept clean, but that the blood must be clean and fresh, ever renewed by a strong and vigorous flow, and they so live that as far as possible it shall always be so. The daintily dressed lady or the dandified man would be horrified at a particle of mud that fell upon the clothes, but sometimes if you are so unfortunate as to catch a whiff of the breath of such a person, its repulsive, sickening odor shows that foulness and uncleanliness have taken possession of the lungs, or digestion, or blood. We should be careful to observe these five degrees of cleanliness, but which should we value most highly? There is still another degree in cleanliness, or purity, which concerns purity of mind and nobility of soul.

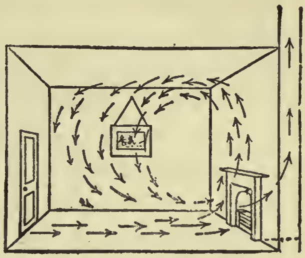


FIG. 150. — Ventilation by an Ordinary Grate or Fireplace.
The coldest air chills the feet.

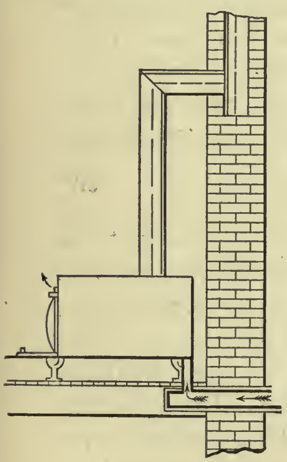


FIG. 151.
The air enters through a special inlet and is warmed as it passes through a hood surrounding the stove.

298. The Mistake of the Overstudious. —The pale student, thinking only of the desire for learning aroused by teacher or parents, and neglecting the promptings of his natural instincts toward complete living, thinks he is doing wisely and right when he is constantly delving into books. On the contrary, he is sinning against part of his nature and unfitting himself for accomplishing the best work he is capable of doing.

299. Consumption, or Tuberculosis, is a disease due chiefly to living constantly in unventilated houses. That the natural curative powers of the body are capable of curing consumption, is shown by the fact that reports of post-mortem examinations in some of the hospitals of the United States and Europe show scars on the lungs in half of the cases examined. These scars were left by consumption, which the persons had had without knowing it or being treated for it, and from which they had entirely recovered, dying afterward from another disease. These facts show that in the early stage consumption is an especially curable disease. Persons are sometimes alarmed because they have heard that consumption is caused by a bacillus, or microscopic germ, commonly called a *microbe.*

300. That it is not caused by microbes alone is proved by the fact that the microbes are floating in the air, and nearly all human beings are exposed to them many times in their lives, yet all do not contract the disease. Consumptives are constantly spitting on the streets of cities, yet a smaller percentage of the street cleaners of Berlin than of almost any other class of the population die of consumption.

301. Outdoor life, simple diet, and exercise seem to be the best treatment. Inhalations through apparatus of medicated air, moist air, dry air, cold air, superheated air, air charged with the pleasant aroma of pine leaves or the repulsive sulphuret of hydrogen, have all been tried. It seems impossible *directly* to destroy the microbes when they once obtain a foothold in the lungs, without the employment of such measures as will destroy the lung tissue as well as the parasitic bacilli. Even if the bacillus could be destroyed by germicides, it would be impossible, since the germs are so widely scattered, to escape infection again, and the disease would return for the same reason that it first gained a foothold: this was because, from indoor life, shallow breathing, indigestion, lack of exercise and fresh air, the blood had become impure and the lung tissue so corrupted and weakened that it furnished a fertile soil for the growth of the germs. (Read note 2, page 191.)

302. Subject for Debate. — *Resolved*, That the Chinese woman has less love for personal deformity than the Caucasian woman and suffers less from it.

BACTERIA AND DISEASE

303. Nature of Germ Diseases. — A plant, as an oak or a pear tree, may become affected by a disease called the *blight*, and such disease is usually regarded as a necessary evil, or an imperfection in creation. Looked at with a broader knowledge, such disease is a sign of growth as well as of decay and is a blessing and not a curse. The microscope shows that trees affected with the blight are the seat of the growth of millions of one-celled plants called *bacteria.* So where there is death and disease, there is flourishing life. The blight did not attack the hardy, sound pear trees, but those of rapid, sappy growth whose tissues had already become injured or dead by the effect of frost or some other agent. The function of the bacteria is to destroy unsound vegetable or animal matter by living upon it as food, thus decomposing it and returning it to the soil and the air to be used again. There is no decay without the action of bacteria; without it organic matter would accumulate indefinitely, interfering with life upon the earth.

304. Molds. — Every one has seen fungus plants, such as mushrooms and puff-balls, that do not bear flowers but multiply by spores. They live upon dead logs or where there is much dead organic matter in the soil. Imagine a fungus that grows on an average about $\frac{1}{100}$ of an inch in height; this is called *mold* (Fig. 152). It grows, for instance, upon moist bread in warm weather. Mold forms a kind of network as it grows through any substance that will nourish it, and sends up stalks with knoblike ends, the knobs being full of minute spores.

FIG. 152.—Ringworm Fungus in a Hair. (Compare with Fig. 8.)

305. Yeast. — Think, if you can, of small plants only about $\frac{1}{32000}$ of an inch in length, composed usually of one oval cell, a plant that makes new plants by "budding," or the forming of a smaller cell on the old one. Yeast cakes consist of yeast plants scattered among the grains of flour of which the cake was made. Yeast plants multiply rapidly, doubling in number in two hours (Fig. 153). They grow upon sugar, decomposing it into alcohol and carbon dioxid. This process is called *fermentation*. In wine making, alcohol is the product sought; in bread making, carbon dioxid is the useful product, this gas giving the bread its lightness, while the small amount of alcohol formed is driven out by the heat in cooking.

FIG. 153. — The Yeast Plant.

306. Bacteria. — But suppose the microscope shows a much smaller vegetable organism which averages $\frac{1}{200000}$ of an inch in diameter and is a one-celled vegetable that multiplies by division like the ameba and other one-celled animals, and lives upon albuminous substances only for its food. This is a *bacterium*. Bacteria are called also *microbes* or *germs*; and they are the smallest of living organisms. A bacterium that is rod-shaped is called a *bacillus* (Fig. 154). Under favorable conditions—abundance of food and considerable warmth and moisture—bacteria may double in numbers every half hour. Thus millions may result from even one in a short time. (You will comprehend this better by referring to "geometrical progression" in your arithmetic.) Dryness and cleanliness prevent their growth; cold retards their growth and division, hence the utility of ice in preserving meat, milk, fruits, and other foods in warm weather.

307. Can you now arrange the names yeast, mold, and bacterium in order of size? Can you give the kind of material that each uses for food? Can you tell how each multiplies, or reproduces its kind? What is a bacillus? For what is "microbe" another name?

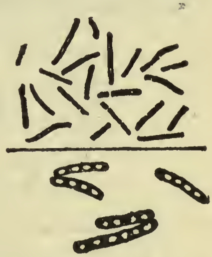


FIG. 154. — Bacilli; the Same Species magnified to Two Sizes.

308. Use of the Small Organisms. — Molds are nature's tools for destroying hard and durable tissue like logs, bone, and hides, which otherwise would not decay but would fill the earth, leaving no room for living creatures. Ringworm is caused by the growth of one form of mold within the skin. It does not grow in a sound and clean skin. Falling of the hair is often accompanied by the growth of mold in the hair follicles, but it must be preceded by overheating and starving of the cells of the scalp by a tight hat, too much brain work, or other cause (Fig. 152). Yeast prevents the calamity of all plant food accumulating in the form of starch and sugar. Bacteria destroy the dead and excreted matter of vegetables and animals so that it melts away and is stored in the soil, ready to be utilized as plant food again. Mold, yeast, and bacteria are great blessings, for they are indispensable friends of all other living beings (Fig. 155).

309. Their Work in the Body. — They do not always wait for the dead or dying material to be excreted, or separated from the animal or plant, before attacking and destroying it. If more food is eaten than can be digested, and it remains longer than five hours in the stomach, starchy food may ferment from yeast plants, giving rise to carbon dioxid gas, and albuminous food may ferment from bacteria, or a moldy growth may form on the lining of the organs, extending up to the mouth and forming a coat upon the tongue. If the lungs are never fully expanded, but by stooping over at work or by tight clothing a part of the lungs is compressed and the blood supply interfered with, or if foul air is constantly breathed, impurities may collect in the lungs and the bacteria are on the alert to remove them. The bacillus tuberculosis is the form of bacteria that usually finds lodgment in the lungs.

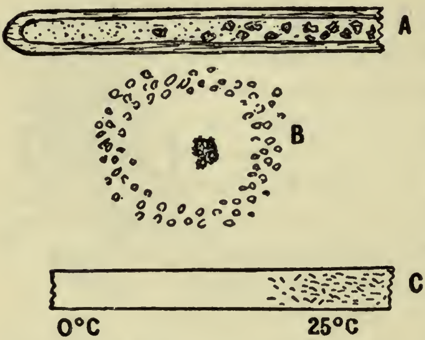


FIG. 155.—Shown by Microscope of High Power.

A, white corpuscles are seen creeping up a tube and devouring bacteria which appear as minute specks.
B, a drop of water containing infusoria. The clump in the middle has been killed by the touch of a hot needle, the others are fleeing from the dead bodies.
C, a capillary glass tube containing bacteria. One end is heated to 25° C, the other end cooled to 0° C. The bacteria have crowded to the warm end.

310. As the bacilli multiply tiny tubercles are formed; hence the name. Tubercles are growths shaped like pin heads, and they may be formed in any tissue of the body. An attack of consumption is usually preceded by indigestion and imperfect nutrition of the body. You have learned that in thousands of cases bacilli remove an injured part of a lung and it heals over. But in thousands of cases the individuals have lived wrong physically for so long, and their lungs have become so weak, that they are gradually destroyed by the bacilli. This is sad to the individual and his friends and loved ones, but it is best for the race, for it prevents gradual degeneration into a race of weaklings.

311. Whether the body has been injured through ignorance or self-sacrifice, through dissipation or selfish ambition for money or fame, through foolish attempts at beauty or through devotion to learning, or through unselfish love and work for others, the result is the same; nature knows no difference. However noble the character or wise the mind (in other directions), when a vital organ has sunk in health below the standard necessary for a human being, condemnation comes.

312. Bacilli are usually found in the sputum only in an advanced stage of consumption. Then recovery is more difficult, but it will often come if the person returns to natural ways, living out of doors and allowing the forces of health to purify the body.

313. Effects of Bacteria. — You learned that they produce decay in unsound tissue. They destroy the albumin in which they grow, producing foul-smelling gases and a number of poisons called *ptomaines*, if formed after death. Ptomaines cause most of the symptoms produced by eating decayed meat. A special kind of ptomaine sometimes forms in milk and ice cream which has been kept for a long while. This is why ice cream which has been melted, and frozen a second time, is dangerous.

314. The growth of bacteria in an unsound, living body, produces poisons called *toxins*, which, circulating among the sound tissues, produce weakness and disease. Disease germs may grow upon the injured cells in an open wound, causing offensive matter to form. In severe cases they cause swelling of the surrounding parts, with erysipelas or blood poisoning. Diphtheria, typhoid fever, consumption, cholera, lockjaw and la grippe are all diseases in which germs have been proved to be present.

Typhoid fever, for instance, is usually contracted through the use of water from an impure source. There have been cases of a spring or well becoming infected with the typhoid germs and giving typhoid fever to the unhealthy members of every family that used water from it. *It requires many bacteria to produce infection; to cause some diseases several millions are necessary.* Certain kinds of communicable diseases can be caught only by coming in contact with the sick person, or with some article that he has touched, or by going into the room where he is sick. These diseases are said to be *contagious*, since they are caught by actual contact. Diseases that are transmitted through the air, *contact* being unnecessary, are said to be *infectious*. Measles, scarlet fever, mumps, whooping cough, and smallpox are contagious diseases, and germs are supposed to be necessary for their existence, but no germ has ever been found.

315. It has never been proved that germs will cause harm or disease to a perfectly healthy body. The germs that produce boils enter the skin at some scratch or break that reaches the lymph spaces. But a person with pure blood and lymph could have a number of breaks in the skin and would probably not have a single boil. Some germs seem to change their nature or the nature of the toxins they form, according to the material upon which they live. Many germs seem to be harmless when living in certain conditions, but, if they find a diseased condition, they seem to change their nature and begin the formation of poisonous toxins. This is known to be true of the colon bacillus and other germs.

316. How Bacteria are destroyed within the Body. — The body of one who is worthy of physical health has three very efficient means of defense:

First. — The white blood cells have it for their chief function to seek out bacteria and to devour and destroy them

(Fig. 156). This explains why so many germs are necessary to transmit a disease.

Second. — The plasma of the blood and lymph, and even mucus, are able in some unknown way to destroy germs of disease.

Third. — The serum of the blood often develops a substance called an *antitoxin*, which poisons the germs and stops their action. When the disease has progressed for a time, the antitoxin is formed in sufficient quantities to kill the germs and the disease is cured.

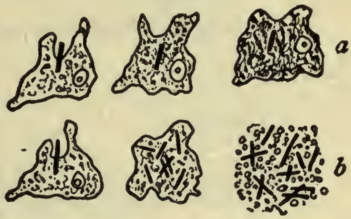


FIG. 156.

a, germ destroyed by white blood cell; *b*, cell destroyed by germs and the germs multiplying, using the cell for food.

317. Malarial fever arises from the presence of a one-celled animal similar to the ameba, that lives through one phase of its existence in the body of a certain kind of mosquito (Fig. 157), and reaches the human system by the mosquito's bite. It then multiplies and destroys the red corpuscles, causing the pale skin of a person suffering from malarial fever. It has not been proved that malarial fever comes in no other way. It may be possible that this fever is caused by the vapors that arise from marshy places. It increases in any region where the trees are felled, as their destruction interferes with the drainage, and thus gives rise to ponds and marshy places where mosquitoes breed. The wiggle-tail takes about ten days to become a mosquito. If kerosene is poured upon the water at shorter intervals than ten days, no mosquitoes will hatch. Tin cans, barrels, and hollow stumps containing water, furnish breeding places for mosquitoes (Fig. 157).

318. The negroes in the Southern states seem to have developed in the blood an antitoxin, which enables them to live in "bottom lands" along rivers. In Africa they do not often have the jungle fever, so fatal to Europeans who have not become "acclimated" — that is, whose blood has

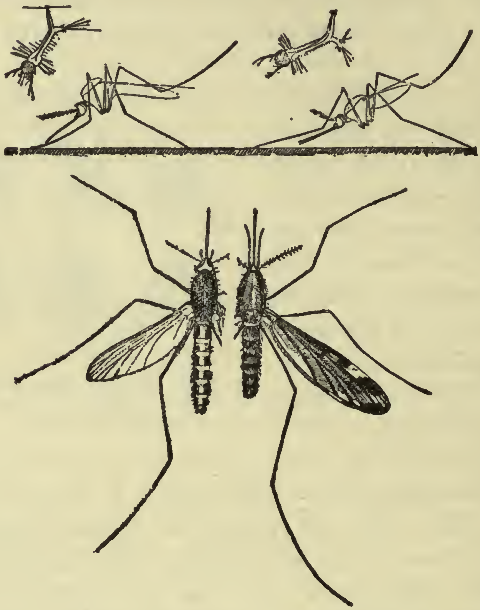


FIG. 157. — Mosquitoes. Comparison of —

The Non-malarial Genus Culex.
- Palpi short.
- Wings not spotted.
- Legs sometimes spotted.
- Position at rest, parallel to surface.
- Larva, or wiggle-tail, breathes, and rests perpendicular to surface of water.

The Malarial Genus Anopheles.
- Palpi long.
- Wings sometimes spotted.
- Legs not spotted.
- Position at rest with abdomen and hind legs elevated at an angle to surface.
- Larva, or wiggle-tail, is parallel to surface of water when it breathes.

The sucking tube and feelers are long in both genera. The long palpi of the malarial genus furnish an infallible sign. The palpi are found on each side of the sucking tube. The feelers are next to the palpi.

not developed the antitoxin which kills the germs causing jungle fever. It has been shown that the mosquito is probably instrumental in transmitting yellow fever.

319. Antitoxin Treatment. — If the toxins from diphtheria germs, grown in suitable material, are injected into the veins of a horse, the horse's blood will soon develop the antitoxin of the disease. If the blood is drawn and allowed to clot, clear serum may be separated. If this is injected into a person suffering from diphtheria, it tends to destroy the germs and stop the disease. It may prevent disease in the case of a person who has been exposed but in whom the disease has not yet developed. The antitoxin treatment has been tried without success in several other diseases. Germs may be transmitted by drinking-water, in the food, or through the air.

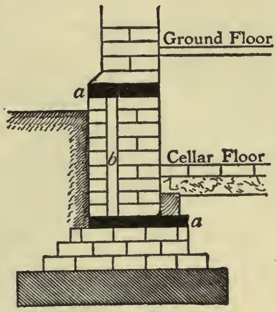


FIG. 158. — How to have a Dry Cellar.
a, damp-proof courses; *b*, air space.

320. Vaccination. — In 1776 E. Jenner of Berkeley, England, learned that the milkmaids of the shire considered accidental cowpox, caught while milking, a sure preventive of smallpox. Twenty years later he began to vaccinate with cowpox material to prevent smallpox. Vaccination protects only for a few years. If exposed to smallpox, one should be vaccinated, unless he has been vaccinated within the last few years. Arm to arm vaccination is dangerous. Only fresh virus from healthy cows should be used. If the arm becomes very much swollen and disabled, it is a sign that the blood has been poisoned by the use of impure material.

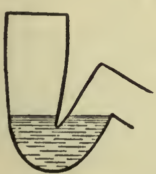


FIG. 159. — A "Trap" of Water to Prevent Gases from coming into Houses through Drainage and Sewer Pipes.

321. Why a Person can have Some Diseases only once. — Why does not one have measles, smallpox, and some other germ diseases a second time? It is believed to be on the same principle that vaccination prevents smallpox the first time. After once having a disease, the antitoxin of that disease, or the power of the blood to develop it, remains and affords protection from the bacteria.

322. Destruction of Bacteria outside of the Body. — The sun is the great destroyer of bacteria in summer and in tropical climates. Cold destroys them in winter and in cold climates. Sternberg has shown that exposure to one hour of sunshine destroys the bacillus of consumption. Wind drives away bacteria. It is almost impossible to transmit disease in the open air. Some germs feed upon

FIG. 160. — Poorly Drained and Unhealthful Site for House.
a, sand; *b*, clay.

FIG. 161. — Healthful House.
a, sand; *b*, rock.

other germs. In the soil are certain kinds of germs which oxidize all organic matter, including other kinds of germs. Thus germs can filter through only a few feet of sand before they are destroyed. Well water is safe to drink in the country, if no impurities reach the soil near the well, but in towns where the ground becomes soaked with germ-laden sewage, impurities penetrate farther and well water is unsafe (Figs. 162, 163).

323. Cleaning with soap and water removes germs. Drying kills many germs, but some species are harder to kill when dry; in that condition they will stand even freezing. Heat, equal to that of boiling water, applied for 15 minutes, will kill almost every kind of germs. It does no harm to leave air in the top of canned vegetables and jars of preserves, but if they are to keep fresh, the germs must be killed by a boiling temperature. Milk is a nourishing soil for germs which cause stomach trouble with bottle-fed babies, unless the milk and the bottles are subjected to heat. Such milk is said to be sterilized.

324. Many chemicals, as carbolic acid (if applied directly to the germs), bichlorid of mercury (1 part to 1000 parts of water), chlorid of lime, destroy germs and are called germicides ("germ-killers"), and *antiseptics* (against decay). They are called also disinfectants, and are applied to houses, clothes, and premises where disease germs are supposed to lurk. The room and bedding where there has been an infectious disease should be thoroughly disinfected. Anything without germs, as pure food, is said to be *aseptic* (without decay).

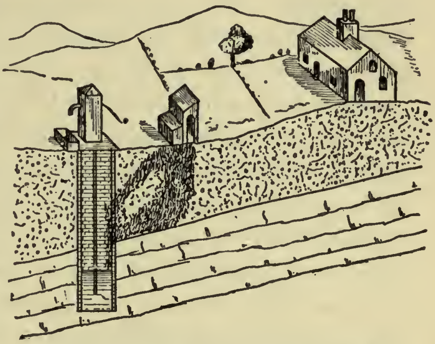


FIG. 162. — Badly Made Well polluted with Sewage.

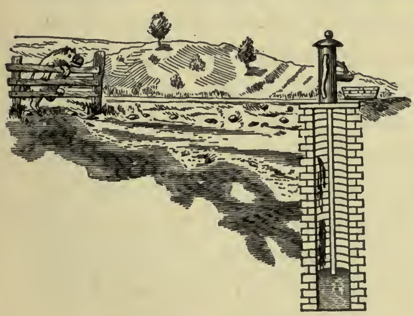


FIG. 163. — Inappropriate Neighbors.

325. Aseptic Surgery. — Some years ago, whenever a leg was amputated, or other surgical operations were performed, there was the great dread that mortification would set in. It caused death in one third of the surgical cases. Now, with aseptic surgery, mortification and blood poisoning are very rare. The surgeon washes and sterilizes his hands and instruments and his aprons. He scrubs the field of operation on the body just as he does his hands. The safety which has been brought about by aseptic surgery depends upon excluding the germs of disease.

326. Alkaloids. — There is another class of organic poisons, closely related to ptomaines, which should be mentioned. They are vegetable and animal alkaloids. Ptomaines are formed by bacteria in dead organic matter; toxins are formed by bacteria in living bodies. The alkaloids are formed without bacteria, but are waste products formed in living animals and plants by their life processes. Among vegetable alkaloids may be mentioned strychnine of nux vomica, daturine of the jimson weed, atropine of the belladonna, nicotine of tobacco, podophyllin of the may-apple root, caffeine of the coffee plant, quinine of the Peruvian bark or cinchona tree, theobromine of coca, theine of tea, morphine of the poppy, etc. They form the active principles of most medicines, and are given for either a narcotic (deadening) or a stimulating (exciting) effect.

327. The dangerous properties of most medicines cause us to wonder why some people experiment with them so rashly without professional advice. Persons who would not think of playing the part of a lawyer, or a theologian, or even of trying to doctor a horse, if the horse was of much value, do not hesitate to prescribe the most virulent remedies for their friends and families. The course in medical schools in the United States is now usually four years in length. Most of our physicians are not mere pill-peddlers and prescribers of drugs, but are capable of advising their patients in every aspect of their physical welfare, and their advice should be taken and paid for as readily as their drugs.

328. Taken in large doses, alkaloids are virulent poisons. The chief animal alkaloids are xanthin, and other compounds related to uric acid. Very little is known about the alkaloids and their properties.

329. A Curious Theory. — There is an artless theory common among unlettered people which holds that disease is a distinct thing, and that when God made the various diseases, he made plants to grow, each of which contains the infallible remedy for one of the diseases. Such persons when they are ill, and after various treatments remain ill, cherish the firm conviction that if they could only find the right remedy that is growing in some plant, somewhere in the world, they would immediately be cured, without any attention to hygiene and the conditions necessary to health and its recovery. Patent medicine venders particularly foster this idea, although each one illogically adds that his medicine will cure all diseases indiscriminately. They give instances of the cat and dog that get sick and cease eating meat for a time and are said to eat grass.

330. This simple theory is opposed to all the facts. The poisons in plants are waste products that the plant seeks to remove. They are therefore found mostly in the parts of the plant that will be shed, as the leaves, seeds, and bark. The poisons serve meanwhile to protect the plant from animals. The only animals (besides man) that will touch the tobacco plant are the goat and the tobacco worm; their bodies seem to have become used to the poison. No sick cat eats nightshade, no sick cow eats jimson weed. The very bitter or repulsive taste of most poisons show them to be unsuited to the animal body. No child would drink a liquid containing the bitter alkaloid caffeine, unless it were influenced by the example of its elders, and the bitter taste were disguised with milk and sugar.

APPLIED PHYSIOLOGY

EXERCISE I

1. State how in the case of a person of poor figure, a gradual **remolding** of the cartilages (which ones ?), the **strengthening** of the muscles (which ones ?), and the practice of **deep breathing** may each contribute toward acquiring a correct and perfect figure.

2. How far is it in one's power to determine the shape and appearance of his own body?

3. Which is most disagreeable, a **smoky fireplace**, a smoky stove, or a **smoky man?**

4. Give reasons why the **weight of our clothing** should hang from the shoulders and not from the waist.

5. Should **a hat** be well ventilated? (A punch for making the holes costs a dime.)

6. Name habits that **impair the power** of the lungs.

7. Which part of ordinary breathing **uses no will power**, although none of the respiratory muscles are involuntary?

8. How could you convince a person that a bedroom should be open while and after it is **swept?** That it should be ventilated at night?

9. Why do some persons "get out of breath" readily **after a meal?**

10. Can a person become so used to **bad air** that he will not notice it? That it will not injure him?

EXERCISE II

11. Which is the more offensive, the **tobacco chewer**, who chiefly pollutes the ground, or the **smoker**, who pollutes the air?

12. Why are those who have **pimples** on the face likely to multiply their number by picking and squeezing them with the fingers?

13. Give the advantages of **slow, deep breathing** as compared with quick, shallow breathing.

14. Why do those who **stand up to hoe** not get tired half so quickly as those who bend or "hump" over?

15. Why do students who sit in rocking-chairs, or from other causes, lean the head forward when they study, often find that they **recover from drowsiness** if they sit erect?

16. How are **high collars** a fruitful source of bad colds?

17. Is ventilation easier in winter or in summer?

18. How do you account for the fact that people of general intelligence on most subjects sometimes use oil stoves, which are **stoves without stovepipes?**

19. If the **draught up the chimney** of the fireplace, when the fire is burning, takes up a volume of air sufficient for many people, why is it unwise to open a window?

NOTES

1. **Respiration in Consumption.** — Doctors Robin and Binet studied the respiration of nearly 400 cases of consumption, and reported their

results to the Paris Academy of Sciences (1901). They discovered that the respiratory changes become greater in consumptive patients than in healthy persons, thus completely overturning the general belief on the subject. The volume of inspired air was nearly doubled.

The investigators therefore believe that the old name "consumption" is a good name for the disease. To cure the disease, it is not sufficient to remove the bacillus. The labored and exhausting breathing due to abnormal functional and nutritive trouble brings the lungs into a condition favorable to the development of the bacillus, and these troubles must first be removed.

2. **The Cure of Consumption.** — D. M. Appel, major and surgeon, United States Army, makes the following statement: —

"We have demonstrated at the Fort Bayard sanitarium for soldiers that we can cure consumption in any stage. I don't mean to say that if people come to us with lungs so far gone as to destroy their breathing power we can cure them, but I do say we can cure what has long been regarded as hopeless — the third stage of the disease. The treatment is merely that which has been for years followed by the practitioners of the rational system. It consists of open-air living, generous diet, and rest. During the daytime the patients are not allowed under cover, and at night all windows are wide open. It is a common thing for these patients to gain ten pounds a week. One increased from 140 to 190, another from 128 to 210, and another from less than 100 to 160."

3. "The degree of vital activity of which we are capable is gauged exactly by the amount of oxygen we breathe. The bird which soars above the clouds has enormous lungs; even its hollow bones are utilized for breathing purposes; it may almost be said that a bird breathes to the very tips of its toes. The frog, on the other hand, has no chest, has merely a small breathing bag, which it fills at comparatively long intervals. Compare the activity of the swallow, easily keeping pace with the lightning express, with that of the frog, croaking amid the slime and miasma of a stagnant pool" (J. H. Kellogg, M.D.).

4. "The Greeks, whose figures remain everlasting and unapproachable models of human beauty, wore no stays. The first stays mentioned that I have ever found, is in the letters of Synesius, Bishop of Cyrene, on the Greek coast of Africa, 400 A.D. He tells how, when he was shipwrecked on a remote part of the coast, and he and the rest of the passengers were starving on cockles and limpets, there was among them a slave girl, out of the far East, who had a pinched, wasp waist, such as you may see on the old Hindu sculptures and such as you may see on any street in any British town. 'And when the Greek ladies of the neighborhood found her out, they sent for her from house to house to

behold, with astonishment and laughter, this prodigious waist, with which it seemed to them impossible for a human being to breathe, or live!'

"In future years, when mankind has learned to obey more strictly those laws of nature and science, which are the laws of God, the present fashion of tight lacing will be looked back upon as a contemptible and barbarous superstition, denoting a very low level of civilization in the people who have practiced it" (Rev. Charles Kingsley).

CHAPTER XII

FOOD

331. Proteids, or Albuminoids. — It was learned in an early chapter that protoplasm, the basic life substance, is not always the same in composition, but there is one material that is always found in it and is the test by which it is known to be protoplasm, and that is albuminous material. It was learned in Chapter II that albumin always contains nitrogen, the most inert and inactive of the elements, and that albumin gives strength and stability to the cells and tissues. The fibers of connective tissue, for instance, are albumin. It is the great tissue-building material, and as the activities of cell life are constantly using up the materials of the cells, we are not surprised that albuminous or nitrogenous food is reckoned as the most essential of all foods for sustaining animal life. Albuminous foods are commonly called *pro' te-ids*, or *pro-te-in foods* (Greek *protos*, first or most important).

332. Carbohydrates, or Sugars and Starches. — Why are roasting-ears sweet, although mature corn is not? It is because the sugar in the first has been changed to starch in the second. On the other hand, ripe apples are sweet because the starch of green apples has been changed to sugar. Starch and sugar are so nearly alike in composition and change so readily into each other, that as foods they are classed together. It was learned in Chapter IX that the sugar in the blood is diminished by muscular exertion. The oxidation of the sugar is accompanied also by increase of the bodily heat. It was learned that fat is stored up in the interior of cells (Fig. 38). Sugar can be changed into fat by the cells and stored away for future use in producing heat and motion. Thus sugars and starches, or the carbohydrate class of foods, have three uses. Knowing the great importance of movement to our life, and also the fact that the body is constantly losing heat, day and night, winter and summer, the importance of this class of foods is easily understood. Some animals and plants have fat and oils or liquid fat in their tissues ready for use as food by man. This gives us a third class of foods, the —

333. Fats. — Fats are exactly the same in function as the carbohydrates. A pound of fat in oxidizing gives out two and one half times as much heat as a pound of sugar or starch, and about the same as a pound of albumin. It may be stored up as fat in the body if not oxidized in the muscles to promote heat and work. Under all circumstances, a certain amount of nitrogenous or proteid food is required by the muscular tissue, for, as in all cells, the real living framework of the muscular fibers contains albuminous substances as one of its essential constituents. We may, then, think of fat and sugar as having the same relation to the structural substance of the muscle as the coal has to the structural parts of the engine.

334. Mineral Foods. — The food stuffs so far mentioned are all organic substances. There are many inorganic or mineral food stuffs, such as carbonate of lime, phosphate of lime, iron, and sulphur that are necessary to the body, yet we cannot get them directly from mineral sources. The bones are largely made of lime, and if we could assimilate lime by eating it, or drinking it in "hard" water, then the people who live in limestone regions and drink hard water might all be giants. We can get phosphates and carbonates of lime from wheat and other grains; sulphur is contained in eggs; iron is contained in grains, tomatoes, and most vegetables. Iron tonics, tincture of iron, etc., do not contain iron in an organic form. Only plants can furnish these mineral foods in a form most suitable for assimilation by our bodies. Animals must get them from vegetables, and they may become part of the bodies of several successive animals as one makes food of another.

335. But you may ask, how is it that plants only have the power of nourishing themselves with mineral substances although we take water and common salt as food? Are these two exceptions to the rule? It is doubtful whether such substances can be strictly called foods, for food must undergo a chemical change in the body, while water and salt do not, but are found to leave the body unchanged in the perspiration and other excretions. They serve only a mechanical purpose of dissolving the true foods and bringing them within the reach of the cells, for it was learned that all the cells lead a watery existence. Nerve cells, as well as others, are bathed in lymph, and it is in a manner true that we even think under water. The mechanical foods, are therefore of the greatest importance in keeping the tissues in the right condition for the cells to work.

336. Table: —

FOOD STUFFS	*Organic*	Proteids — Nitrogenous substances.	
		Fats and oils	Non-nitrogenous substances.
		Sugars and starches	
	Inorganic	Water.	
		Salts (salines).	

The non-nitrogenous foods are sometimes called carbonaceous foods because they contain a greater amount of carbon than the proteids; remember, however, that the proteids have some carbon.

337. Composition of Foods. — Very few of the articles of food we eat consist of only one of the classes of foodstuffs mentioned; most foods consist of several foodstuffs combined. Oatmeal, for instance, contains starch, a small proportion of oil, a large proportion of proteid, some mineral salts, and water. Let us see how the four classes are represented in milk. The part that makes it liquid is water, the sweetness comes from the sugar, the cream rises as oil, and the curd will furnish cheese, which contains casein, a form of proteid.

338. Experimental Tests of Starch and Proteid. — With ten cents' worth of iodine from the drug store the teacher may try the following experiments: — Dilute a part of the iodine with water to a light brown color. Make a thin paste by boiling laundry starch in water. Put some of this paste into an ordinary glass and pour a little of the dilute iodine upon it. Notice that the starch turns instantly to a beautiful blue color. This is one of the chemical tests for starch, and is called the *iodine test.*

339. Put a little piece of lean meat into some of the undiluted iodine; the meat turns brown. This is the iodine test for proteid.

340. Soak some grains of corn, wheat, rye, and other grains for a few hours. Make thin slices across each kernel. Place a slice of each grain in a few drops of dilute iodine in a saucer, and notice which part turns blue. Put slices of each grain into strong iodine, and after they have been acted on for several minutes, rinse off the iodine. Notice which part is blue and which parts are brown. In the grain of corn, for instance, the white part of the kernel turns blue, showing the presence of starch, while the germ and the part around it turn brown, showing the presence of proteid. The oil in the corn is mixed with the starch and proteid, and cannot be shown by a simple experiment. If the grain of corn is burned, a small amount of ashes remains, showing the mineral matter. Cereals contain all of the four classes of food.

341. Sources of Food.—All parts of a plant may furnish food: the *seed*, as the various grains, nuts, and fruits; *leaves*, as lettuce, cabbage, dandelion; *roots* and *tubers*, as potatoes, beets, turnips, tapioca (root of cassava); *stem*, as sago (pith of sago palm); *saps*, as sugars (of cane, beets, and maple tree); honey; and oils (from peanuts, cottonseed, olives, pecans and other nuts).

342. Sources of proteid: albumen, in white of egg; gluten, the sticky or gluey part of grain; casein, in cheese and the curd of milk; fibrin, in the blood of animals; myosin, the basis of lean meat; gelatin, obtained from bones and ligaments by boiling; vegetable casein, in beans, peas, and nuts.

343. Sources of fats and oils: cream of milk, yolk of egg, oil of nuts, olives, cottonseed, cocoanut, and fat of meat.

344. Sources of starch: corn, wheat, rice, oats, and other grains, potatoes, cassava, arrowroot, sago (in this country the last two are usually potato starch sold under those names), beans, peas.

345. Sources of sugar: sugar cane, sorghum, dates, honey (almost pure sugar), bananas (20 per cent), grapes, fruits, beets, maple trees.

346. Study the table showing composition of foods (§ 434). Which grain has the least proteid? Which has the most? the most starch? the least? the most fat? the least? What vegetable foods are rich in proteid? In oil? Which food has least nutrition (contains most water and cellulose)? Which has most nutrition?

347. Experience has shown that the diet best suited for the body must contain, besides water, one part of nitrogenous food to four parts of non-nitrogenous food. Which of the foods in the table approximate this proportion?

348. Outline of Digestion. — The food is made soluble in the alimentary canal and is absorbed by the blood vessels and lymphatics in its walls. This canal is about thirty feet long (Plate III) and consists of —

(1) The *mouth*, where the food remains about a minute, while it is chewed and mixed with the saliva; the saliva changes a portion of the starch to malt sugar.

(2) The *gullet*, a tube nine inches long, running from mouth to stomach and lying just in front of the vertebral column.

(3) The *stomach*, a large pouch where the food is stored and from which it passes in the course of several hours, having become semi-liquid, and the proteids having been partly digested by the gastric juice, an acid secretion from small glands in the stomach walls.

(4) The *small intestine*, a narrow tube more than twenty feet long, where the fats are acted upon for the first time, and where the starches and proteids are also acted upon, and where, after about ten hours, the digestion and absorption of the three classes of foods is completed (Figs. 175, 177).

(5) The *large intestine*, about five feet long, where the last remnant of nutriment is absorbed and the indigestible materials in the food are gathered together (Plate IV).

349. Water and salt require no digestion preliminary to absorption. After the food is digested and absorbed and carried to the tissues by the blood and lymphatics, it must be assimilated, or made into material similar to the contents of the cells, and stored up for future use. Drugs, narcotics, and alcohol are not stored up in the cells, but, it is believed, are largely oxidized in the blood and lymph, or expelled from the system unchanged.

350. The Waste of the Body. — When the foods are oxidized in the body, there are several products of oxidation called *waste products*. The starches and sugar, fats and oils, when oxidized, give rise to water and carbon dioxid.

The proteids give rise to urea. This is excreted by the kidneys, and when it is separated from the kidney secretion by chemical means, it appears as a white, crystalline powder. There are also found in the secretion of the kidneys small quantities of phosphate and sulphate of lime, sodium, and potassium. Urea is a substance of great importance, as it is the chief waste substance produced by the process of decay and growth in the cells of the body. Carbon dioxid leaves the body through the lungs, and water leaves it through the lungs, kidneys, and skin.

351. How the Waste is measured. — If a man were to live all day in a small chamber placed upon very delicate platform scales, he would find that he lost weight every second of his existence except when taking food, and more rapidly at some times than at others, the amount of loss depending upon the activity of his body. The loss of weight occurs through the excretions which the man gives off. At average temperature of the air and average activity of his body, the day's loss to be replaced by food eaten, water drunk, and air breathed, would be about as follows: —

From the large intestine .	5 oz. excrement.
From the skin	25 oz. perspiration.
From the kidneys . . .	50 oz. excretion.
From the lungs	35 oz. carbon dioxid and water.
Total	115 oz.

The total loss is, then, nearly 8 pounds, three fourths of which is water (nearly 6 pounds). The remainder, except the 5 ounces of excrement, consists of those waste materials (solid or gaseous) which result from the breaking down of the active living protoplasm into simple chemical substances, through the process of oxidation. This amounts to $27\frac{1}{2}$ ounces and is apportioned as follows: perspiration, $\frac{1}{4}$ ounce of salts, and a trace of urea; the kidney secretion, 1 ounce of salts and $1\frac{1}{4}$ ounces of urea; the lungs, 25 ounces of carbon dioxid gas.

352. Variation in the Amount of Food. — Suppose the man in the little room on the scales were to work, — for instance, turn a hand mill or swing dumb-bells, — would the amount of waste be increased? Would the increase be chiefly urea (from proteid) or carbon dioxid (from carbonaceous food)? If it were to turn very cold, the loss of heat from his body would be greatly increased, and the waste correspondingly increased. If he were to think very hard, the increase would be marked. If he were to remain perfectly quiet in body and calm in mind, the waste would be decreased; likewise, if the temperature became mild. The effect upon the waste would not always be perceptible until some hours after its cause, for it takes time for the circulation and organs of excretion to remove the waste after the material of the waste has been formed.

353. The Most Important Class of foods is the proteids. They are substances consisting of nitrogen, carbon, hydrogen, oxygen, sulphur, and phosphorus. As sugar and starches, fats and oils, contain no nitrogen, the tissues cannot be built from them alone. Proteids not only build tissue, but are a source of some heat and energy, so life could be sustained on this class of foods alone; but it would not be the best and healthiest way of living, because in order to get enough carbon, there would be taken in an excess of nitrogen, and the digestive organs would be given extra work which would be of no value to the body.

354. Proportions of Nitrogenous and Carbonaceous Food needed. — The carbon dioxid gas which is daily lost by the body contains 8 ounces of carbon, while the urea which is lost contains a little more than $\frac{1}{2}$ ounce of nitrogen. The body thus loses carbon and nitrogen in the ratio of about 1 to 15. The food, of course, must supply these elements in the same proportion. If one foodstuff be taken in excess, part of it will be wasted. If the amount of one foodstuff absorbed be too little, the man must consume part of his body substances, and will lose in weight. In pure albumin, such as the white of egg, the proportion of nitrogen to carbon is 1 to $3\frac{1}{2}$. Since the proportion needed in his body is 1 to 15, if he eats enough white of egg to get just enough nitrogen, he would only get about one fourth as much carbon as he requires; for the body needs 15 times as much carbon as nitrogen instead of $3\frac{1}{2}$ times as much. But if he were to eat enough of egg white to get the carbon required, he would eat four times as much nitrogen as the body would use. If he subsisted on lean meat, he would eat four pounds a day to gain sufficient carbon, while three fourths of a pound would have supplied sufficient nitrogen.

355. A dog could readily live on lean meat alone. If a man attempted to do so, the kidneys would have to excrete the larger part of the nitrogen unused, and would probably become diseased from overwork, if, indeed, the meat did not become nauseous to the palate and stop the experiment. Yet, so flexible is the human system, if only plenty of fresh air and exercise are taken, that the Gauchos (a tribe of Indians on the Pampas of South America) live upon dried beef alone. But the habit is a strain upon the organs, and must have been acquired gradually. They are a very short-lived tribe.

356. Proteid contains carbon as well as the carbonaceous foods, but not so much; and it is found that proteid and carbonaceous food in the proportion of 1 to 4 gives the needed proportion of nitrogen to carbon (1 to 15).

357. How the Proportion of One to Four is attained. — Since fat, starch, and sugar do not contain nitrogen, it is impossible to live upon them alone. A dog fed only upon carbonaceous food, died in a few days. Since these foods contain plenty of carbon, it is obvious that by mixing them with proteid, the required proportion of nitrogen to carbon can be attained. In about two pounds of bread there is enough carbon for the day's needs, but it gives only half enough nitrogen. So, by combining lean meat, cheese, beans, or nuts with bread, a sufficiency of both elements is obtained without unnecessary work or waste. With the addition of plenty of water and a little salt, the diet is chemically complete.

358. How Different Peoples attain the Proportion. — Milk has an excess of nitrogen, and oatmeal an excess of carbon; oatmeal and milk form a perfect food, and it is not surprising that a whole race (the Scotch) have lived upon it and thrived. Potatoes are mostly starch and water; the starch in them is more than four times as much as the proteid, and an Irishman who tried to live on potatoes alone, would have to eat seven pounds a day to get enough proteid. By eating milk and eggs also, he can get along on half the amount of potatoes named above, and every Irish peasant is said to keep a cow and chickens. The Mexicans eat bread made of corn meal, and supply the proteid by using beans as a constant article of diet. The Zulus live on cracked corn by adding milk to it. The Arabs live on barley and camels' milk, rarely eating the camels' flesh. Hundreds of millions of people in Asia (the Hindoos, Chinese, and others) subsist mainly on rice, which is more nearly pure starch than any of the grains, containing only 6 per cent of proteid, about half as much as wheat and corn; the chief addition they make is butter or other fat, and beans, which contain vegetable proteid. Their meagre diet may partly account for their lack of energy and bravery, and the ease with which they are conquered and controlled by European nations. The greatness of a people is largely dependent upon their diet.

359. The Body's Method of regulating the Food. — We should not think that the food eaten must be regulated with the greatest precision. Any reasonable excess will either pass through the canal unabsorbed, or be excreted from the blood, without great injury to the body. A want of any of the necessary elements will be well tolerated for a time until a craving for a certain kind of food will lead later to the supply of the elements needed. If a person feels bad, or the digestion seems weak, some will advise dieting. There is a tendency among certain writers on hygiene to overrate the importance of this subject. If the laws of health in regard to fresh air, muscular exercise, sleep, cleanliness, temperature, and the use of stimulants be observed, our appetites will be a sufficient guide in the matter of diet. These matters should first be looked to, and dieting then will probably become unnecessary.

360. It is an instructive and important fact, that too much consciousness of what is eaten and too much dwelling on what might be the consequence of eating this food or that food, will bring about serious derangement of the digestion. If we do not abuse our tastes, but give the proper heed to them, we may keep a delicate indicator which will, in a more perfect way than any scientific table has yet done, tell us what is needed.

In this Chapter alcohol and other narcotics have not been mentioned as they are not to be classed as true foods. Professor Atwater recently found proof of what has always been believed by physiologists, namely; that alcohol is oxidized in the body and that it may to a slight extent for a few days take the place of carbohydrates. Yet alcohol causes the lining of the stomach to become unnaturally congested, and habitual drinking causes it to become inflamed and even ulcerated. A true food must be capable of nourishing the body without injuring it.

CHAPTER XIII

THE DIGESTION

361. The Digestive System. — The food, in order to be of service to the body, must undergo several changes. Its nutritious portion must be separated from the innutritious; and the former must be made soluble, or in fit condition to be taken up by the blood and carried to the tissues. This process is called *digestion*, and the assemblage of organs by which it is carried on is called the *digestive system.* The tube which forms the receptacle for the food during digestion is called the *alimentary canal.* In the carnivora, or flesh-eating animals, whose food contains but a small amount of indigestible matter, the alimentary canal is comparatively short, being, when stretched out, only three or four times the length of the body. In the herbivora, or grass-eating animals, the canal is thirty times the length of the body. In the hog, which is omnivorous ("all-eating"), it is ten times the length of the body. If man's trunk only is counted, the canal is twelve times as long; if his height is counted, the canal is six times as long.

362. The Alimentary Canal has three coats in its walls throughout its whole length. What is each for? The inner coat, or lining, is a delicate epithelial tissue called the *mucous membrane.* It forms a smooth lining to prevent friction, and secretes a mucus which serves the same purpose. The next coat is the submucous coat; it is of elastic connective tissue, and serves to toughen and strengthen the wall, and to bind the mucous coat to the muscular coat. Outside of this is the third coat. It is composed of several layers of involuntary muscular tissue, which, by its contraction, causes the food to move along the canal (Fig. 169).

363. In the walls of the alimentary canal are numerous blood vessels and lymphatics. Opening on its inner surface are mouths of ducts from the various glands of the digestive system. Some of the glands are of considerable size and lie outside of the canal; others are very minute and are embedded in the walls of the canal; their secretions render the food soluble.

364. The Real Inside of the Body. — When we swallow food or drink, we are accustomed to say that it is in the body, but anatomically and physiologically this is not correct. It is on the outside anatomically, because the mucous membrane is continuous with the skin, which is the external covering. It is on the outside physiologically, because the food must pass through the mucous membrane before it can be assimilated by the tissues and become of use to the body. In many kinds of sickness the secretion of the digestive fluids diminishes or ceases altogether, and persons sometimes make a sad mistake in thinking they are giving food to the patient, when the food is only irritating the alimentary canal and fermenting or decomposing, and never really getting inside of the body. A lean person often eats a great deal, expecting to get fat, and finds that although he has swallowed the food, the nourishment has never really entered his body. Many a dyspeptic is tortured with the gnawings of hunger yet is continually eating, and is hungry still, because he does not really get the food.

365. The Mouth. — The food is held in the mouth for a short time while it is mixed with the watery alkaline fluid called the *saliva*, and is ground up fine by the teeth. The partition between the nose and the mouth is formed by the palate bones, covered with mucous membrane. The larger part of the roof of the mouth is formed by these bones and is called the *hard palate*. The roof is completed in the rear by the fleshy *soft palate*. The floor of the mouth is occupied mostly by the tongue; the lips form the front wall, and the cheeks the side walls. The cheek is composed partly of a large flat muscle called the *buccinator* ("trumpeter," because used in blowing a trumpet). The contraction of the trumpeter muscles, together with the movements of that flat muscle called the *tongue*, keeps the food between the teeth in the act of chewing, or mastication.

366. Salivary Glands. — There are three pairs of glands that secrete saliva. In structure one of these glands with its duct resembles a minute bunch of grapes with a hollow stem. The largest, called the *parotid*, is just beneath the skin in front of the ear. Its duct opens into the mouth in the upper jaw opposite the second molar tooth. This gland swells in a disease called the *mumps*. The next largest gland is the *submaxillary*, lying within the angle of the lower jaw. Its duct opens into the floor of the mouth. The smallest, the *sublingual*, lies farther to the front; both glands of the pair lie beneath the tongue, and open by a number of ducts. The fluid produced by these glands becomes mixed with the mucus from the mucous membrane of the mouth and is called the *saliva*.

367. Saliva. — This is a thin, colorless, alkaline liquid, slightly sticky, and often containing air bubbles. About $\frac{1}{1000}$ part of the saliva is a white substance called *ptyalin*, which has the power to change starch to malt sugar while remaining unchanged itself. Hence ptyalin is a ferment. *Ferment* is the name given to certain organic substances which act chemically upon other substances, and change their nature without becoming changed themselves. From one to three pints of saliva are produced daily. Its flow is excited by the act of chewing and by anything held in the mouth, especially if it be of an agreeable taste or odor. Hunger, or the sight or thought of agreeable food, makes the mouth water by stimulating the cells in the glands to activity by means of the nerves. But by far the most powerful of all the excitants to the salivary flow is dryness of the food. Only one fourth as much saliva is deposited in the same length of time when eating oatmeal and milk as when eating crackers or dry toast (Fig. 164).

FIG. 164. — Cells of the Salivary Gland.

A, after rest; *B*, after a short period of activity; *C*, after a prolonged period of activity. Shriveling and loss of granules occur.

368. Absorption, or the passage of digested food into the blood vessels, is an important sequel of the digestive process. A little of the water containing sugar and salts is absorbed from the mouth directly into the blood vessels. Poisonous substances may sometimes be absorbed from the mouth in sufficient quantities to produce death. If a drop or two of prussic acid be placed on the tongue or on the mucous membrane, death occurs in a few minutes, although not a particle of it has reached the stomach. Boys who take their first chew of tobacco learn in a disagreeable way that the entire body may be affected by absorption from the mouth. The absorption in the mouth is insignificant in amount compared to the absorption that takes place in the small intestine.

369. The Pharynx (*fär-inks*), a muscular bag opening from the nose and mouth, is four and a half inches in length and lies against the spinal column. It is commonly called the *throat.* There is an air passage from nose to lungs and a food passage from mouth to stomach. They cross each other, and the intersection is called the *pharynx.* There are seven openings from the pharynx: one to the mouth, one below the mouth into the trachea, one behind the trachea into the gullet, and two pairs of openings in the upper pharynx; one of these pairs is to the nasal passages, and the other pair is into the Eustachian tubes, which lead to the ears. When swallowing, all of the openings close but the one to the mouth and the one to the gullet (see Plate VII).

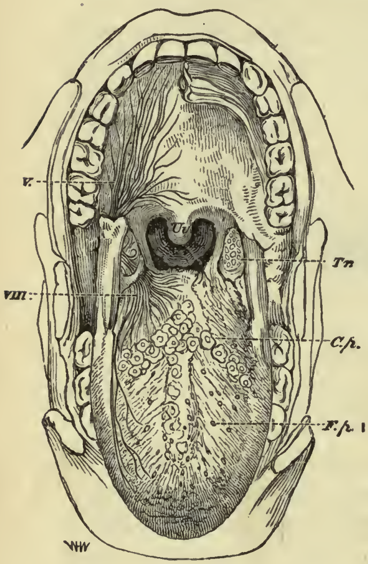


FIG. 165. — The Mouth wide open to show the Tongue and Palate.

Uv, uvula; *Tn*, tonsils; *C.p.*, taste papillæ; *F.p.*, taste papillæ. On the right side, branches of the fifth nerve to the palate, and of the ninth to the tongue, are represented.

370. The upper part of the pharynx, and thus the openings to the nose and ears, can be closed by raising the tip of the soft palate, or *uvula*, against the spinal column (Fig. 165). Sudden laughter or coughing while swallowing may cause the soft palate to relax, and then a portion of the food or drink is sometimes forced into the nose. The opening to the windpipe can be closed in three ways: by the vocal cords approaching one another; or by the descent of the epiglottis, the cartilaginous lid of the larynx; or third, by the tongue arching itself back over the windpipe. The opening from the mouth, called the *fauces*, can be closed by the contraction of upright muscles, called the *pillars* of the fauces, which connect the posterior part of the soft palate and the base of the tongue. These muscles come together in the middle like sliding doors. There are two of them on each side, and the tonsils lie between them. The tip of the soft palate hangs down between the pillars, and is called the *uvula*. By looking into a mirror with the mouth very wide open and the tongue flattened, you can see the palates, the pillars, the uvula, and perhaps the tonsils.

371. The Tonsils (Fig. 165) resemble the lymphatic glands. They are oval in shape, and lymph cells, resembling white blood corpuscles, are formed in them by multiplication, and pass out of the tonsils into the saliva as salivary corpuscles. They are supposed to be germicidal and protective. Sometimes the tonsils swell, and by pressing the soft palate backward and upward, cut off the passage from the upper pharynx and nose, necessitating mouth breathing. They are often partly or entirely removed by the surgeon without noticeable injury to the health.

372. The use of tobacco is a common cause of diseases of the throat. It causes a dryness and thirst, and frequently leads those who use it to take alcoholic drinks. Often the habit of smoking produces a troublesome disease called *smokers' sore throat*, which can be cured only after smoking has been discontinued. The heat of smoking is very trying to the organs, although not so injurious to them as the poison of the tobacco. A still more dreadful disease which can be traced to the same cause is that of *tobacco cancer*. Persons dying of tobacco cancer lose their voices in the advanced stage of the disease. This disease is practically incurable.

373. The Esophagus, or gullet (Fig. 166), opens from the lower part of the pharynx. It is about nine inches long, and lies along the spinal column behind the trachea. It has the three layers found elsewhere in the alimentary canal, and its walls are soft and lie collapsed when no food or drink is passing. The food is under reflex control after passing the fauces. The contraction of the pharynx presses the food down into the esophagus. A ring of the muscular tube contracts just above the morsel. This contraction runs down to the stomach, forcing the food before it as if a tight ring were slipped down over the esophagus. A contraction of any part of the alimentary canal in this manner, as if a wave were traveling along, is called *peristalsis*. While a horse is drinking, the peristaltic waves of the esophagus may be plainly seen along the neck (Plate VII).

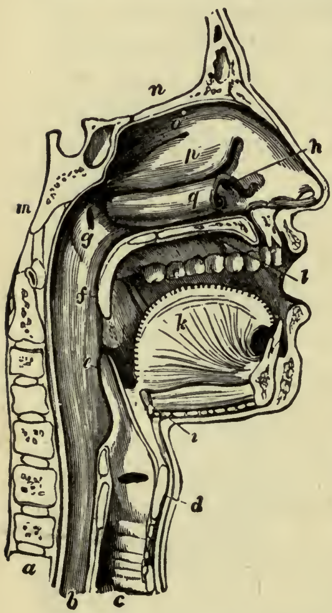


FIG. 166. — Mouth and Upper Part of Esophagus (see Plate VII).

a, vertebral column; *b*, esophagus; *c*, trachea; *d*, larynx; *e*, epiglottis; *f*, soft palate and uvula; *g*, opening of left Eustachian tube; *h*, opening of left lachrymal duct; *i*, hyoid bone; *k*, tongue; *l*, hard palate; *m*, *n*, base of skull; *o*, *p*, *q*, the scroll-like, or turbinated bones.

374. The Stomach. — The gullet pierces the diaphragm to the left of the center and enlarges into a pouch called the *stomach*. This organ lies just under the diaphragm, mostly on the left side of the abdomen and half covered by the lower ribs. It is capable of holding about two quarts. When full, it is about a foot long and five inches broad. Its shape is not easily described (Fig. 167). It is placed across the abdomen, and its left end is the larger. Its outline is curved inward above and outward below. When empty, it flattens and its walls touch, and the mucous lining then lies in deep wrinkles or folds. The opening where the gullet ends and through which the food enters, is called the *cardiac orifice* because it is near the heart. The opening where the intestines begin and through which the food leaves, is called the *pyloric orifice;* both openings can be closed by circular muscles in their walls.

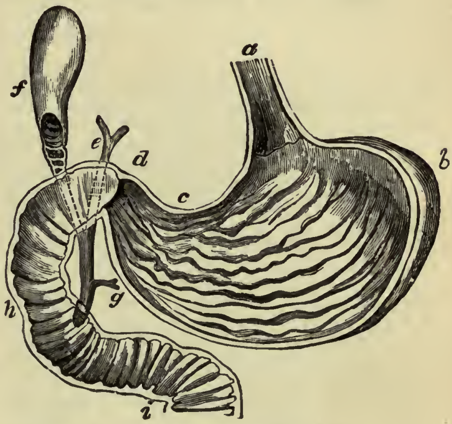


FIG. 167. — The Stomach laid open.

a, esophagus; *b*, cardiac dilatation on left side of stomach; *c*, the upper wall; *d*, the pylorus; *e*, bile duct; *f*, gall bladder; *g*, pancreatic duct, opening with bile duct into *h*, *i*, duodenum (see Plate V).

375. Peritoneum.— The abdominal cavity, or the portion of the large cavity of the trunk below the diaphragm, has, like the thoracic cavity, a lining to prevent friction. This membranous lining is called the *peritonéum*, and like the pleura, it is double. It comes up the wall of the cavity all around, lining it like a thin sheet, until it reaches the place under the diaphragm where the gullet and larger blood vessels (aorta and vena cava) enter, where it is reflected and courses downward, enveloping the stomach and other digestive organs. It penetrates between them by means of foldings and turnings, thus assisting to hold them in place. The largest fold of all is called the *great omentum* and surrounds the small intestine. It is fan-shaped and its contracted part is attached to the spinal column for a firm support. The alimentary canal, beginning with the stomach, may be said, therefore, to have a fourth layer, or covering, the peritoneum.

376. The Peristalsis of the Stomach.—Anything taken into the stomach causes wavelike contractions in its muscular walls. The food is caused to go from the gullet to the left of the cardiac orifice, then down to the right and back again, the circuit from left to right, then from right to left, taking from one to three minutes, according to the activity of the peristalsis. The muscular fibers in the walls of the stomach are in three layers (Fig. 169); one layer runs lengthwise, another around, and the third obliquely, so that the varied contractions cause the food to become thoroughly mixed with the —

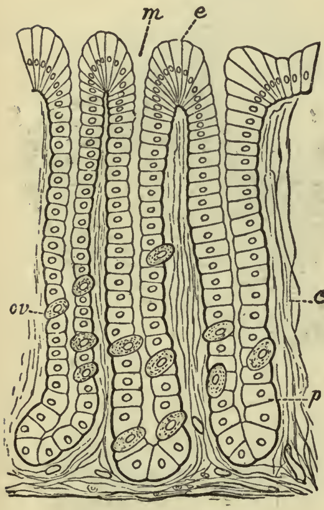


FIG. 168. — Three Glands of the Stomach.

e, epithelium at inner surface of stomach; *m*, mouth of gland; *p*, principal cells of gland; *ov*, ovoid cells; *c*, connective tissue below and between the glands.

377. Gastric Juice. — This is a yellowish fluid and consists of water, having in solution hydrochloric acid and two ferments. These remarkable substances, although existing in very small quantities, are able to change the composition of large quantities of food. In times of rest, when there is no food present, the mucous membrane of the stomach is of a pale red color. But when food is introduced, a change at once takes place. The membrane becomes charged with blood and consequently turns to a deep red color. The gastric juice, secreted by many small glands (Fig. 168), appears on the walls of the stomach, and peristaltic action begins (Fig. 169).

378. The **ferment** of the gastric juice called *rennin* acts by coagulating milk, a change somewhat like the coagulation of the blood. It causes coagulation by acting upon the proteid part of the milk. It is especially abundant in childhood. The other ferment, called *pepsin*, softens the proteid part of food and reduces it to peptone, in which form it is soluble in water. Pepsin, however, can act only when the hydrochloric acid has accumulated to an amount sufficient to neutralize the alkaline condition caused by the saliva. This usually requires about thirty or forty minutes. The hydrochloric acid, by its presence in sufficient quantity, not only enables the pepsin to act, but also prevents fermentation of the food and kills all germs that may enter the stomach.

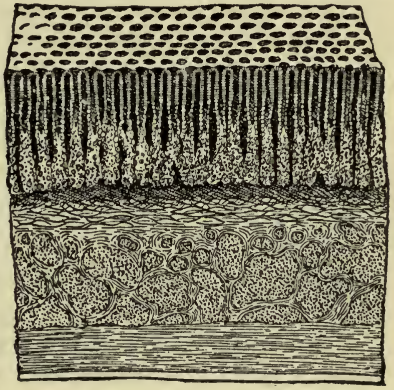


FIG. 169. — A Section through the Walls of the Stomach. Magnified only 15 diameters.

1, surface of the mucous membrane, showing the openings of the gastric glands; 2, mucous membrane, composed almost entirely of glands; 3, submucous or areolar tissue; 4, transverse muscular fibers; 5, longitudinal muscular fibers; 6, peritoneal coat.

379. The saliva continues its work even in the stomach until neutralized by the acid. The pepsin then begins to act. The outside of the food particles is acted upon first, and this digested part is then rubbed off by the peristaltic movements, and the next layer is acted upon. Its action is confined to the proteids. In fat meat the albuminous walls of the cells are eaten away and the fat is set free but not digested. Starch may also be set free from albuminous envelopes.

380. The food is thus reduced to a semi-fluid condition and is called *chyme*. A slight **absorption** may take place in the stomach, of a portion of the proteids digested there. Some of the sugar resulting from the salivary digestion of starch by the saliva, may also be absorbed. Nearly all the absorption of the food takes place in the small intestine, and it is there likewise that most of the digestion takes place; for, upon leaving the stomach, the greater part of the proteids, sugars, and starches, and all the fats and oils, remain to be acted upon.

381. After the food has been reduced to chyme, the **pyloric orifice** opens every minute or two, permitting a little of the chyme to escape into the intestine. But if some hard object, as a button, or a lump of raw starch from an unripe apple insufficiently masticated, enters the stomach, the pylorus, after a while, will become fatigued and will relax and allow it to pass without becoming semi-fluid (Fig. 170).

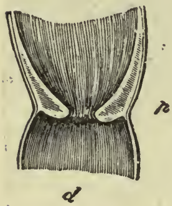


FIG. 170. — Pylorus. *p*, pyloric sphincter, *d*, stomach.

382. It is a common notion that digestion is carried on chiefly in the stomach. Some physiologists give tables stating that pork requires five hours for digestion, fried beef four hours, roasted beef three hours, apples one hour, etc.; what is meant is that it requires that length of time for these foods to leave the stomach, the digestion being far from complete. The tendency of investigation in the last few years is to show that the stomach is a kind of storeroom or antechamber which enables us to eat food in a shorter time, and in which it is stored, being softened and kept free from germs in the meanwhile, that it may be delivered gradually to the intestine. There were four persons in the world in the year 1900 without stomachs (this organ having been removed by surgeons on account of cancerous or other incurable conditions), and the small intestine joined to the esophagus. These persons had to eat very slowly, taking their food in a semi-fluid condition.

383. Retrospect.—Of the thirty or more feet of the alimentary canal, the food, upon leaving the stomach, has traversed about two feet. Of the fourteen hours required for digestion, about three or four hours have passed. A portion of the starch and proteid has been digested and a small amount of each absorbed by the blood vessels. The fats have not yet been acted upon.

384. It is essential that the part performed by each prior organ should be well performed, for this determines whether the changes in the food in the next organ shall be easily and completely accomplished. If the food is thoroughly masticated in the mouth and the saliva well mixed with it, this alkaline condition excites the flow of the acid gastric juice, which otherwise would be scanty. If the gastric juice is strong and acts freely upon the food, the acidity of the food as it leaves the stomach and enters the small intestine, excites the flow of the alkaline intestinal juices.

385. THOUGHT LESSON. **Indigestion.**

I. *A Fetid Breath.*

1. Name three causes of bad breath.

2. Let us investigate whether indigestion could cause a bad breath. In what kind (two qualities) of weather does meat spoil the quickest?

3. Suppose that meat or other food is put into a stomach with its gastric glands exhausted and its muscular walls tired out, what will be the rate of digestion, and what might happen to the food?

4. Odorous contents of the stomach (*e. g.* onion) can be taken by the blood to the lungs.

After answering mentally the above points, write in a few words a logical statement of how indigestion may cause a bad breath.

II. *A Coated or Foul Tongue.*

1. When the doctor visits you, at what does he first look?

2. What sometimes forms on old bread?

3. Do you think such a growth possible on undigested food in the stomach (§ 309)?

4. The microscope shows the coating on the bread to be a vegetable growth. If it forms on the walls of the stomach, it may extend to what?

III. *Stomach Ache.*

1. How can you tell whether fruit preserved in a sealed glass jar is spoiling?

2. What connection is there between belching at times after eating too freely of sweet or starchy food and the observation above?

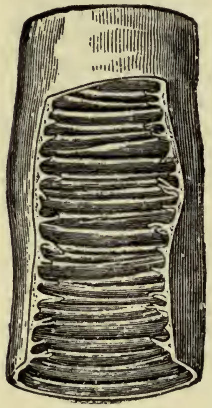


FIG. 171. — A Portion of Small Intestine cut open to show the Folds on its Inner Surface.

3. Why does belching sometimes give relief to an uneasy stomach?

4. Can you, by using these facts, explain a cause of stomach ache?

Be ready to give logical explanation in class, of cause of bad breath, furred tongue, and stomach ache.

386. The Small Intestine. — When the chyme passes the pylorus, it enters the small intestine, which is a tube about as large around as the thumb, and about thirty feet long, lying coiled in the central part of the abdominal cavity. The first part of it, about ten inches in length, is called the *duodenum* (from a word meaning *twelve*, because its length is twelve fingers' breadth) (Fig. 167). The mucous and submucous coats of the small intestine are wrinkled by numerous folds which are crescent-shaped, since no single fold goes entirely around the tube (Fig. 171). The folds are so numerous that they occupy almost the entire inner surface. The small intestine is the chief organ of absorption as well as of digestion, and the absorbing surface is greatly increased by the folds. On and between the wrinkles are innumerable tiny projections called *villi* (Fig. 172). Each villus contains a loop of blood vessel and a very small lymphatic called a *lacteal*. Since the villi are so thickly placed as to cover the entire mucous coat of the intestine like the fibers in a piece of velvet, the absorbing surface is enormously increased.

The digestive fluids that enter the small intestine are the *pancreatic* fluid from the pancreas, the *bile* from the liver, and the *intestinal juice* from the small intestinal glands (Figs. 172 and 174).

387. The Pancreas and its Secretions. — The pancreas, or sweetbread, is flat, narrow, and about six inches long. It lies behind the stomach, and tapers toward the left, ending above the left kidney. Its shape has been compared to a dog's tongue, and like the root of the tongue, it bends downward at its broader end, where its duct leaves it and joins the bile duct just before emptying into the duodenum. Its internal structure resembles the salivary gland, and it is called by the Germans the abdominal salivary gland. The amount of digestion accomplished in the small intestine is greater than in any other division of the canal, and the pancreas is the most active and powerful of all the glands. Its secretion, the

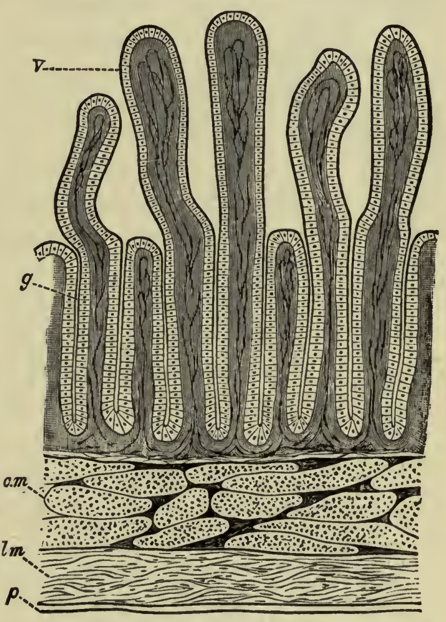


FIG. 172. — To show the Structure of the Wall of the Small Intestine.

v, villi, and *g*, glands of the mucous membrane; *c.m.*, circular muscle layer; *lm*, longitudinal muscle layer: *p*, peritoneum, or serous coat.

pancreatic juice, is alkaline, and contains three ferments, one of which (amylopsin) is hardly to be distinguished from the ptyalin of the saliva, and continues the digestion of the starchy food; another (trypsin) has an action similar to pepsin, and digests proteids; while the third (steapsin) begins the digestion of an important class of foods, the fats, which have not heretofore come in contact with a digestive fluid that could act upon anything more than the proteid envelopes of the fat cells (see Plates).

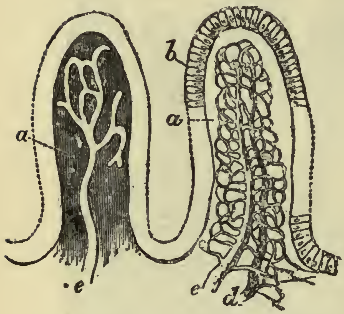


FIG. 173. — Semi-diagrammatic View of Two Villi of the Small Intestine. Magnified about 50 diameters.

a, substance of the villus; *b*, its epithelium; *c*, *d*, the artery and vein, with their connecting capillary network which envelopes and hides *e*, the lacteal that occupies the center of the villus and opens into a network of lacteal vessels at the base.

388. Digestion of Fats. — Fats are digested not by going into solution, but by the large globules of fat being broken into very minute globules. Such globules, floating in a liquid, form what is called an *emulsion*. Milk is an emulsion of cream. It is the cream in sweet milk which gives it the white appearance, for the globules of fat reflect the light. When it is churned these minute particles touch and adhere, forming butter. Fats are not acted on by acids, but they are acted upon by alkaline fluids. The steapsin ferment from the pancreas, aided by the alkaline bile from the liver, emulsifies the fats, and prepares them for absorption.

389. Absorption of the Fats. — The fats are absorbed by the lymphatic system. Many minute lymphatics called *lacteals* (Fig. 173) are found in the villi of the intestines, and the epithelial cells of the mucous lining take up the fat and transmit it, slightly changed, to these lacteals, which unite one to another and empty into the thoracic duct. Where does this duct empty? The fats are thus taken into the blood stream.

390. The Intestinal Glands. — Besides the two large glands, the pancreas and liver, there are a great number of very small glands (Fig. 172) which furnish a digestive fluid to the intestine. The intestinal glands are scattered throughout the lining membrane, and their secretion is called the intestinal juice. It is difficult to isolate and to study because of the minuteness of the glands, and although their functions are not fully known, it has been proven that their secretion can digest cane sugar and maltose and change them into grape sugar, or glucose. If cane sugar is injected into the arteries, it is excreted from the body unchanged. This proves that the body is incapable of assimilating cane sugar until it is digested.

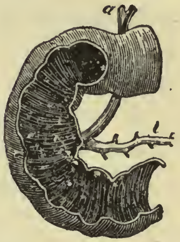


FIG. 174.—The Duodenum cut open so as to show the Bile Duct (*a*) and the Pancreatic Duct (*b*) opening by a Common Orifice.

391. Forms of Sugar and Starch. — *Cane sugar* is found in sugar cane, sorghum, and sugar beets. *Milk sugar* is found in milk. *Malt sugar* is produced by the action of saliva upon starch. *Grape sugar* (and *fruit sugar*, which is nearly the same) is the sweet element in fruits and honey.

Malt sugar, while passing through the mucous membrane of the intestine, is converted into grape sugar, and in this form it is absorbed into the blood. It may be

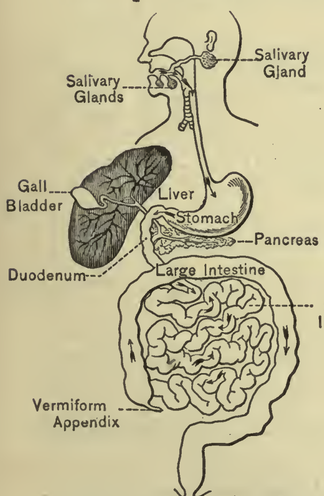


FIG. 175.—The Digestive System.

produced artificially by the action of vegetable diastase, which resembles ptyalin or the ferment found in saliva. Glucose, produced artificially by boiling starch with dilute sulphuric acid is of the same chemical composition as grape sugar, but the presence of sulphur and other chemicals interferes with its usefulness as a food.

Dextrin is intermediate between starch and sugar.

Starch, unlike the sugars, is insoluble in cold water.

392. Analysis of Digestion. —

1	Part of alimentary canal.	Glands.	Secretion.	Food acted upon.
2	Mouth.	Salivary (three).	Saliva.	Starch.
3	Stomach.	Gastric glands.	Gastric juice.	Proteids.
4	Small intestine.	Liver.	Bile.	Fats.
		Pancreas.	Pancreatic juice.	Starch. See Proteids. See Fats. See
		Intestinal glands.	Intestinal juice.	Cane sugar.
5	Large intestine.		Absorption.	Amount of diges-

393. Thought Lesson.

(Answers to be found by reference to table called "Analysis of Digestion.")

1. In which of the digestive organs is only one kind of secretion furnished from glands?

2. In which organ are three kinds of secretions furnished it by glands?

3. Which classes of foods go through the lymphatics?

4. Which classes of foods go through the liver?

5. Which classes of foods are digested in only one organ?

6. Which classes of foods are digested in two organs?

How do the facts given in the table show —

7. That the pancreatic juice is the most important of the digestive secretions?

8. That bread needs to be kept in the mouth for a longer time than lean meat.

What it is changed to.	How it gets into the blood.	What it will be used for.	Final product of oxidation.	1
Sugar.	Capillaries of portal vein.	Work, heat, and fat.	Carbon dioxid and water.	2
Peptones.	Ditto.	Building tissue.	Chiefly urea.	3
Emulsion.	Lacteals of lymphatic system.	Heat, work, and fat.	Carbon dioxid and water.	4
second line.				
third line.				
fourth line.				
See second line.				
tion here is insignificant.				5

9. That lean meat (a form of proteid) fried so that the grease soaks into it, is hard to digest? (Suggestion: Where is fat digested? Where should the digestion of proteids begin?)

10. That doughnuts, or batter-cakes, or any starchy food cooked so as to become grease-soaked, are hard to digest.

394. How the Food gets into the Tissues. — The absorption of the emulsified fats by the lymphatics has been described. The digested starch (glucose) and digested cane sugar (glucose) and the digested proteids (peptones) pass into loops of the blood vessels contained in the tiny projections called villi, and are carried to the liver. Both the small amount of these substances which is absorbed by the stomach, and the large amount which is absorbed from the small intestine, are taken by means of a system of veins called the *portal circulation* (Fig. 178), to the liver, where they may be stored or may pass through the liver and vena cava to the general circulation. The mineral substances, iron, lime, sulphur, and phosphates are contained in the proteid food and are digested and absorbed with it. Water and salt do not require digestion.

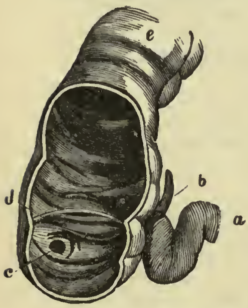


FIG. 176. — The Valve between the Large and Small Intestine.

a, small intestine; *e*, large intestine; *d*, *c*, valve; *b*, appendix.

It was formerly believed that the food passes into the lacteals and capillaries strictly according to the physical law of **osmosis** which governs the passage of fluids through dead membranes. It is now believed that the epithelial cells lining the canal take up the food and give it into the absorbent vessels by a process resembling secretion; but osmosis aids the process.

395. The Large Intestine or Colon (Fig. 177) is about five feet long. Its walls are drawn into pouches, or puckers, by bands of muscles running lengthwise along it. The small intestine joins it in the lower part of the abdomen on the right side (Fig. 176). The junction is not at the end of the large intestine but above the end. The part below the junction is called the *cæcum*. Attached to the *cæcum* is a small tube called the *vermiform appendix*. Above the juncture the large intestine is called the *colon*. The ascending colon runs up along the right side nearly to the waist. It is then called the *transverse colon*, and it comes forward and crosses just in front of the lower line of the stomach. It then retreats to the rear wall and passes downward, being now called the *descending colon*. Near the left hip it makes a double bend called the *sigmoid flexure* (from *sigma*, the Greek letter S). The nine inches remaining are without the pouched appearance, the walls being smooth; this part is without bends and is, therefore, called the *rectum* (from Latin *rectus*, "straight").

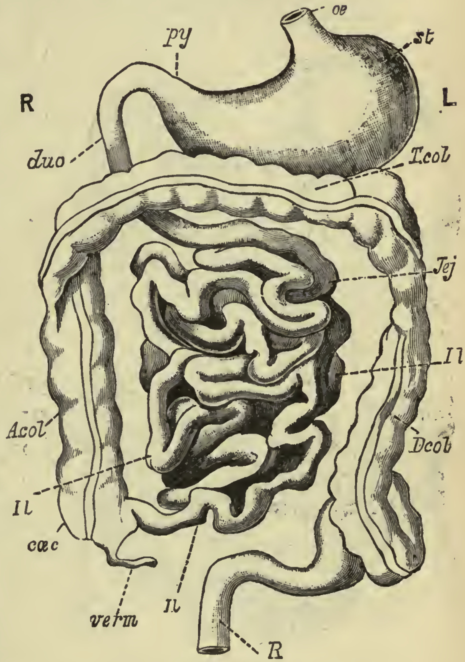


FIG. 177. — The Alimentary Canal in the Abdomen.

R, right; *L*, left; *œ*, esophagus; *st*, stomach; *py*, pylorus; *duo*, duodenum; *cæc*, cæcum; *A.col*, ascending colon; *T.col*, transverse colon; *D.col*, descending colon; *R*, rectum.

396. Absorption in the large intestine is very active and its contents soon lose their fluidity. Although it is mostly the watery portion that is absorbed, any digested food that may have escaped absorption in the small intestine, is absorbed by the colon. How saving and economical the body is! All the undigested and indigestible food gathers in the sigmoid flexure, and descends at intervals into the rectum.

THE LIVER

397. The Liver not merely a Digestive Gland. — The liver has three functions, (1) The bile secreted by it goes down the chief duct and "backs up" into the gall bladder, where it is stored until food is eaten, when it enters the alimentary canal and aids in the digestion of the fats. (2) It serves as a storeroom for digested food. You learned that all foods but the fats were carried to the liver when absorbed (Fig. 178). Some of them are stored there and given out gradually as needed. (3) The liver is an excretory organ. As the blood containing the food passes through it, poisonous substances in the blood from the tissues, or poisons that may be in the food, are destroyed and the products resulting from the destruction are sent out of the body by either of two routes: by way of the bile duct and alimentary canal or by way of the blood vessels and kidneys.

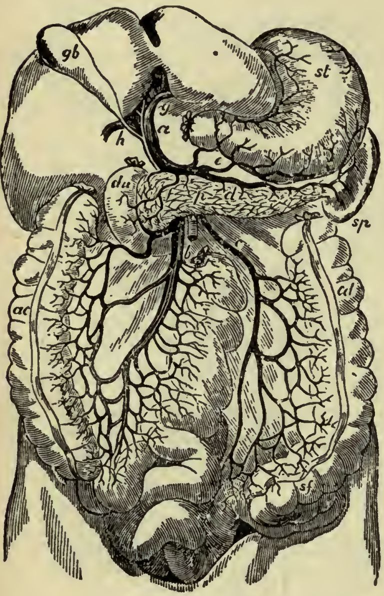


FIG. 178. — Abdominal Viscera displayed so as to show the Portal Vein carrying the Blood from the Viscera to the Liver.

l, liver; *gb*, gall bladder; *st*, stomach, and *du*, duodenum. These have been divided from each other. *p*, pancreas; *sp*, spleen; *ac*, *cd*, large intestine. The transverse colon and the small intestine have been removed.

As only one of these three functions is strictly digestive, it is more logical to treat the liver somewhat apart from the digestive organs.

398. Its Duty as a Guardian. — The food (except the fats) must pass the test in the liver before it can reach the system. All the blood in the body passes through it once every three or four minutes, and as it passes it is purified. The waste products resulting from the work done in the body are made more soluble, so that they can be carried through the kidneys. The yellow color of the bile is due to a pigment resulting from the destruction in the liver of worn-out red corpuscles. The bile is partly an excretory product, but such is the economy of the system that it serves to aid digestion, and to keep the alimentary canal in an aseptic condition on its way out of the body. A man could not smoke were it not for the liver. This organ takes up the nicotine, if not too great in amount, and destroys it. If one drinks alcohol, the liver endeavors to oxidize it and get rid of it, so that the body may not suffer harm and injury from it, and oftentimes the liver of a habitual drinker is crippled or destroyed by its long struggle with alcohol.

399. It has been shown by experiments upon frogs and other animals that twice as large a dose of poison is required to kill an animal that has a liver as to kill one that has been deprived of this organ. Similarly, it requires twice as much poison to kill a man when it is given through the stomach and passes through the liver, as when it is injected through the skin. Those who take morphine by hypodermic injection are more hopelessly bound to the habit than those who take it by the mouth.

400. A man would live many years longer than he does if he were not all the time producing waste products in his body by his ordinary activities. The excretory organs are taxed to remove them. In the young child as it is growing and developing, the skin is so active, the kidneys are so healthy, and the liver is so vigorous, that the waste is all removed and the blood is pure. That is why a healthy child has so sweet a breath, such bright eyes, and so fair a skin. When he becomes old it is different. The same is true of a dog; the puppy's breath is pure, its body is clean, so that it may lie in a lady's lap or on a sofa and leave no unpleasant odor. But when he is old, the dog becomes so offensive that he has to be driven out of the house. The strong odor results from the accumulation of waste substances in the body.

401. Gross Anatomy of the Liver.—The liver is the largest gland in the body. It is of a reddish brown color and weighs about three and one half pounds. The upper and front surfaces of the liver are very smooth and even. The under surface is very irregular; it is here that the various vessels with which this active organ is supplied make their entrance or exit. It is located under the right portion of the dome of the diaphragm, and its lower edge reaches a little below the border of the thoracic cage. (Does its left end overlap the stomach? See Plates.) Its connecting vessels, besides the lymphatics, are the hepatic artery from the aorta, bringing pure blood; the portal vein, bringing the digested food; the hepatic vein, carrying impure blood to the vena cava; and the bile duct, carrying the bile to the intestine. The bile duct, on its way from the liver, gives off a side branch to the gall bladder. This is a little dark green bag, in which the bile is stored until it is required for digestion (Plates III and IV).

402. With each inspiration the liver is pushed downward and compressed by the diaphragm, the blood being forced out toward the heart, and it fills again as soon as the breathing muscles relax. This rhythmic compression is of great importance in keeping the blood supply to the liver fresh and pure, and preventing congestion in it. By tight clothing the liver is often forced downward, out from the cover of the ribs, and becomes permanently displaced. As a result, other organs, lower in the abdomen and pelvis, are crowded upon each other and also become displaced. The circulation in the liver is diminished, and hence its activity is decreased and the complexion loses its freshness.

403. Circulation through the Liver, or Portal Circulation.—The portal vein and its function have been mentioned (Fig. 178). When it enters the liver, it does a very unusual thing; in fact, it conducts itself as no other vein in the body does, except some of the veins in the kidneys. It subdivides into capillaries. Thus the portal vein (Latin *porta*, a gate, since it enters under a kind of archway) both begins and ends in capillaries, for it begins in the capillaries of the digestive tract and ends in the capillaries of the liver. After these capillaries have passed in among the cells, they unite again to form the hepatic veins, which go directly to the ascending vena cava. There is another large blood vessel in the portal circulation. This is the hepatic artery, which enters the liver directly from the aorta and supplies the liver cells with arterial blood with which to repair themselves and carry on their work (Plate VII). The capillaries from this artery unite with those of the portal vein in forming the hepatic vein. A cow's liver, cut in two, shows in places small gaping holes, which are branches of the hepatic veins.

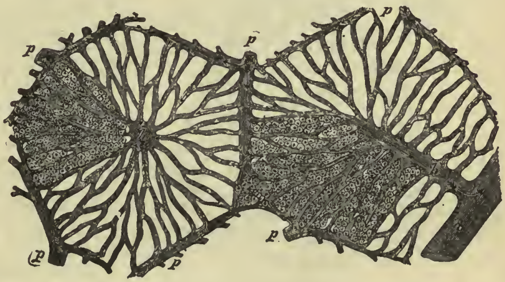


FIG. 179. — Diagrammatic Representation of Two Hepatic Lobules.

The left-hand lobule is represented with the intralobular vein cut across: in the right-hand one the section takes the course of the intralobular vein. *p*, interlobular branches of the portal vein; *h*, interlobular branches of the hepatic veins; *s*, sublobular vein; *c*, capillaries of the lobules passing inwards. The arrows indicate the direction of the course of the blood. The liver-cells are represented in only one part of each lobule.

404. Minute Anatomy of the Liver. — If you examine the surface of a piece of liver obtained from the butcher, you will find it to be of a dark red color, and mottled over with little areas, each measuring about one twentieth of an inch across. These are the round lobules of the liver arranged around a branch of the hepatic vein (Fig. 179). The capillaries of the portal vein and hepatic artery and the branches of the bile duct pass between these cells. Study carefully Figure 180, which represents a segment of a lobule. When you understand the circulation in a lobule, you will understand the circulation in the entire liver, for a lobule is the liver in miniature. Represent a lobule by a wagon wheel. The rim corresponds to the capillaries of the portal vein and hepatic artery circulating around the lobule. The spokes correspond to the two kinds of capillaries united and on the way to the hepatic vein in the hub, which will take the blood away from the liver. Between the spokes are located the hard-working liver cells which get oxygen and food from the capillaries in the spokes, and relieve themselves of impurities by means of the finest bile ducts and lymphatic ducts, which begin among the cells (Fig. 181). What are the two large vessels which bring material to the liver? What are the two large vessels (besides the lymphatics) which take material out of the liver?

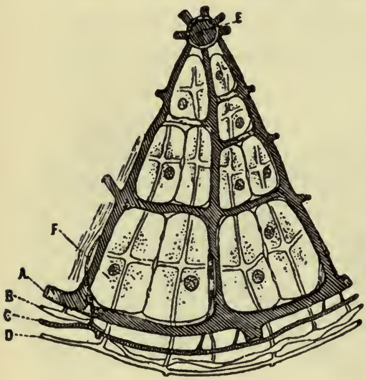


FIG. 180. — Microscope, high power. Diagram of a Portion of a Lobule of the Liver, showing the Blood Vessels and Bile Ducts injected with Fluid.

A, branch of portal vein sending capillaries to open into *E*, a branch of the hepatic vein which lies in the middle of the lobule; *B*, a lymphatic; *C*, branch of hepatic artery; *D*, branch of bile duct; into this open the ducts which lie between the liver cells *F*. Are the liver cells nucleated?

405. The Liver as a Storeroom. — If a frog be dug up in the first part of its winter sleep, and its liver be examined under the microscope, the cells will be found swollen and full of glycogen, a substance stored up for the winter needs of the frog. It is a carbohydrate material resembling starch and made from digested sugar. The liver cells of a frog which has just come out in the spring will be found shrunken and containing no glycogen (Fig. 182). If a starving rabbit be killed and its liver cells examined, no glycogen will be found, but the liver cells of a rabbit which has recently been fed on turnips will be full of glycogen. If two rabbits be well fed and one kept in a cage and the other hunted around all day, much glycogen will be found in the liver of the quiet rabbit, and very little in the liver of the hunted one. The glycogen stored up is used during muscular work or starvation.

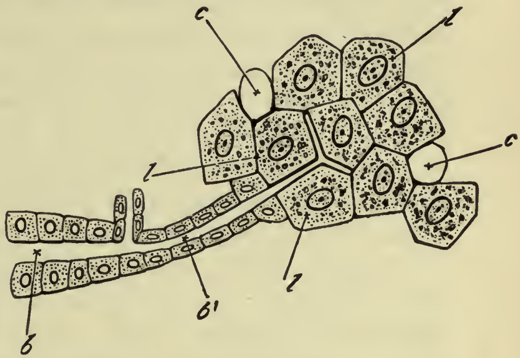


FIG. 181. — Diagram to show the Termination of a Fine Bile Duct.

b, small bile duct becoming still finer at *b'*: *l*, hepatic cells; *c*, capillaries cut across.

406. The sugar absorbed by the small intestine reaches the liver through the portal vein. It is taken up by the liver cells and changed into granules of glycogen, to be turned into sugar again during times of hunger and hard work. Thus only a small amount of sugar is allowed to enter the circulation at one time, only $1\frac{1}{2}$ ounces in every 1000 ounces of arterial blood. If more than this quantity enters the blood, sugar passes out through the kidneys, and the function of the kidneys may become disordered, a condition known as "diabetes."

FIG. 182. — Liver Cells of Dog after a Thirty-six Hours' Fast; also Fourteen Hours after a Full Meal — in the Latter Case swollen with Glycogen.

407. Urea is the chief **waste product** which results from the breaking down of proteid, and it is believed that the nitrogenous urea as well as the carbohydrate glycogen is formed by the liver. An excess of proteid, such as lean meat and cheese, in the diet, produces an increased excretion of urea through the kidneys. It is obvious that excess of food and lack of exercise may lead to the choking up of the liver cells with food products which are not required. This condition may be relieved by a spare diet and by vigorous exercise. The poor, overworked liver should not be blamed, however, nor the statement made that "the liver is not acting." At the very time the complaint is made, the skin and eyes may be yellow, showing the presence of too great a quantity of bile, which is a product of the activity of the liver.

408. Biliousness may result from three causes: (1) The first and most usual form of biliousness is not biliousness at all, but is caused by fermentation and other forms of indigestion, and by the poisonous products therefrom entering the blood. (2) Stoppage of the chief bile duct because of congestion, which extends to it from the stomach. This congestion is caused by irritation of undigested food (§ 597). (3) The liver cells and ducts may become choked up from excessive food (§ 407).

409. Alcohol in the Liver. — When alcohol is drunk, the portal vein carries it directly to the liver. There the alcohol greedily uses up the oxygen needed by the liver cells for their vital operations. This prevents natural action of the liver, for its cells have not enough oxygen to do their work properly. All physicians know that a drunkard's liver presents a greatly modified appearance. The alcohol does not build up useful tissue, but if taken in weaker form, such as beer and wine, it promotes an abnormal deposit of fat in the cells.

410. Drinking whisky and other distilled liquors causes the connective tissue of the liver first to increase in amount and afterward to shrivel and harden, drawing up into many little knots. This condition is called "hobnailed" or "gin drinkers' liver."

411. Influence of Carriage and Dress on Digestion. — Faulty carriage of the body and relaxation of the abdominal muscles, which lessens the abdominal type of respiration and diaphragmatic motion, are among the most frequent causes of sluggishness in hepatic circulation and secretion. Disorders of the stomach and intestines are likely to produce abnormal conditions of the liver. Improper dress aggravates all of these conditions.

Free and properly related movements on the part of the stomach, liver, and intestines are necessary for the correct performance by these organs of their natural functions. A certain amount of tension within the abdomen is necessary if the organs of that region are to be held in their proper places and relations. When the body is held erect and the chest is kept raised to its normal position; when the abdominal muscles are strong and are not allowed to relax and thus favor the descent of the organs, this abdominal tension and the proper relations of the organs are possible. Mothers should dress their children so that the chest may have the greatest possible freedom of motion. All garments should be suspended from the shoulders, thus preventing the downward displacement of the stomach, intestines, kidneys, liver, etc. Physicians who have given the subject careful study agree that more than fifty per cent of the women of civilized nations have developed the condition known as *enteroptosis*, which means that of the stomach, the intestines, frequently the kidneys, and sometimes the liver, are dragged downward and remain permanently out of proper position. This condition is largely responsible for the debility, backache, headache, biliousness, and early loss of complexion with which so many women of civilized countries are afflicted. Even if suffering from the enteroptosis caused by methods of dress, those who have strong constitutions and who keep the body healthy by living much out of doors, may enjoy moderate comfort. The greater proportion of women, however, lack these conditions and hence suffer to a greater or less extent from the symptoms mentioned.

412. The mistake in regard to dress begins so early in life that the wearer almost ceases to consider the discomfort arising therefrom. Many women say that their

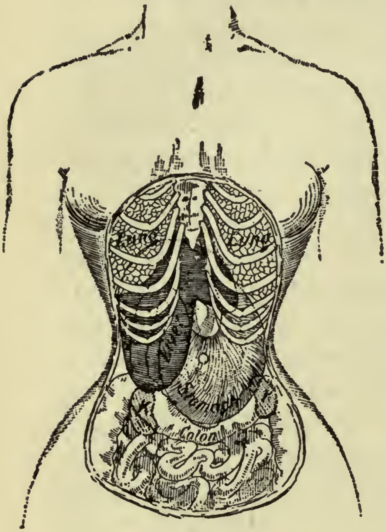


FIG. 183.

The breastbone cannot be moved down by a corset. Use its lower end for a stationary point, in comparing Figs. 183 and 184. How much have the liver and stomach descended?

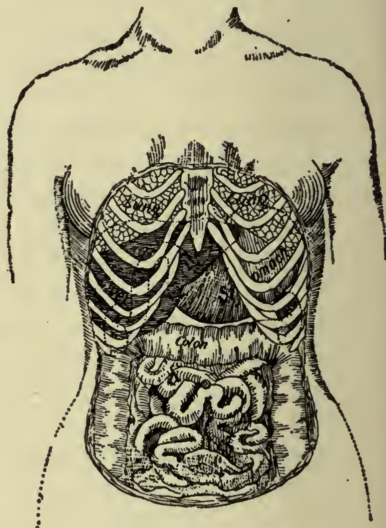


FIG. 184.

How far have the kidneys been moved? Has only the middle of the transverse colon descended or all of it? Is the waist of Fig. 183 deformed more than the usual amount?

dress is perfectly comfortable, because they do not know what comfort and freedom is. Dr. Kellogg found the average waist measure of girls from 9 to 12 years of age to be $23\frac{1}{2}$ inches, and he found the waist measure of young ladies from 18 to 30 years of age to be $23\frac{1}{3}$ inches. If their waists had been allowed to grow as God designed, they would have become 28 or 30 inches in circumference. In all these years the bones, muscles, digestive and other organs had been growing, but the waist had not. The organs had been growing out of place. The muscles of the trunk had not been growing, because their exercise was prevented by tight skirt-bands or corsets. The weak abdominal muscles become distended by the weight of the organs, and the abdomen sags downward and extends too far forward. The proper support being removed, the stomach, liver, kidneys, and other organs sag downward and drag and pull upon their points of attachment and cause pain and distress in all parts of the trunk, especially in the back, because of the pulling and stretching of the nerves leading from these organs to the spine.

413. Having worked perseveringly to get the organs down out of the waist and make it small, the woman would now give treasures to get them back again. The contortions such as the "straight front" and "Grecian bend" are attempts to conceal deformities of waist and abdomen. The cause of the trouble dates back to the year the growing girl began to wear her skirts tied around the waist instead of sewed to the upper part of the dress. Growth at the waist immediately ceased. If she had only waited, the chest and hips would have developed and the waist would have become rightly proportioned soon enough. It is said that a majority of women are sufferers from headache, backache, and other weakness which could have been obviated by comfortable and therefore graceful clothing. This want of foresight has made invalids and nervous wrecks of thousands of women, who try one surgeon and physician after another, seeking relief. Such a woman is unsuited for the proud position of presiding over the household, her diseases cast a gloom over the family life. The world is not so bright to her, and life is not so joyous as it should be. Yet many a delicate woman would have been able to retain her health if she had not had a dissipated and drunken, or a nervous, tobacco-soaked, husband. It is possible also that many a man would have been able to bear up through the struggles of life and finally to succeed, instead of succumbing to stimulants and dissipation, if he had not been burdened with a hysterical invalid for a wife, instead of a brave, cheerful, and healthy woman. The drooping lily style of woman has become very distasteful to men; the drinking, dissipating man is becoming equally repulsive to women. Health is an indispensable foundation for happiness.

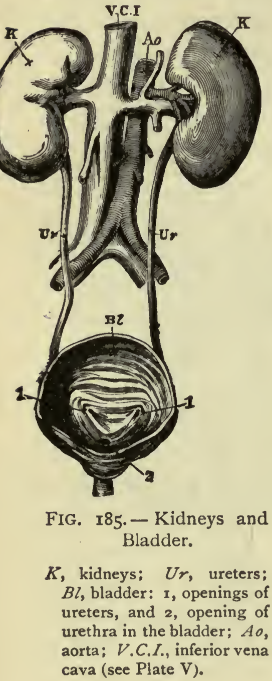


FIG. 185.— Kidneys and Bladder.

K, kidneys; *Ur*, ureters; *Bl*, bladder: 1, openings of ureters, and 2, opening of urethra in the bladder; *Ao*, aorta; *V.C.I.*, inferior vena cava (see Plate V).

THE KIDNEYS

414. The kidneys lie one on each side of the vertebral column, against the rear wall of the abdomen, on a level with the lower ribs. They are purplish red organs, about four inches long and two inches broad, and somewhat bean-shaped. A man's kidney (Fig. 185) is very much like a pig's kidney, which you may have seen.

415. A large artery, the renal artery, leads from the aorta to each kidney, and a large vein, the renal vein, leads from each kidney to the inferior vena cava. There also passes out from each kidney a white tube called a *ureter*. The two ureters run down the back and open into the bladder (Plate V).

416. **Function.** — Urea is the most important substance excreted by the kidneys. It is brought by the blood to the kidneys, and you learned that it is probably formed in the liver. It is a nitrogenous substance, and is more abundant if a large amount of proteid food is eaten.

417. In summer, when the circulation in the skin is active, the secretion of the kidneys diminishes in amount. On the other hand, cold drives the blood from the surface to the internal organs, and the secretion of the kidneys is increased, although probably but little, if any, more urea passes off.

418. The blood leaving the active kidney is still of a bright red color. It is probably the purest blood in the body. Can you explain why this is so.

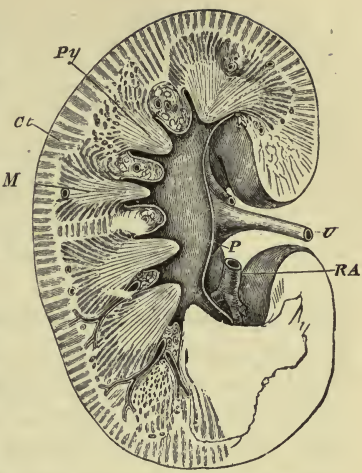


FIG. 186. — Section of the Kidney.
Ct, cortex; *M*, medulla; *Py*, pyramid; *P*, pelvis; *U*, ureter; *RA*, renal artery.

CHAPTER XIV

HYGIENE OF DIGESTION

419. Is Good Health "Catching"? — A wit once said that if he had been consulted at the creation of the world, he would have made good health "catching" instead of disease. Observations show that happiness, industry, health, faith, and other of the strong elements that make up life, are more contagious than misery, idleness, sickness, worry, and the other weak elements that tend to destroy life. Fear causes a tightening of the muscles and a waste of energy, as well as oppressed breathing and a lack of oxygen. Courage brings calm, full breathing which purifies the blood, and a steady and economical use of the muscles which saves the vital energy. A brave and cheerful visitor can inspire an ailing friend and assist in his recovery. A happy, unselfish teacher or pupil can dispel worry or gloom, and impart strength and increased power for work to the whole school. The body tends to health and not to disease. The dyspeptics that we see have been able to break down their health only after long-continued attacks upon it, and outrages many times repeated. Fresh air brings health, and forces its way into the home to bring it, but the dyspeptic made every attempt to keep it out. Sunshine brings health, but he shut himself up in a stuffy ill-lighted office, a slave to dollars or to fame. He curtained the sunshine out from the home to protect the carpets and hangings from fading. Exercise brings health, but the promptings to stir about, to walk, to run, or to work with the hands, were repressed until the impulses ceased. When activity was lessened, the appetite for food diminished, but instead of following the prompting of nature, he sprinkled more salt and pepper and other condiments upon the food, that he might eat with an unnatural appetite.

420. By keeping up these artificial ways for months and years, he at last succeeded in breaking down his health. It took more perseverance to weaken the body than it will take to make it strong again. There must be a return to reasonable ways of living with trust in the inherent tendency of the cells to restore soundness when given a chance. If, however, he commits the folly of thinking that months are not needed for recovery, but that disease brought on by months or years of wrong living can be cured in a few days by taking magical drugs and patent medicines, he will probably injure himself still more and lose his chance of recovering sound health.

421. Environment of Primitive Man. — It is believed that the race originally did not dwell in houses, and had few tools or cooking utensils. Man probably first lived in the tropics and subsisted upon the fruits which ripened in the never-ending summer, and, as he migrated to the colder climates, subsisted upon the results of the chase. That individual who refused to peel his apples because, as he said, Adam had no pocket knife, and slept with his windows open because Adam had no house, had a right principle in view. If his teeth were as sound as the teeth of primitive man, and his habit of mastication as thorough, the peeling would be only an aid to digestion.

422. Man possesses a stomach intended to digest the pure food of the forest, obtained by activity in the open air. **If a man eats plain food and leads an active life, his appetite is a perfect guide.** If he does not, it is unsafe to trust to the appetite alone, for the reason that he lives under conditions unlike those for which this instinct was built up. A cow's appetite is a certain guide to her among poisonous plants and berries, yet she will eat a bucket of paint and harm herself; this is beyond the range of her inherited habits. Even if man's instincts had their early strength, they could hardly guide him among the many food concoctions and preparations undreamed of by primitive man. We can train our taste into wrong ways, and we can likewise train it into right ways and into liking food that we know is wholesome.

423. The uncertainties of man's early savage life, the times of drought or of ill luck in hunting, accustomed his cells to periods of starvation and repletion, of feast and of famine. His organs could withstand irregularity better than they could withstand continuous scarcity or overfeeding, continuous overwork or idleness. The Indian lies around the camp and gorges himself in times of peace and plenty, his cells laying up strength which enables him to follow the trail or the chase for days at a time, going sometimes fifty miles a day. It is said that the business of one age becomes the recreation of the next.

424. It is found that returning to natural habits by going on camp hunts and fishing trips is one of the most effective hygienic measures for the restoration of health.

425. Hobbies about Nutrition. — The subject of food and digestion is a more complicated one than that of exercise or breathing, and more common sense is required to master it. Therefore, more persons fail to master it, and allow their minds to come to rest on some one fact or view of the subject and so become extremists.

426. Hot Water Fad. — Some would cure every digestive ill by means of water. Their belief is "water internally, externally and eternally." They sometimes drink it as hot as it can be borne, yet hot water is very relaxing to the walls of the stomach and weakens the flow of the gastric juice. This extreme belief arose from the fact that hot water removes the mucus from a stomach suffering from catarrh (or congestion) and diminishes the activity of the gastric glands if too much acid is being secreted.

427. Raw Food Fad. — Some persons have a fad called the raw food doctrine, and eat no cooked food. They should consider that man's digestive organs are not as vigorous now as they were ages ago, before he learned the use of fire. This fad is a reaction from bad cooking. Cooked vegetables are more likely to ferment in a weak stomach than raw vegetables. The thorough chewing required by raw food is an advantage to digestion.

428. No Condiment Fad. — Some persons will not have condiments or any kind of seasoning, not even salt, in their food. This is because many cooks destroy the natural flavors of the food by bad cookery and hide the result by high seasoning. There are many delicate and delicious flavors of grains, fruits, and fresh vegetables that a natural appetite takes pleasure in; but because of long use of badly cooked and highly seasoned foods the sense of taste in many persons has become so depraved and dull that they have only five kinds of taste left: the taste for grease, salt, pepper, vinegar, and sugar. Their dull nerves require everything to be very salty or peppery or sweet or greasy or sour.

429. Other Fads which may be mentioned are the vegetarian fad, distilled water fad, fasting fad, no breakfast fad.

430. THOUGHT LESSON. **Cooking.** *Meat.* — 1. In making soup, why should the meat be put in while the water is cold?

2. In roasting meat, why should the oven be hot at first, and more moderate afterward? How should you regulate the temperature in boiling or stewing meat?

3. What happens to salt or anything salty on a cloudy, damp day? This is because the salt attracts ——. This

shows that meat should not be salted until after it has been cooked, because if salted before, the salt will ——.

4. Very —— meat should never be broiled, because broiling does not —— it. Such meat should be —— b——ed or st——ed.

5. Meat is allowed to become grease-soaked when it is —— by —— cooks. The two ways to prevent this are to have the grease very ——, use very ——, simply greasing the ——.

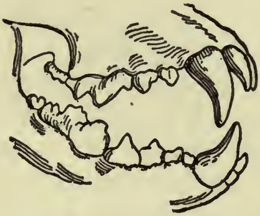


FIG. 187. — Teeth of Cat.

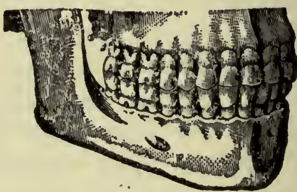


FIG. 188. — Teeth of Man.

FIG. 189. — Teeth of Cow.

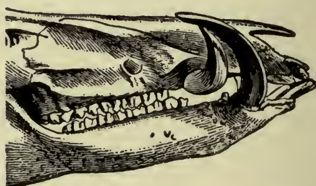


FIG. 190. — Teeth of Hog.

6. *Bread.* — Bread crust causes the —— to be used more and cleans them. It will not —— together in the stomach like the crumb. It increases the quantity of the ——, and is more digestible than the crumb, since the —— has been changed by slow heat to ——. Therefore loaves or biscuit should be [large or small?] and they should [touch or be separated?] in the pan.

How can you tell whether the oven has been too hot while the bread was cooking?

431. Classification of mammals according to food: —

	Carnivora, or flesh-eaters.	Herbivora, or herb-eaters.	Omnivora, or all-eaters.	Frugivora, or fruit-eaters.
Examples.	Cat, dog, lion, tiger, bats.	Cow, sheep, horse, camel.	Hog, peccary.	Man, ape, monkey.
Length of Alimentary canal.[1]	3 times length of body.	30 times length of body. Stomach with five chambers.	10 times length of body.	12 times length of trunk or body.
Teeth.	Pointed for tearing flesh. Canine teeth long.	Made of alternate layers of enamel and dentine, forming ridges for grinding. Canines lacking.	Cutting teeth project in front. Canines form tusks.	Teeth of even length, close together. No space between teeth. Canines not projecting.
Extremities.	Sharp claws.	Hoofs.	Hoofs.	Flattened nails.
Colon.	Smooth.	Sacculated.	Smooth.	Sacculated.

432. Thought Lesson. **Comparison of Mammals.** — Which of the kinds would probably have quickest digestion? Slowest? Which eats food that would spoil if not quickly digested? Which eats food that would keep sound? Is there an appropriate relation between extremities and teeth? Which kind of mammals has closest resemblance to the frugivora? Which kind has least resemblance to the frugivora? Why?

433. **Man's Original Food Resources and how they have been enlarged.** — Cuvier, Owen, Huxley, and other comparative anatomists agree that man was originally frugiv-

[1] Body measured from tip of nose to end of backbone. Mammals are the highest vertebrates. The mother nourishes the young with milk. The mammary glands are on the abdomen for all of the kinds of mammals except the fourth. With the frugivora they are on the thorax.

orous: he ate tree fruit, both nuts and fleshy fruits. Tree fruits contain all the four chemical classes of foods, — proteids, fats, carbohydrates, and minerals. The present sources of his food, besides the original nuts and fruits, are flesh, grains, herbs, and he has added them to his dietary probably in the order named above. In the warm regions of the earth, the banana, plantain, mango, orange, and cocoanut trees bear their luscious fruit the year round. But the multiplication of the race and perhaps times of drought and famine led man to use the food stored up in the flesh of other animals which had obtained it from grass and herbs. This necessity doubly increased with migration to colder climates. In the frigid zones the inhabitants live very largely on animal food. They consume immense quantities of blubber, or the fat of certain animals, such as the whale, the walrus, and the seal. This kind of diet, by sustaining the necessary bodily heat, enables these people to withstand the intense cold to which they are subjected.

Grains in their natural state are too small and collecting them was too tedious before the time of that long-forgotten genius who first thought of cultivating them in order to improve them. Hunting is known to have preceded agriculture in all wild tribes. After flesh and grains, last of all came vegetables. Fruits and grains belong to the seed part of the plant. The coarser woody leaves and stem and roots were probably not added to man's food until the art of cooking was much advanced. The degree of digestibility seems to coincide in most persons with the order of adoption of the classes of foods by the race. If one leads a sedentary life, or his digestion becomes impaired, the weedy, fibrous vegetables should be the first to be discarded from the diet, while flesh and fruits seem to furnish the main substance for invalids even after grains and starches prove hard to digest.

434. Composition of Foods.

	Proteids.	Fats.	Carbohydrates.	Water.	Salts.	Cellulose.
I. Nuts.						
Pecan	10.3	70.8	14.3	3.		
Walnut	15.8	57.4	16.	13.		
Almonds	23.5	53.	12.	7.8		
Cocoanut	5.6	51.		35.		4.
II. Fruits.			Sugar.			
Peach	0.5		1.6	85.		
Plum	0.5		2.0	78.		
Blackberry	0.5		4.0	86.		
Cherry	0.5		10.	84.		
Grape	12.5		.15			
Fig	4.0	1.4	.50			
Banana	5.0		20.	75.		
III. Animal Food.						
Lean beef	20.5	3.5	.9	75.	1.6	
Fat pork	9.8	48.9		39.0	2.3	
Smoked ham	24.8	36.5		27.8	10.1	
Whitefish	18.1	2.9		78.0	1.0	
Poultry	21.0	3.8		74.0	1.2	
Oysters	17.5	0.5		80.0	1.5	6.0
Cow's milk	3.5	4.0	4.0	87.0	0.7	3.2
Eggs	12.5	12.0		73.5	1.0	4.29
Cheese	33.5	24.3		36.8	5.4	
Butter	0.3	91.0		6.0	2.1	
IV. Pods or Legumes.			Starch.		3.5	
Beans	24.5	2.0	52.	12.5	2.8	
Peas	21.7	1.9	57.7	12.		
Peanuts	29.47	49.20	16.2		2.77	
V. Grains.						
Wheat flour (white)	11.0	2.0	70.3	15.0	1.7	0.3
Wheat bread	8.0	1.5	49.0	40.0	1.2	0.3
Oatmeal	12.6	5.6	63.0	15.0	3.0	1.6
Maize (corn)	10.0	6.7	64.5	13.5	1.4	1.5
Rice	5.0	0.8	83.2	10.0	0.5	4.0
VI. Vegetables.						
Potatoes	2.0	0.16	21.0	74.0	1.0	1.0
Cabbage	1.8	5.0	5.8	91.0	0.7	1.5

435. **Nuts** are the most concentrated and nutritious of all foods. Beefsteak is three fourths water, while nuts are less than one fourth water (see Table). Nuts are how many times as nutritious as beefsteak? This refers to the nut "meats" or kernels. Nuts may be said to consist of one half fat, one fourth proteid, and the remaining one fourth water and mineral. The fat, unlike that of butter, oil, and fat meat, is emulsified in nuts, and does not need to be divided up before absorption by the lacteals in the small intestine. Their density encourages the habit of thorough chewing. Nuts are made up of little cells, each of which has its proportion of proteids, fat, and dextrine, a kind of sugar. The small boy climbs the tree and gathers the nuts, cracks and eats them, and digests them thoroughly. The man stays in his office, has some one else to gather them, masticates less thoroughly, and he may find them less digestible, especially if he always eats a full meal before taking the nuts. Green or rancid nuts are not digestible. Nuts should be eaten during the meal the same as meat. They are digestible raw. Persons who usually eat nuts after they have already eaten too much, consider them very indigestible. They are not good for the digestion if eaten between meals, or if not thoroughly chewed.

436. **Pods, or Legumes,** resemble nuts very closely in chemical composition, but they require long and thorough cooking. Their seed coats, or hulls, consist of cellulose or woody fiber, which may well be removed. The hulls can be loosened by soaking them in cold water before they are cooked. Beans and peas have been called the lean meat of the vegetable kingdom, and they take the place of meat with those who discard meat (vegetarians).

437. **Fruits** have four important advantages: (1) Their agreeable flavors are a natural and healthy stimulus to the digestion. (2) They contain vegetable acids (either citric, malic, or tartaric) that are perfect germicides, and are

very powerful in purifying the alimentary canal. (Fruits have almost no proteid. How does this show that a fruit diet would starve the germs, even if the fruit acids did not destroy them?) (3) They contain very valuable mineral salts that are of highest use to the blood and tissues. (4) The carbohydrate in ripe fruits is all in the form of levulose or fruit sugar, which is predigested starch, and is absorbed without digestion. With these advantages, there is the disadvantage that fruits are largely water, so that the nutriment they contain is very scant, except in the case of grapes, bananas, and olives.

438. The proverb that fruit is golden at breakfast, silver at noon, and lead at night, is not true. Fruit is golden at all times, if it is sound and ripe, and if the stomach is not already filled with food. Fruit juices are valuable as restoratives to health, since they tax the digestive organs very little and are quickly assimilated. Since germs will not grow in fruit juices, a fruit diet for several meals will disinfect the alimentary canal and ward off a "bilious" attack. Juicy apples, pears, lemonade, orangeade, pomegraniteade, ripe peaches, etc., are pleasanter than medicines.

439. **Animal Food.** *Meat.* — Proteid is the principal food substance in meat. Beef contains the largest amount of any of the common meats, and pork the least. The fat of meat is also of great importance: fat is abundant in pork. Meat that is salted and smoked, or dried, or prepared in any way so that germs will not grow in it, can be kept for a long time, but its digestibility is greatly impaired. This is because its fibers have been hardened so that the gastric juice cannot readily penetrate them. Meat which has much connective tissue is tough; the most tender and digestible of meats consist almost wholly of muscular tissue and fat.

440. Experiments show that ordinarily one fifth of the proteid in vegetable food passes through the intestine undigested and unabsorbed, and is thus wasted, while only one thirtieth of the proteid in meat escapes digestion. A pound of fat requires three times as much oxygen in its oxidation as a pound of sugar, and therefore yields three times the heat and energy. The digestibility of fat is increased by the fact that it ferments with difficulty, while sugar and starch ferment more easily. Meat should be thoroughly cooked to avoid the danger of diseases from the trichina and other parasites.

441. *Milk* of cows is suited for calves, and was intended to be obtained by sucking and to be swallowed gradually. It contains too large a proportion of proteid for infants, and therefore water is added. The casein or proteid part is coagulated in flakes by the rennin, and when a child throws up coagulated milk, it does not mean that it is suffering from indigestion, although it may sometimes mean that it is being overfed. The tendency of milk to produce "biliousness" and constipation in some persons may be explained as follows: when adults drink sweet milk rapidly, especially toward the end of the meal, when much acid is present in the stomach, the acid coagulates the casein into large lumps of curd, which may seriously disturb digestion, for milk was not intended to be drunk rapidly. Heat retards the production of acid in the gastric juice and increases the secretion of rennin. If taken before meals, hot and slowly, milk will agree with those who have found it to produce indigestion. Buttermilk is one of the most digestible of foods.

442. *Cheese* is a concentrated food, and is one of the cheapest although not one of the most digestible forms of proteid.

Does a pound of *eggs* contain more or less nourishment than a pound of meat (§ 434)? At usual prices, which is more economical, eggs or meat (see Table, § 434)?

443. Meat Extracts. — Researches concerning the nutritive value of meat extracts, show that in none of them is a large quantity of food concentrated in a small bulk as the public are led to believe. A glass of milk contains far more nourishment than a cup of beef tea. The best way to get the nourishment out of a steak is to eat it. The beef extract contains but a fraction of the proteids in beef, and all of the nitrogenous waste material allied to urea. The most nutritious part of the beef is not soluble, but the excretory part of the meat is soluble, and this is found in the beef tea or beef extract. This extract throws work upon the kidneys and is harmful. The part of the beef that has most value is thrown away in making the extract. Many lives are no doubt annually sacrificed by starvation through the popular faith in beef tea as a concentrated and nourishing food. Beef tea and meat juice can be used as flavoring agents with other food since they stimulate the secretion of pepsin, but they should not be regarded as real food.

444. By drying meat it can be reduced to one fourth its weight (since it is three fourths water). Thus 100 pounds of beef can be reduced to 25 pounds and sold in a form useful to travelers. The meat will keep fresh as long as it is kept dry. Water is added to the meat when it is cooked.

445. Grains. — Nearly all the starch of our food is supplied by grains. They also contain from 8 to 15 per cent of a proteid called *gluten*. The chief grains are wheat, oats, barley, corn, rice, buckwheat. The more of gluten there is in grain, the more gluey or sticky its flour will be. Sticky flour will retain the bubbles of gas formed from baking-powders or by the growth of the yeast plant. Wheat has much gluten, and its flour makes very light bread. Coarse meal has not enough gluten to make it very sticky, and corn bread will not rise well. Corn contains more fat than any other grain, yellow corn containing more fat than white corn. Rice is poorer in albumin and richer in starch than any other grain (see Table, § 434).

446. Three Kinds of Flour. — There are three ways of grinding flour: (1) Using the whole grain and the husk which incloses the grain. This makes graham flour. (2) By using the whole of the grain. This makes whole wheat flour. (3) By rejecting the outer and darker portion of the grain, thus losing part of the gluten and retaining all of the starch. This makes the ordinary flour. Graham flour is most stimulating to peristalsis in the canal. Its large amount of waste matter furnishes something for the intestine to contract upon, and thus sweep all waste matter on and out of the body, contributing to the cleanliness of the canal. It sometimes causes congestion in irritable stomachs. Sometimes flour which is merely dark with dirt is sold for graham flour. The whole wheat flour is stimulating to the canal but is not irritating. Some believe that it furnishes more of the mineral salts and bone-making and tissue-building material than the fine flour.

447. The Cooking of Grains.—You learned that the starch of fruit, when it ripened, was turned to sugar. Ordinary cooking bursts the cells of starch in the grain and begins the transformation into dextrin, a substance intermediate between starch and sugar. This is a great help, for the saliva does not act upon raw starch, and the pancreatic juice acts only slightly and after several hours' delay. Cooking that amounts to little more than moistening and heating the starch, is a disadvantage, and makes it more likely to ferment than if eaten raw; but thorough cooking adds greatly to the digestibility of starch. Oatmeal, cracked wheat, and other grain foods should be cooked at least 40 minutes.

448. How Grains may be made to resemble Fruit. — If cooked several hours, the starch of grains is so thoroughly dextrinized that it is changed to sugar almost instantly when brought in contact with the saliva. Grains may be cooked during the preceding meal and the cooking finished in preparing the meal at which they are to be eaten. If oatmeal and other mushes are sticky, it shows the presence of half-cooked starch. The yellow crust of bread will not stick together because the starch has been changed into the last stage of dextrin, called *yellow dextrin.* Rice and oatmeal may be first browned in the oven and afterward steamed. Toast and brown crust are almost as digestible as ripe fruit and are given to invalids.

449. Cellulose has the same chemical composition as starch. It forms the cell walls and woody fibers of plants, and is hardly digested at all by man ; hence, starch requires cooking to burst the cellulose envelopes of the starch grains. Cellulose and water are the chief constituents of grass, and of greens, cabbage, and other fibrous vegetables. It forms the fibers in watermelons, which also contain cane sugar, the sweetest of the sugars. The woody skins of beans and peas are cellulose. Hence, many find the legumes more digestible in a purée, or cooked with the skins removed. Cellulose is the natural stimulant to peristalsis and activity of the canal. Cattle digest cellulose, and with them it takes the place of starch.

450. Vegetables. — Root vegetables and tubers, such as potatoes, sweet potatoes, and turnips, contain a small percentage of starch. But vegetables in general consist almost entirely of water and woody fiber (cellulose). This is especially true of green vegetables, or those which consist of the leafy part of the plant. But green vegetables contain nucleo-albumin, or iron-bearing albumin, which is of great value to the blood and tissues. This form of albumin is easily destroyed in the intestine before it reaches the blood, if fermentation takes place. As some leafy vegetables are more likely to ferment if cooked, there is an advantage in eating them raw. Iron and valuable mineral salts are thus obtained.

451. The nostrum venders who shamelessly advertise their iron tonics "to enrich the blood" are only attempting to prey upon the ignorant. The magical power of the sun's rays can turn iron into food. The brown color of the grain, the red cheek of the tomato, strawberry, and peach are due to iron, and iron in this form will enrich the blood. For a student to learn that iron colors the red corpuscles, may be of some value, but if the only purpose the knowledge serves is to aid in entrapping him into believing that the patent-medicine man makes a valuable blood tonic out of rusty nails and alcohol, his method of study has not cultivated his judgment, nor cured him of the natural propensity to jump at conclusions.

452. Leonard Hill, Professor of Physiology in the Royal College of Surgeons, says: "In these days of advertisements it is necessary to strongly warn the reader against the lies of the trader and the quack. The method of fortune-making by advertisement is to sell a well-known and cheap article at a dear price, under a new name, with a flavor added, and the vaunted pills, when submitted to analysis in chemical laboratories, are found to consist of aloes, salts, or other common drugs, which the quack buys for a few pence a pound, and sells for a shilling an ounce. Most of the minor ailments are produced by errors in diet and lack of healthy exercise. These ailments are relieved temporarily by a purge, and the public are persuaded thus to buy fruit salt or pills for a shilling, when the required article, aloes or Epsom salts, can be obtained for a penny. Among the numberless quack medicines sold for nervous exhaustion, many are altogether valueless, and sometimes contain stimulants, such as alcohol or coca. Nervous exhaustion can be cured, not by drugs, but by changing the habits of life. Bicycling, bathing, and gymnastic exercises are worth infinitely more than all the drugs in the world. Errors in living can be atoned for, not by the taking of medicines, but by learning the art of living, and of this lesson, spare diet, hard work, and exercise form the first and last page.

"In countries other than England the patent-medicine venders are forced to publish the ingredients of their concoctions, and the governments warn the public and state the nature and exact price of the ingredients. In England the people are allowed to be fooled and defrauded of millions of money by quacks, while the government, to its disgrace, does nothing to protect the poor, weak, and the ignorant from them."

453. Is England the only country in which this fraudulent business is allowed to flourish unchecked? The formula should be required by law to be printed upon the bottle. Most patent medicines in large bottles, such as sarsaparillas, bitters, etc., contain about the same proportion of alcohol as brandy contains. Even in grogshops the character of the drink that is being sold is not entirely misrepresented to the customer.

454. An Error of Vegetarians. — Those with whom meat does not agree, or who for humane scruples, or other causes, adopt a vegetarian diet, sometimes fall into serious error. If fruits and nuts are not freely used, but the diet is confined to grains and green vegetables, a large excess of starch is consumed, and the diet is very bulky, in spite of the fact that it is greatly lacking in fat and proteid. Persons who do not eat meat should replace the proteid of meat with that of nuts, cheese, beans, and peas, and employ fat in the form of nuts, cream, milk, eggs, and butter.

455. Many millions of people, the most populous nations of the earth, eat no meat. The inhabitants of the countries largely vegetarian in diet, as India, China, etc., constitute a majority of the human race. It may be possible that they would be a more vigorous people if they lived upon a more varied diet. People of warm countries flourish on a vegetarian diet; it is also possible to do so in a temperate climate, but it is hardly possible in the frigid zone. An Eskimo will eat fifteen pounds of walrus fat in a day. Too much meat in the diet affects students and sedentary individuals more injuriously than it does muscle workers.

456. Should the Diet be Bulky or Concentrated? — The way this question is answered will determine whether graham or white flour is better, whether the skins of beans and peas and fruits should be removed, whether one should eat coarse vegetables, such as cabbage, greens, celery. It is probable that the true answer is that sedentary persons with weak peristalsis of the stomach should not eat much woody material as it causes the food to remain too long in the stomach before it is reduced to chyme, while persons whose business requires muscular activity and whose alimentary canal possesses a more vigorous peristalsis, will find a bulky food preferable.

457. If, some hours after eating boiled cabbage, you could still taste it, or another could detect the odor of it on your breath, what inference might be drawn? If greens were added to the usual dinner, and you had a feeling of heaviness or dullness after dinner, what would you infer? What would be the conclusion if you felt more vigorous than usual? If you had fallen into the bad habit of taking the feverish haste of business to the dinner table with you, but on one day you "took things easy" at dinner, as well-bred people should, eating very leisurely, and you had a feeling of unusual lightness and energy in the evening, what would you infer?

458. Should a Person drink at Meals? — Slow, careful eaters, whose throats refuse to receive anything that is not thoroughly chewed and mixed with saliva, should not drink while eating, as it would dilute the digestive fluids already abundant. But those who eat rapidly or do not chew thoroughly, often find that some liquid at meals aids digestion, for with this manner of eating, the natural secretions are insufficient. Should the liquid be sipped with each mouthful, or should it be taken at intervals and when the mouth is empty? Which method would have less effect in decreasing the flow of saliva? Which method would be more likely to increase the tendency to bolt the food down?

459. Individual Wants. — The student readily sees that the question of individual needs is of importance. There is truth in the old adage, "What is one man's meat is another man's poison." No cast-iron rules can be laid down for any one's life. Common sense can never be dispensed with. Persons with moderate powers of observation find by experience what is best, and they should have will power enough to adhere to what they find is best for them, although opposite ideas may be presented to them as the only correct way, by persons of narrow views. What is enough for one is a surplus for another. Sex, age, occupation, and heredity, each has its influence on diet. The wear and tear of an active body requires a class of food which to one of sedentary occupation would be a burden. Exercise lights the fire that burns up the refuse of the body, and thus it increases the appetite and strengthens the digestion.

460. Indigestion in Sound Digestive Organs. — If a person confines himself closely with brain work and takes no exercise whatever, he may not digest his food well, but he need not think his digestive organs unsound, and begin dieting himself. He should take more exercise, and by better habits of life stir up his circulation, use the food stored in the cells, and they will become hungry for more, and digestion will be perfect. There is a saying, "You can lead a horse to water, but you can't make him drink." So you may put food in the alimentary canal, but you cannot make the cells assimilate it, although, by the use of much pepper and condiments, you may have aroused an appetite for it. Such food may not be digested, but it does not mean that the digestion is weak, it means only that too much food and too many condiments have been used.

461. Two Ways out of a Difficulty. — Exercise is the best way out of digestive troubles; yet, if a student or office man is under the delusion that he "just simply has not time" to take plenty of exercise, he may partly meet the difficulty and keep his brain clear by an abstemious diet. Many a plow boy has gone to college, and failing to take up athletics or to perform any manual labor, yet has continued to eat the same quantity of food which before sustained him in his labor, but which now only clogs the organs and stupefies the brain. Thus his work as a student does not accomplish half that it should accomplish.

462. Cooking. — *Meat* should be *roasted* by putting it into a hot oven at first, to form a crust to keep in the juices, then lowering the temperature of the oven to prevent drying out and hardening. When *broiling* meat, it should be turned over every ten seconds to send the juices back and prevent their escape, thus broiling the meat in the heat of its own juices. Tender meat should be broiled, but tough meat is often better fried. Grease for *frying* should be boiling hot when the meat is put in, to form a crust and prevent any of the grease from soaking in. Fried meat that is grease-soaked is the most unhealthful of all cooked meat. Meat should not be *salted* until after it has been cooked, for salt draws the juices out.

463. *Bread* is best if made of whole-wheat flour. It should be cooked in a slow oven, so that the inside of the loaf may be well baked. The loaves should be made small and not touching, so that there may be much crust. *Crust* (1) cleans the teeth like a brush and makes them healthy from use; (2) it increases flow of saliva by its dryness and the longer chewing required; (3) it is more easily digested than the crumb, or white portion, as it resembles sugar. *Beaten bread* is the most digestible, like the hoe cake and johnny-cake and other unleavened breads. *Yeast bread* comes next in digestibility. Baking powders, if they contain alum, and soda, if not thoroughly neutralized by sour buttermilk, are injurious even to the healthy. It is quite possible that the depression and nervousness caused by innutrition from trying to live on such abominations as soda biscuit and grease-soaked food, are often the forerunners of drunkenness and other misfortunes that a small amount of intelligence in the kitchen would have prevented.

464. *Yeast* belongs to the class of plants called fungi, which can live in darkness, and have neither leaves nor blossom. Most plants get nourishment from the soil, air, and water, but yeast and other fungi derive their sustenance from vegetable or animal matter in process of decomposition. Yeast plants are microscopic cells of oval shape, and, like other plants, require food in liquid form. They cannot absorb dry or solid food. Their most suitable food is sugar. The flour of wheat contains starch, a small amount of which is converted into sugar by the diastase which lies next the bran. Yeast grows best at a temperature of from 70° to 80°. A slow growth at a lower temperature favors the development of other micro-organisms, which make the yeast unhealthy and produce bad flavors. With a high temperature its growth is rapid and of extremely short duration. Fermentation may go through several stages; in the first stage, or alcoholic fermentation, the yeast decomposes the sugar, splitting it into alcohol and carbon dioxid gas. This is the stage for bread-making, the gas causing the bread to rise. In the second stage, or vinegar fermentation, alcohol is changed to acetic acid — the acid in vinegar. Hard wheat has more gluten than other wheat, and the bubbles formed in its flour will not break easily. Why does bread from such wheat rise well? Why is bread set in a warm place to rise? Why does it "fall" if left to stand too long? Under what conditions does bread made from yeast become sour? Why does bread set to rise in a cold place sometimes have a bad flavor?

465. *Irish potatoes*, to become mealy instead of soggy, should be put into boiling water, and, after they are cooked, the water should be poured off, and the pot should be set on the back of the stove for the potatoes to dry. Roasting them in the oven with their skins on also retains their flavor and makes them mealy.

466. *Cucumbers* are as digestible as apples if eaten raw and when sweet. Pickles are absolutely indigestible, and are treated as foreign substances. *Onions* are better if cooked, to drive off the acrid, irritating oil. Raw *cabbage*, which is water and woody fiber, is treated by the stomach as a foreign substance, and sent promptly to the intestine; but the stomach attempts to digest boiled cabbage, and it remains there several hours. The skins of *peanuts*, after boiling water has been poured over them for a moment, can be easily removed. If then allowed to simmer on the stove for hours, until they can be easily pressed through a colander, they form a nutritious and palatable food, with the addition of a little salt. Raw and roasted peanuts are not easy to digest. *Eggs* should be cooked by placing them in boiling water and taking the pot off the stove. They cook while the water is cooling, and the albumen is jellied but not hardened.

467. Is Alcohol a Food? — When alcohol is taken, about ninety-five per cent of it is oxidized and changed into carbon dioxid and water. This was found out many years ago and raised the question as to whether it should be classed as a food. Investigations were made, and the result was that alcohol was classed with the poisons and not as a food. The question has been reopened several times in the last half-century, but always with the same result.

Scientific men generally continue to classify it as a poison and not as a food. Morphine, mushroom poison, strychnine, and other dangerous poisons are oxidized in the body and yield up their energy, yet they are recognized as poisons. A substance cannot be classified as a food simply because it is oxidized in the body.

468. Leading scientists define a food as follows: **A food is a substance of such a nature that, when absorbed into the blood, it nourishes the body without injuring it.**

469. Sugar is a food but a solution of sugar can undergo a change caused by the growth of millions of yeast plants and the food is lost. The change is called fermentation, and alcohol is one of the poisonous products of this process of decay or fermentation.

The condition of the body after it has oxidized alcohol is quite different from its condition after it has oxidized sugar or bread. Benzine is very easily oxidized. If poured upon the fire of a locomotive, it would make the water boil so rapidly that there would be danger of straining or bursting the boiler. It would burn so rapidly as almost to make an explosion, and a very large part of the heat caused by the oxidation would be lost. A stove needs a slower burning substance than gunpowder or benzine. A locomotive needs a slow-burning fuel which will develop heat at such a rate that it will be possible to utilize it. The body needs even slower burning substances than the locomotive, such as sugar, starch, and fat; not a more rapidly burning substance, such as alcohol, which in burning will weaken the tissues and shock and injure the delicate cells of the one who drinks it. In the chapter on the blood it was learned that alcohol does not even cause a gain of heat in the end; since the paralysis of the capillaries resulting from a drink causes the warmth to be taken to the surface and escape, so that the body is cooler than before the drink.

470. True food does not burn in the blood; it is stored in the cells in the form of very unstable compounds. These compounds break down under the stimulus of oxygen and the nerve current, and set free energy. The cells of the nerves and muscles correspond to the furnace and steam chest of the engine. Suppose, instead of pouring benzine into the furnace, you burned it in the cab or the smokestack. Do you think it would increase the power of the locomotive? Alcohol is not stored in the cells, nor does it enter into combination to form the energy compound, the breaking down of which sets free the energy stored up. Alcohol burns quickly after entering the body; a large part of it, indeed, never gets beyond the liver, and is burnt in this long suffering organ. But some of it gets into the general circulation, and is distributed throughout the body, irritating the nerve cells and poisoning them and every other tissue.

471. Does Alcohol warm the Body as well as a Coat? — It may occur to a user of alcohol to say, "It certainly gives warmth, for it burns; so it is of some benefit. It is equal to a good overcoat, if it is not food, and like the overcoat, it may save the burning of some of the fuel-food, sugar and fat." Benzine may tear up the machinery, but it certainly gives heat. But suppose you put most of the benzine in the cab just before the furnace door. It will use up the oxygen and furnish carbon dioxid in the draught to the furnace, instead of fresh air. Will this make the fire burn brighter, or will it smother it? This is exactly what alcohol does; it uses up the oxygen supplied to the blood by the ever-faithful lungs, and the blood carries carbon dioxid to the brain, muscles, and other tissues. An overcoat does not smother the tissues by using up the oxygen they need. Thus it happens that the drinker's nerves become deadened, his faculties dulled, his muscles weak and unsteady. If he drinks much at a time, he falls into a profound stupor — he is "dead drunk." Thus the heat from the oxidation of the alcohol prevents the true tissue activity which is necessary for the life processes, and burdens the liver with an unnecessary activity in destroying the poisons. The poison, in the meanwhile, has paralyzed the arterial walls and allowed the capillaries to become flushed, and the warmth of the blood rapidly escapes through the skin. By using up the oxygen, it checks the production of heat in the usual way, while the heat resulting from its own oxidation is soon lost to the body, and much more of the bodily heat besides.

472. One ounce of alcohol requires two ounces of oxygen to oxidize it. The lungs furnish twenty-four ounces of oxygen daily. How many hours will it take the lungs to supply oxygen enough to oxidize one ounce of alcohol? Three drinks of whisky contain one ounce of alcohol. How many drinks would be necessary to use up a day's supply of oxygen? A man would probably die long before he had drunk that quantity.

473. The Secret of the Influence of Alcohol. — It is a fact that we are clearly conscious only of the energy that we are exerting, and not of the energy that is stored up in our bodies. When alcohol is first taken, the cells treat it as an intruder, and the activity excited by the attempt to expel it from the body causes the man to think the alcohol is giving him strength, when it is only taking it away. It deludes the drinker into thinking that he is strong, though before the drink he had been feeling weak; warm, though he had been feeling cold; it makes him careless, when he had been careworn; confident, when he had been feeling timid. These are pleasant effects. But the later effects of headache and depression and gloom, worse than before, he does not attribute to alcohol, since they are not so closely associated in time with the drinking. He does not remember the crazy or idiotic scenes that were enacted when he was wholly under its influence, the wild or maudlin talk, the loss of all self-control, the quarrel with the best friend, and the abuse of wife and children, and afterward the drunken stupor. If he did recognize these effects, he would stop the use of the poison. If remembered at all, they are only as an unreal dream that is not a part of his life. A man once fell into a fire while intoxicated, and just as falling into cold water will sometimes sober a man, the pain and danger brought him to his senses; he realized what alcohol was doing for him and never drank again. The various inebriate cures, so called, are founded on the principle of making the patient disgusted with alcohol by secretly adding some nauseating drug to the drink, thus giving the man the belief that alcohol is making him sick. As long as the belief in the repulsiveness of its effects remains, the man can abstain; but most drunkards relapse into their old ways. Their bodies have been already ruined, and they have no strength of will left. When they once drink again, the association of alcohol with the agreeable emotions previously mentioned is renewed and the power of the habit reasserts itself.

474. Time for Eating. — Different nations have various habits of eating. The number of meals varies from two to five, or even eight, meals daily. Such facts show the adaptability of the stomach to different habits. It is an organ which readily forms habits, and is greatly benefited by regularity. If a person avoids disturbing the stomach between meals and allows it needed rest, both appetite and digestion are promoted. Three meals a day seem to be needed, especially by hard workers. The Greeks ate two meals a day, and developed the most beautiful and perfect bodies in the world, as shown by the statues left by them.

475. Very active exercise tends to hinder the work of the stomach, but facilitates that of the intestines. For a half-hour after a full meal, hard work of every kind should be avoided, but hard work an hour or two later will aid digestion. The arrangement of the meals must take into account the other habits of the individual. For example, if three meals are eaten in twenty-four hours, the last ought to be the lightest; but, as business is transacted in large cities, a business man can hardly find time for a hearty meal in the middle of the day. Hence he does right in eating a lunch at noon, and having the heartiest meal come in the evening, when the day's labor is over and there is time to relax. If he takes the principal meal in the latter part of the day, he should not eat very heartily the next morning or during business hours; to do so would surfeit the system. Late suppers should not be eaten, as they prevent sound sleep. The lower animals may lie down in the shade and sleep after eating, but it is only for a short nap. A nap of ten minutes, just long enough to bring about relaxation, is often of benefit after a meal. During sleep the heart beats less frequently and with less force; the lungs breathe less freely; the brain ceases its activities; the muscles relax and become motionless; peristalsis and secretion in the alimentary canal become slow, and the digestive organs should have rest. If a person is troubled with a too great flow of blood to the brain, some light, digestible article of food taken just before retiring may bring sleep; but it should be taken simply to regulate the circulation, and should be so digestible as to give little work to the stomach. A farmer will do a better afternoon's work if he will rest for half an hour after the noon meal.

476. The rule that every individual must be a law unto himself may be abused by those who consult their appetites alone without reference to their common sense. If we believe that regularity in eating is desirable, the stomach and appetite can be trained to it, although if one is used to eating at all times and between meals, the desire to do so may remain for a time. An appetite for whisky is an acquired one, and it is not an evidence of a normal and healthy demand. Emaciated and half-starved persons may suffer from want of appetite, but it may be a sign that they should increase the activity of other organs, as the muscles, not that they should eat insufficient food.

477. A good and healthy appetite comes from the expenditure of energy and rebuilding of the tissues, and a person with such an appetite enjoys best the simple foods that will best give energy and build tissue. The best pleasures of eating are for those who have appetites of this kind, not for the epicure or glutton. This is only one example of the general truth that mere pleasure seekers do not have the best pleasures; but they enjoy life best whose living is complete, all the duties and pleasures of life being given their place, and none allowed to usurp.

478. Subject for Debate. — *Resolved*, That the evils resulting from bad food and improper eating in the dining room (aside from the inestimable benefits of food) have been as great a curse to the human race as the evils resulting from the barroom.

479. THOUGHT LESSON. **Clothing.** *The Head.* — The position and extent of bald spots show that baldness is caused by ——. The best kind of a hat is [stiff or soft? light or heavy? ventilated by holes or air-tight?] and worn [as much or as little?] as possible.

The Neck. — The neck is very [flexible or inflexible?] It is healthier [with or without?] covering. Stiff or high neck clothing [destroys or preserves?] its beautiful curves, and makes the neck [skinny or full?] and makes one [more or less?] apt to take cold.

The Trunk. — The most flexible portion of the trunk is the ——. I find by measuring with a tape line that the circumference of my chest is —— inches more with the lungs expanded than when they are contracted. This is called *chest expansion*.

My *waist expansion* is —— inches. If I have my clothing cut to fit the larger waist measure, and support it by the waist, its weight will cause it to —— when the waist contracts in breathing. If cut to fit the smaller waist measure, the —— cannot —— and my breathing will be ——. The [shoulder or waist ?] is made mostly of tough bone and muscle, it contains no delicate vital organs, it does not expand or contract; it is horizontal while the —— is vertical. Therefore the —— is better for a support to the clothing than the ——. The seven vital organs at the waist are the st——, l——, sp——, two k——, p——, and a portion of the large ——.

The weight of the clothing on the shoulders may flatten the chest and draw the shoulders forward if the weight is supported over the front of the chest. Therefore the weight should fall mostly at the sides. (The buttons for men's suspenders should be at the sides, just over the pockets.)

The "Health" corsets, and "Good Sense" health waists, with straps at shoulders, are misnamed, for as worn the straps are loose and useless. No clothing can be supported from the shoulders unless it is loose enough to slip down at the waist when unfastened or loosened at the shoulders.

Among the first five of acquaintances thirty years old or older, of whom I happen to think, —— are sickly. Of five gentlemen, —— are sickly.

APPLIED PHYSIOLOGY

EXERCISE I

1. How do you explain the difference in the way a **dog** eats meat and a **horse** eats grain ? (Compare with Question 8.)

2. Clothing and shelter for man or beast **economize** what kind of **food ?**

3. Why does wheat bread **rise better** than corn bread?

4. Why is corn bread one of the most fattening of grain foods?

5. Why is it that you can tell best about the **digestibility** of bread while you are **slicing** it?

6. What kind of persons would not find it well to take a long **walk before breakfast?**

7. Why are **late suppers** unhealthful (§ 475)?

8. Why should **bread** remain longer in the mouth than **meat?**

9. In snowballing what is the appearance of the hands when they itch from cold? Why is it that **ice water** does not satisfy the thirst, but often produces **a craving** to drink more water?

10. Why is it more difficult to **swallow a small pill** than a large one (§ 373)?

EXERCISE II

11. When is hunger a safe guide?

12. Why does not fat meat taste as well in summer as in winter?

13. Name organs which receive more **benefit from the blood** than they give to it.

14. Name organs which give greater **benefits to the blood** than they receive from it.

15. Why should pork be thoroughly cooked?

16. What necessary step in preparing **salt meat** to be cooked lessens its nutrutive value?

17. Should **biscuits,** having a yellow tint or dark spots due to **soda,** be eaten or thrown away?

18. Why, during an **epidemic,** are those who have used **alcohol** as a beverage, usually the first to be attacked?

19. What is the effect of alcohol upon **albuminous** substances?

20. Explain how it is that when people speak of an **inactive liver** they usually mean an overworked one (§§ 407, 408).

EXERCISE III

21. How does the possession of a **gall bladder** furnish evidence that man should have meal times and not eat at all times?

22. Who attains greater success in life and true happiness, the man who **makes millions** of dollars but loses his health by close application to money making, and has to live on gruels and soups, and does not have sound sleep, or the man who **makes a living** and no more, sleeps soundly, enjoys his food, and has strong nerves? Which do

you regard as a truly successful man? Which does public opinion regard as more successful?

23. Do you **buy more wood** (cellulose) when you buy beans or when you buy nuts (§ 434)?

24. Do you **buy more water** when you buy bread or when you buy meat?

25. Which is true, the original saying: "Stuff a cold, and you will have to starve a fever," or the modern way of stating it?

26. Why is soda sometimes good medicine to neutralize a sour stomach, and very bad for digestion if eaten in bread (§§ 91, 377)?

27. What advantage in digestibility may a hot biscuit have over a loaf of stale bread? *Vice versa?*

28. Some physiologists hold that the eating of much meat causes an irritable temper. Does your observation of others or your personal experience confirm or disprove this?

29. Why do people who live in overheated rooms often have poor appetites?

30. Why may the taking of prepared pepsin weaken the stomach?

31. Why is there often an outbreak of colds when a warm moist spell of weather succeeds several weeks of cold dry weather (§§ 6, 587)?

32. Explain how the stomach may be weakened by the eating of predigested foods.

NOTES

1. **What the Carpenter said.** — "You literary fellows talk about the breakfast question. All you need to do is to get out and do some work. Use your hands. Take some exercise like I do, and you can eat anything. You sit there all day cooped up in your office and write, write, write. You cannot enjoy food or sleep as long as you do that. Come out here and shove the jack-plane an hour or two; that will give you an appetite. Let me get you at one end of this cross-cut saw at six o'clock in the morning, and I will settle the breakfast question for you in a hurry. You will have no need of patent cereals or fancy foods in pasteboard boxes."

2. **Cotton Seed as a Food.** — *The American Analyst* says: "Two thirds of the olive oil sold in the markets of the world is born in the cotton fields of the Southern States."

Dr. Allan McLane Hamilton says: "I consider one of the most healthful articles of diet that we can possibly have, to be cotton-seed oil. It is one of the best fats, and is much more healthful than lard."

Dr. R. O. Beard, a professor in the College of Medicine, Minneapolis, Minn., says: "Cotton-seed oil is a wholesome, nutritious vegetable oil which delicate stomachs bear without injury."

3. **The Mouth shirks Duty at the Expense of the Stomach.** — The average chronic dyspeptic needs to eat pure food and avoid soft and sloppy food. Why? Because when the food is in the form of slops it is well lubricated, and when taken into the mouth it goes down before you can say "Jack Robinson," and the food has not had saliva mixed with it and thus escapes mouth digestion. Now mouth digestion is just as necessary as stomach and intestinal digestion; the mouth must do its work properly in order that the other steps in the digestive process may be well performed. The process of digestion is like setting up a long row of bricks, each being a little space from the other, so that when the first brick is tipped it strikes the next brick and knocks it down, and that strikes the next, and so on till all the bricks are down. Mouth digestion prepares for stomach digestion. — *Good Health.*

4. **Sick Headache, and How to Avoid It.** — Sick headache means germs and foul matter in the alimentary canal, especially the stomach. These attacks are always preceded by well-marked symptoms; by noting and profiting by these, and by using common-sense treatment, no one need agonize through such painful experiences at any time.

Among the **warning symptoms** are dullness, sleepiness after eating, floating specks before the eyes, a coated tongue, and often constipation. Sometimes there is a voracious appetite. In fact, large quantities of food are taken into the body and retained there, and but little is eliminated. The natural result is that there is stagnation from clogging up with spoiled food and retained waste matter. The poisons produced are carried by the circulation to all parts of the body. Much blood naturally goes to the head, and with it a large amount of poison.

Common sense would say that when the source of a disorder is known the proper thing would be to remove it; instead of giving some opiate to quiet the symptoms, which are only the wise protest of the bodily organs against abuse, it would be more rational to relieve them by removing the unhealthy matter from the stomach and bowels; or if the treatment is begun in time, all that may be needed is **a fast, or a fruit diet for twenty-four hours, and free water drinking,** to give the system time to dispose of the excess of waste matter.

— J. H. Kellogg, M.D.

5. Pawlow, an eminent Russian medical authority, made a kind of window in a dog's stomach, so that he could look in and see what was going on. He found that when he brought savory food to the dog and placed it before his nose and eyes and didn't let him eat it or taste of it, by looking into his stomach he could see the gastric juice trickling down

the walls of the stomach; he could see that the stomach was getting ready to digest that food. The flavor of the food had given notice that it was coming, but it didn't come, so the poor stomach was disappointed. In like manner your mouth will water for grapes which you see and which are out of your reach, and so a boy's mouth will water for a pie which is placed upon a top shelf or somewhere where he can see it, and it is out of his reach. Now when this dog didn't see the food brought to him and didn't smell of it, nor get a chance to chew it, and it was surreptitiously slipped into his stomach, there was no flow of gastric juice, and no digestion. Now if you eat food too fast, or in the form of mushes, for example, it slips down into the stomach before the stomach has notice of its coming, and so has not made preparation for the disposal of the food. The nose does not smell the food, and the mouth does not chew and taste the food sufficiently to excite the stomach to set up the general process of digestion. Numerous similar facts might be presented, showing very clearly the close relation existing between the various digestive processes and intellectual states. Long observation and experience prove that it is far better for a person to eat what is set before him, asking no questions, either for conscience' sake or the stomach's sake, than to take food in an anxious and worried state of mind, questioning or doubting the nutritive value of the food to be eaten. Many a chronic dyspeptic maintains his disorder by keeping his stomach in a sort of "stage fright," through the concentration of his attention upon this portion of his anatomy during the whole digestive process. — *Good Health.*

CHAPTER XV

STIMULANTS AND NARCOTICS

480. In the year 1881 Dr. Hammond, a New York physician, made the assertion that a forty days' fast was a physical impossibility. This led Dr. Tanner, a Minnesota physician, to attempt such a feat. He arrived in New York weighing 184 pounds. He was six weeks making arrangements for his fast, and when he began his experiment, his weight was 157½ pounds. He weighed 121½ pounds on the day his fast ended. He had therefore lost 36 pounds since his fast began. The first thing he ate to break his fast was a watermelon, swallowing only the juice. Dr. Hammond came out in a card in the New York papers declaring that he believed the fast had been fairly conducted.

481. Succi, an Italian, successfully accomplished a fast of 50 days in London, being likewise constantly watched to make sure of his fasting. There is reported, on good authority a case of an insane person who suddenly became possessed by the idea of taking no food, and who took 60 days to starve himself to death. Long fasts are a great injury to the body, no doubt, but what can we learn from such experiences? Certainly it shows the wisdom with which we are made, certainly that our physical organization is very provident.

482. Once some miners were shut in by caving of part of the mine. But unlike the cases mentioned above they were without water as well as food. When, by digging, the rescuers reached them, seven days after, several were still found alive, although most of them had succumbed. The miners, no doubt, had nourishment in their bodies for some weeks more of life, but the necessary solvent in the form of water was lacking to dissolve it and bring it within the reach of the cells most needing it.

483. A Fact of Immense Importance. — This fact concerning the amount of nourishment stored in the human body (in one case a two months' supply!) is one of the most stupendous facts with which the science of physiology has to deal, and it should be borne in mind, or we may greatly deceive ourselves about some very simple matters.

484. Foolhardiness. — Did you ever get so tired that you had to give up and stop, however much you would have liked to continue at work or play? To rest was the wise thing to do. Now, although you learned from physiology how much energy you have stored up within your frame, you should not on that account, be tempted to go on until you almost break down. Probably you know people who are conceited about their bodies and say they are made of cast iron; nothing can hurt them. Did you ever know anybody who was conceited about his mind and thought he was very bright? It is just as foolish to be conceited about the body.

485. A Blessing in Disguise. — It is a very wise arrangement that under ordinary conditions we cannot get at the surplus energy we have. We are compelled to be provident, as it were; yet stimulants and narcotics, by irritating the cells, will cause them to expend some of this reserve energy; they will enable man to get at this precious store which he should save for emergencies, such as a spell of sickness when he cannot digest food, or when he is making some mighty effort. This reserve energy will enable him to undergo some trying ordeal successfully.

Did you ever know of a weak sick man who had eaten very little for weeks, yet was so powerful that it took several strong men to hold him? This sometimes happens in the case of sick men who are delirious and crazed with pain and with the poisons formed in their bodies during illness. But the delirious mania often uses up the little energy left and costs people their lives.

486. The Meaning of Fatigue, the Blues, etc. — Suppose you are tired or worked down. The fatigue depresses you, and you feel discouraged. What ought you to do? Why, rest, of course, and you will soon feel all right again. This seems very simple, yet some people will not do this way, but take an alcoholic beverage or tobacco, which will keep them from feeling tired when they are tired. If you have been working hard preparing for examinations, or gathering hay, or in attending to some important business, or have been under the excitement of some pleasure trip, and feel blue and worn out, then bear the result like a man, or like a true boy or girl, as the case may be. Giving up for a while, or "toughing it out" with the blues, or losing a little time from business, will not hurt you but will make you strong, while a stimulant will leave you less of a man than before.

487. There is only one source of energy for man's body, and that is the union of food and oxygen. He must get his energy from the same source that the engine does, and that is from his food, which serves as fuel, and the oxygen that burns it. The millions of little workers, the cells, will store up food within themselves and get rid of the ashes and refuse, and the pure, sound body will be ready for work again.

488. Alcohol is a Whip or a Spur. — It is to get strength out of a man, not to put it in. When a person feels that he is all tired out and his nerves are weak, and takes a stimulant, it is the same as if, when his horse shows signs of breaking down, he should lash him with a keen whip, or pierce him with a sharp spur, instead of letting him rest. Many a fine horse under the sting of the whip has been spoiled in a few hours, and many a man has been physically ruined for life by overworking, goaded on by alcohol, during one season of business rush.

489. How Stimulants arouse Energy. — You remember those wonderful little one-celled animals, the amebas. If poison is brought near, they will try to escape it. They also throw out the impurities generated by their own life processes. If anything touches one roughly, it will draw back from the danger. Likewise, if a man takes poison, such as alcohol or tobacco, into his body, the cells will try to throw it off. The heart, although it may be already tired, goes to thumping anew, secretions are poured out by the cells to dilute and weaken the poison, and the great activity excited diverts the man from noticing his fatigue, and makes him think the poison has given him renewed strength. It is the same as if he thought the whip instead of the oats gave the horse strength. The horse, like the cells of the body, is only trying to avoid something harmful, and like them, he uses up his strength in so doing. After a while he will be very stiff and tired. There is no artificial stimulant that does not cause a reaction. The stronger the stimulant, the worse the poison. Strychnine is one of the deadliest poisons known, and also one of the most powerful stimulants. If an animal is given strychnine, its nerve tissue is sometimes reduced to such an irritable condition that a loud sound, or merely touching any part of it, will throw every muscle of its body into a spasm.

490. Natural Stimulants do not cause depression. The chief natural stimulants are cold air, sunlight, pure air, physical exercise, interest, joy, and other emotions. A deep breath of pure air is a better stimulus than a glass of beer; climbing a hill or sawing a log of wood will make the blood flow faster than alcohol; a pleasant talk with a friend is a better sedative than a cigar; a cold day will steady the nerves better than an opiate; a trust that a good Power rules over all will drive away worry quicker than cocaine; a cold bath will bring steadier nerves than coffee; a cold wind will give a better appetite than food soured with vinegar or hot with pepper. Natural stimulants do not produce a reaction because they do not excite the body to an injurious degree, nor cause the energies to be consumed beyond the danger point. Persons who go through life under the stimulus of these natural blessings have sound steady nerves and clear brains. They do not have to take anything "to quiet their nerves."

491. Some people are coffee topers and tea topers. It is a mistake to say these things quiet the nerves. Who is so nervous as the old lady who drinks frequent cups of tea to quiet her nerves? It is the tea that is making her nerves unsteady. Some people unaccustomed to tea will lie awake most of the night, wearing out their energies by sleeplessness if they drink only one cup of it.

492. It is easy to understand how a person sitting up with a friend who is dangerously ill will take tea or coffee to keep him wide awake. If he has some great duty to perform, or trust imposed upon him that will soon be over, there may possibly be some reason in stimulating his activities, even if he must suffer reaction and depression thereafter. But why one will habitually disturb his body with narcotics, such as alcohol, tobacco, or even mild narcotics, such as tea and coffee, so as always to keep his vital force and reserve energy at a low ebb, is difficult to understand. It can only be explained by ignorance of the fundamental laws of his being.

493. The Use of Natural Stimulants. — Man's body was beneficently designed to keep a large amount of energy stored up, so that he can feel conscious of his power and go through life buoyantly and happily, and prepared for all emergencies, — the highest being in the world that he inhabits. He is in a world full of interest. Delicious fruits and nutritious nuts and grains abound to awaken and satisfy his appetite. The bright sun not only shines upon his skin, but deep into it, and stimulates the cells; the fresh breezes striking his nerves, start currents coursing through his body. The oxygen penetrates to every cell, purifying and awakening to life. The pleasure of association with his fellow-creatures, and various other pleasures, arouse him to do his part in the world. There is no need to seek in the jungle for some bitter berry, or among the weeds for some nauseating leaf, or among decaying apples or grapes or fermenting grain for a burning and revolting liquid in order to stir his being to action. He lives the life for which his body was designed.

494. How Man comes to deprive himself of Natural Stimulants. — But suppose he becomes wise and wishes to improve on the simple blessings of life. He must stay in the house continually in order to transact much business and make money, or to acquire precious wisdom in musty books. He must curtain off the sunshine for fear it will cause his fineries to fade; must shut out the air and keep in the dust. His great knowledge tells him that cool draughts are dangerous upon a skin made delicate with a load of clothing. The joys and stimulus of friendship and of unreserved communion with his fellows leave him, as he narrows his view and fixes his gaze on some selfish object. The voluntary motions of his body are confined mostly to his fingers and his tongue, as he writes and talks in transacting business, for he is too proud to walk, or to work with his hands, and thus the circulation throughout his body becomes sluggish. His natural appetite becomes weak and would regulate the amount of food according to the narrow incomplete life he is living, but he gets an artificial one, with sour or peppery seasonings, and the half-digested food makes poison for his blood. His nerves become weak, his wits blunted, his body sluggish and depressed.

495. What this leads to. — He adopts the use of poisonous stimulants that, in the effort to rid themselves of the poisons, the cells may have an incentive to activity, and the awakening of his weakening system may give him the feeling of power and enable him to stick to his work and his unhealthy life. Coffee, tea, tobacco, wine, beer, whisky, form a gradual progression toward ruin. He may feel worn out, but a strong cigar, sending the poisonous fumes of nicotine into his delicate thin-walled lungs, will so set his nerves on fire that he feels vigorous, and says, "What nerve-strength comes from tobacco!" For it seems we feel vigorous only when we are expending energy very rapidly, even if the store of energy is nearly exhausted. He feels discouraged and weak, and takes a glass of whisky; this disturbance to the system, with the great amount of energy expended in getting rid of it, makes him think he has had a sudden accession of strength, for he forgets the work that the faithful old stomach has been doing in storing away food in the cells (alcohol is never stored in the cells, but all foods are); he forgets the industrious lungs and the oxygen they have been storing in the blood and cells. He is like the man who has piled up money in a bank and draws it out with checks and says: "What a wonderful thing a check is! How valuable is my check book!" But, if he were to lose the check book, the bank would give him another for nothing. The check, when written, is only a sign that money must come out of the bank, and the alcohol when taken into the body is only a sign that strength must come out of the body in expelling the enemy. No wonder the man has a bad headache the next morning.

496. Spendthrifts of Vitality. — Did you ever know persons who could not keep any money or property? Dollars seem to burn holes in their pockets. They do not know how to economize when funds are low, but are always getting in debt and borrowing, and mortgaging their crops or their stock or their homes. There are many such people, and there are just as many who cannot store up any of that precious capital consisting of bodily health and strength. If they feel buoyant and strong, they will not economize their strength, but work or go until they are worn out, and then take tobacco or alcohol to deaden the tired feeling. If a man is weary, it is not to his interest to *feel* rested until he *is* rested. Such feelings are a cheating of nature, a breaking down of the protective barriers around life's citadel. Such a one deceives himself. One who deceives another is called a liar; one who habitually deceives himself brings the same destruction upon himself as the fool.

497. C. F. Hodge, Professor of Physiology in Clark University, made a **series of experiments** upon four kittens and four spaniels. Moderate non-intoxicant doses of alcohol were given daily to two of each.

(Dogs could be killed in a few minutes or a few days or months by sufficiently large doses of alcohol. While such experiments might have some interest to toxicology, they could not have much to physiology.)

498. At the end of ten days, the two kittens dosed with alcohol took severe colds. Up to this time, purring and playfulness had been disappearing from their lives. They were dwarfed in growth to 63 and 39 per cent, respectively, as compared with the others.

499. Of the two pairs of spaniels, the pair treated with alcohol weighed less, and developed only 71 and 57 per cent of the activity of the other pair, as shown by the pedometer. The dogs treated with alcohol also developed strange symptoms of timidity and fear, suggesting the terrible fears of delirium tremens and alcoholic insanity.

500. In Dr. Hodge's opinion the experiments above described have direct bearing on the question of the effect of alcohol on the human system. The experiments proved that **alcohol causes depression of activity**. For man the highest aim is to develop useful activity, the will, the determination to do as much of the world's necessary work as he is capable of doing, and a sound, vigorous body to enable him to carry out such determination. It is of the utmost importance, therefore, that we understand the conditions of our physical systems under which this great end can best be attained.

501. In no other country are there so many people who **refrain from using intoxicating liquors** as in the United States. Many forces have united to bring about this condition, chiefly temperance organizations, ministers, teachers, and the newspapers. To a greater extent than in other countries also intemperance has been driven out from the upper classes by the force of public opinion; it is no longer fashionable. Temperance has gained in spite of the fact that the climate of the United States tends strongly to cause the excessive use of alcoholic liquors.

502. A Knowledge of Physiology is a great help in promoting the cause of temperance. All who acquire such knowledge are the better able to contribute their share to the good work. There can be no doubt that the use of alcohol is steadily diminishing as the people learn more of physiology, especially of the true nature of alcohol and of its effects on the system. General education also fights against intemperance, as few people interested in gaining knowledge care to indulge to excess in intoxicating drinks.

503. Why the Drinker increases his Dram. — Tanner and Succi have proved that for the ordinary man the energy stored up is sufficient for many weeks of life without replenishing it by taking one morsel of food. When a man begins to drink, the energy of his body may be of large amount, and a small amount of alcohol suffices to stimulate and exhilarate him. But a few stimulations serve to cause a large part of his energy to be consumed, and a larger amount of stimulant is therefore required to arouse to action the exhausted cells. Thus it goes on; the more he abuses his system by arousing it to expel the poison, the less energy he has left and the more difficult it is to arouse. The nearer worn out the tired horse is, the sharper must it be lashed to keep it going. The habitual user of alcohol is not only its slave, but a slave that is constantly being drawn closer and closer within its relentless clutches. The energy of the cigarette user sinks to a lower and lower ebb, and he constantly increases the nicotine in order to arouse it.

504. Inebriate Cures. — These are sometimes successful, but are usually failures. What makes the cure of the drunkard so difficult is, that he is not really willing to undergo the pain and trouble necessary to stop. During some unselfish moments, and when he realizes more than usual the destruction that dissipation is bringing upon him, he may truthfully desire to make any sacrifice to free himself and become restored to manhood, but so ruinous has been the effect of alcohol upon his moral nature, that such moments do not last long, and when the first promptings of the appetite return, he falls, and would sell the roof from over the heads of his wife and children to get money to gratify his thirst. The inebriate cures base their method upon convincing him, by secretly adding a nauseating dose to his drink, or by some other plan, that alcohol has turned against him and no longer gives him pleasure, and he becomes convinced that he must stop, and willing to try to quit. The best way to quit alcohol, opium, tobacco, or other narcotics, is by a straightforward resolve to do so, and by stopping at once. While the poison is being removed from the body, the nerves are so irritable that the least sound or change of temperature may bring torture to the patient, and sometimes it is necessary to keep him in a quiet room, submerged in a bath just the temperature of the body, for several days at a time.

505. The Discovery of Alcohol. — A long time ago learned men called alchemists (the predecessors of the chemists of the present day) believed that they could succeed in discovering the elixir of life, the water of perpetual youth. In the year 1000, an Arab alchemist, while seeking the elixir of life, discovered alcohol. Of course it had existed long before, wherever fermentation of sugar took place, and had been drunk in wine, in which it occurs in a diluted condition. But this alchemist succeeded in distilling, or evaporating and condensing, it from the water of the wine. When he first drank alcohol, he felt that he had some new and strange liquid which he believed would prove to be the water of life. But experience soon showed that the use of it, instead of giving freedom from death and perpetual youth, shortened life

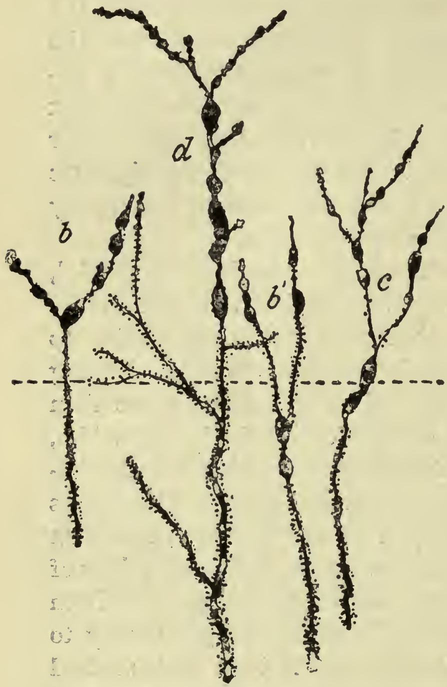


FIG. 191. — An illustration of the nerve branches and fibers in a case of alcoholic insanity. The patient died of this disease and when the nerve fibers were examined under the microscope, they were shown to be swollen and broken down in the manner illustrated in the drawing. The swellings of the nerve fibers, as seen in this illustration, are characteristic effects produced by alcohol, and are usually seen in the brain of those dying from alcoholic insanity.

instead. Yet the name "water of life" is still the term used for brandy in the French language, and one may see in immense letters on a wall at the end of a street near the University of Paris, the suggestive sign, *Dépôt de l'Eau de Vie*, "Storehouse of the Water of Life."

506. Truly the Bible gives the heart of the matter when it speaks of wine and those who are *deceived* thereby; for the deception of a part of mankind has been complete. The use of narcotics has been pronounced a blot upon civilization, and physiologists and sociologists have united in declaring that alcohol ranks ahead of war and other evils as the greatest obstacle to civilization and the happiness of mankind, that exists in the world.

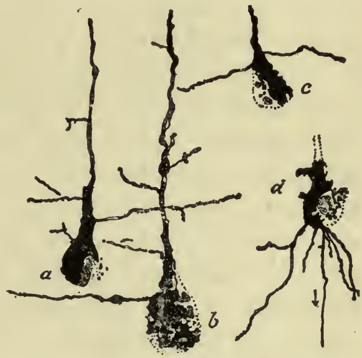


FIG. 192. — This figure shows four nerve cells from the brain of a man who died of alcoholic insanity. It will be noticed that the body of the cells and the nerve fibers are broken up and degenerated. The changes shown in Fig. 191 are the more severe changes, and represent complete destruction of the nerve tissue.

507. Of all the Diseases that have been named as being caused by alcohol, no one person ever has more than a small part. Those of the organs that are weakest give way first, and death results before the others are attacked. The stomach may become so ulcerated that it cannot even bear water, which throws the victim into a spasm. In such a case, he will probably die in delirium tremens, a condition of horrible temporary insanity.

The body seems in some instances to become used to the moderate use of poisons such as nicotine and alcohol, and in outward appearance to escape serious harm. For one that apparently escapes, many are destroyed. We sometimes see very old men that have smoked tobacco for fifty years. But if such men had begun when young boys, or had used cigarettes and inhaled the smoke, they would be even fewer than they are.

508. Review of Effects of Alcohol. — Give the effect of alcohol upon (1) the skin and bones; (2) the muscles; (3) the stomach; (4) the liver; (5) the circulation; (6) the respiration; (7) the nervous system. (8) Discuss whether alcohol is a food.

509. Drug Habits are growing with such rapidity that it is a question whether the drug fiend will not, before long, be as common as the drunkard. The physician meets few more pitiable sights than that presented by the typical morphine or cocaine fiend. The evil is invading all classes of society, including numbers of physicians. Many patent medicines, cough cures, headache powders, colic cures, etc., contain morphine. It is a deep-seated fallacy existing in the minds of the masses, that they can violate with impunity the laws of health and life which have been instituted by infinite power and wisdom, and then dodge the unpleasant consequences by simply swallowing a few drops of some sedative or anodyne. About $200,000,000 worth of patent nostrums are annually disposed of. The average invalid demands something more substantial than extravagant claims. As there is no drug that will so effectually smother, for a time, the cries of an outraged nerve as some form of opium, and as there is no drug that is so deceptive a stimulant as cocaine, these two are most often found in these quack remedies. They assist in securing convincing testimonials as to the wonderful curative power, which is supposed to be identical with the relief from pain furnished. The invalid soon learns to buy the active agent in the nostrum in its pure form, and this often seals his fate.

510. Subjects for Compositions. — Cooking. Health and the Home. The Body subject to Law. Improved Dress.

Some of my Observations and Experiences from the Standpoint of Physiology. Tight Shoes. An Incident from Life. Physical Education compared with Mental. Hygiene of the Schoolroom. Extremes in Hygiene. Microbes. Health and Country Life. Looking Back. Looking Ahead. Health and City Life. The Right Way the Easiest.

PART IV. HOW THE BODY IS CONTROLLED

CHAPTER XVI

THE NERVOUS SYSTEM

511. Function of Nervous System. — The ameba and other one-celled animals need no nervous system, but the larger animals, consisting of a colony of cells, as it were, need a means of communication between the cells, in order that their life may be harmonious. Robinson Crusoe could not have used a telephone or a post office system, but a number of individuals living together and practicing a division of the labor of the community for their mutual advantage, are compelled to communicate with each other in order to make their necessities known. The lowest of the many-celled animals, such as the sponges, have no cells specially set apart for carrying messages between the cells, but each cell passes the impulses it receives to its neighbor cell. This will do for a small and simple community of cells, but a larger community, like one of the higher animals, possesses certain cells, called *nerve cells*, whose chief function is to keep up the communication between the cells. In the chapter on the master tissues you learned that the nerve cells did this by means of long branches, which in some cases are several feet long.

512. Communication is not All that is necessary. — Did you ever see a crowd of people at a fire when a neighbor's house was burning? Everybody ran about, yet very little was done. Everybody shouted orders which nobody obeyed. But on the arrival of the chief of the fire department or the head of a fire company, who had had experience in the control of men fighting a fire, the scene changed; valuable property was saved, and the fire was stopped.

513. Every community has certain deliberative and controlling bodies; these may be a board of aldermen, a court of justice, a legislature, or a congress. In a similar way the great number of individual cells which make up the human body must be controlled by some central power, or they will not work in harmony; nothing will be accomplished, but a state of anarchy and helplessness called disease, will follow. The seat of this central controlling power is believed to be located in the brain.

514. Coördination. — The nerve cells receive, modify, and send out impulses. By these three kinds of acts the nervous system accomplishes what is called *coördination.* This term signifies not only that the cells work together at the same time, but that they work together as a part of a plan for the accomplishment of some definite result. Suppose that a man sees a bright dollar in the road and picks it up. In order that he may do this, the cells receiving through the optic nerve the impression of the shining coin must be in communication, either directly or indirectly, with the muscles of the hand; and that the hand may reach the coin, the muscles of the arms, legs, trunk, head, and neck must act together. Even the heart and respiratory muscles must modify their action somewhat to suit the movement.

515. Other Organs besides Muscles must be coördinated. — Suppose a boy sees a large red apple. He notices the odor which tells him that it is ripe, and his "mouth waters" for it; that is, the salivary glands begin to work, even before he puts the apple to his mouth. The chewing and swallowing, the secretion and peristalsis in the digestive organs, are all carried on under the control of impulses that reach them through the nerves. Without these impulses, the salivary glands would not work when the mouth was chewing the food; the dry food would stick to the esophagus and have to be washed down with water; the gastric juice would not be secreted at just the right time; the food would ferment in the stomach, and the person would soon be ill.

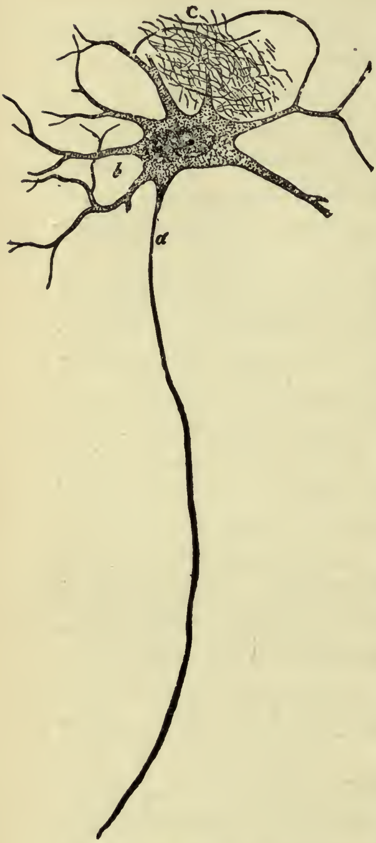


FIG. 193. — Branched Nerve Cell from Spinal Cord.

a, axis cylinder or axon; *b*, dendrons; *c*, neuroglia.

516. Nerve Cells (Fig. 193). — You learned when studying the master tissues that the nervous system consists of nerve cells with their branches, called *nerve fibers*. Nerve cells are microscopic bits of protoplasm, like other cells, yet they are remarkable among animal cells for their large size. Some of the cell bodies in the spinal cord are so large as to be almost visible to the unaided eye, and have branches leading from the cord to the hand or foot. Each cell contains a nucleus, within which is a nucleolus (Fig. 193). Nerve cells are the most remarkable in the body for irregularity of shape; some of them have so many branches that they have a star-like appearance.

517. The Dendrons of a nerve cell are the treelike branches which bring impulses to the cell (Fig. 193). Through the dendrons the cell may be in communication with numerous other cells. A branch of one cell does not join the branch of another cell. It has not yet been settled by physiologists whether the ends of the dendrons of communicating cells actually touch.

518. The Axis Cylinder, or Axon. — In most of the fully developed nerve cells, one of the branches is very greatly prolonged as a fine thread of protoplasm, which becomes the core of a nerve fiber (Fig. 193). Every nerve fiber has such a core. In most of them this central thread of protoplasm becomes covered with two coats; an outside protective coat forms a tube, called the *connective sheath:* and between the walls of this tube and the central thread is a coat of semiliquid, fatty substance called the *medullary sheath*, which, shining through this outer sheath, gives a silvery white appearance to the fiber. Such fibers are called *medullated fibers*, or white fibers (Fig. 194). Some fibers lack the medullary sheath, and are called *non-medullated*, or gray fibers (Fig. 194).

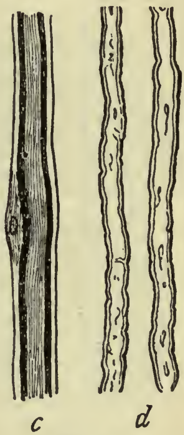


FIG. 194.

c, medullated or white nerve fiber; *d*, two non-medullated or gray fibers.

519. A Neuron. — One nerve cell together with all its branches, both dendrons and axon, is called a *neuron*. A neuron is the unit, and the nervous system is built up of an enormous number of these units, together with supporting tissue (Fig. 193).

520. A Nerve. — Many nerve fibers may be bound together by connective tissue until they form a cord large enough to be seen by the unaided eye (Fig. 195). A bundle of nerve fibers is called a *nerve*. The sciatic nerve in the thigh is as large as the end of the little finger and strong enough to support the weight of the body. The fatty sheaths of the fibers are supposed to insulate the fibers so that a nerve impulse cannot go across to another fiber; they serve the same purpose as the insulating substances with which wires used to conduct electricity are sometimes coated. As a rule, a large nerve accompanies an artery down the inside of each limb, and across the joint on the side *toward* which the limb bends. Thus they are well protected. One exception to this is a nerve cord which crosses the elbow on the side *away* from which the elbow bends. Therefore it is sometimes hit, and the end of the bone there is called the *funny bone* because of the tingling sometimes felt, as if it were in the hand at the termination of the nerve.

FIG. 195. — Section of Nerves, showing Many Nerve Fibers in Connective Tissue Sheaths.

521. A Nerve Ganglion and a Nerve Center. — The cells are not scattered singly throughout the nervous system but are gathered into groups. This seems to afford easier communication from one cell to another through their branched dendrons, which are unusually short. One such group of cells is called a *ganglion*. One or more ganglia, performing a definite function, such as controlling the muscles of breathing, form what is called a *nerve center*. The brain consists of a number of large nerve centers with their connecting fibers. There are many nerve centers in the spinal cord also. We usually speak of the brain and spinal cord as the central nervous system. Where ganglia and gray fibers are abundant, the nerve substance is gray; where medullated fibers with their hidden gray cores are abundant, the nerve substance is white in appearance. This led anatomists and physiologists in times past to classify nerve substance as gray matter and white matter.

522. Neuroglia. — The fibers and cells of both the gray and the white matter are held in place by a tissue called *neuroglia*, which is composed of extremely fine fibers and minute cells. Though like connective tissue in function, its chemical composition is different, nor is neuroglia developed from connective tissue (Fig. 193).

523. How Nerve Fibers terminate. — If we could trace toward the central nervous system the course of the various nerve fibers in a nerve like the great sciatic, for example, we should find that every one of its thousands of nerve fibers ends, without exception, in a nerve cell in the spinal cord or brain, or in one of the ganglia near the central nervous system. If we should trace these same fibers away from the central nervous system, they would be found to have various endings. Some enter the muscles where they subdivide, and finally end in the muscle cells. Others follow the blood vessels, and end in the muscle fibers forming the middle layer of their walls. Others go to the gland cells; for example, the sweat glands in the skin, or to some other internal gland. Others, passing to the skin, terminate at the roots of the hair, or in curious little bodies composed of cells and called *touch corpuscles* (Fig. 196). Every nerve fiber ends centrally in a nerve cell, and outwardly in either a muscle cell, gland cell, or sense organ cell.

524. Motor and Sensory Fibers. — Fibers which connect nerve cells with muscles or glands are called *motor* or *efferent* (outward bearing), fibers; those which connect nerve cells with sense organs are called *sensory* or *afferent* (into bearing) *fibers*. There is a third kind, which connects nerve cell with nerve cell in the brain; they are known as *association fibers* (Figs. 203, 207).

525. Nerve Action. — If the sensory nerve be irritated at its outer endings in the cells of the other tissues or anywhere in its course, an influence will travel to the central nervous system. If the impulse reaches the brain before dying out, it will be felt as a sensation. On the other hand, the brain can originate impulses which travel to the cells of the body and cause them to act. Transmitting impulses is the whole duty of nerves. The endings of the nerves are so abundant in the skin just beneath the epithelium, that the point of a fine needle cannot enter without causing pain. They are more numerous there than in any other part of the body. Sensory nerves are not so abundant in the muscles and internal organs as in the skin, so that a cut gives most pain as it enters the skin and may be continued into deeper parts with only slight pain. Motor nerves begin at the central nerve cells and end in the cells of the body. Motor nerves and motor impulses are for three purposes: for controlling motion, secretion, and growth.

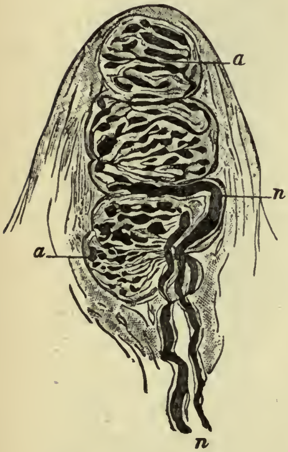


FIG. 196. — Tactile Corpuscle within a Papilla of the Skin of the Hand, stained with Chlorid of Gold.

n, two nerve fibers passing to the corpuscle; *a*, *a*, ramifications of the axis cylinders within the corpuscle.

526. Special Sensations. — When something outside of the body acts upon the nerves, it produces a feeling or sensation by which the mind forms ideas of the surroundings of the body. The meanings of these feelings must be learned when first perceived, and they are mostly learned in childhood. The special senses are of such importance that all except the sense of touch will be included in a separate chapter.

527. General Sensations. — The cells of the body are constantly sending impulses to the central nervous system, signifying their needs. These impulses give rise to feelings to which the mind assigns no definite location in the body; hence they are called *general sensations*. Such feelings as hunger, thirst, fatigue, and sleepiness belong to this class. They are as well understood by a baby or any young animal as by a man, and unlike the special sensations, the meaning of general sensations does not have to be learned, as the memory of them owing to inherited habit seems to reside in the nervous system. General sensations are sometimes called *instincts*.

528. Hunger and Thirst. — Thirst seems to be located in the mouth, yet moistening the mouth satisfies it for a short time only. On the other hand, if water is introduced into the body through the intestine or veins, the thirst ceases, even if the mouth has not received water. Hunger appears to be located in the stomach, yet it cannot be satisfied by filling the stomach if the food is innutritious or remains undigested.[1]

529. Touch. — The four special senses of sight, sound, smell, and taste are located in special organs. Touch is located in all parts of the body. When an object touches the skin, an impulse is taken to the brain (Figs. 196, 197, 3). There it gives rise to a sensation of touch, temperature, pain, or weight. Four kinds of sensations are thus included in the general name of touch. Touch strictly gives only such ideas as those of size, shape, location, smoothness, hardness, and dampness. The ends of the fingers can distinguish two points as separate points if they are only $\frac{1}{12}$ of an inch apart, while if the two points are applied to the back, they feel as if they were one point until they are separated two inches.

530. The covering of epidermis not only protects the nerves and the other delicate organs in the true skin, from injury, but also modifies any impression, so that in producing a sensation it is spread over several nerve endings instead of one, and is thus turned into a gentle instead of a painful sensation (Fig. 3).

[1] If nutritious food is introduced into the body through the intestine in a form ready to be absorbed, the feeling of hunger will soon pass away, although the stomach is still empty.

531. Temperature. — This part of the sense of touch is located only in certain points or spots, called *heat spots* and *cold spots*, situated a small fraction of an inch apart (Fig. 198). Some spots give a sensation of heat only, and some of cold only. The sense is so delicate that a difference of $\frac{1}{5}$ of a degree of temperature between two objects can be detected. Extremely hot and cold objects injure the tissues and do not give sensations of temperature, but only of pain.

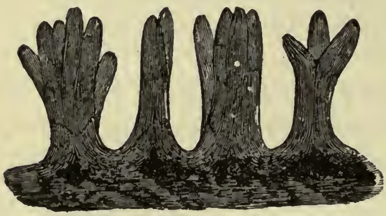


FIG. 197. — Four Papillæ of the True Skin, magnified. The epidermis has been removed. Most papillæ contain touch corpuscles.

532. Pain. — A sensation greatly increased or often repeated becomes unpleasant and is called *pain*. The same physical influence may be felt at one time as a pleasant touch, and at another time as a pain, depending upon the state of the nerve tissue. When an influence is becoming strong enough to endanger the body, the simple sensation of touch becomes changed into one of pain and warns us to avoid the danger. When a nerve is laid bare and touched, or cut midway in its course, the feeling is not one of touch, but of pain. Pain is a protection, and therefore more of a good than an evil. In many

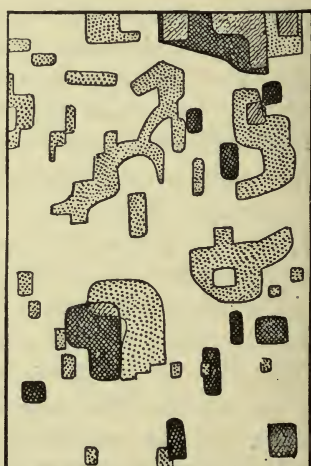


FIG. 198. — Cutaneous "Cold" Spots (light shading) and "Hot" Spots (dark shading); Anterior Surface of the Thigh.

diseases it is a prominent symptom, and the physician is begged to give relief. But the wise physician hesitates before giving morphine or other sedatives, knowing that to drown the pain is to conceal the danger, and take away his best evidence as to the state of the disease. At the same time, he runs a risk of starting a habit in the patient of deadening pain and hiding unpleasant feelings by taking narcotics, a habit that may become fastened upon the patient and ruin his life. Hence when sick we should bear pain bravely.

533. Tickling is intermediate between touch and pain. It is produced in parts which are supplied with few nerves of touch, as under the arm. It may produce great suffering. Some persons who can endure great pain cannot control themselves when tickled, as the movements excited are largely reflex. Itching is a sensation akin to tickling. It may be overcome by producing a greater sensation, as by scratching. Sometimes it may be so great as to lead a person to injure the skin seriously by deep scratching.

534. The Muscular Sense. — When an object is lifted, it is felt to be distinctly heavier if its weight is increased by only $\frac{1}{17}$, but when it is laid upon the skin, its weight must be increased by $\frac{1}{3}$ before it feels heavier. Hence it is concluded that sensations of weight and resistance to the muscles depend upon the amount of muscular effort needed to overcome the resistance as well as upon the feelings of pressure upon the skin and body.

535. If **Motor or Efferent Nerves** going to a muscle are cut, there is paralysis of the muscle, so that there can be no voluntary or reflex action in the part. If an efferent nerve going to a gland is cut, the function of the gland will be almost suspended. Even if food is taken into the mouth and the sensory nerves carry the news to the brain, the efferent nerve being cut, no impulse can return and the secretion will be very slight. When the motor nerve to a part is cut, the cells will be almost too inactive to absorb and carry on growth and repair; hence unless continually under the influence of motor nerves the cells dwindle away. When the cells are much used, the impulses sent cause them to take in more nourishment and grow in size. Thus a muscle increases in size and strength when much used. You learned that during the action of a muscle, the vasomotor nerves going to the arteries in the muscle cause what change? Will this also aid in growth? When a nerve is cut, the ends, if placed together, will grow again, the parts supplied by it being paralyzed in the meantime.

536. Disease of Nerves and Effect of Alcohol. — Nerves may become inflamed, and the disease is called neuritis, just as inflammation of the tonsils is called tonsilitis, or of the stomach is called gastritis. Neuritis of the sciatic nerve is called sciatica; it is a very painful disease. One of the many dangers of using alcohol is that it may produce neuritis. Either slow, steady drinking or occasional sprees may cause it. The disease gives no warning before it comes, and may remain a long while. Rheumatism or malaria may also cause it, but alcohol produces the disease as often as all other causes combined.

537. The Rate of Transmission of the nerve impulse in white fibers is about one hundred feet per second. In the gray fibers the impulse travels much slower, probably about twenty feet per second.

THE SPINAL CORD

538. The various white nerve fibers, both motor and sensory, of the entire body unite and form forty-three pairs of larger nerves; twelve of these pairs, called *cranial nerves*, go to the brain, and thirty-one pairs, called *spinal nerves*, go to the spinal cord. Each one of the sixty-two spinal nerves enters the spinal cord by two roots, one posterior and one anterior (Fig. 199). It is significant that all of the motor and sensory fibers of a spinal nerve separate from each other. The motor fibers enter by the anterior root, and the sensory nerves by the posterior root. The sensory fibers do not really enter the cord but end in a ganglion on the posterior root, and the ganglion sends dendrons into the cord by the posterior root. The spinal cord extends from the foramen magnum "or great opening," in the occipital bone down to about the second lumbar vertebra. What parts of a vertebra form the canal for the cord? Is the canal made of bone throughout its length? How are the vertebræ united with one another?

FIG. 199. — Cross-section of the Spinal Cord, showing Gray and White Matter, and Anterior and Posterior Nerve Roots. Ganglion on Posterior Root.

539. The spinal cord is about the size of the little finger. It is only about two thirds as large as its tube, so that it is not likely to be injured by bending the backbone. The rest of the space in the canal is taken up by a lymphlike liquid and three membranes called *meninges*, which form a triple covering for the cord. These membranes extend into the skull and cover the brain. An inflammation of them constitutes a very serious disease called cerebro-spinal meningitis.

540. A Cross-section of the spinal cord shows that it is a double organ (Fig. 199), the halves being united by a narrow portion; it shows also that the central part of the cord is of gray matter in the outline of a butterfly, and surrounded by a thick layer of white fibers. The gray portion is made up of nerve cells that give off fibers, many of which go to the spinal nerves and some go upward in the outer white portion of the cord. The white tract also contains motor threads, bringing impulses from the brain to the cells in the gray matter.

541. Voluntary Motion and Action of the Spinal Cells. — The brain sends impulses to the cells in the spinal cord, and they, being aroused, in turn send motor impulses to the muscles. When a person wills to move his hand, an impulse goes to the spinal cells, and they in turn send impulses that cause a contraction of the muscles in the arm. The brain sends about ten impulses per second to keep the muscle in action. Thus, before it can relax, another impulse reaches it. Each muscle has its own set of spinal cells in the cord which act as a relay station between the muscle and the brain.

542. The Spinal Cord and Reflex Action. — The cells of the spinal cord have another very important duty; they largely control reflex action. At times it would take too long for the brain to act, so the body needs a quicker governing power to supply its needs or protect it from injury. If the finger touches a hot object, the brain becomes conscious of the burn and of the movement of the finger at about the same time. There are also many acts that are performed so often that the spinal cord acquires the habit of sending back the appropriate impulses. Thus muscles and other organs may be controlled and the brain be relieved to attend to other duties.

543. The same motor cells of the spinal cord that produce motion in a part, also exercise an oversight that controls the growth and nutrition of the cells in that part. The impulses from the spinal cells furnish a constant stimulus to growth and repair.

544. Examples of Reflex Action. — A crumb entering the larynx brings on a fit of coughing. A dash of cold water makes us hold our breath. A pinch of snuff or pepper causes us to sneeze. If the foot of a sleeping person is tickled, he will kick; if a fly settles on his face, he will brush it off. Sometimes a person in an unconscious condition will drink a cup of water if it is placed to the lips.

545. If the back is broken, reflex actions persist although all sensation and volition concerning the parts below the injury are suspended. The leg will kick when the foot is tickled, etc. A surgeon tickled the foot of a man whose spinal cord was injured, and the feet kept up a vigorous kicking. He asked the man if he felt it; he said, "No, but you see that my feet do." On carefully testing the sensibility of such a man, a line can be traced girdling the body, dividing the sensitive from the insensitive part. The brain also may act seemingly in a reflex manner as in cases of somnambulism, or sleep-walking.

546. When one is learning **new movements**, such as walking, skating, writing, riding a bicycle, each movement is a voluntary one as far as the will is capable of watching so many muscles. The movements are, therefore, slow and awkward. After the movements have been made many hundreds of times, they becomes easy and graceful, and also less voluntary. Finally, one may learn to walk, cycle, or play the piano with the attention fixed on something else. Such movements are called "acquired reflexes." There is evidence to show that the axons become covered with a medullated coat, as each new pathway and tract is beaten through the nervous system by repeated experiences. Thus the structure, like the habit, becomes fixed.

547. Reflex Action and Education. — Education of reflex action consists mainly of the formation of habits. The impression on the nervous system from the training is made chiefly on the spinal centers. When the muscles of the hand are educated, it is really the spinal cells that are educated. During youth, one is always acquiring good habits or bad habits. The habit of an upright, easy walk, the habit of dropping into a stooping posture, of putting the hands in the pockets, of making wry faces, of mumbling and stammering, or of talking distinctly and without hesitation, may be acquired, and will probably remain through life, for impressions made on the nervous system in youth are lasting. The habit of eating temperately of pure food, the habit of stuffing, of awaking the nerves with stimulating condiments, of using alcoholic stimulants, of using tobacco, are easily acquired, but are lost with difficulty. Good habits are good friends; bad habits are enemies. It often requires years of constant effort to root out bad habits, but it is very easy to keep them out in the first place. Yet if the wish and will for a better habit is really strong, one need never despair, for on account of the large size and great activity of the brain, and its preponderance over the lower reflex centers, man is distinguished above all other animals by his power of forming new habits. If our ideals are high, we can go on forming better habits, and intrusting them to the keeping of the nerve centers, and thus make step after step toward our ideal. If our ideals are not high, or if they are mere theories and never affect our acts, we may never improve, but may even degenerate. The brain and the spinal cord with the nerves that branch from them form the *cerebro-spinal system.*

THE SYMPATHETIC, OR GANGLIONIC, SYSTEM

548. This System consists of numerous ganglia situated apart from the brain and spinal cord, and many gray nerve fibers which connect these ganglia with the spinal cord, with each other, and with the cells controlled through this system. (What is lacking in the gray fibers that is present in white fibers?) The sympathetic nervous system controls the functions of unconscious life, while the brain and spinal cord control the functions of conscious life.

549. The chief functions controlled through the sympathetic system are the peristalsis of the intestine, the growth of cells, and the contraction of the heart, arteries, and veins. The nerves that go to the arteries and veins are named the vasomotor nerves. The ganglia of the system vary in size from minute specks to the size of a grain of wheat, a pea, or a bean. There is a double row of the large ones that runs down in front of the backbone, all connected by nerves. The nerves of the system form several intricate networks, each called a *plexus* (Fig. 200). The largest and most important is the *solar plexus*, just behind the stomach; its nerves supply the muscular walls of the abdominal organs. Another plexus is found in connection with the heart.

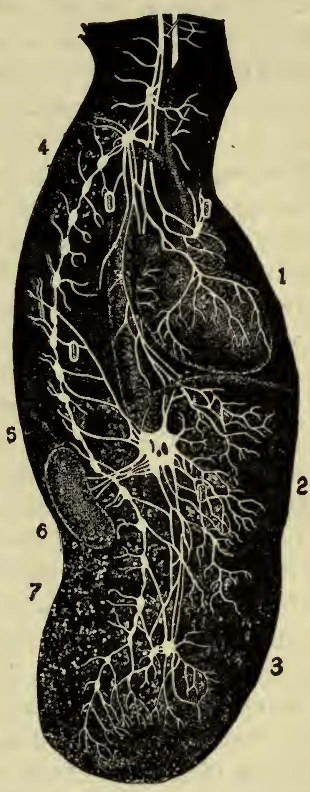


FIG. 200. — Diagram of Trunk showing One of the Two Rows of Sympathetic Ganglia near the Spinal Column and the Plexuses.

1, cardiac plexus; 2, solar plexus; 3, hypogastric plexus; 4, 5, 6, 7, row of ganglia near spinal column.

550. Sensory Nerves of the Sympathetic System. — The sensory impulses through these nerves are slow and faint, seldom reaching beyond the spinal ganglia to the brain. Thus the circulation of the blood and the digestion of the food usually go on without our consciousness, but a very strong irritation may give rise to consciousness and pain in the abdominal organs, as in colic or in vomiting. Sensory impulses, signifying the needs of the cells and the necessity for movement in the arteries and intestines, are being continually sent to the spinal ganglia. Only very strong impulses caused by disturbances that may injure the body, reach the brain, and cause pain.

551. Motor Sympathetic Nerves. — The motor nerves carry impulses which cause the epithelial cells of the glands to make their secretions, and the muscles of the arteries and intestines to contract. They do this as a reflex response to the impulses going to the spinal ganglia from the sensory nerves of the system. The pressure of food in the stomach excites the flow of the secretions. At a flash of bright light the eye winks and the pupil contracts. The sweat glands secrete under the influence of warmth. It was formerly believed by physiologists that the sympathetic ganglia themselves sent the reflex motor impulses, but it is now believed that these come from the spinal ganglia. The sympathetic ganglia are supposed to reënforce the current and aid in the nutrition of the nerves that pass through them.

552. The **Brain has Considerable Influence** over the sympathetic nerves, but in an indirect way. We cannot control the digestion or the heart beat by the will, yet the thoughts and emotions may powerfully affect them. The face blushes from dilatation of its blood vessels when one is embarrassed or self-conscious. It becomes pallid with fear. Sorrow depresses the activity of the cord, which in turn sends out fewer orders, so that the food is not digested and the cells are not nourished. Yet to guard against too great interference by the emotions and the mind, nature has arranged that impulses starting at the brain must pass through at least two sets of ganglia before they can affect nutrition and circulation. The examination of the food is carried on by the higher senses and the brain, for it is important that hard things and poisonous substances should not be swallowed. But the regulation of the flow of the saliva is left to the gray matter at the top of the spinal cord; the secretion of the saliva is a reflex act excited by the taste of the food, and does not enter into consciousness.

553. Strong influences are needed to **impair the action** of the sympathetic nerves and ganglia. Poisons which are swallowed or produced in the body by disease, may excite them to vigorous action and cause vomiting, or may injure them so that their impulses almost cease. Aside from this, about the only danger to which the system is exposed is a blow upon the abdomen or neck; such a blow is always dangerous. Death may then result through shock to the heart, or through paralysis of the vasomotor nerves, which causes the arteries to enlarge and hold so much blood that too little goes to the brain. "Fidgets" is caused by poisons from fermented food going to the sympathetic ganglia and irritating them. Backache in women is sometimes caused by the abdominal organs being prolapsed or pushed downward by the pressure of a tight corset, or pulled down by the weight of skirts supported by these organs. This causes the sympathetic nerves to be stretched at their attachment near the spine.

554. **Sympathy** in functional activity between the various vital organs is brought about through this system, and gives it its name. Derangement of the stomach may affect the heart. One organ seems to share in the illness when another is deranged. This is well, for when one organ is diseased, the others do not continue to act and impose work upon the ailing organ. A feeling of weakness, which rests the muscles, and a loss of appetite, which rests the digestive organs, accompany most forms of illness.

555. Thought Lesson. **Obedience to Natural Law.** —

1. What is the natural direction of growth of the big toe?

2. Think of six evil results, direct or indirect, which will follow the transgression of God's design in this simple matter.

3. Which part of the spinal column, designed in infinite wisdom to be most flexible, do some people try to make the most inflexible?

4. The mobility of the false and floating ribs was intended

as a blessing. Some people interpret the blessing as an opportunity to do what?

5. Name six articles which God has warned us are injurious by giving them bitter, burning, or nauseating tastes, yet which are used by man.

6. Name six feelings which are intended as warnings for our guidance, but which are commonly disregarded.

THE BRAIN

556. The spinal cord can act only in response to impulses at the moment they are received. The brain can originate impulses which are not in direct response to a stimulus from the outer world. Its acts are apparently spontaneous, but they probably result from the combination of impulses previously received, which *memory* has enabled it to store up and retain. The brain not only causes action and directs the cord in giving order to voluntary movements, but it can restrain excessive action in the spinal cord. Self-control comes largely through the power possessed by the brain of restraining the spinal cells from sending out reflex impulses when strong and sudden impulses are received from the outer world. This is called the *inhibitory power*. If a door slams, a person whose brain is not exerting good control jumps suddenly.

557. The Coverings of the Brain. — What facts did you learn about the skull, showing that it is well constructed for protecting the brain? The brain is covered by three membranes; the outer tough one lines the skull and the spinal canal. The next is thinner. There is a lymphlike fluid, called the *cerebro-spinal fluid*, within this membrane, so that the brain is surrounded by a kind of water bed. The third, and innermost covering, is hardly a membrane, for it is merely a thin network of fine blood vessels and connective tissue. It dips down into every depression and fold of the outer layer of gray cells of the brain, carrying its supply of blood. This layer is called the **cortex.** The folds are called **Convolutions** (see Plate VII).

558. The Weight of the Brain of the average man is forty-nine ounces (a little over three pounds), and of the average woman is forty-four ounces. The woman's brain is as large in proportion to the size of her body as man's brain. Man's brain is surpassed in weight by the brains of only two animals. A whale, measuring seventy feet long, has a brain weighing only five pounds, and an elephant's enormous body is controlled by a brain of about eight pounds. Birds' brains are heavier in proportion to their bodies than the brain of any other animal. The brain grows very rapidly till the fifth year, then very slowly; the growth after twenty is very slight. Cromwell's brain is said to have weighed almost eighty ounces. Other great men have had large brains, but some great minds have inhabited very small brains. Quality is as important as quantity. The brains of idiots are usually very small.

559. The Parts of the Brain are the cerebrum, cerebellum and cerebral ganglia. The cerebrum, or great brain, is highest in the skull, and covers all the other parts; man is the only animal of which this is true (Plate VI). Sense-perception, consciousness, reason, and the will are located in the cerebrum.

The cerebellum, or small brain, is at the base of the skull behind. If a pigeon has its cerebellum removed, it is restless and has wide-open eyes; it flutters, but cannot fly. If the cerebrum is removed, leaving the cerebellum, it is stupid, but flies if thrown into the air. By placing the hand at the back of the skull between the occiput and the neck, you will cover the part occupied by the cerebellum. Coördination of the muscles is believed to be carried out by the cerebellum. You will to walk through activity of the cerebrum; the control of the muscles while walking is the function of the cerebellum.

The cerebrum and cerebellum, like the spinal cord, are divided by deep clefts into hemispheres. The cerebral ganglia are in the lower central region of the cavity (see Plate VII).

560. The Medulla Oblongata. — This, the most important of the cerebral ganglia, is sometimes called the *spinal bulb.* It may be looked upon as the part of the spinal cord within the skull. It is just within the foramen magnum, and is intermediate in position and function between the brain and spinal cord. The spinal cord acts reflexly; the brain acts consciously. Conscious actions are those which are influenced by mental images or ideas. The medulla contains reflex centers and the centers of automatic action. This kind of action should not be confused with acquired reflexes, such as walking, to which the term automatic is sometimes applied. Automatic centers are those which are controlled by the condition of the blood. They are stimulated by an increase of carbon dioxid in the blood. The chief of these centers is the respiratory center of the medulla. If it is injured, death ensues by suffocation. It is sometimes called the vital knot, because, although the cerebellum or even the cerebrum may be injured or removed from the lower animals without causing death, the smallest injury to the respiratory center kills the animal immediately. In cases of hanging, it is injury to this center that causes death. Another very important center in the medulla, controlled by automatic action, that is, by the varying condition of the blood, is the center for vasomotor nerves, which regulate the size of the blood vessels. It was previously learned that the vasomotor fibers belong to the sympathetic system. There are also important reflex centers in the medulla, viz., the centers for the secretion of saliva, for swallowing, for vomiting.

561. How Automatic Centers work. — As the blood becomes deficient in oxygen and charged with carbon dioxid, the respiratory center is irritated and sends out impulses which cause deeper breathing. This improves the condition of the blood, and the respiration is quieter until the blood again loses oxygen; then stronger impulses are

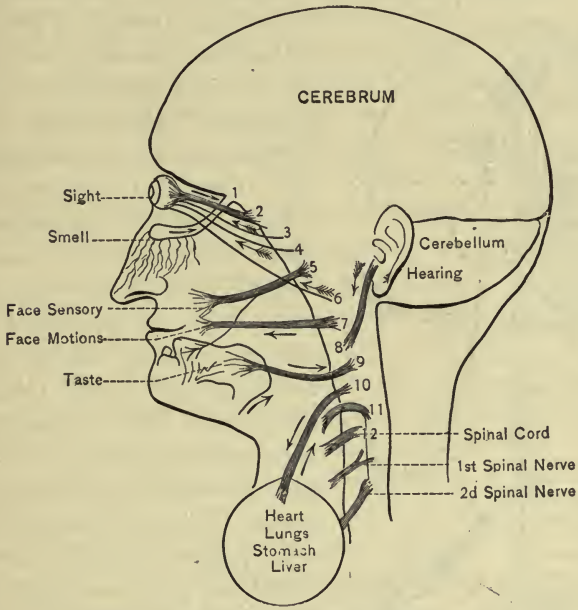


FIG. 201. — Diagram of the Twelve Cranial Nerves.

There are twelve pairs of cranial nerves which arise from the brain and go out through holes in the lower wall of the skull. (How many pairs of spinal nerves are there?) The cranial nerves are numbered, according to the location of their roots, from above downward.

sent, and so on, thus regulating the condition of the blood automatically. The size of the blood vessels is regulated in the same way by the vasomotor center in the medulla, increase of carbon dioxid causing contraction of the surface vessels, decrease of it causing relaxation. Automatic acts take place in series. Reflex acts, as for example, walking, can take place in series also, but the first stimulus in reflex acts comes from without the body; in automatic acts from the blood.

FUNCTIONS OF THE CEREBRUM

562. "There was once a man who, holding out a piece of his own skull, begged for money in the streets of Paris. The upper portion of the vault of his skull had been torn off by an accident, and his brain was protected only by the strong fibrous covering of the dura mater. The wound otherwise was healed, and the man strong and well. Now for a small sum the beggar would allow any one to press upon his brain, and when this was done he lost consciousness, and, as it were, fell into a deep sleep. But when the pressure was withdrawn, consciousness returned, and the man awoke. So soon as the blood was squeezed out of the cerebral hemispheres, these organs ceased to work and consciousness vanished" (Hill). If the blood vessels of the neck are compressed so as to cut off the oxygen from the brain, a person becomes unconscious. If the heart suddenly weakens its action very much, or if the vasomotor nerves allow the arteries to lose tone suddenly and increase their capacity for blood, the person faints, from a

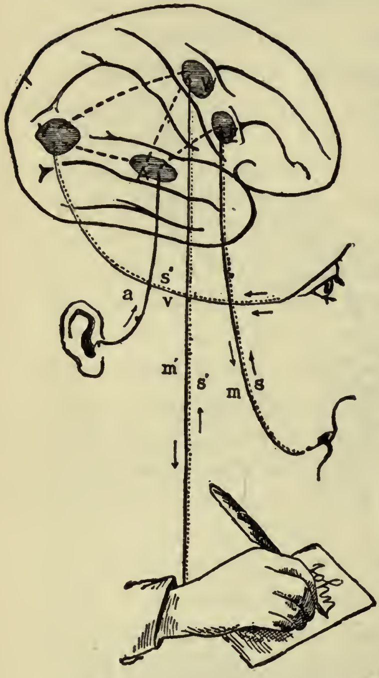


FIG. 202. — A Sketch to show how One Set of Nerves takes Messages *to* Certain Centers in the Brain, and how Another Set of Nerves carries Orders *from* these Brain Centers *to* the Mouth, the Hand, etc.

weakening of the circulation through the brain. Recovery is brought about by placing the head on a lower level than the body, so that the blood may run to the brain with less exertion on the part of the heart. A violent blow on the head may make one insensible at once. By breathing chloroform, ether, or carbon dioxid, by taking morphine, the quality of the blood may be so altered as to bring sleep. In order that the brain may act, it must be constantly aroused by impulses from the outer world. There is a case reported of a man all of whose sensory nerves had lost sensibility except in one eye and one ear. He fell asleep immediately if the remaining sense organs were closed. The conclusion to be drawn from the foregoing facts is, that a man loses consciousness so soon as his cerebral hemispheres cease to act; but his heart and lungs keep at work. It is curious that touching the cerebrum, or stimulating it with electricity, when it has been exposed by accident, arouses no sensation, although this organ is believed to be the seat of consciousness. This fact is of great interest, for it shows that impressions coming from the sense organs alone enter into consciousness.

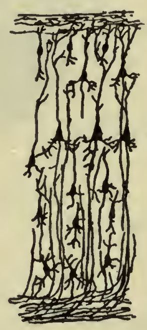


FIG. 203. — Microscopic Diagram of the Cells in the Cortex of the Great Brain.

A, external layer of association cells, axons, and dendrons; *B*, pyramidal cells which send off axons to enter the layer of medullated fibers *C*. The dendrons of the pyramidal cells pass into layer *A*.

563. Effect of removing Cerebrum. — After destruction of the cerebrum, an animal may continue to live if fed by hand. It can run about, and swallow food placed within its mouth. It will be disturbed by a loud sound, such as the blowing of a horn. It might avoid a bright flame if placed in its path, but would go stupidly against other objects; but it is idiotic, for all acts of intelligence cease. Its time is spent in sleep or mechanical wandering. A frog having its cerebrum re-

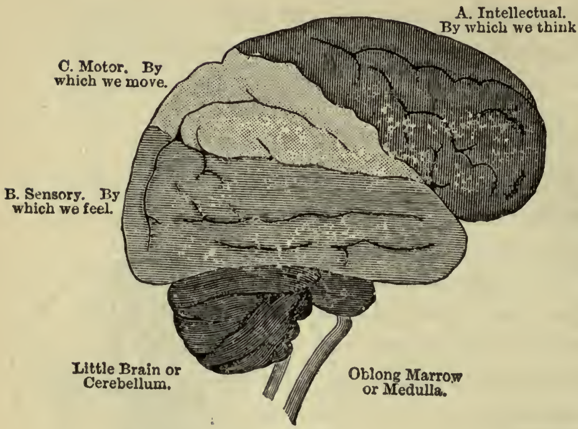


FIG. 204. — The Area *A* has not been as definitely located as the Areas *B* and *C*.

moved retains some more extensive powers than a warm-blooded animal. It starts to hopping when touched, avoids obstacles in its path, recovers its usual position when placed on its back, swims when thrown into water, and when placed on a board that is slowly tilted, it will preserve its balance by climbing to the top. These actions are reflex

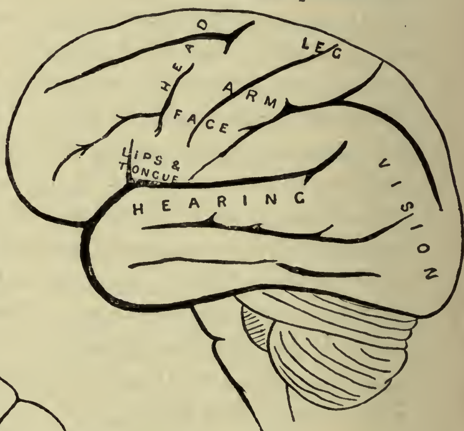


FIG. 205. — Motor and Sensory Centers. Most Centers occur in Both Hemispheres, and if One is injured, the Other will continue to work.

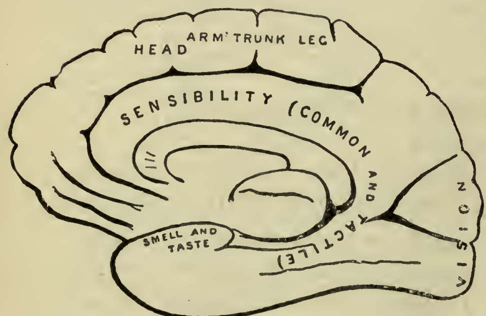


FIG. 206. — View of One Cerebral Hemisphere from between the Hemispheres, showing Motor and Sensory Centres.

but of a higher order than a simple reflex act. The reason the frog continues hopping after being touched is that each hop, owing to the contact of the skin with the ground, excites another hop; the animal never begins to move of its own accord.

564. Function of the Cerebellum. — The removal of the whole of the cerebellum from an animal does not produce death so long as the medulla is not injured, but the animal becomes weak and unsteady in its movements. If the cerebrum remains, the mental faculties are retained. Disease of the cerebellum in man produces dizziness and leads to a staggering, reeling gate. Hence it is believed that the function of the cerebellum is to aid the cerebrum in the control of the muscles. It brings about proper coördination of the muscular movements, so that in such movements as standing, walking, talking, the different muscles may each act at the right moment and with due force. The spinal cord also coördinates movements. For instance, if a frog is decapitated and left quiet for an hour or two, so that the spinal cord may recover from the shock due to the injury, it may be made to execute seemingly purposeful movements. If a drop of acid be placed on the flank of such a frog, the leg will be drawn up and the acid wiped off with the toes. But such coördinated movements are not accompanied by consciousness.

565. The Motor Area in the Brain (Figs. 204, 205, 206). — A wounded soldier was brought to the surgeons of the German army with part of his skull torn away. The surgeons used an electric current to test whether the nerves were paralyzed. They were astonished by finding that whenever the electric current was applied to the wounded part of the head, muscular movements were excited. It was soon determined that by stimulating electrically a certain area of the cerebral cortex movements on the opposite side of the body can be excited. This area lies under the parietal bone, and extends from the top of the brain to the level of the ear. By experiments on monkeys and dogs, and by studying cases of accidents to the skull in human beings, this area has been subdivided. Stimulation of the lowest part causes movements of the face; of the middle part, the arm; and of the upper part, the leg, the

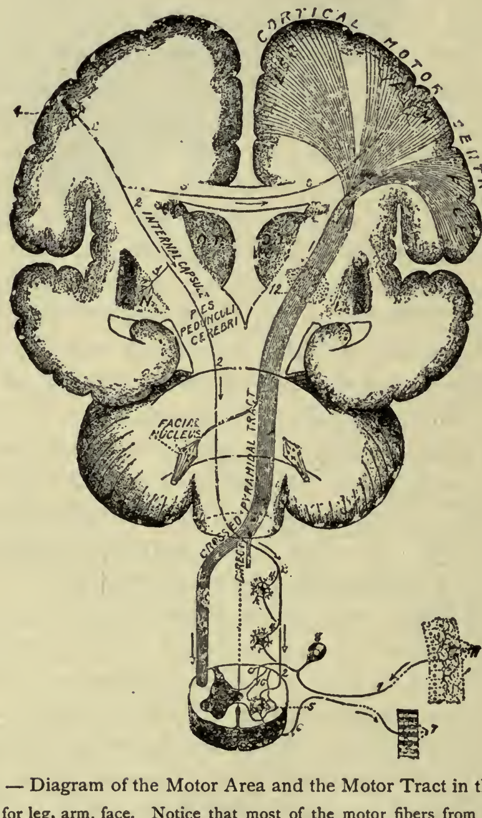


FIG. 207. — Diagram of the Motor Area and the Motor Tract in the Brain.

Find centers for leg, arm, face. Notice that most of the motor fibers from one hemisphere cross to the opposite side of the spinal cord; and if one half of the brain is injured the opposite half of the body loses motion and sensation (paralysis).
Trace nerve impulse from cell in cortex at 1 to muscle at 7.
Trace reflex impulse from skin at *n* to muscle at 7.

movement always being on the side opposite to the stimulation. When the lowest part of the area on the left side in right-handed persons is injured, the power of speech is lost. The comprehension of words and the ability to write, read, and hear language is not lost. With left-handed persons, this center is on the right side.

566. Other Centers in the Cerebrum (Figs. 205, 206). — When the part of the cerebrum that lies behind the ear is destroyed, a loss of the memory for the meaning of words may result. One can speak, but his words follow each other without sense or meaning. The sense of hearing is supposed to be located in the same region. The sense of sight is located in the rear part of the cerebrum. If the rear part of the left hemisphere is destroyed, a man is unable to see anything to the right of his nose when his eyes are directed straight forward. The sense of smell lies at the base of the cerebrum toward the front (Fig. 206).

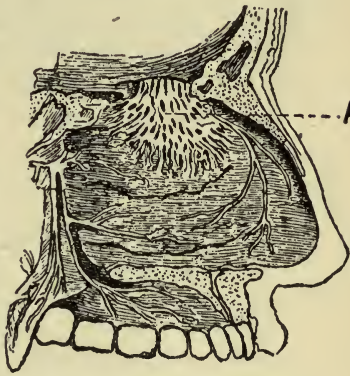


FIG. 208.— The Olfactory Nerve. The main nerve ends in the form of a bulb on the floor of the skull. The fibers branch from this bulb like the roots from an onion and spread out on the walls of the nasal chamber.

HYGIENE OF THE NERVOUS SYSTEM

567. Sleep. — The cells of the body with all their industry are not tireless, and at intervals require rest (Fig. 210). During sleep the heart beats more slowly, respiration is less rapid, the muscles in general are relaxed, the gland cells diminish their secretions, and digestion is slow. The production of heat is lessened and the body must be protected from cold. Yet consciousness is the only function entirely in abeyance. The sound of a passing vehicle quickens the pulse of the sleeper without awaking him; if he is touched, he moves. Sleep is deepest during the second hour, and it then takes a much louder sound to awaken him than during later hours. Sleep becomes gradually lighter until awakening occurs. When consciousness is partly awake, the condition is called dreaming. In somnambulism, the sleeper may talk or walk as he dreams.

568. For a sound nervous system, nothing is so indispensable as plenty of sound sleep. It is necessary for growth and repair of the cells (Fig. 210). Infants sleep almost all the time; children of four or five, nearly half the time; those of ten or twelve, ten hours; most college

FIG. 209.

A, auditory center; *B*, visual center; *C*, speech center; *D*, motor cells of speech nerves in the spinal bulb. Sight of dog, bark of dog, word "dog" and sensations from speech muscles are represented by arrows passing into the brain. The centers are connected by association fibers, so that when the child has learned the word "dog" by sound or when written, the spoken or written word calls up the image, the sound of its bark and the muscular memory of how to speak the word "dog."

students require eight hours, and this amount is required by most adults until old age is reached. Repair being less in old age, less sleep is required.

569. The morning should bring a feeling of vigor. If we wake tired and discouraged, there is something amiss. It may be that there was over-exertion the day before and the sleep has not been long enough, or that we have been up too late or have eaten improper things. If the last is the case, there is apt to be a bad taste in the mouth on awakening. By going to bed at the same hour every night, the habit is formed of dropping off promptly and soundly to sleep. A cheerful state of mind with resolute avoidance of worry promotes sound sleep at night. The sleeping room should be cool, but it is not necessary that water freeze in the pitcher. It should be well ventilated, a window being left partly open even in moderately cold weather in the northern states, and in very cold weather in the Gulf states, unless the room is loosely built.

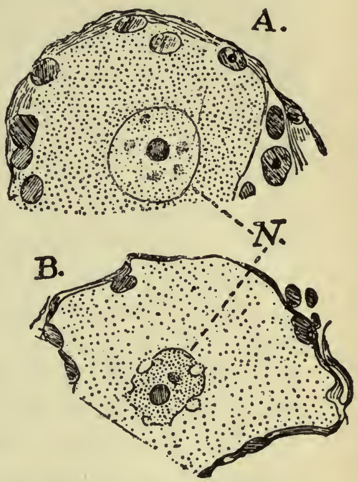


FIG. 210. — A Study of Fatigue.

Portions of nerve cells from the spinal ganglia. *A*, resting cell. *B*, cell from a ganglion that had been electrically eliminated for five hours. The shrinkage of the nucleus and structure of the fatigued cell is marked.

570. Effect of Activity of Nervous System. — If the cells of any tissues are not active, they become weakened. It is the same with the nervous system. Fresh and new sensations are necessary for the health of the brain; those mental faculties that are used become strong. Unused muscles become flabby and ill-nourished because the circulation in them is weakened; the circulation in inactive nervous tissue also becomes less active. Mental activity strengthens the nervous system and the body in general. If one protects his sensory nerves by too warm clothing and never lets the cold air strike them, they become weakened and unreliable and allow the blood vessels to lose tone. They are likely to do strange things with the circulation, causing colds and disease. If, because of pulpy or soft food, the nerves of the alimentary canal are not stimulated mechanically, peristalsis is weakened and the intestine becomes clogged. The loss of tone in the circulation and the sluggish peristalsis, with the troubles that follow, can often be cured by taking a cold bath every morning. The stimulus to the sensory nerves spreads reflexly to the vasomotor nerves and to the sympathetic fibers of the intestine; these are "toned up" and restore activity to the involuntary muscles.

571. Connection of Body with Brain and Mind. — The pulse rate is affected by every emotion. Shame causes the blood vessels of the face to dilate. Painful emotions excite the activity of the lachrymal or tear glands. Joy increases ease of movement. If an excited or angry man who is walking to and fro sits down, his excitement decreases. A starving man and one suffering from fever have hallucinations. The Romans had the proverb "a sound mind in a sound body." The care of the body for the mental effect as well as for the sake of the body itself, is only gradually regaining the high place it held among the Greeks and the Romans, a place which it lost during the Dark Ages. "Hysteria and nervous exhaustion are the fruits not of overwork, but of lack of varied and interesting employment. The absurd opinion that hard work is menial and low, leads to most pernicious consequences. The girl who, turning from brain work to manual labor, can cook, scrub, wash, and garden, invites the bloom of health to her cheeks; while the fine do-nothing lady loses her good looks, suffers from the blues, and is a nuisance to her friends and a misery to herself."

572. Two Kinds of Tired Feeling. — If a person works hard mentally or physically, the nutrition stored in his cells is consumed by the oxygen. Carbon dioxid, urea, and other products of oxidation, accumulate; this decreases the production of heat, smothers the vital fire, as it were, and stops the setting free of energy. The muscles may ache with fatigue or the brain grow drowsy; this is the natural and healthful kind of tired feeling. It leads to rest and recuperation. During the interval of rest, even if no new food is absorbed from the canal, digested food, already in the blood, and lymph are built up into living tissue again, a process called *assimilation*. But suppose one does not work, but is idle, or suppose one works with only a small part of his bodily organs and forces the other organs to loaf; the oxidation in the cells does not take place completely. Instead of urea, uric acid and other poisonous products of incomplete oxidation result. These poisons circulated by the blood to the nerves can give them a tired feeling as effectually as hard work. Often with inactive, idle persons the digestion also becomes sluggish, fermentation takes place and the food is changed to poisons. These additional poisons are absorbed by the blood and carried to the nerves to increase further the tired feeling. Some persons never work, yet are always tired and are said to have been "born tired." They belong to this second class. If they did some honest, vigorous work for a few days, it would lead them to breathe deeply and freely and burn up this refuse material. They would again have that self-confident, buoyant feeling that all men may have and that every man that takes care of his body does have.

573. The Source of Pain not always where it seems to be. — When the "funny bone" is hit, the tingling is referred to the finger, although, of course, the pain is in neither the funny bone nor the finger, but in the brain. If the scar grows too tight over the stump of an amputated arm, the itching that seems to be in the fingers may not stop until the scar is opened by a new cut, and the tightness, which is the source of the pain, is removed. Some forms of neuralgic pains and headaches appear to travel quickly from one part of the face to another. This is because the source of the trouble is not in the face at all, but in the medulla. Bad headaches are not so often neuralgic as from other causes (Fig. 211). When the spine is habitually held crooked, or, in rare cases, some of the vertebræ are displaced by a fall or jar, the circulation may be interfered with near the roots of the spinal nerves, and give the feeling of pain in various places in the body where the nerves terminate; for "pain is the cry of a starved nerve for fresh blood or better blood." The reason the mind always refers the pain to the *end of the nerve* is that nearly all pain from a nerve does come from some irritation at the end of the nerve, and the mind reflexly, as it were, interprets the pain as coming from its usual source. When the position is corrected, the circulation is freed and relieves the nervous system. Downward displacement of the abdominal organs may cause pressure upon some of the sympathetic nerves and ganglia and cause pain and derangement of different organs. What causes the foot to "go to sleep"? Can you explain the self-deception in "Aristotle's experiment" (Fig. 212)?

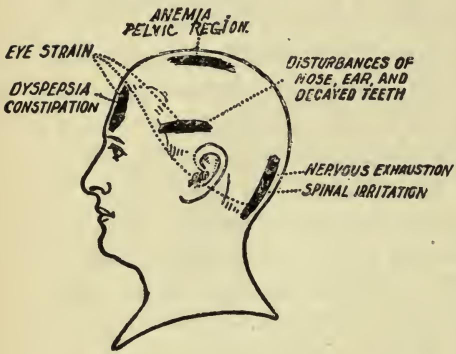


FIG. 211.—The Situations of Headaches with Relation to their Causes.

Neuralgic headaches (not marked) are believed to arise from congestion in the nerve centers.

574. Effects of Alcohol on the Nervous System. — As alcohol acts on many organs through its action on the nervous system, it would naturally be supposed that the nervous matter itself would be injured, and such is the case. In fact, it is upon the delicate nervous system that its most destructive effects are wrought. One of the first effects of alcohol is a flushing of the face and a feeling of warmth on the surface of the body. This

FIG. 212. — Aristotle's Experiment.

is due to the quickened action of the heart and the dilatation of the small blood vessels from the effects of alcohol on the nerve centers controlling these organs. The mind is at first more active, because the little vessels of the brain are dilated and blood is sent more freely to that part. A little later the alcohol begins to disturb the reflex and coördinating powers of the nervous system, and ordinary muscular movements are performed imperfectly and with difficulty. The nerve centers seem to be attacked and paralyzed progressively by alcohol, beginning with the highest and proceeding toward the lowest. The will power and judgment first become paralyzed, and only the emotional and impulsive instincts of human nature are left; these, being no longer under control of the higher faculties of reason and judgment, are likely to cause the individual to act in an irrational manner. In the last stages, consciousness and volition are lost, and only that part of the nervous system in the medulla which governs circulation and respiration remains active. In other words, the man is "dead drunk." A large quantity of alcohol may produce death by paralyzing even these nerve centers, thus stopping all organic functions. This overaction and irregular action of the nerves, when repeatedly occurring, has the effect finally of deforming or destroying the nerve tissues (Fig. 191).

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

576. Subjects for Compositions. — Prevention better than Cure. Habits. Sunshine. Natural Cures and Medicines. The Influence of the Digestive Organs upon the Other Organs. The Influence of the Muscles upon the Other Organs. The Influence of the Blood upon the Body. The Influence of the Nervous System upon the Other Organs. Heredity. The Causes of Disease. The Rewards of Right Living. The Influence of the Body upon the Mind. The Body a Temple. Housekeeping. The Way of the Transgressor is Hard. Nature as a Physician. Health and the Disposition. The Mind and Health. Wonders of the Body. Mysteries of the Body. What Fools these Mortals Be. Health Fads. Medicine Crazes. Exposure and Coddling. Pampering and Hardening. The Blessings of Temperance. Effects of Use. Effects of Disuse. Why are we Sick? Adam's Apothecary Shop.

577. Phrenology. — There is a fantastic theory called phrenology that young people should learn to estimate correctly. It is based on dividing the head by guesswork into sections supposed to be the seats of the various attributes of the mind, such as firmness, benevolence, self-esteem, acquisitiveness, and what not. This attempt at science was made over a century ago, and it has been known for a hundred years to be nonsense. But it is turned to financial profit by charlatans, who take advantage of the unlearned seeking a short cut to science. Bumps on the head, instead of indicating the presence in the brain of more gray matter, are due in many places to thickening of the bone, or to air spaces in the bone. Phrenology belongs in the realm of exploded sciences along with astrology, or reading one's future in the stars; palmistry, or telling the fortune by reading the lines in the hand; and alchemy, or the search for the philosopher's stone, which was to turn everything it touched into gold.

578. Hypnotism, etc. — Even when awake our actions are largely controlled by the suggestions or influence of others. Although we are awake, this influence is largely unconscious. But if one goes to sleep at the suggestion of another and while hearing his voice and believing in his power to influence, the subjection to that influence continues during the sleep which follows. This sleep seems to be a kind of induced somnambulism. That there is no animal magnetism concerned is shown by the fact that the most delicate electrical instruments fail to show the faintest disturbance. Frequent repetition of the hypnotic condition is believed by some to weaken the will of the individual. The nature of the hypnotic condition is not fully settled. Like other subjects on which science is unable to pronounce a definite verdict, this whole subject has been surrounded by rogues with humbuggery and quackery. Some persons by practice can read the intended movements of another by grasping the hand of the other with his arm held in an unstable position. This muscle-reading is based upon the fact that when the mind is concentrated on making a certain movement, the muscles will resist an opposite movement. Again, the mystery of ordinary sleep has never been solved. It is not surprising that its variations, such as trances, somnambulism, and the hypnotic sleep, are not understood. The relation of mind and matter, the connection of the soul and body, are mysteries that may be beyond the power of man ever to solve.

APPLIED PHYSIOLOGY

EXERCISE I

1. Why is **playing the organ** less trying to the nerves of the player than playing the **piano?**

2. Why is it best to change from very absorbing work to work of less interest a while before retiring ?

3. Why is the **power of habit** a blessing? A danger?

4. How does **travel** often **cure** a sick person when all else fails?

5. Why should we never study immediately after eating?

6. Why is **working** more healthful than " taking exercise "?

7. Is it better for children to play or to **take exercise?**

8. What causes the **peristaltic action** of the stomach?

9. Is one more likely to sleep soundly who does his **brain work** in the forenoon and muscular work in the afternoon than if he reverses the order?

10. Why can one walk and carry on a conversation **at the same time?**

EXERCISE II

11. How does indigestion cause a headache?

12. Does perfectly comfortable clothing from head to foot contribute to one's **ease in company?**

13. Does uncomfortable clothing make one self-conscious?

14. Is it as important to have the shoes and the clothing perfectly comfortable when going out as when staying at home?

15. Would you get more rest by sleeping for four hours undisturbed, or by sleeping eight hours but being awakened every half hour by some noise and going immediately to sleep again (§ 567)?

16. When one sits with the leg under the body, why is it that the compression causes a tingling sensation or paralyzed feeling in the foot?

17. When one's finger is cut, where is the pain?

18. Why does a hand still seem to itch after it is amputated?

19. Does the act of assuming artificial positions like the "straight-front" tend to make one stiff or graceful, self-conscious or spontaneous?

20. Do the girl who frets over washing the dishes, working with an unwilling mind, and the boy who, while he is sawing wood, is wishing to go to a baseball game, do their work with more or less fatigue than if they worked cheerfully and willingly? Why?

EXERCISE III

21. How is a **sneeze** a protective act?

22. Why may a dyspeptic digest a large Thanksgiving or **Christmas dinner** when he often has trouble with an ordinary dinner?

23. Why is it more **difficult for an adult** to learn to speak a language than for a child? Why do adults find drawing and languages more difficult to acquire than history and mathematics (§ 546)?

24. In what **two ways** may opening a window when a student is becoming dull and drowsy at his books enable him to wake up and study with ease?

25. What is the basis of the saying among mothers that a "croupy" child can be cured of the tendency by being allowed to **go barefoot** a great deal?

26. Did you ever know any person to whom the terms "afflicted by the **disease of work**" applied? Also the opposite, "disease of idleness"?

27. Muscles may be classed as minor, such as those of the eye, voice, hand; and major, such as those of upper arm, leg, trunk. Why is the use of the **minor muscles** exhausting to the nerves, while the use of the **major muscles** strengthens the nerves (§§ 227, 234)?

28. What **kind of cells shrivel** like a baked apple when they become fatigued (Fig. 210)?

29. A nerve or nerve fiber **does not become tired** or fatigued in any way. What do we mean when we say the nerves are worn out (Fig. 210)?

30. Why do you throw cold water upon a fainting person?

31. Nightmares are caused by poor circulation of the blood about the solar plexus, which is just behind the stomach. Explain how sleeping on the back may bring them on. How eating a heavy supper may cause them.

32. What is the effect of a thin skin and of a thick skin upon the disposition of a person ?

33. Why may cold feet cause sleeplessness?

34. Why does constant moderate drinking undermine the health more than occasional intoxication?

35. The vasomotor nerves control the size of the blood vessels. Which nerve centers control these nerves? Why does a draught blowing on the back of the neck often cause a cold (Fig. 200) ?

CHAPTER XVII

SOME SPECIAL REGULATIVE PROCESSES

REGULATION OF TEMPERATURE

579. Necessity for Regulation. — Man lives in the torrid zone and in the frigid zone, yet his temperature remains the same as he goes from one zone to another, and as summer changes to winter. The temperature of the healthy body is about 98.6° F. This is unmistakable evidence that some means of maintaining a uniform temperature exists in his body. The wonderful ease with which the human body maintains a normal temperature when exposed to extremes of heat and cold is a fascinating and instructive subject for study; but it remains partly a mystery, and the mechanism by which this end is attained has never been fully explained.

580. The Highest Temperature which living tissue may reach without destroying life is 113° F., but it could remain at such a temperature only a short time.[1] "A man can for a short time remain in an oven heated to the boiling point of water (212° F.), provided the air is dry. With felt slippers on his feet he could stand there while his dinner cooked beside him. He is able to do this owing to the profuse perspiration which pours from his skin and cools his body by evaporation. If the oven were full of steam, the

[1] Once a man took the pulse of his daughter who was ill, and found it to be 120. He was greatly alarmed, and summoned several physicians. He had confused the pulse with the temperature. The pulse rate during vigorous exercise sometimes reaches 160 per minute.

man would be instantly killed, because evaporation of the sweat would be prevented" (Leonard Hill, M. D.). If the cells of either plant or animal life be subjected to a temperature of 114° or over, the life of the protoplasm is destroyed beyond recovery.

581. Breathing and the Temperature. — Since oxygen is the supporter of combustion and carbon dioxid retards combustion, the quantity of oxygen and carbon dioxid in the body affects the temperature. When the body is at an abnormally high temperature, as during a fever, the breathing is generally more vigorous than usual. Those animals, such as the bat, that hibernate and go without food in cold weather, cease breathing altogether during the trancelike condition, and their temperature sinks nearly to freezing point. The absence of the oxygen, other than what may diffuse through the windpipe into the motionless lungs or through the skin, and the accumulation of carbon dioxid, cause the fire of life to sink very low.

582. The Source of Animal Heat is the combustion of the food in the body by the oxygen. Wherever cell activity is taking place, heat is produced. The muscles are the greatest heat producers of all the organs. Their activity gives rise to one half the heat of the body. A frog's body keeps at the temperature of the surrounding objects in winter and summer. He cannot stand the heat of summer and retires to a cool ditch or well. In winter he buries himself to escape the cold. He is stimulated by warmth and benumbed by cold. Man and other warm-blooded animals, on the contrary, are stimulated by cold and are less active during warm weather. The temperature of birds is 104°. A chick before hatching is like a cold-blooded animal. As soon as it begins to peck its way out of the shell, it begins to acquire the power of regulating its temperature ; the power may be acquired in a few minutes. This new power comes from the new muscular activity of the chick, the beginning of the habit of breathing, and the drying of its downy feathers.

583. The Loss of Heat occurs by conduction through the skin, also by the evaporation of water from the skin and lungs, and by the taking in of cool food, drink, and air.

584. How the Nerves regulate the Heat. — The temperature of the body is raised by increasing the heat production, or by diminishing the loss of heat. The temperature is lowered by the opposite processes. There are believed to be three classes of nerve centers to regulate the processes. One class of centers in the brain when stimulated by cold causes the heat production to increase; another class when stimulated, causes heat production to diminish. The third center is in the spinal cord and is automatic, but may be influenced by the centers in the brain. We should be in danger of being killed by the cold long before the thermometer reached the freezing-point, if it were not true that cold, in whatever form it may be applied, starts impulses in the skin which excite the tissues that generate heat, so that there is increased production of heat.

585. The Distributor of Heat generated by the active organs, to the resting organs, is the blood. The blood also causes heat to leave the body, giving it off while passing through the blood vessels of the skin.

586. How does perspiration cool the body? Why is it an advantage for you to shiver and for your teeth to chatter when you are very cold? Why is it an advantage for the skin to turn pale when one goes out into a cold wind? What effect upon perspiration does the blanching of the skin have? What effect does the blanching have upon the loss of the heat of the body from the contact with the cold air?

587. Clothing conserves the heat of the body, but cannot generate it. Such heat arises from the combustion in the system of the food by the oxygen of the air. In hot weather the body naturally requires less heat than in colder seasons; hence less food, especially fats and sugars, are consumed in summer than in winter, in the tropics than in temperate or frigid regions. Suppose you have changed your clothing in summer to the very coolest, and are still oppressed by the heat, what changes should you make in your diet? Suitable food eaten in moderation adds greatly to one's comfort in warm weather, and enables one to work with energy and pleasure, but partaking abundantly of heating foods renders all exertion disagreeable.

REGULATION OF THE STORE OF ENERGY

588. Fatigue. — You learned in the chapter on stimulants and narcotics that a man has energy stored up sufficient to support him for a certain number of days without food. (How many days?) Stored energy is simply a store of food and oxygen in the tissues. The nervous system so acts as to prevent any undue exhaustion of that supply from taking place. When the brain is long active, fatigue and sleepiness ensue. When the muscles are long active, fatigue and aching ensue. The wise person rests in each case. These warnings come before the exhaustion has progressed to an injurious degree. They are caused by the accumulation of the products of combustion in the tissues. These products affect the nerves and the warning is thus given.

589. In what other way besides by work may poisons accumulate so as to cause a feeling of exhaustion and lack of energy? What are the two kinds of tired feeling of which you learned? Has a person any more right to injure his own body or allow diseased conditions to come to it than he has to injure the body of another?

590. Improvidence. — Just as there are many persons who cannot keep financial capital ahead sufficient for one month's needs, so there are many people who cannot keep physical capital in their bodies sufficient for forty days ahead. This is the amount that every sound person should have. They expend their energy until they are "worn out" temporarily, or they neglect proper care of their bodies so that the mechanism does not work properly, their energy is diminished, and they become depressed. When one is depressed and exhausted from overwork or improper working of the physical organism, his first care should be to restore the strength. Rest will often accomplish it, but many persons are not wise enough to observe this; they have a mistaken notion of the nature of stimulants and of the bodily strength. They arouse the nerves to renewed action by taking poisons; activity ensues that leads to expenditure of a part of the precious strength remaining. A drunkard during a period of intoxication often keeps up this course until his strength is exhausted. He is physically bankrupt; then he stops. After a few weeks or months of soberness, during which the organs have stored up energy again, he begins to apply poisonous stimulants to enable him to use up this strength and becomes physically bankrupt again, thus proving himself unworthy to have as much capital intrusted to him as is intrusted to other men.

591. Are Feelings always a Reliable Guide? — Feelings may be deceptive, not only when the nerves are confused by stimulants, but also as the result of bad habits. A man who has stooped over a book or desk all day does not feel like doing muscular work, yet it is the very thing he needs to expand those flattened lungs that brought the feeling of fatigue. If one habitually overeats, it may cause a gnawing at the stomach that gives him a desire to continue the habit. After using alcohol or tobacco, a desire for these worst enemies of the body is implanted. The body seems to acquire injurious habits and desires *almost* as readily as healthy ones. The warnings against destructive acts come *at first*. If the warnings are disregarded, natural instincts, those heaven-sent guardians of our welfare, withdraw, and evil habits and desires assume control.

592. Natural and Artificial. — Everything in the world is natural. We and our most artificial acts are a part of nature. That which comes by nature apart from man, or that which he does truthfully copying nature, is usually called natural. That which is done by man in such a way as to disregard the usual processes of the rest of the natural world, is called artificial. Artificiality is usually marked by ugliness and weakness, but it is not recognized as such by any one whose taste has become depraved from following artificial customs.

DISEASE

593. Use of Pain and Disease. — Most diseases have for their purpose to repair, to protect, or to purify. If the body can set to work to repair a cut in the flesh or a broken bone, how much more easily can it purify unsound organs or tissues and make them sound again. It used to be the custom to apply liniments and healing ointments to wounds and broken bones to assist in the healing, but now it is found that to set the bone and bind the edges of the wound together is sufficient. If kept clean and undisturbed, nature will work a perfect cure.

594. Sometimes Poisons accumulate in the body and interfere with the working of the organs. This may be caused by drinking poisonous substances, or using them as food, or by indigestion, in which case germs may find sustenance and multiply, giving poisons into the circulation. The automatic regulative apparatus of the body is usually equal to the difficulty. These poisons are oxidizable, especially at a little higher temperature than that which the body usually has. So nature sets to work to create more heat in the body and literally to burn up the poisons. If the impurities are in one place, as in a joint or in the throat, there arises local heat, called **inflammation.** If the poisons are distributed in the body, a more general heat, called a fever, may begin.

Fever in itself is harmless and should not be combated unless very high and of long duration, under which conditions it may destroy the tissues. Fever is nature's method of ridding the body of poisons which, if allowed to accumulate indefinitely, may produce death or permanent weakness. One who has fever should avoid using strong remedies to lower the temperature, unless the fire that is burning up the rubbish threatens to destroy the house also. While a fever is in progress, nature takes away the appetite to prevent adding fuel to the flame; takes away the inclination to move, as the exercise would be carried on by combustion in the muscles; gives great thirst for cold water, which cools the body and dissolves the poisons, and adds to the activity of the kidneys in excreting the products of the combustion. In former days, when nature was entirely distrusted, a patient burning with fever was not allowed a drink of cold water, as it was supposed it would kill him. (Read notes 1 and 2, page 329.)

595. If a grain of sand gets into the eye, nature first causes pain to prevent winking the lid and injuring the eye, and then produces tears which tend to wash out the sand.

If a boy eats green apples, he has colic, which should teach him to wait next time until they are ripe. He has taken indigestible things into his stomach, and the stomach, acting for his welfare, under the direction of the nervous system, ejects the food. When a person habitually partakes of things which are irritating to the stomach and injurious to its delicate lining, nature creates mucus to lubricate or oil the lining, so that the mucous membrane may not suffer serious damage. In this way arises catarrh of the stomach, which is very disagreeable, but is a protective and curative process.

596. A man has painful **gout** in a joint; what is the matter? The man did not burn up by honest muscular work the food he ate, and it turned into poisonous acid, which collected in the loose spaces around the joint. The natural regulative power of the body forces that man to rest, by sending a pain every time he moves actively, in order to prevent damaging the joint by moving it too much while the inflammation is burning up the poison. If the man were allowed to exert himself actively, unconscious of the damage, the joint would soon be destroyed. (Read note 3, page 330.)

597. Indigestion is another trouble that is usually misunderstood. If one suffers from "biliousness," the liver is at once blamed, when usually the liver has nothing to do with it. You learned that the condition, as a rule, results from taking food into the stomach out of all proportion to the work its owner does; or, in warm spring weather, from eating enough to keep one warm in freezing weather. Then follows a combination of symptoms which, at a guess, is called biliousness, — loss of appetite, nausea, headache, loss of energy. The first symptom is sent because nature insists on giving the stomach a rest when it is incapable of digesting; the nausea may produce vomiting to expel the offending substance. The headache and loss of energy are to prevent exercise that would stir up the circulation and distribute the poisons throughout the body before the proper organs could dispose of them.

598. One who is suffering from nervous exhaustion, unable to do anything whatever, abhors the idea of working or attending to business; but the presence of this symptom is a protection. If the individual were not forced to rest, he might continue at his business and complete the exhaustion.

599. Symptoms and the Disease. — A distinction should be made between the symptoms and the disease. The symptoms are to warn the patient to allow the curative process to go on, and they should not be combated. If a log fell on a man and he yelled aloud, would it suffice to stuff a handkerchief into his mouth? No, the important thing would be to remove the log. If you have a headache, the quickest way to relief is to take antikamnia, or some of the other poisonous coal-tar compounds, or perhaps morphine. But if you do not wish to cause further injury to the body, drink plenty of water to cleanse the stomach, if the trouble is there, or go out and breathe fresh air and rest the mind, if the trouble is mental. If you had a corn on the toe, would you burn it off with salicylic acid only to have it come back, or would you wear comfortable shoes so that the corn would go away of itself? If the cause were not promptly removed, the corn might become so deeply rooted that it would be very slow to leave.

600. Remove the Cause of the disease, and the symptoms usually disappear of themselves. It is said that there are one thousand seven hundred diseases. There are hardly more than half a dozen ways of getting sick; errors in **diet** and **dress, poor ventilation, overwork, underwork, exposure, worry,** are the underlying **causes** of all diseases. The ways of getting well are likewise few. Correct the habits of eating and drinking, avoid poisons, work enough but not too much, breathe clean air, keep the body clean and free enough for perfect ease of movement, and keep the mind contented, — these are the first laws of healing. (Read notes 5 and 6, page 332.)

601. What common drug causes insalivation (uncontrollable flow of saliva for a time) with loss of most of the teeth, and weakness for life? Do these evil effects occur more often when the drug is prescribed by a physician, than by one of the self-appointed home doctors that recklessly tinker with the health of family and friends? What common drug causes defective hearing and deafness? Whether the trouble is located in the heart or the stomach, or the feet or the head, what organ must always bear the burden of taking the medicine into the system? How is dyspepsia caused by drugs? Which system first becomes diseased from frequent use of stimulant or narcotic drugs? Is it easier to prevent sickness by hygiene than to cure it? Did you ever know of any one who took better care of his horse than he did of himself? If Dr. Tanner had worked hard during his fast, what would have been the result?

NOTES

1. **Treatment for a Cold.** — Rest; sleep; a light diet of toasted bread, and fruits. This may be followed by a hot mustard foot-bath, the patient drinking, meanwhile, several glasses of hot water to start a free perspiration and open the pores of the body. Thus impurities are gotten rid of and the circulation of the blood is restored. After the feet have been soaked in hot water for ten or fifteen minutes, immerse them for a second in cold water and dry with a rough towel The patient should go immediately to bed. It is well to provide a rubber bag of hot water or a hot brick for the feet.

2. **Approach of a Cold.** — On the threatened approach of a cold, the nose should be kept clear at all hazards, by frequently blowing it in such a way as to cause as little irritation as possible, and by keeping the mouth tightly closed, drawing every breath through the nose. This treatment often averts the cold, provided chilling or overheating of the body is avoided for a time, the body being naturally more susceptible to draughts or to any kind of exposure, than it is at other times. The coming of a cold is often made known by a slight hoarseness. There may yet be time promptly to moderate the diet, or cease the exposure, or change the bad habit, which is bringing on the cold. Omitting a meal may do good now when it would accomplish little if tried later. Why are colds caused more quickly by draughts on a part of the person than by draughts that blow on the whole body? Question for discussion: Should the vital

organs or the limbs be the more warmly clothed if there is any difference between the protection given them? Suggestions: Distance from heart, delicacy, natural activity of circulation, effect of exercise. (Read note 7, page 332.)

3. **Chronic Rheumatism.** — Wherever it is located, the general treatment should be about the same. You must improve the general health. You must use the muscles of the entire body, moderately, daily, particularly those in or near the part affected. If you can move a finger, a wrist, an elbow, or any joint affected, in the least without pain, do so, and continue to do so several times daily. You can in due time make the affected parts move more and more freely. You must practically live out of doors, breathing fresh air freely and constantly. Your food must be plain, very moderate in quantity, and thoroughly chewed. These are important.

Too much food, and improper kinds, particularly meats, and lack of exercise, beyond question, are the chief causes of the condition of the body that allows rheumatism to gain a foothold. Exposure to dampness, sitting on the ground, getting chilled when heated from exercise, — these may be the immediate inciting causes, and they should always be avoided, but there is an unhealthful condition of the body back of them. To cure, remove this unnatural condition. Unless the trouble has gone too far, and the joints have become solid, nature will remedy the trouble if she has a fair chance. Bathing and brushing and rubbing the skin are important, as they help more impurities to work out through that channel. And do not forget to drink freely, all you have the slightest desire for, of pure, soft water. In most cases it requires years of improper living to cause the condition that makes rheumatism possible. It takes months and perhaps years of care and persistent effort to get entirely rid of it. Most of those who have suffered with chronic rheumatism have no faith in the power of medicine to effect a permanent cure. Nature must do it, and you must help by giving her every chance.

The great trouble in effecting a cure of this disease is the long and persistent effort necessary. Many will not stick to it long enough. But perseverance with the treatment described will bring the desired result and it is the only way in which a lasting cure can be made. Medicines may relieve at times, but there is something wrong in the way of living that causes rheumatism, and until that is changed there can be no permanent cure.

4. **Water-drinking.** — "The body of man is about four fifths water. The teeth, the hardest and densest tissue in the body, contain ten per cent of water; the bones are thirteen per cent water, the muscles are

three quarters water, and the blood four fifths. Gastric juice is ninety-seven per cent, sweat is ninety-eight per cent, and saliva is ninety-nine per cent water.

All the vital processes are carried on more or less through the agency of water. Without food a man can exist for sixty days, as has been demonstrated by experience. But six or eight days without water in some form means a horrible death. As one authority expresses it: "Water is a very important food element, as all physiologic changes take place in a watery solution. Water is the medium through which the body is nourished."

It must always be remembered that the water excreted from the body is heavily laden with various poisonous matters. For instance, the sweat contains about one half of one per cent of urea, besides certain lactates, sudorates, and inorganic salts. The kidney secretion contains nearly, two per cent of urea, also uric acid, creatin, creatinin, xanthin, leucin, cystin, taurin, besides many other poisons.

Few people drink enough water. Nine out of ten people who suffer from chronic constipation, "biliousness," habitual headache, kidney disorders, etc., are, in reality, merely in need of more fluid, with which the impurities formed in their bodies may be washed away. One week of free water-drinking will "cure" many of these cases.

Water is the best "cathartic" — the only safe cathartic — known. The cathartics usually given act by causing an irritation in the intestinal tube, as a result of which a large amount of water is drawn from the rest of the body to the intestine. But the general system suffers for the fluid thus drained off, and the after effect is to leave the intestine in a worse condition than in the beginning. Only by another dose can the fluid be drawn back into the intestine, and then the reaction and resulting constipation are more marked than before. So with repetitions the matter becomes worse and worse. As all practical physicians know, the most intractable cases of constipation are those resulting from the habit of taking cathartic drugs.

In disorders of the kidneys, water-drinking is quite the most important feature of the treatment. The kidneys are mainly filters, their function being mainly to separate and rid the body of a certain portion of water laden with impurities. The more pure water taken into the system, up to a certain point, the less work there is for the kidneys. There need be no fear of overtaxing the kidneys by free drinking of pure water. When, however, one drinks large quantities of any other fluid, such as wine or beer, the work of the kidneys is enormously increased. In fact, it is safe to say that kidney disease always follows the excessive use of beer.

For one unaccustomed to free water-drinking it is not always easy to contract the habit. Some application is necessary. The following is a good rule for general usage: On rising, two tumblers of cold water. Then allow half an hour's interval before breakfast. Two hours after breakfast, and until within a half hour of lunch or dinner, three tumblers of water. During the interval between two hours after the midday meal and one half hour before supper or dinner, three or four tumblers. During the time between two hours after dinner or supper until bed-time, two tumblers. This means ten tumblers, or about two quarts per day; and this is as little as any one can afford to take."

— Adapted from W. R. C. LATSON, M.D.

5. **Nature alone can cure.** — This is the highest law of practical medicine. . . . Nature creates and maintains; she must therefore be able to cure. — ROKITANSKY.

6. **Appetites given away.** — A lady once asked a physician where she could get an appetite. "Out in the fresh air," he said; "just go right out and get one. Nature has thousands of appetites to give away. The winter atmosphere is full of them. All that Nature asks is that you come after them yourself."

7. That modern clothing is ugly and inartistic, that it is destructive of ease, grace, and expressiveness, that it produces stiffness, rigidity, and awkwardness, there can be no doubt.

One of the most learned and famous physicians in Europe has stated that the principal cause of modern disease is clothing. **A cramped body means disease.** The body must be free from pressure. Continuous pressure anywhere means derangement of function. The worst feature of clothing is that it occasions pressure at certain critical points, namely, around the chest, about the waist, at the back of the neck, and about the limbs. The tightly-buttoned coat and the snug-fitting dress make natural breathing impossible. The ribs are drawn inward and downward, the breastbone is depressed, and the beautiful rotundity of the arched chest is lost—usually forever. The pressure upon the back of the neck from a shortened coat-collar causes the head to fall forward and affects the chest in the same manner.

The most injurious effect of the corset is that it depresses and contracts the chest, and thus not only impedes the action of the heart, lungs, and stomach, but causes a prolapse, or falling, of all the organs. Another injurious result of the corset-wearing is that it interferes with the action of the intestines (peristalsis) and with the blood circulation, thus producing constipation and various inflammatory conditions and displacements of abdominal and pelvic organs.

The pressure of a tight hatband is undoubtedly the principal cause of baldness among men. Women, who wear hats that sit lightly upon the head, are seldom bald. In men the pressure of the tight hatband cuts off the blood supplying the roots of the hair with nutriment, and thus causes the death of the hair. I have known obstinate chronic headache to disappear promptly upon the removal of a tight neck dressing. These high, tight neck dressings which have been so much the fashion recently have, in many cases, completely ruined the exquisite contour of the neck.

Another evil effect of modern clothing is that by its thickness, it interferes with the excreting and respiratory action of the skin. The work of excretion is thus either thrown upon other organs already overtaxed, or upon some tissue which the body selects as a possible medium for elimination. Thus it is likely that catarrh is always caused by the inactivity of the skin. The matter thus left in the body seeks egress by means of the mucous membrane, which is merely a kind of internal skin, and so we have catarrh. — Condensed from *Health Culture.*

CHAPTER XVIII

THE SPECIAL SENSES

602. In the special senses — sight, hearing, smell, taste, touch (including the temperature sense) — we refer the sensations to some external cause, but general sensations (fatigue, pain, hunger), as previously stated, are referred to our own bodies. You learned that the muscular sense is made up of special sensations of touch and general sensations from the muscles. Hence the much discussed question as to whether the muscular sense is a sixth special sense, is best answered by classing it with the general sense. The special sense of touch has been studied in a previous chapter.

603. The Sense of Taste (Fig. 165). — It was mentioned that the tip of the tongue has a very keen sense of touch. The tongue is a very muscular organ, and when we are eating, it helps to keep the food between the teeth; it also does the chief part of the work in the beginning of the process of swallowing. But perhaps its most important function is to afford a home for the nerves of taste. These nerves consist of a branch of the fifth pair of nerves, which are distributed over the front part of the tongue, and the ninth pair, which go to the back part of the tongue (Fig. 201). Although we often speak of food as being palatable, the sense of taste in the palate is very feebly developed.

604. What we call **flavors** affect us through the sense of smell. If the nose be closed with the hand, a piece of onion placed on the tongue does not have the "taste" of onion at first, nor at all, unless particles are wafted up and pass through the pharynx into the nose. An apple is, under the same conditions, as tasteless as an Irish potato. If the nose is held shut, ground coffee placed upon the tongue loses its flavor and is as tasteless as sand, if the tongue is wiped dry. The way to make these tests is to obtain the articles and have them given to you for tasting without knowing which you are getting; then find whether or not you can tell the difference.

Substances, in order to be tasted, must first be dissolved on the tongue. The tip of the tongue is most sensitive to sweets and salines, the back part to bitters, and the sides to acids.

605. The Sense of Smell (Fig. 208). — In quiet breathing most of the air passes along the lower parts of the nasal passages, just above the hard palate. Fibers of the olfactory nerve end mostly in the higher part of the nasal passages. When we wish to test an odor, we sniff, that is, we take a sudden inspiration by jerking the diaphragm down; a volume of air larger than usual rushing in, more of it passes over the parts of the walls in which the olfactory fibers are located. It is necessary that the substance producing the odor be in a very finely divided condition, probably gaseous.

606. Smell has its source in the beginnings of the respiratory passages, just as taste, is at the gateway of the alimentary canal; and just as taste by its influence on the salivary and gastric glands, greatly influences digestion, so the sense of smell greatly influences the respiratory acts. The breathing of a pleasant odor increases the depth of the breathing. Pleasant odors, as of flowers and of fresh country air and of the forest, contribute to our health and well-being. Why do foods lose flavor when one has a very bad cold in the nose?

Subject for Debate. *Resolved*, That Dr. Oliver Wendell Holmes's assertion is false, viz: If all the drugs in the world were dumped into the sea it would be a great deal better for mankind — and a great deal worse for the fishes.

607. Thought Lesson. **How the Body shows that God is Good. —**

1. Name six beneficent natural provisions for repair of accidental or unusual injuries to the body.

2. State six facts in anatomy showing provisions for protection.

3. State six similar facts in physiology.

4. Name four anatomical provisions for convenience in use.

5. Name four devices used in machinery, examples of which occur in the body.

6. Name three devices of architecture found in the body.

7. Why have the ears, eyes, nose, and mouth been assigned the positions relative to one another which they occupy in the head?

SIGHT

608. By the use of the senses thus far studied, we learn almost nothing of the external world except by actual contact. Sight and hearing tell us of objects at a distance. Without the eye the body is comparatively helpless.

609. The Orbit (Fig. 51). — The deep bony socket in which the eye rests is called the *orbit*. Its walls are formed by inward processes of the frontal, malar, and several other bones. There is an opening in the deepest part of the socket for the entrance of the optic and oculo-motor nerves, and the blood vessels that supply the eye; the deep portion of the orbit is partly occupied by a cushion of fat upon which the eyeball rests, and which yields to some extent when the eye is struck.

610. Oculo-motor Muscles (Fig. 213). — The eyeball is capable of being turned in all directions by means of six slender muscles which begin in the back part of the orbit. Four of them are straight. The one above turns the eye upward, the one below turns it downward, the one toward the nose turns it inward, and the one toward the temple turns it outward. The other two are oblique. The superior oblique muscle passes forward through a loop which serves as a pulley near the inner upper front part of the orbit (Fig. 213). It rotates the eye in one direction, and its antagonist, the inferior oblique muscle, rotates it in the opposite direction. "Cross eyes" are caused by too great contraction of the internal straight muscles, and "wall eyes" are caused by too great contraction of the external straight muscles. The defects may be remedied by a skillful surgeon, who cuts the proper muscle with a suitable instrument, and permits it in healing to become attached to another point farther back.

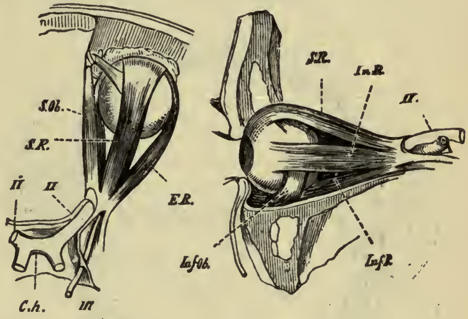


FIG. 213. — *A*, the Muscles of the Right Eyeball (viewed from above). *B*, the Muscles of the Left Eyeball (viewed from the outer side).

S.R, superior rectus; *Inf.R*, inferior rectus; *E.R*, external rectus; *S.Ob*, superior oblique; *Inf.Ob*, inferior oblique; *II*, the optic nerves; *ch*, their crossing or chiasma; *III*, the third cranial nerve.

611. A person is blind while the eyes are moving. Watch while some one in front of the class tries to move the eyes gradually and uniformly across the field of vision. Do the eyes move by jumps or steadily? The motions of the lids and eyeball give the expression of the eye. The eyeball itself has hardly more expression than a glass eye.

612. The Conjunctiva. — The eye is apparently set in a slit in the skin of the face, but this is not really the case. The skin of the eyelids turns inward over their edges and becomes a thin, transparent, and exceedingly sensitive mucous membrane, called the *conjunctiva*. It is, like other mucous membranes, composed of epithelial cells. The conjunctiva goes back under the lid and over half the eyeball itself to the other lid, so that the eye is really *behind the skin*. When the eye is directed very much to one side, the conjunctiva is sometimes seen lying in wrinkles. The veins which we think we see in the white wall of the eyeball when the eye is "blood-shot" are usually in the conjunctiva, which is so transparent that we do not easily see it unless its vessels are swollen.

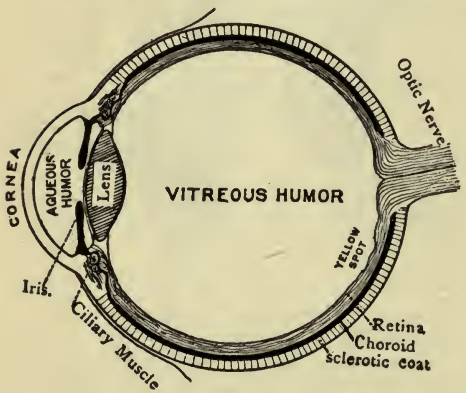


FIG. 214. — The Anatomy of the Eye.

613. The Eyeball (Fig. 214) is a globular chamber filled with transparent fluids. By studying Fig. 214 you will see that its wall is made of three layers, or coats. The **sclerotic** coat in the "white of the eye" is the tough white outer coat of connective tissue. It preserves the shape of the eye and serves for the attachment of the muscles. This coat is pierced in only one place, and that is for the entrance of the optic nerve. It is continuous over the front of the eye, where it becomes transparent, and is called the *cornea*. You can see the cornea bulging out in the front of a classmate's eye if you look at the eye from the side. The middle coat, the coat just within the sclerotic, is the *choroid*. It consists of pigment cells and blood vessels; its function is to absorb the superfluous light which may pass through the *retina*, or third and innermost coat. This light, if reflected to and fro within the ball, would confuse the vision. The continuation of the choroid's layer of pigment in front is the iris, which may be of various colors, and which, besides the pigment, contains muscular fibers. Unlike the sclerotic, the choroid is not continuous in front, for the iris is provided with an opening called the *pupil*. The *retina* is inside the choroid and lines the chamber. It is made by the distribution of the hundred thousand or more fibers of the optic nerve. Just behind the iris is the *crystalline lens* whose function is to bring the rays of light to a focus on the retina. It is in a transparent capsule from the edges of which muscular fibers radiate to the wall of the eyeball. The lens divides the chamber into two cavities. The small front cavity, between it and the cornea, is filled with the watery fluid called *aqueous humor*. The main cavity is filled with the jellylike *vitreous humor*. A ray of light in going from the outer world to the retina, passes through four parts of the eye. Name them. This does not count the pupil, which is simply a hole.

614. Use of the Lens. — Take a lens that is rounded outward (convex) on both sides, such as a hand magnifier, or even a strong lens from an old person's spectacles. Hold this up on the side of a room opposite to a window and catch the image of the window on a white card-board held back of the lens. This illustrates how the image of an external object is formed by the crystalline lens upon the retina. If some one stands up in the window, does he appear in the upper or lower part of the image? If he moves to the

FIG. 215. — Refraction of Light.

A coin in a basin of water. This illustrates the changing by a lens of the course of light rays.

right, in what direction does his image move? The reversals are explained by the crossing of the rays of light as they pass through the lens. If two lenses of different thickness be used, it will be found that the cardboard must be moved closer to catch the image from the thicker lens.

615. Accommodation (Fig. 216).—Hold a pencil or finger in line with some object, as a picture on the wall. When

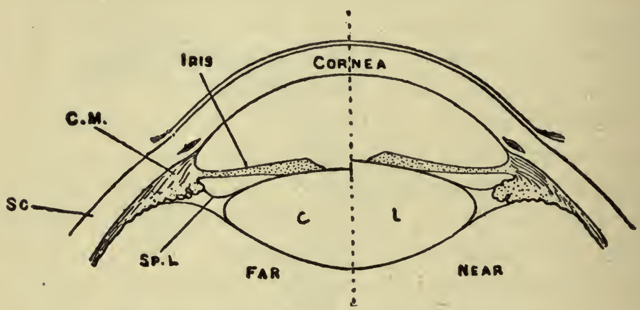


FIG. 216.—Diagram to illustrate Accommodation.

Sc, sclerotic; *C.M.*, ciliary muscle; *Sp. l*, suspensory ligament; *C l*, crystalline lens.

looking at the finger, the picture is blurred and *vice versa.* When looking up from a book that we are reading, to a distant object, we do not realize that any change in the eye is necessary; but the lens changes in shape, becoming more flattened for the more distant object, and becoming thicker again when a near object is looked at, thus always bringing the rays to a focus upon the retina at whatever distance the object may be. But the power fails at a point called the *near point*, about four inches from the eye for most persons, and the image becomes indistinct. The change in shape of the lens is

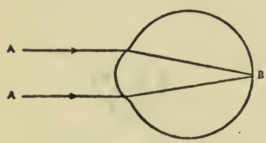


FIG. 217.

Normal Eye, in which Parallel Rays of Light (*A*, *A*) focus the Image on the Retina at *B*.

called *accommodation;* it is brought about by means of the muscular fibers around the lens. Straining of the muscles is required for looking at very near objects.

616. Defects of Vision. — In near-sighted eyes (Fig. 218) the eye is too long from front to back, and the rays come to a focus before reaching the retina. Among savage nations, where no books are used, almost every one has good sight, and nearsightedness is hardly known. Nearsightedness may be inherited or may begin with children at school. Some children seem to have a natural wish to get their eyes close to the book or writing. This is the very worst

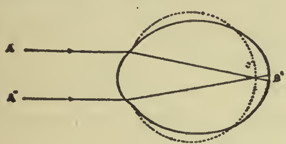


FIG. 218.

Myopic, or Nearsighted, Eye, in which Parallel Rays of Light (A'',A'') focus the Image in Front of the Retina at C', producing a Blurred Image on the Retina at B'', the Rays diverging from C'.

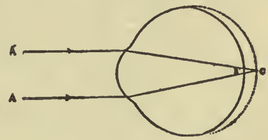


FIG. 219.

Hypermetropic, or Farsighted, Eye, in which Parallel Rays of Light (A', A') are focused behind the Retina at C, producing a Blurred Image at B'.

thing for nearsightedness. The head should be held erect in reading, to prevent the blood congesting in the eyes, and to prevent round shoulders and flat chest. The proper distance for reading is fourteen to eighteen inches. The farsightedness (Fig. 219) that occurs in youth is caused by the eyeball being too flat. In the farsightedness of old age the lens has also lost its elasticity, so that its shape cannot be sufficiently changed to bring the lights from near objects to a focus on the retina. In farsightedness, convex glasses are used, and in nearsightedness, concave glasses are used. Astigmatism is a defect caused by unequal curvature of the cornea in different directions (Fig. 220).

617. Regulation by Iris of Amount of Light admitted. — Look toward a bright window or the sky and note by means of a hand mirror the size of the pupil. Turn at right angles to the light, still looking in the mirror, and note the size of the pupils. What have you noticed about the eyes of a cat at night or in a darkened room? How do your own eyes feel when going from the dark into a lighted room? Can you see as well when you first go from a brightly lighted room into a dim lighted one, as after being in the dim light for a short time? The iris contains circular muscle fibers, which reduce the size of the pupil, and radiating fibers, which enlarge the pupil. The arrangement of pigment sometimes follows the line of the fibers. Have you ever noticed lines in the iris?

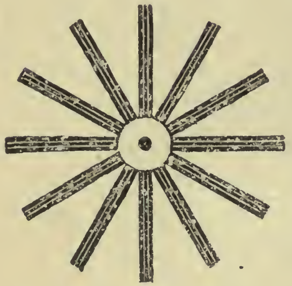


FIG. 220. — Test for Astigmatism. If this defect exists, the lines that run in a certain direction will appear brighter than the lines in other directions.

618. After-images. — Did you ever whirl a stick with a glowing coal on its end? What was noticed? Can you notice anything similar if you shake the hand up and down quickly before the face? If you gaze for a moment at a bright light, then quickly close the eyes, what is noticed after the eyes are closed? These effects are produced by the bleaching action of light upon the pigment of the retina, an effect which persists for a fraction of a second after the light is removed.

619. The Yellow Spot, or center for most distinct vision (especially for color), is near the middle of the back part of the retina (Fig. 214).

620. Blind Spot. — Light falling on the optic nerve itself does not give the sensation of light, but gives it only when falling upon the ends of the nerve fibers. Where the optic nerve enters the eyeball, there are none of these endings, and the light that falls there does not enable us to see anything. In the following experiment shut the right eye, and be careful not to let the eye waver:—

* Read this line slowly. Can you see the star all the time?

If not, change the distance to the book and read the line again. In the human eye the optic nerve enters not in the center, but at a point toward the other eye. Although the optic nerve along its course is not sensible to light, yet if it be cut, it does not give pain, but gives the sensation of a flash of light.

621. Thought Lesson. **The Eye.**—(In writing out this lesson, underline the words you supply.)

1. The eye is shielded from blows by bony projections of ——, ——, and ——.

2. The hairs of the eyebrows lie inclined toward —— in order to turn —— from the ——.

3. The eyelashes are to keep out —— and ——. I find by trying it that I [can or cannot] see the position of a window with my eyes closed.

4. The tears are to ——. We wink in order to carry the —— over the ——, also in order to —— and to ——.

5. The front of the eyeball looked at from the side is seen to be ——. It is called the cornea. The colored portion of the eye, the iris, is to —— the amount of ——.

6. The hole in the iris, occupied by the transparent aqueous humor is called the ——. It is for the purpose of ——.

7. It appears to be black because no —— is —— from the interior wall of the eye. I know that the iris is partly muscle, because it —— the size of the ——.

8. By holding my finger in line with writing on the blackboard, I find that I [can or cannot] see both finger and writing distinctly at one time. This is because in order to focus the —— upon the ——, the —— must change shape for every change in the distance of the object looked at.

622. Care of the Eyes. — *Sight is Priceless.* (When reading is mentioned in these suggestions, it is meant to include such work as writing, sewing, embroidering, etc.)

1. *The light* should be steady, not flickering; we should not read after sunset by the fading twilight; we should not read with the sunlight falling on the book; we should not read facing a window or with a light directly in front, unless the eyes are protected by a shade. The lamp should also be shaded. Incandescent electric lights give an uneven light, because of the shadow cast by the filament; a shade diffuses its light more evenly and protects from the glare. Light curtains diffuse the light evenly, but dark curtains cause lights and shadows.

2. *The state of the eyes* is of importance: We should not read when tired or sleepy; when convalescing from an illness; with the head bent down; or heated by the burner; when the eyes are sore; when they are tired, unless we rest them every few minutes by looking at far objects; when riding in jolting cars and carriages; when the circulation is impeded by tight clothing around the neck.

"Tobacco blindness" sometimes results from smoking. The first symptom is color blindness, which is followed by haziness of vision, and finally, by partial or complete loss of sight.

3. *The kind of work* is of importance: The type from which books are printed should be large. The paper should not be pure white or glazed, but a neutral tint; it should be opaque, so that the printing will not show through from the reverse page; the lines should not be more than four and a half inches long. Publishers of magazines are the worst offenders in using shiny glazed paper because it brings out the beauty of fine engravings.

623. The Tear Gland is located above the eyeball, between the ball and the bony arch on the side toward the temple. It is flattened and oval in shape, about three quarters of an inch in length. About ten small ducts lead from it and open on the under side of the upper lid. The secretion that it furnishes to the conjunctiva is formed continually. The tears pass across the eye and flow into two small ducts, the openings into which can be seen on the borders of each eyelid near the inner angle of the eye. They lead to a canal which empties into the nasal passage (Fig. 166). When one weeps, why is it necessary to blow the nose frequently? At the ordinary rate of supply, the tears do not overflow, as there is a waxy secretion along the edge of the eyelid that turns them toward the ducts. When have you noticed a waxy secretion in the corner of the eye?

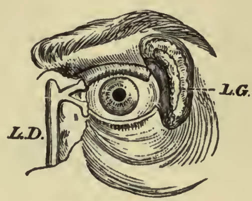


FIG. 221.

A Front View of the Left Eye, with the Eyelids partially dissected to show Lachrymal Gland, *L.G.*, and Lachrymal Duct, *L.D.*, to Nose.

624. The Need of Two Eyes. — We judge the distance of objects by the lines of convergence of the two eyes. A boy with one eye has difficulty in knowing when a ball thrown will reach his hand. When we look at a solid object, each eye sees a little more of the object on its side than does the other. Thus two eyes make it easier to distinguish solid bodies. By taking two photographs of a scene from slightly different points and arranging them so that the eyes look at the pictures separately at the same time, the idea of solidity is given. The stereoscope (Fig. 222) secures this arrangement.

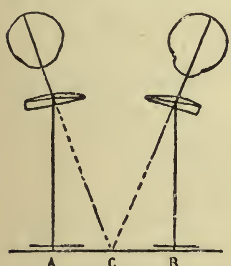


FIG. 222. — Diagram of a Stereoscope.

Two photographs, *A* and *B*, are seen combined at *C*. The rays of light from *A* and *B* are refracted by the prisms into the eyes so that they appear to come from *C*.

625. Coöperation of Eye and Touch. — The infant reaches for the moon. It is learning by reaching for things seen to judge of distance. By feeling of things seen it soon learns to tell round things from flat things by sight alone. The aid that touch gives to the sense of sight is illustrated by the case of a boy who had been blind from birth and received sight at the age of twelve years by means of a surgical operation. At first he could not distinguish a globe from a circular card until he had touched them. He had become acquainted with dogs and cats by feeling but did not know them apart by sight alone. One day he picked up the cat and recognized for the first time the connection between the new sense of sight and the old familiar one of touch. On putting the cat down he said, "So, puss, I shall know you next time."

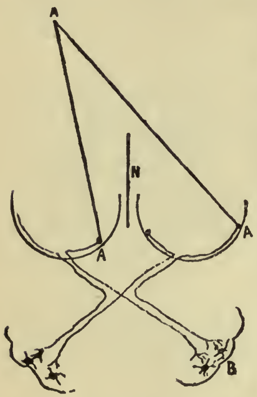


FIG. 223. — Diagram of the Course of the Retinal Nerve Fibers.

Light from *A* strikes the outer part of the right, and the inner part of the left, retina. The fibers from these parts go to the right half of the brain, *B*. *N* represents the nose. The spots *A* and *A* on the retinæ are habitually stimulated together.

HEARING

626. The ear may be described in three parts, the outer, middle, and inner ear (Fig. 224). The outer ear consists of the cartilaginous *concha*, the part that is usually spoken of as the "ear," and the *meatus*, the canal leading into the head from the lower part of the concha. Which part of the concha is not cartilaginous but fatty tissue? Part of the wall of the meatus is of cartilage, but the deeper part has a wall of bone. The entrance to the meatus is guarded by hairs, and its wall is covered with a bitter wax secreted by glands in the lining. Its inner end is closed by the tympanic membrane, which is sometimes called the *drum*, but it is only a drum skin. Three little bones stretch across the true drum, which is the middle ear, to a small film separating the middle ear from the internal ear. These three little bones are called the *hammer*, *anvil*, and *stirrup*. The middle ear communicates with the pharynx by a narrow tube called the *Eustachian tube*. This tube is for the purpose of admitting air to the middle ear, so as to equalize the air pressure on each side of the membrane and prevent straining it. Sometimes blowing the nose may press the air up into the middle ear and press the walls of the Eustachian tube together and close it. This causes slight deafness for the time. The pressure may be relieved by holding the nose closed and swallowing, thus opening the passage to the middle ear. One end of the hammer is attached to the inner surface of the drum skin; the other end is attached to the anvil; and one prong of the anvil is attached to the stirrup, which in turn is fastened by base to the small film stretched across a round hole in the bone, opening into the inner ear, or labyrinth. The inner ear consists of several cavities containing a liquid in which rest the endings of the auditory nerve. The cavities are the snail-shell and the three loops, or semicircular canals.

FIG. 224. — Diagram of Left Ear.

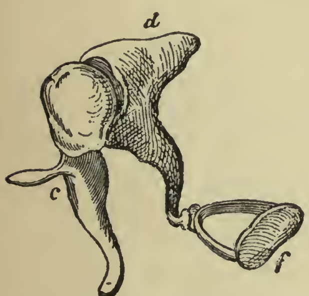


FIG. 225. — Bones of Right Ear, enlarged.
c, hammer; *d*, anvil; *e*, *f*, stirrup.

627. Sound waves, entering by the meatus, set the drum skin to shaking; the vibrations are conveyed by the chain of bones across the middle ear to the liquid of the inner ear. The wave travels through air in the outer ear, solids in the middle ear, and liquids in the inner ear. The vibrations of the liquid start nerve impulses in the fibers of the auditory nerve, and when these impulses are received and interpreted in the brain, the miracle of the conversion of the external sound wave into the sensation of sound is complete.

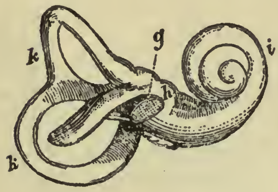


FIG. 226. — The Inner Ear, or Labyrinth.
g, vestibule; *i*, snail shell; *k*, semicircular canals.

628. The Equilibrium Sense. — It is now believed that the semicircular canals of the inner ear are not concerned in hearing. The weight of the liquid they contain pressing upon the nerve fibers located in them and exerting a varying pressure according to the position of the body, gives us the "equilibrium sense," which enables us to know the position of the body at all times, that we may preserve its equilibrium. Sight and the muscular sense also probably contribute to maintain the equilibrium.

629. Care of the Ear. — The meatus is self-cleansing; the wax changes into dry scales, which fall out. The external ear should be washed, but when we reach the passage, we should go no deeper than we can easily reach with the tip of the finger covered with a damp cloth; especially the finger should not be forced into the tender ears of children. A blow with the flat hand upon the ear may force the air in and injure the tympanum. Picking the ear with hard or sharp objects is dangerous to the tympanum.

630. Sometimes the wax collects in a lump near the drum, causing deafness. The remedy is to syringe the meatus with warm water until the lump is softened and comes away. The bitter wax is a protection against insects. Quinine often does great damage to the hearing. Chronic cold in the throat reaching the ear through the Eustachian tube sometimes injures the hearing.

THE VOICE

631. The larynx, in which the voice originates, is a cartilaginous box with three sides, the sharpest corner forming a ridge in front (Fig. 227). In many persons the larynx is prominent in the neck, and is called the *Adam's apple*. The lid of the voice-box, or larynx, is also of cartilage, and is called the *epiglottis*. Across the middle of the box are stretched two bands, or half-curtains, called the *vocal cords* (Fig. 228). Their ends are attached to the front and back of the larynx. They are not true cords, however, as they are thin and flat, and one edge of each band is attached to the side of the larynx. Since the cords run across the middle of the chamber from front to back, the free edges are brought near together. The slit, or opening between these edges, is called the *glottis*. During ordinary respiration the cords are relaxed and the slit is wide open. To make the voice the vocal cords must be brought very near together and drawn tight, and a current of air must be forced through the narrow slit and throw the cords into vibration. The front ends of the cords are attached to the larynx just

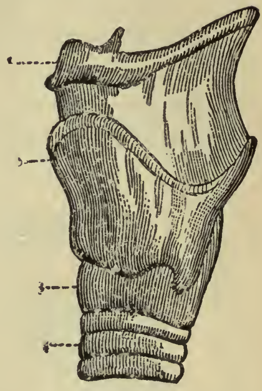


FIG. 227.

View of the left side of the larynx; 1, front portion of hyoid bone; 2, upper edge of larynx; 3, lower portion of larynx; 4, second ring of trachea.

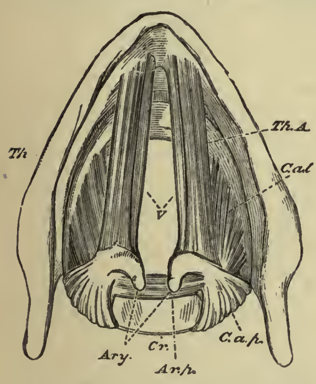


FIG. 228. — Cross-section of the Larynx above the Vocal Cords, with the Mucous Membrane removed.

Showing right vocal cord; left vocal cord; cartilages to which the vocal cords are attached behind; front edge of the larynx.

within the angle, or ridge, called the Adam's apple. The rear ends are attached to two little movable cartilages at the back of the chamber. The moving of these little cartilages by the muscles of the larynx brings the edges together and tightens the cords.

632. Sound Waves, or sound vibrations, are imparted to the air by the tremulous motion of the cords. The limits of the vibrations which the human voice is capable of making are from 42 vibrations per second for the lowest tone, to over 2000 vibrations per second for the highest tone.

FIG. 229. — The Shape of the Mouth in sounding the Vowels *a, e, oo.*

Lower C of the soprano is produced by 256 vibrations per second. The limits of vibrations which the human ear is capable of hearing are from 16 to 50,000 vibrations per second, but until they reach a rate of about 50, the sound is more like a buzz than a tone. Some people cannot hear the voice of mice, or the squeak of a bat, because of the high pitch being beyond the limit of their hearing.

633. THOUGHT LESSON. **How the Voice may vary.** — The rate of vibration of a cord, and hence the *pitch* of a sound, are influenced in several ways. Is the string of a violin or of a guitar tuned up or down by tightening it? Which is higher in pitch, a long or a short string of a harp or a piano? Which makes a higher note, the light or the heavy string of a violin or a guitar? The pitch of the note given by a string may be raised in three ways: tightening, shortening, or decreasing the weight of the string. From these facts explain why the voice rises in pitch when we are excited, the muscles at that time being contracted with greater force. Why does a cold with congestion of the cords cause a person to speak in a hoarse, deep voice? Why does a man, whose larynx is larger than a woman's,

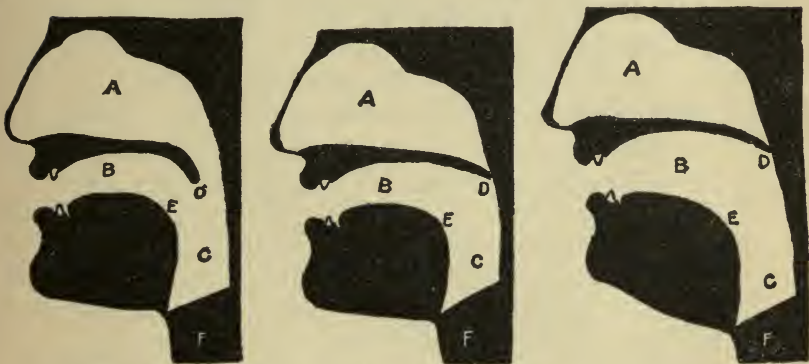


FIG. 230. FIG. 231. FIG. 232.

A, Resonance Cavity of the Nose; *B*, Resonance Cavity of the Mouth; *C*, Resonance Cavity of the Pharynx; *D*, Soft Palate; *E*, Tongue; *F*, Point at which Vibration begins.

Fig. 230 shows soft palate (*D*) in normal position, allowing air in naso-pharynx to vibrate in unison with initial note. Fig. 231 shows soft palate raised, shutting off this resonance and rendering tone thin and hard. Fig. 232 shows another common fault. The tongue is lowered, increasing the size of the mouth cavity. This increases the volume of the tone but renders the quality harsh and hollow. (Latson.)

have the deeper voice? Why does a boy's voice change as his larynx enlarges?

A man's voice has usually a pitch of one octave below that of a woman or a boy. The range of the human voice is about two octaves. The voice may also vary in —

634. *Volume*, or loudness, as well as in pitch. How do we speak loudly at one time and softly at another? If a tin pan is struck gently, the sound is weak; if it is struck with force, the sound is louder. We make the voice louder by stronger expiration of the breath, thus sending the air with more strength against the tightened vocal cords.

Two persons sing a song together in the same pitch and with the same loudness; yet you can readily distinguish a difference in the two voices. This is because of a difference in —

Quality, which is the third variation possible in a voice. Sound in wind instruments is strengthened by resonance, which is a kind of instantaneous echo in the pipes.

635. The vibration of the vocal cords alone produces a weak, squeaky sound, but their vibrations are reënforced or strengthened by the vibration of the walls of the lungs and windpipe below, and of the nose and mouth above. These echoes, combining with and reënforcing the vibration of the cords, determine the quality of the voice. Just as the shape and material of the walls of the violin give the quality to its tone, so the shape and condition of the nasal passages, throat, etc., give characteristic quality to each human voice. If the nasal passages are stopped up by catarrh, the person is said to speak in a nasal tone, or through the nose, but a "nasal" tone really results only when the sound cannot come through the nose. Such a person's voice does not change its quality, when he speaks with his nose stopped with his fingers. But a voice which has correct nasal resonance will change its quality when the nose is held. Try it, and see whether your voice retains its nasal resonance. Let one pupil read aloud at the back of the room where the others do not see him, and find whether they can tell, by the change in his voice, at which word he closes his nose in the midst of the reading. The vocal cords are not used at all in whispering. It is akin to whistling.

636. Duration of Sound. — In singing, single sounds are more or less prolonged. In speech, the principal changes are in the duration of the sound, and in the resonance in the mouth. In whispering, audible breathing is cut off by the tongue and lips, and words are articulated, although no sound comes from the vocal cords. A public speaker ordinarily utters 125 words per minute. If there are four sounds to a word, this amounts to 500 sounds each minute or eight each second.

637. Is the Voice a Stringed or a Wind Instrument? — The inappropriate names of the vocal cords may lead a student incorrectly to suppose that the voice is a stringed instrument. It is a wind instrument; the vocal bands correspond to the vibrating edge in the opening in an organ pipe, the throat and air passages correspond to the pipe, and the lungs correspond to the bellows that furnish the current of air.

638. Alcohol and Tobacco. — Smokers are frequent sufferers from affections of the throat. Smoking may produce a constant "hacking" cough. The hot, poisonous smoke, to say nothing of the poisonous vapor of nicotine, brought in contact with the vocal cords, is almost certain to produce mischief. Singers and public speakers usually have to give up the use of tobacco on this account. Cigarette smoking is especially bad for the voice, as the smoke is inhaled. The deep-toned voice of the chronic drinker may be an indication of inflammation of the larynx, a disease from which beer drinkers often suffer.

639. Care of the Voice. — The voice should not be used more than is absolutely necessary when it is hoarse. Catarrh may injure the voice by injury to the vocal cords or by obstruction of the nasal passages.

640. The best way for a child to acquire distinct and refined speech, is to hear it habitually. The number of people that are allowed to grow up handicapped by hasty, harsh, indistinct, or disagreeable speech, is very great. Parents and teachers should remember as children are growing up, what an advantage to them in after life a refined, melodious voice will be. Nearly all children have sweet voices when young, but many lose them before adult life on account of acquired nervous habits, dusty and ill-ventilated rooms, deformity of lungs due to restrictive clothing, or from singing during the time their voices are changing or attempting tunes beyond the compass of their voices.

641. Culture of Voice. — Voice culture is often more of a straining than a training. Its mechanical nature is revealed by the term "voice building" (whatever that may mean) used by some singing teachers. The pupil is taught to raise the soft palate and depress the larynx, etc. (see Figs. 230, 232). Rigidity of the muscles of chest, neck, jaw, and larynx results and self-consciousness assumes charge.

When the singer does not listen too closely to his own voice, the muscles are more likely to be free from rigidity. Muscles in this condition are perfectly dominated by the mental state; this applies to both tone and gesture. Breathing exercises which call for a rigid, over-filled chest destroy this flexibility.

Conclusion

642. Thus we see with reference to the care of the voice, as with taking care of the health in general, that overcare and too much effort have an effect opposite to that intended. We must trust largely to the natural tendencies of our wonderful organisms toward sound health and perfection of function. If we exert great effort and attempt very much interference, we are likely, in our ignorance, to do more harm than good. We do not even know what life is. When we say that life consists of activity of the cells, we are simply stating the limitations of science. The power which causes this birth, growth, and destruction of cells is beyond our comprehension. We know nothing of the mechanism occurring in the protoplasm of the cells. All that the wisest can say is: —

> "In Nature's infinite book of secrecy
> A little can I read."

APPENDIX

EMERGENCIES

Cuts. — There is danger of bleeding to death if an artery of any size is cut. Stop the flow of blood immediately by compressing the artery with the finger, between the wound and the heart. Next twist a handkerchief and tie a hard knot in the middle. Place the knot over the artery and carry the ends around the limb and tie it loosely. Place a stick under the handkerchief and twist until the fingers can be removed from the compression without return of the bleeding (see Figs. 233 and 234).

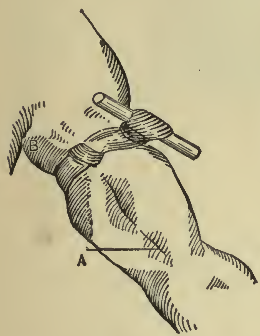


FIG. 233
The method of applying the knotted handkerchief, to compress a divided artery. *A*, *B*, track of the inner artery of the left arm.

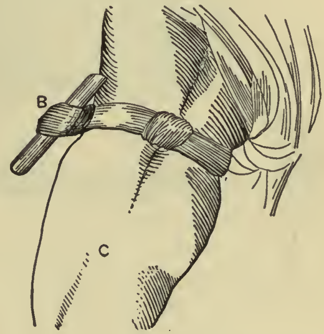


FIG. 234.
A, *C*, the track of the left femoral artery; the compress applied near the groin.

Sprains. — See Chapter VI, § 124.

Broken Bones. — See Chapter VI, § 122. A convenient bandage may be made out of a piece of calico one yard square, by cutting it across from one corner to another (Fig. 235). For method of using bandage as a support for a broken arm, see Fig. 236.

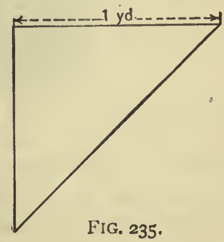


FIG. 235.

To prevent Mouth-breathing, bands may be arranged as shown in Fig. 237. Dr. Tafts, of Pittsburg, gets good results by sticking a strip of court plaster across the closed lips.

Burns. — If the clothes catch fire, *do not run*, as this only fans the flames, but wrap quickly around the body a coat, rug, shawl, blanket, or other woolen article. The skirts of girls are a source of danger when they stand near a fire in an open fireplace without a fender, or by a fire out of doors. Life has sometimes been saved by throwing the victim to the ground, and then putting sand or dirt on the burning clothes.

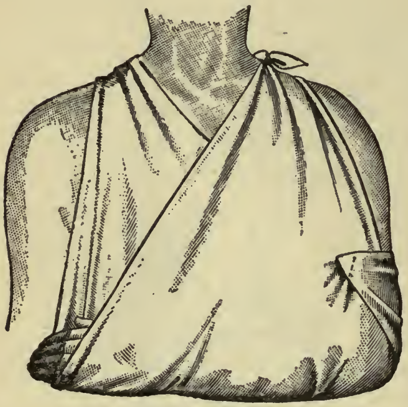


FIG. 236.

FIG. 237.

FIG. 238. — Resuscitation: Inspiration. (Brinckley.)

In Cases of Drowning the first thing to be done is to **remove the water from the throat and lungs** by holding the person up by the waist, with the face downward. Then draw the tongue forward and keep it in place by tying with the middle of a handkerchief or band, so that it may not fall back and close the throat ; the ends of the band should cross under the chin and be tied around the neck. Next proceed to restore by artificial breathing according to **the method shown in Figs. 238 and 239**. The teacher should illustrate the method of fastening the tongue, the pupil holding a short stick between the teeth to represent the tongue. The teacher should then work the arms of

FIG. 239. — Resuscitation : Expiration. (Brinckley.)

the pupil to show inspiration and expiration in artificial breathing. The boy need not lie down but should stand where the class may see him.

Artificial Breathing (Sylvester's Method), applicable to asphyxia from fire, gas, electric shock, or drowning. A coat or cushion should be placed under the shoulders to serve as a support. *First Step* (Fig. 238) : The arms should be raised above the head with force in order to raise the ribs. *Second Step* (Fig. 239) : The arms should be lowered and pressed against the sides so as to compress the chest. *Repeat* these movements about fifteen times each minute, continuing for an hour or several hours until natural breathing is restored.

Snake Bites. — Very few snakes are poisonous. The four snakes of the United States that are virulently poisonous are the rattlesnake (diamond rattler and common rattler), ground rattlesnake (has no rattles), moccasin, and copperhead. The last-named is the most dangerous. The copperhead is of a golden brown color, with dark V-shaped blotches meeting on the back. All venomous snakes have broad triangular heads and short tails. Their bite is known from the marks left by the two fangs. Other snakes do not have fangs. The wound made by a venomous snake should be immediately sucked. The blood should be confined to the bitten member (see Figs. 233, 234). Potassium permanganate and peroxide of hydrogen are valuable remedies. They should be used only under direction of a physician.

POISONS AND ANTIDOTES

Poisons	Symptoms	Treatment and Antidotes
Opium		
Morphine Codeine Laudanum Paregoric Soothing sirup Dover's powder	Drowsiness; stupor; contracted pupils; slow breathing; perspiration profuse	*Cause vomiting* or use stomach tube; keep patient awake by vigorous walking and other means; dash cold water on face and chest; give strong coffee freely
Carbolic Acid		
Creosote	Severe pain; odor of the acid; mucous membrane white; skin clammy	*Do not cause vomiting;* give milk, or flour and water, white of eggs
Arsenic		
Rough on rats Paris green White arsenic	Intense pain in abdomen; thirst; vomiting; skin cold and clammy	*Cause vomiting* repeatedly; give hydrated oxide of iron with magnesia (druggist), then strong salt water
Phosphorus		
Rat poison Matches	Vomiting; pain in stomach; purging	*Cause vomiting;* give strong soap suds, magnesia in water
Belladonna		
Deadly nightshade Atropin	Enlarged pupils; eyes bright; mouth and throat dry	*Cause free vomiting*
Concentrated Acids		
Sulphuric (vitriol) Muriatic Nitric Oxalic	Feeling of burning in mouth, throat, and stomach; blisters on lips; vomiting and weakness	*Do not cause vomiting;* give baking soda, 4 teaspoonfuls to a glass of water; chalk; soap; lime; magnesia
Alkalies		
Lye Caustic potash Soda Ammonia	Burning sensation; pain in stomach; vomiting; difficulty in swallowing; skin cold; pulse weak	*Do not cause vomiting;* give olive oil; thick cream; melted butter and vaseline; vinegar; lemon juice

NOTE. — In those cases of poisoning where *vomiting* is necessary, it may be induced by a drink of warm water, or powdered alum in a little molasses, or a mixture of ground mustard in warm water. The vomiting should be repeated until the stomach is thoroughly washed out.

INDEX

The meaning of each technical word is fully explained in the text when the word is first used. This explanation can be found by using the first reference given. The numbers below refer to pages.

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