A Practical Physiology

Albert F. Blaisdell

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[Transcriber's Note: Figures 162-167 have been renumbered. In the
original, Figure 162 was labeled as 161; 163 as 162; etc.]

A Practical Physiology

A Text-Book for Higher Schools

By

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"Our Bodies and How We Live," Etc., Etc.

Preface.

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The author has aimed to prepare a text-book on human physiology for use in higher schools. The design of the book is to furnish a practical manual of the more important facts and principles of physiology and hygiene, which will be adapted to the needs of students in high schools, normal schools, and academies.

Teachers know, and students soon learn to recognize the fact, that it is impossible to obtain a clear understanding of the functions of the various parts of the body without first mastering a few elementary facts about their structure. The course adopted, therefore, in this book, is to devote a certain amount of space to the anatomy of the several organs before describing their functions.

A mere knowledge of the facts which can be gained in secondary schools, concerning the anatomy and physiology of the human body, is of little real value or interest in itself. Such facts are important and of practical worth to young students only so far as to enable them to understand the relation of these facts to the great laws of health and to apply them to daily living. Hence, it has been the earnest effort of the author in this book, as in his other physiologies for schools, to lay special emphasis upon such points as bear upon personal health.

Physiology cannot be learned as it should be by mere book study. The result will be meagre in comparison with the capabilities of the subject. The study of the text should always be supplemented by a series of practical experiments. Actual observations and actual experiments are as necessary to illuminate the text and to illustrate important principles in physiology as they are in botany, chemistry, or physics. Hence, as supplementary to the text proper, and throughout the several chapters, a series of carefully arranged and practical experiments has been added. For the most part, they are simple and can be performed with inexpensive and easily obtained apparatus. They are so arranged that some may be omitted and others added as circumstances may allow.

If it becomes necessary to shorten the course in physiology, the various sections printed in smaller type may be omitted or used for home study.

The laws of most of the states now require in our public schools the study of the effects of alcoholic drinks, tobacco, and other narcotics upon the bodily life. This book will be found to comply fully with all such laws.

The author has aimed to embody in simple and concise language the latest and most trustworthy information which can be obtained from the standard authorities on modern physiology, in regard to the several topics.

In the preparation of this text-book the author has had the editorial help of his esteemed friend, Dr. J. E. Sanborn, of Melrose, Mass., and is also indebted to the courtesy of Thomas E. Major, of Boston, for assistance in revising the proofs.

Albert F. Blaisdell.

Boston, August, 1897.

Contents.

Chapter I.

Introduction.

1. The Study of Physiology. We are now to take up a new study, and in a field quite different from any we have thus far entered. Of all our other studies,--mathematics, physics, history, language,--not one comes home to us with such peculiar interest as does physiology, because this is the study of ourselves.

Every thoughtful young person must have asked himself a hundred questions about the problems of human life: how it can be that the few articles of our daily food--milk, bread, meats, and similar things--build up our complex bodies, and by what strange magic they are transformed into hair, skin, teeth, bones, muscles, and blood.

How is it that we can lift these curtains of our eyes and behold all the wonders of the world around us, then drop the lids, and though at noonday, are instantly in total darkness? How does the minute structure of the ear report to us with equal accuracy the thunder of the tempest, and the hum of the passing bee? Why is breathing so essential to our life, and why cannot we stop breathing when we try? Where within us, and how, burns the mysterious fire whose subtle heat warms us from the first breath of infancy till the last hour of life?

These and scores of similar questions it is the province of this deeply interesting study of physiology to answer.

2. What Physiology should Teach us. The study of physiology is not only interesting, but it is also extremely useful. Every reasonable person should not only wish to acquire the knowledge how best to protect and preserve his body, but should feel a certain profound respect for an organism so wonderful and so perfect as his physical frame. For our bodies are indeed not ourselves, but the frames that contain us,--the ships in which we, the real selves, are borne over the sea of life. He must be indeed a poor navigator who is not zealous to adorn and strengthen his ship, that it may escape the rocks of disease and premature decay, and that the voyage of his life may be long, pleasant, and successful.

But above these thoughts there rises another,--that in studying physiology we are tracing the myriad lines of marvelous ingenuity and forethought, as they appear at every glimpse of the work of the Divine Builder. However closely we study our bodily structure, we are, at our best, but imperfect observers of the handiwork of Him who made us as we are.

3. Distinctive Characters of Living Bodies. Even a very meagre knowledge of the structure and action of our bodies is enough to reveal the following distinctive characters: our bodies are continually breathing, that is, they take in oxygen from the surrounding air; they take in certain substances known as food, similar to those composing the body, which are capable through a process called oxidation, or through other chemical changes, of setting free a certain amount of energy.

Again, our bodies are continually making heat and giving it out to surrounding objects, the production and the loss of heat being so adjusted that the whole body is warm, that is, of a temperature higher than that of surrounding objects. Our bodies, also, move themselves, either one part on another, or the whole body from place to place. The motive power is not from the outside world, but the energy of their movements exists in the bodies themselves, influenced by changes in their surroundings. Finally, our bodies are continually getting rid of so-called waste matters, which may be considered products of the oxidation of the material used as food, or of the substances which make up the organism.

4. The Main Problems of Physiology briefly Stated. We shall learn in a subsequent chapter that the living body is continually losing energy, but by means of food is continually restoring its substance and replenishing its stock of energy. A great deal of energy thus stored up is utilized as mechanical work, the result of physical movements. We shall learn later on that much of the energy which at last leaves the body as heat, exists for a time within the organism in other forms than heat, though eventually transformed into heat. Even a slight change in the surroundings of the living body may rapidly, profoundly, and in special ways affect not only the amount, but the kind of energy set free. Thus the mere touch of a hair may lead to such a discharge of energy, that a body previously at rest may be suddenly thrown into violent convulsions. This is especially true in the case of tetanus, or lockjaw.

The main problem we have to solve in the succeeding pages is to ascertain how it is that our bodies can renew their substance and replenish the energy which they are continually losing, and can, according to the nature of their surroundings, vary not only the amount, but the kind of energy which they set free.

5. Technical Terms Defined. All living organisms are studied usually from two points of view: first, as to their form and structure; second, as

to the processes which go on within them. The science which treats of all living organisms is called biology. It has naturally two divisions,--morphology, which treats of the form and structure of living beings, and physiology, which investigates their functions, or the special work done in their vital processes.

The word anatomy, however, is usually employed instead of morphology. It is derived from two Greek words, and means the science of dissection. Human anatomy then deals with the form and structure of the human body, and describes how the different parts and organs are arranged, as revealed by observation, by dissection, and by the microscope.

Histology is that part of anatomy which treats of the minute structure of any part of the body, as shown by the microscope.

Human physiology describes the various processes that go on in the human body in health. It treats of the work done by the various parts of the body, and of the results of the harmonious action of the several organs. Broadly speaking, physiology is the science which treats of functions. By the word function is meant the special work which an organ has to do. An organ is a part of the body which does a special work. Thus the eye is the organ of sight, the stomach of digestion, and the lungs of breathing.

It is plain that we cannot understand the physiology of our bodies without a knowledge of their anatomy. An engineer could not understand the working of his engine unless well acquainted with all its parts, and the manner in which they were fitted together. So, if we are to understand the principles of elementary physiology, we must master the main anatomical facts concerning the organs of the body before considering their special functions.

As a branch of study in our schools, physiology aims to make clear certain laws which are necessary to health, so that by a proper knowledge of them, and their practical application, we may hope to spend happier and more useful, because healthier, lives. In brief, the study of hygiene, or the science of health, in the school curriculum, is usually associated with that of physiology.[1]

6. Chemical Elements in the Body. All of the various complex substances found in nature can be reduced by chemical analysis to about 70 elements, which cannot be further divided. By various combinations of these 70 elements all the substances known to exist in the world of nature are built up. When the inanimate body, like any other substance, is submitted to chemical analysis, it is found that the bone, muscle, teeth, blood, etc., may be reduced to a few chemical elements.

In fact, the human body is built up with 13 of the 70 elements, namely: oxygen, hydrogen, nitrogen, chlorine, fluorine, carbon, phosphorus, sulphur, calcium, potassium, sodium, magnesium, and iron. Besides these, a few of the other elements, as silicon, have been found; but they exist in extremely minute quantities.

The following table gives the proportion in which these various elements are present:

Oxygen	62.430 per cent
Carbon	21.150 " "
Hydrogen	9.865 " "

Nitrogen	3.100	" "
Calcium	1.900	" "
Phosphorus	0.946	" "
Potassium	0.230	" "
Sulphur	0.162	" "
Chlorine	0.081	" "
Sodium	0.081	" "
Magnesium	0.027	" "
Iron	0.014	" "
Fluorine	0.014	" "

	100.000	

As will be seen from this table, oxygen, hydrogen, and nitrogen, which are gases in their uncombined form, make up 3/4 of the weight of the whole human body. Carbon, which exists in an impure state in charcoal, forms more than 1/5 of the weight of the body. Thus carbon and the three gases named, make up about 96 per cent of the total weight of the body.

7. Chemical Compounds in the Body. We must keep in mind that, with slight exceptions, none of these 13 elements exist in their elementary form in the animal economy. They are combined in various proportions, the results differing widely from the elements of which they consist. Oxygen and hydrogen unite to form water, and water forms more than 2/3 of the weight of the whole body. In all the fluids of the body, water acts as a solvent, and by this means alone the circulation of nutrient material is possible. All the various processes of secretion and nutrition depend on the presence of water for their activities.

8. Inorganic Salts. A large number of the elements of the body unite one with another by chemical affinity and form inorganic salts. Thus sodium and chlorine unite and form chloride of sodium, or common salt. This is found in all the tissues and fluids, and is one of the most important inorganic salts the body contains. It is absolutely necessary for continued existence. By a combination of phosphorus with sodium, potassium, calcium, and magnesium, the various phosphates are formed.

The phosphates of lime and soda are the most abundant of the salts of the body. They form more than half the material of the bones, are found in the teeth and in other solids and in the fluids of the body. The special place of iron is in the coloring matter of the blood. Its various salts are traced in the ash of bones, in muscles, and in many other tissues and fluids. These compounds, forming salts or mineral matters that exist in the body, are estimated to amount to about 6 per cent of the entire weight.

9. Organic Compounds. Besides the inorganic materials, there exists in the human body a series of compound substances formed of the union of the elements just described, but which require the agency of living structures. They are built up from the elements by plants, and are called organic. Human beings and the lower animals take the organized materials they require, and build them up in their own bodies into still more highly organized forms.

The organic compounds found in the body are usually divided into three great classes:

1. Proteids, or albuminous substances.
2. Carbohydrates (starches, sugars, and gums).

  3. Fats.

The extent to which these three great classes of organic materials of the body exist in the animal and vegetable kingdoms, and are utilized for the food of man, will be discussed in the chapter on food (Chapter V.). The Proteids, because they contain the element nitrogen and the others do not, are frequently called nitrogenous, and the other two are known as non-nitrogenous substances. The proteids, the type of which is egg albumen, or the white of egg, are found in muscle and nerve, in glands, in blood, and in nearly all the fluids of the body. A human body is estimated to yield on an average about 18 per cent of albuminous substances. In the succeeding chapters we shall have occasion to refer to various and allied forms of proteids as they exist in muscle (myosin), coagulated blood (fibrin), and bones (gelatin).

The Carbohydrates are formed of carbon, hydrogen, and oxygen, the last two in the proportion to form water. Thus we have animal starch, or glycogen, stored up in the liver. Sugar, as grape sugar, is also found in the liver. The body of an average man contains about 10 per cent of Fats. These are formed of carbon, hydrogen, and oxygen, in which the latter two are not in the proportion to form water. The fat of the body consists of a mixture which is liquid at the ordinary temperature.

Now it must not for one moment be supposed that the various chemical elements, as the proteids, the salts, the fats, etc., exist in the body in a condition to be easily separated one from another. Thus a piece of muscle contains all the various organic compounds just mentioned, but they are combined, and in different cases the amount will vary. Again, fat may exist in the muscles even though it is not visible to the naked eye, and a microscope is required to show the minute fat cells.

10. Protoplasm. The ultimate elements of which the body is composed consist of "masses of living matter," microscopic in size, of a material commonly called protoplasm.[2] In its simplest form protoplasm appears to be a homogeneous, structureless material, somewhat resembling the raw white of an egg. It is a mixture of several chemical substances and differs in appearance and composition in different parts of the body.

Protoplasm has the power of appropriating nutrient material, of dividing and subdividing, so as to form new masses like itself. When not built into a tissue, it has the power of changing its shape and of moving from place to place, by means of the delicate processes which it puts forth. Now, while there are found in the lowest realm of animal life, organisms like the amoeba of stagnant pools, consisting of nothing more than minute masses of protoplasm, there are others like them which possess a small central body called a nucleus. This is known as nucleated protoplasm.

[Illustration: Fig. 1.--Diagram of a Cell.

  A, nucleus;
  B, nucleolus;
  C, protoplasm. (Highly magnified)
]

11. Cells. When we carry back the analysis of an organized body as far as we can, we find every part of it made up of masses of nucleated protoplasm of various sizes and shapes. In all essential features these masses conform to the type of protoplasmic matter just described. Such bodies are called cells. In many cells the nucleus is finely granular or

reticulated in appearance, and on the threads of the meshwork may be one or more enlargements, called nucleoli. In some cases the protoplasm at the circumference is so modified as to give the appearance of a limiting membrane called the cell wall. In brief, then, a cell is a mass of nucleated protoplasm; the nucleus may have a nucleolus, and the cell may be limited by a cell wall. Every tissue of the human body is formed through the agency of protoplasmic cells, although in most cases the changes they undergo are so great that little evidence remains of their existence.

There are some organisms lower down in the scale, whose whole activity is confined within the narrow limits of a single cell. Thus, the amoeba begins its life as a cell split off from its parent. This divides in its turn, and each half is a complete amoeba. When we come a little higher than the amoeba, we find organisms which consist of several cells, and a specialization of function begins to appear. As we ascend in the animal scale, specialization of structure and of function is found continually advancing, and the various kinds of cells are grouped together into colonies or organs.

12. Cells and the Human Organism. If the body be studied in its development, it is found to originate from a single mass of nucleated protoplasm, a single cell with a nucleus and nucleolus. From this original cell, by growth and development, the body, with all its various tissues, is built up. Many fully formed organs, like the liver, consist chiefly of cells. Again, the cells are modified to form fibers, such as tendon, muscle, and nerve. Later on, we shall see the white blood corpuscles exhibit all the characters of the amoeba (Fig. 2). Even such dense structures as bone, cartilage, and the teeth are formed from cells.

[Illustration: Fig. 2.--Amoeboid Movement of a Human White Blood Corpuscle. (Showing various phases of movement.)]

In short, cells may be regarded as the histological units of animal structures; by the combination, association, and modification of these the body is built up. Of the real nature of the changes going on within the living protoplasm, the process of building up lifeless material into living structures, and the process of breaking down by which waste is produced, we know absolutely nothing. Could we learn that, perhaps we should know the secret of life.

13. Kinds of Cells. Cells vary greatly in size, some of the smallest being only 1/3500 an inch or less in diameter. They also vary greatly in form, as may be seen in Figs. 3 and 5. The typical cell is usually _globular_ in form, other shapes being the result of pressure or of similar modifying influences. The globular, as well as the large, flat cells, are well shown in a drop of saliva. Then there are the _columnar_ cells, found in various parts of the intestines, in which they are closely arranged side by side. These cells sometimes have on the free surface delicate prolongations called cilia. Under the microscope they resemble a wave, as when the wind blows over a field of grain (Fig. 5). There are besides cells known as _spindle, stellate, squamous_ or pavement, and various other names suggested by their shapes. Cells are also described as to their contents. Thus _fat_ and _pigment_ cells are alluded to in succeeding sections. Again, they may be described as to their functions or location or the tissue in which they are found, as _epithelial_ cells, _blood_ cells (corpuscles, Figs. 2 and 66), _nerve_ cells (Fig. 4), and _connective-tissue_ cells.

14. Vital Properties of Cells. Each cell has a life of its own. It manifests its vital properties in that it is born, grows, multiplies, decays, and at last dies.[3] During its life it assimilates food, works, rests, and is capable of spontaneous motion and frequently of locomotion. The cell can secrete and excrete substance, and, in brief, presents nearly all the phenomena of a human being.

Cells are produced only from cells by a process of self-division, consisting of a cleavage of the whole cell into parts, each of which becomes a separate and independent organism. Cells rapidly increase in size up to a certain definite point which they maintain during adult life. A most interesting quality of cell life is motion, a beautiful form of which is found in ciliated epithelium. Cells may move actively and passively. In the blood the cells are swept along by the current, but the white corpuscles, seem able to make their way actively through the tissues, as if guided by some sort of instinct.

[Illustration: Fig. 3.--Various Forms of Cells.

A, columnar cells found lining various parts of the intestines (called _columnar epithelium_);
B, cells of a fusiform or spindle shape found in the loose tissue under the skin and in other parts (called _connective-tissue cells_);
C, cell having many processes or projections--such are found in connective tissue, D, primitive cells composed of protoplasm with nucleus, and having no cell wall. All are represented about 400 times their real size.
]

Some cells live a brief life of 12 to 24 hours, as is probably the case with many of the cells lining the alimentary canal; others may live for years, as do the cells of cartilage and bone. In fact each cell goes through the same cycle of changes as the whole organism, though doubtless in a much shorter time. The work of cells is of the most varied kind, and embraces the formation of every tissue and product,--solid, liquid, or gaseous. Thus we shall learn that the cells of the liver form bile, those of the salivary glands and of the glands of the stomach and pancreas form juices which aid in the digestion of food.

15. The Process of Life. All living structures are subject to constant decay. Life is a condition of incessant changes, dependent upon two opposite processes, repair and decay. Thus our bodies are not composed of exactly the same particles from day to day, or even from one moment to another, although to all appearance we remain the same individuals. The change is so gradual, and the renewal of that which is lost may be so exact, that no difference can be noticed except at long intervals of time.[4] (See under "Bacteria," Chapter XIV.)

The entire series of chemical changes that take place in the living body, beginning with assimilation and ending with excretion, is included in one word, metabolism. The process of building up living material, or the change by which complex substances (including the living matter itself) are built up from simpler materials, is called anabolism. The breaking down of material into simple products, or the changes in which complex materials (including the living substance) are broken down into comparatively simple products, is known as katabolism. This reduction of complex substances to simple, results in the production of animal force and energy. Thus a complex substance, like a piece of beef-steak, is built up of a large number of molecules which required the expenditure of force or energy to store up. Now when this material is reduced by the process of digestion to simpler bodies with fewer molecules, such as carbon dioxid, urea, and water, the force stored up in the meat as potential energy becomes manifest and is used as active life-force known as _kinetic energy_.

16. Epithelium. Cells are associated and combined in many ways to form a simple tissue. Such a simple tissue is called an epithelium or surface-limiting tissue, and the cells are known as epithelial cells. These are united by a very small amount of a cement substance which belongs to the proteid class of material. The epithelial cells, from their shape, are known as squamous, columnar, glandular, or ciliated. Again, the cells may be arranged in only a single layer, or they may be several layers deep. In the former case the epithelium is said to be simple; in the latter, stratified. No blood-vessels pass into these tissues; the cells derive their nourishment by the imbibition of the plasma of the blood exuded into the subjacent tissue.

[Illustration: Fig. 4.--Nerve Cells from the Gray Matter of the Cerebellum. (Magnified 260 diameters.)]

17. Varieties of Epithelium. The squamous or pavement epithelium consists of very thin, flattened scales, usually with a small nucleus in the center. When the nucleus has disappeared, they become mere horny plates, easily detached. Such cells will be described as forming the outer layer of the skin, the lining of the mouth and the lower part of the nostrils.

The columnar epithelium consists of pear-shaped or elongated cells, frequently as a single layer of cells on the surface of a mucous membrane, as on the lining of the stomach and intestines, and the free surface of the windpipe and large air-tubes.

The glandular or spheroidal epithelium is composed of round cells or such as become angular by mutual pressure. This kind forms the lining of glands such as the liver, pancreas, and the glands of the skin.

The ciliated epithelium is marked by the presence of very fine hair-like processes called cilia, which develop from the free end of the cell and exhibit a rapid whip-like movement as long as the cell is alive. This motion is always in the same direction, and serves to carry away mucus and even foreign particles in contact with the membrane on which the cells are placed. This epithelium is especially common in the air passages, where it serves to keep a free passage for the entrance and exit of air. In other canals a similar office is filled by this kind of epithelium.

18. Functions of Epithelial Tissues. The epithelial structures may be divided, as to their functions, into two main divisions. One is chiefly protective in character. Thus the layers of epithelium which form the superficial layer of the skin have little beyond such an office to discharge. The same is to a certain extent true of the epithelial cells covering the mucous membrane of the mouth, and those lining the air passages and air cells of the lungs.

[Illustration: Fig. 5.--Various Kinds of Epithelial Cells

A, columnar cells of intestine;
B, polyhedral cells of the conjunctiva;

C, ciliated conical cells of the trachea;
D, ciliated cell of frog's mouth;
E, inverted conical cell of trachea;
F, squamous cell of the cavity of mouth, seen from its broad surface;
G, squamous cell, seen edgeways.
]

The second great division of the epithelial tissues consists of those whose cells are formed of highly active protoplasm, and are busily engaged in some sort of secretion. Such are the cells of glands,--the cells of the salivary glands, which secrete the saliva, of the gastric glands, which secrete the gastric juice, of the intestinal glands, and the cells of the liver and sweat glands.

19. Connective Tissue. This is the material, made up of fibers and cells, which serves to unite and bind together the different organs and tissues. It forms a sort of flexible framework of the body, and so pervades every portion that if all the other tissues were removed, we should still have a complete representation of the bodily shape in every part. In general, the connective tissues proper act as packing, binding, and supporting structures. This name includes certain tissues which to all outward appearance vary greatly, but which are properly grouped together for the following reasons: first, they all act as supporting structures; second, under certain conditions one may be substituted for another; third, in some places they merge into each other.

All these tissues consist of a ground-substance, or matrix, cells, and fibers. The ground-substance is in small amount in connective tissues proper, and is obscured by a mass of fibers. It is best seen in hyaline cartilage, where it has a glossy appearance. In bone it is infiltrated with salts which give bone its hardness, and make it seem so unlike other tissues. The cells are called connective-tissue corpuscles, cartilage cells, and bone corpuscles, according to the tissues in which they occur. The fibers are the white fibrous and the yellow elastic tissues.

The following varieties are usually described:

I. Connective Tissues Proper:

1. White Fibrous Tissue.
2. Yellow Elastic Tissue.
3. Areolar or Cellular Tissue.
4. Adipose or Fatty Tissue.
5. Adenoid or Retiform Tissue.

II. Cartilage (Gristle):

1. Hyaline.
2. White Fibro-cartilage.
3. Yellow Fibro-cartilage.

III. Bone and Dentine of Teeth.

20. White Fibrous Tissue. This tissue consists of bundles of very delicate fibrils bound together by a small amount of cement substance. Between the fibrils protoplasmic masses (connective-tissue corpuscles) are found. These fibers may be found so interwoven as to form a sheet, as in the periosteum of the bone, the fasciae around muscles, and the capsules of organs; or they may be aggregated into bundles and form rope-like

bands, as in the ligaments of joints and the tendons of muscles. On boiling, this tissue yields gelatine. In general, where white fibrous tissue abounds, structures are held together, and there is flexibility, but little or no distensibility.

[Illustration: Fig. 6.--White Fibrous Tissue. (Highly magnified.)]

21. Yellow Elastic Tissue. The fibers of yellow elastic tissue are much stronger and coarser than those of the white. They are yellowish, tend to curl up at the ends, and are highly elastic. It is these fibers which give elasticity to the skin and to the coats of the arteries. The typical form of this tissue occurs in the ligaments which bind the vertebrae together (Fig. 26), in the true vocal cords, and in certain ligaments of the larynx. In the skin and fasciae, the yellow elastic is found mixed with white fibrous and areolar tissues. It does not yield gelatine on boiling, and the cells are, if any, few.

[Illustration: Fig. 7.--Yellow Elastic Tissue. (Highly magnified.)]

22. Areolar or Cellular Tissue. This consists of bundles of delicate fibers interlacing and crossing one another, forming irregular spaces or meshes. These little spaces, in health, are filled with fluid that has oozed out of the blood-vessels. The areolar tissue forms a protective covering for the tissues of delicate and important organs.

23. Adipose or Fatty Tissue. In almost every part of the body the ordinary areolar tissue contains a variable quantity of adipose or fatty tissue. Examined by the microscope, the fat cells consist of a number of minute sacs of exceedingly delicate, structureless membrane filled with oil. This is liquid in life, but becomes solidified after death. This tissue is plentiful beneath the skin, in the abdominal cavity, on the surface of the heart, around the kidneys, in the marrow of bones, and elsewhere. Fat serves as a soft packing material. Being a poor conductor, it retains the heat, and furnishes a store rich in carbon and hydrogen for use in the body.

24. Adenoid or Retiform Tissue. This is a variety of connective tissue found in the tonsils, spleen, lymphatic glands, and allied structures. It consists of a very fine network of cells of various sizes. The tissue combining them is known as adenoid or gland-like tissue.

[Illustration: Fig. 8.--Fibro-Cartilage Fibers. (Showing network surrounded cartilage cells.)]

25. Cartilage. Cartilage, or gristle, is a tough but highly elastic substance. Under the microscope cartilage is seen to consist of a matrix, or base, in which nucleated cells abound, either singly or in groups. It has sometimes a fine ground-glass appearance, when the cartilage is spoken of as hyaline. In other cases the matrix is almost replaced by white fibrous tissue. This is called white fibro-cartilage, and is found where great strength and a certain amount of rigidity are required.

Again, there is between the cells a meshwork of yellow elastic fibers, and this is called yellow fibro-cartilage (Fig. 8). The hyaline cartilage forms the early state of most of the bones, and is also a permanent coating for the articular ends of long bones. The white fibro-cartilage is found in the disks between the bodies of the vertebrae, in the interior of the knee joint, in the wrist and other joints, filling the cavities of the bones, in socket joints, and in the grooves for tendons. The yellow fibro-cartilage forms the expanded part of the ear, the epiglottis, and other parts of the larynx.

26. General Plan of the Body. To get a clearer idea of the general plan on which the body is constructed, let us imagine its division into perfectly equal parts, one the right and the other the left, by a great knife severing it through the median, or middle line in front, backward through the spinal column, as a butcher divides an ox or a sheep into halves for the market. In a section of the body thus planned the skull and the spine together are shown to have formed a tube, containing the brain and spinal cord. The other parts of the body form a second tube (ventral) in front of the spinal or dorsal tube. The upper part of the second tube begins with the mouth and is formed by the ribs and breastbone. Below the chest in the abdomen, the walls of this tube would be made up of the soft parts.

[Illustration: Fig. 9.--Diagrammatic Longitudinal Section of the Trunk and Head. (Showing the dorsal and the ventral tubes.)

A, the cranial cavity;
B, the cavity of the nose;
C, the mouth;
D, the alimentary canal represented as a simple straight tube;
E, the sympathetic nervous system;
F, heart;
G, diaphragm;
H, stomach;
K, end of spinal portion of cerebro-spinal nervous system.
]

We may say, then, that the body consists of two tubes or cavities, separated by a bony wall, the dorsal or nervous tube, so called because it contains the central parts of the nervous system; and the visceral or ventral tube, as it contains the viscera, or general organs of the body, as the alimentary canal, the heart, the lungs, the sympathetic nervous system, and other organs.

The more detailed study of the body may now be begun by a description of the skeleton or framework which supports the soft parts.

Experiments.

For general directions and explanations and also detailed suggestions for performing experiments, see Chapter XV.

Experiment 1. _To examine squamous epithelium._ With an ivory paper-knife scrape the back of the tongue or the inside of the lips or cheek; place the substance thus obtained upon a glass slide; cover it with a thin cover-glass, and if necessary add a drop of water. Examine with the microscope, and the irregularly formed epithelial cells will be seen.

Experiment 2. _To examine ciliated epithelium._ Open a frog's mouth, and with the back of a knife blade gently scrape a little of the membrane from the roof of the mouth. Transfer to a glass slide, add a drop of salt solution, and place over it a cover-glass with a hair underneath to prevent pressure upon the cells. Examine with a microscope under a high power. The cilia move very rapidly when quite fresh, and are therefore not easily seen.

For additional experiments which pertain to the microscopic examination of the elementary tissues and to other points in practical histology, see Chapter XV.

[NOTE. Inasmuch as most of the experimental work of this chapter depends upon the use of the microscope and also necessarily assumes a knowledge of facts which are discussed later, it would be well to postpone experiments in histology until they can be more satisfactorily handled in connection with kindred topics as they are met with in the succeeding chapters.]

Chapter II.

The Bones.

27. The Skeleton. Most animals have some kind of framework to support and protect the soft and fleshy parts of their bodies. This framework consists chiefly of a large number of bones, and is called the skeleton. It is like the keel and ribs of a vessel or the frame of a house, the foundation upon which the bodies are securely built.

There are in the adult human body 200 distinct bones, of many sizes and shapes. This number does not, however, include several small bones found in the tendons of muscles and in the ear. The teeth are not usually reckoned as separate bones, being a part of the structure of the skin.

The number of distinct bones varies at different periods of life. It is greater in childhood than in adults, for many bones which are then separate, to allow growth, afterwards become gradually united. In early adult life, for instance, the skull contains 22 naturally separate bones, but in infancy the number is much greater, and in old age far less.

The bones of the body thus arranged give firmness, strength, and protection to the soft tissues and vital organs, and also form levers for the muscles to act upon.

28. Chemical Composition of Bone. The bones, thus forming the framework of the body, are hard, tough, and elastic. They are twice as strong as oak; one cubic inch of compact bone will support a weight of 5000 pounds. Bone is composed of earthy or mineral matter (chiefly in the form of lime salts), and of animal matter (principally gelatine), in the proportion of two-thirds of the former to one-third of the latter.

[Illustration: Fig. 10.--The Skeleton.]

The proportion of earthy to animal matter varies with age. In infancy the bones are composed almost wholly of animal matter. Hence, an infant's bones are rarely broken, but its legs may soon become misshapen if walking is allowed too early. In childhood, the bones still contain a larger percentage of animal matter than in more advanced life, and are therefore more liable to bend than to break; while in old age, they contain a greater percentage of mineral matter, and are brittle and easily broken.

Experiment 3. _To show the mineral matter in bone_. Weigh a large soup bone; put it on a hot, clear fire until it is at a red heat. At first it becomes black from the carbon of its organic matter, but at last it turns white. Let it cool and weigh again. The animal matter has been burnt out, leaving the mineral or earthy part, a white, brittle substance of exactly the same shape, but weighing only about two-thirds as much as the bone originally weighed.

Experiment 4. _To show the animal matter in bone_. Add a teaspoonful of muriatic acid to a pint of water, and place the mixture in a shallow earthen dish. Scrape and clean a chicken's leg bone, part of a sheep's rib, or any other small, thin bone. Soak the bone in the acid mixture for a few days. The earthy or mineral matter is slowly dissolved, and the bone, although retaining its original form, loses its rigidity, and becomes pliable, and so soft as to be readily cut. If the experiment be carefully performed, a long, thin bone may even be tied into a knot.

[Illustration: Fig. 11.--The fibula tied into a knot, after the hard mineral matter has been dissolved by acid.]

29. Physical Properties of Bone. If we take a leg bone of a sheep, or a large end of beef shin bone, and saw it lengthwise in halves, we see two distinct structures. There is a hard and compact tissue, like ivory, forming the outside shell, and a spongy tissue inside having the appearance of a beautiful lattice work. Hence this is called cancellous tissue, and the gradual transition from one to the other is apparent.

It will also be seen that the shaft is a hollow cylinder, formed of compact tissue, enclosing a cavity called the medullary canal, which is filled with a pulpy, yellow fat called _marrow_. The marrow is richly supplied with blood-vessels, which enter the cavity through small openings in the compact tissue. In fact, all over the surface of bone are minute canals leading into the substance. One of these, especially constant and large in many bones, is called the _nutrient foramen_, and transmits an artery to nourish the bone.

At the ends of a long bone, where it expands, there is no medullary canal, and the bony tissue is spongy, with only a thin layer of dense bone around it. In flat bones we find two layers or plates of compact tissue at the surface, and a spongy tissue between. Short and irregular bones have no medullary canal, only a thin shell of dense bone filled with cancellous tissue.

[Illustration: Fig 12.--The Right femur sawed in two, lengthwise. (Showing arrangement of compact and cancellous tissue.)]

Experiment 5. Obtain a part of a beef shin bone, or a portion of a sheep's or calf's leg, including if convenient the knee joint. Have the bone sawed in two, lengthwise, keeping the marrow in place. Boil, scrape, and carefully clean one half. Note the compact and spongy parts, shaft, etc.

Experiment 6. Trim off the flesh from the second half. Note the pinkish white appearance of the bone, the marrow, and the tiny specks of blood, etc. Knead a small piece of the marrow in the palm; note the oily appearance. Convert some marrow into a liquid by heating. Contrast this fresh bone with an old dry one, as found in the fields. Fresh bones should be kept in a cool place, carefully wrapped in a damp cloth, while waiting for class use.

A fresh or living bone is covered with a delicate, tough, fibrous membrane, called the periosteum. It adheres very closely to the bone, and covers every part except at the joints and where it is protected with cartilage. The periosteum is richly supplied with blood-vessels, and plays a chief part in the growth, formation, and repair of bone. If a portion of the periosteum be detached by injury or disease, there is risk that a layer of the subjacent bone will lose its vitality and be cast off.[5]

30. Microscopic Structure of Bone. If a very thin slice of bone be cut from the compact tissue and examined under a microscope, numerous minute openings are seen. Around these are arranged rings of bone, with little black bodies in them, from which radiate fine, dark lines. These openings are sections of canals called _Haversian canals_, after Havers, an English physician, who first discovered them. The black bodies are minute cavities called _lacunae_, while the fine lines are very minute canals, _canaliculi_, which connect the lacunae and the Haversian canals. These Haversian canals are supplied with tiny blood-vessels, while the lacunae contain bone cells. Very fine branches from these cells pass into the canaliculi. The Haversian canals run lengthwise of the bone; hence if the bone be divided longitudinally these canals will be opened along their length (Fig. 13).

Thus bones are not dry, lifeless substances, but are the very type of activity and change. In life they are richly supplied with blood from the nutrient artery and from the periosteum, by an endless network of nourishing canals throughout their whole structure. Bone has, therefore, like all other living structures, a _self-formative_ power, and draws from the blood the materials for its own nutrition.

[Illustration: Fig. 13.

A, longitudinal section of bone, by which the Haversian canals are seen branching and communicating with one another;
B, cross section of a very thin slice of bone, magnified about 300 diameters--little openings (Haversian canals) are seen, and around them are ranged rings of bones with little black bodies (lacunae), from which branch out fine dark lines (canaliculi);
C, a bone cell, highly magnified, lying in lacuna.
]

The Bones of the Head.

31. The Head, or Skull. The bones of the skeleton, the bony framework of our bodies, may be divided into those of the head, the trunk, and the limbs.

The bones of the head are described in two parts,--those of the cranium, or brain-case, and those of the face. Taken together, they form the skull. The head is usually said to contain 22 bones, of which 8 belong to the cranium and 14 to the face. In early childhood, the bones of the head are separate to allow the brain to expand; but as we grow older they gradually unite, the better to protect the delicate brain tissue.

32. The Cranium. The cranium is a dome-like structure, made up in the adult of 8 distinct bones firmly locked together. These bones are:

One Frontal,
Two Parietal,
Two Temporal
One Occipital,
One Sphenoid,
One Ethmoid.

The frontal bone forms the forehead and front of the head. It is united with the two parietal bones behind, and extends over the forehead to make the roofs of the sockets of the eyes. It is this bone which, in many races of man, gives a dignity of person and a beauty of form seen in no other animal.

The parietal bones form the sides and roof of the skull. They are bounded anteriorly by the frontal bone, posteriorly by the occipital, and laterally by the temporal and sphenoid bones. The two bones make a beautiful arch to aid in the protection of the brain.

The temporal bones, forming the temples on either side, are attached to the sphenoid bone in front, the parietals above, and the occipital behind. In each temporal bone is the cavity containing the organs of hearing. These bones are so called because the hair usually first turns gray over them.

The occipital bone forms the lower part of the base of the skull, as well as the back of the head. It is a broad, curved bone, and rests on the topmost vertebra (atlas) of the backbone; its lower part is pierced by a large oval opening called the _foramen magnum_, through which the spinal cord passes from the brain (Fig. 15).

The sphenoid bone is in front of the occipital, forming a part of the base of the skull. It is wedged between the bones of the face and those of the cranium, and locks together fourteen different bones. It bears a remarkable resemblance to a bat with extended wings, and forms a series of girders to the arches of the cranium.

The ethmoid bone is situated between the bones of the cranium and those of the face, just at the root of the nose. It forms a part of the floor of the cranium. It is a delicate, spongy bone, and is so called because it is perforated with numerous holes like a sieve, through which the nerves of smell pass from the brain to the nose.

[Illustration: Fig. 14.--The Skull]

33. The Face. The bones of the face serve, to a marked extent, in giving form and expression to the human countenance. Upon these bones depend, in a measure, the build of the forehead, the shape of the chin, the size of the eyes, the prominence of the cheeks, the contour of the nose, and other marks which are reflected in the beauty or ugliness of the face.

The face is made up of fourteen bones which, with the exception of the lower jaw, are, like those of the cranium, closely interlocked with each other. By this union these bones help form a number of cavities which contain most important and vital organs. The two deep, cup-like sockets, called the orbits, contain the organs of sight. In the cavities of the nose is located the sense of smell, while the buccal cavity, or mouth, is the site of the sense of taste, and plays besides an important part in the first act of digestion and in the function of speech.

The bones of the face are:

Two Superior Maxillary,
Two Malar,
Two Nasal,
Two Lachrymal,
Two Palate,
Two Turbinated,
One Vomer,
One Lower Maxillary.

34. Bones of the Face. The superior maxillary or upper jawbones form a part of the roof of the mouth and the entire floor of the orbits. In them is fixed the upper set of teeth.

The malar or cheek bones are joined to the upper jawbones, and help form the sockets of the eyes. They send an arch backwards to join the temporal bones. These bones are remarkably thick and strong, and are specially adapted to resist the injury to which this part of the face is exposed.

The nasal or nose bones are two very small bones between the eye sockets, which form the bridge of the nose. Very near these bones are the two small lachrymal bones. These are placed in the inner angles of the orbit, and in them are grooves in which lie the ducts through which the tears flow from the eyes to the nose.

The palate bones are behind those of the upper jaw and with them form the bony part of the roof of the mouth. The inferior turbinated are spongy, scroll-like bones, which curve about within the nasal cavities so as to increase the surface of the air passages of the nose.

The vomer serves as a thin and delicate partition between the two cavities of the nose. It is so named from its resemblance to a ploughshare.

[Illustration: Fig. 15.--The Base of the Skull.

A, palate process of upper jawbone;
B, zygoma, forming zygomatic arch;
C, condyle for forming articulation with atlas;
D, foramen magnum;
E, occipital bone.
]

The longest bone in the face is the inferior maxillary, or lower jaw. It has a horseshoe shape, and supports the lower set of teeth. It is the only movable bone of the head, having a vertical and lateral motion by means of a hinge joint with a part of the temporal bone.

35. Sutures of the Skull. Before leaving the head we must notice the peculiar and admirable manner in which the edges of the bones of the outer shell of the skull are joined together. These edges of the bones resemble the teeth of a saw. In adult life these tooth-like edges fit into each other and grow together, suggesting the dovetailed joints used by the cabinet-maker. When united these serrated edges look almost as if sewed together; hence their name, sutures. This manner of union gives unity and strength to the skull.

In infants, the corners of the parietal bones do not yet meet, and the throbbing of the brain may be seen and felt under these "soft spots," or _fontanelles_, as they are called. Hence a slight blow to a babe's head may cause serious injury to the brain (Fig. 14).

The Bones of the Trunk.

36. The Trunk. The trunk is that central part of the body which supports the head and the upper pair of limbs. It divides itself into an upper cavity, the thorax, or chest; and a lower cavity, the abdomen. These two cavities are separated by a movable, muscular partition called the diaphragm, or midriff (Figs. 9 and 49).

The bones of the trunk are variously related to each other, and some of them become united during adult life into bony masses which at earlier periods are quite distinct. For example, the sacrum is in early life made up of five distinct bones which later unite into one.

The upper cavity, or chest, is a bony enclosure formed by the breastbone, the ribs, and the spine. It contains the heart and the lungs (Fig. 86).

The lower cavity, or abdomen, holds the stomach, liver, intestines, spleen, kidneys, and some other organs (Fig. 59).

The bones of the trunk may be subdivided into those of the spine, the ribs, and the hips.

The trunk includes 54 bones usually thus arranged:

I. Spinal Column, 26 bones:
  7 Cervical Vertebrae.
  12 Dorsal Vertebrae.
  5 Lumbar Vertebrae.
  1 Sacrum.
  1 Coccyx.

II. Ribs, 24 bones:
  14 True Ribs.
  6 False Ribs.
  4 Floating Ribs.

III. Sternum.

IV. Two Hip Bones.

V. Hyoid Bone.

37. The Spinal Column. The spinal column, or backbone, is a marvelous piece of mechanism, combining offices which nothing short of perfection in adaptation and arrangement could enable it to perform. It is the central structure to which all the other parts of the skeleton are adapted. It consists of numerous separate bones, called vertebrae. The seven upper ones belong to the neck, and are called cervical vertebrae. The next twelve are the dorsal vertebrae; these belong to the back and support the ribs. The remaining five belong to the loins, and are called lumbar vertebrae. On looking at the diagram of the backbone (Fig. 9) it will be seen that the vertebrae increase in size and strength downward, because of the greater burden they have to bear, thus clearly indicating that an erect position is the one natural to man.

[Illustration: Fig. 16.--The Spinal Column.]

This column supports the head, encloses and protects the spinal cord, and forms the basis for the attachment of many muscles, especially those which maintain the body in an erect position. Each vertebra has an opening through its center, and the separate bones so rest, one upon another, that these openings form a continuous canal from the head to the lower part of the spine. The great nerve, known as the spinal cord, extends from the cranium through the entire length of this canal. All along the spinal column, and between each two adjoining bones, are openings on each side, through which nerves pass out to be distributed to various parts of the body.

Between the vertebrae are pads or cushions of cartilage. These act as "buffers," and serve to give the spine strength and elasticity and to prevent friction of one bone on another. Each vertebra consists of a body, the solid central portion, and a number of projections called processes. Those which spring from the posterior of each arch are the spinous processes. In the dorsal region they are plainly seen and felt in thin persons.

The bones of the spinal column are arranged in three slight and graceful curves. These curves not only give beauty and strength to the bony framework of the body, but also assist in the formation of cavities for important internal organs. This arrangement of elastic pads between the vertebrae supplies the spine with so many elastic springs, which serve to break the effect of shock to the brain and the spinal cord from any sudden jar or injury.

The spinal column rests on a strong three-sided bone called the sacrum, or sacred-bone, which is wedged in between the hip bones and forms the keystone of the pelvis. Joined to the lower end of the sacrum is the coccyx, or cuckoo-bone, a tapering series of little bones.

Experiment 7. Run the tips of the fingers briskly down the backbone, and the spines of the vertebrae will be tipped with red so that they can be readily counted. Have the model lean forward with the arms folded across the chest; this will make the spines of the vertebrae more prominent.

Experiment 8. _To illustrate the movement of torsion in the spine, or its rotation round its own axis_. Sit upright, with the back and shoulders well applied against the back of a chair. Note that the head and neck can be turned as far as 60 degrees or 70 degrees. Now bend forwards, so as to let the dorsal and lumbar vertebrae come into play, and the head can be turned 30 degrees more.

Experiment 9. _To show how the spinal vertebrae make a firm but flexible column._ Take 24 hard rubber overcoat buttons, or the same number of two-cent pieces, and pile them on top of each other. A thin layer of soft putty may be put between the coins to represent the pads of cartilage between the vertebrae. The most striking features of the spinal column may be illustrated by this simple apparatus.

38. How the Head and Spine are Joined together. The head rests upon the spinal column in a manner worthy of special notice. This consists in the peculiar structure of the first two cervical vertebrae, known as the axis and atlas. The atlas is named after the fabled giant who supported the earth on his shoulders. This vertebra consists of a ring of bone, having two cup-like sockets into which fit two bony projections arising on either side of the great opening (_foramen magnum_) in the occipital bone. The hinge joint thus formed allows the head to nod forward, while ligaments prevent it from moving too far.

On the upper surface of the axis, the second vertebra, is a peg or process, called the _odontoid process_ from its resemblance to a tooth. This peg forms a pivot upon which the head with the atlas turns. It is held in its place against the front inner surface of the atlas by a band of strong ligaments, which also prevents it from pressing on the delicate spinal cord. Thus, when we turn the head to the right or left, the skull and the atlas move together, both rotating on the odontoid process of the axis.

39. The Ribs and Sternum. The barrel-shaped framework of the chest is in part composed of long, slender, curved bones called ribs. There are twelve ribs on each side, which enclose and strengthen the chest; they somewhat resemble the hoops of a barrel. They are connected in pairs with the dorsal vertebrae behind.

The first seven pairs, counting from the neck, are called the _true_ ribs, and are joined by their own special cartilages directly to the breastbone. The five lower pairs, called the _false_ ribs, are not directly joined to the breastbone, but are connected, with the exception of the last two, with each other and with the last true ribs by cartilages. These elastic cartilages enable the chest to bear great blows with impunity. A blow on the sternum is distributed over fourteen elastic arches. The lowest two pairs of false ribs, are not joined even by cartilages, but are quite free in front, and for this reason are called _floating_ ribs.

The ribs are not horizontal, but slope downwards from the backbone, so that when raised or depressed by the strong intercostal muscles, the size of the chest is alternately increased or diminished. This movement of the ribs is of the utmost importance in breathing (Fig. 91).

The sternum, or breastbone, is a long, flat, narrow bone forming the middle front wall of the chest. It is connected with the ribs and with the collar bones. In shape it somewhat resembles an ancient dagger.

40. The Hip Bones. Four immovable bones are joined together so as to form at the lower extremity of the trunk a basin-like cavity called the pelvis. These four bones are the sacrum and the coccyx, which have been described, and the two hip bones.

[Illustration: Fig. 17.--Thorax. (Anterior view.)]

The hip bones are large, irregularly shaped bones, very firm and strong, and are sometimes called the haunch bones or _ossa innominata_ (nameless bones). They are united to the sacrum behind and joined to each other in front. On the outer side of each hip bone is a deep cup, or socket, called the _acetabulum_, resembling an ancient vinegar cup, into which fits the rounded head of the thigh bone. The bones of the pelvis are supported like a bridge on the legs as pillars, and they in turn contain the internal organs in the lower part of the trunk.

41. The Hyoid Bone. Under the lower jaw is a little horseshoe shaped bone called the hyoid bone, because it is shaped like the Greek letter upsilon ([Greek: u]). The root of the tongue is fastened to its bend, and the larynx is hung from it as from a hook. When the neck is in its natural position this bone can be plainly felt on a level with the lower jaw and about one inch and a half behind it. It serves to keep open the top of the larynx and for the attachment of the muscles, which move the tongue. (See Fig. 46.) The hyoid bone, like the knee-pan, is not connected with any other bone.

The Bones of the Upper Limbs.

42. The Upper Limbs. Each of the upper limbs consist of the upper arm, the forearm, and the hand. These bones are classified as follows:

Upper Arm:
  Scapula, or shoulder-blade,
  Clavicle, or collar bone,
  Humerus, or arm bone,

Forearm:
  Ulna,
  Radius,

Hand:
  8 Carpal or wrist bones,
  5 Metacarpal bones,
  14 Phalanges, or finger bones,

making 32 bones in all.

43. The Upper Arm. The two bones of the shoulder, the scapula and the clavicle, serve in man to attach the arm to the trunk. The scapula, or shoulder-blade, is a flat, triangular bone, placed point downwards, and lying on the upper and back part of the chest, over the ribs. It consists of a broad, flat portion and a prominent ridge or _spine_. At its outer angle it has a shallow cup known as the _glenoid cavity_. Into this socket fits the rounded head of the humerus. The shoulder-blade is attached to the trunk chiefly by muscles, and is capable of extensive motion.

The clavicle, or collar bone, is a slender bone with a double curve like an italic _f_, and extends from the outer angle of the shoulder-blade to the top of the breastbone. It thus serves like the keystone of an arch to hold the shoulder-blade firmly in its place, but its chief use is to keep the shoulders wide apart, that the arm may enjoy a freer range of motion. This bone is often broken by falls upon the shoulder or arm.

The humerus is the strongest bone of the upper extremity. As already mentioned, its rounded head fits into the socket of the shoulder-blade, forming a ball-and-socket joint, which permits great freedom of motion. The shoulder joint resembles what mechanics call a universal joint, for there is no part of the body which cannot be touched by the hand.

[Illustration: Fig. 18.--Left Scapula, or Shoulder-Blade.]

When the shoulder is dislocated the head of the humerus has been forced out of its socket. The lower end of the bone is grooved to help form a hinge joint at the elbow with the bones of the forearm (Fig. 27).

44. The Forearm. The forearm contains two long bones, the ulna and the radius. The ulna, so called because it forms the elbow, is the longer and larger bone of the forearm, and is on the same side as the little finger. It is connected with the humerus by a hinge joint at the elbow. It is prevented from moving too far back by a hook-like projection called the _olecranon process_, which makes the sharp point of the elbow.

The radius is the shorter of the two bones of the forearm, and is on the same side as the thumb. Its slender, upper end articulates with the ulna and humerus; its lower end is enlarged and gives attachment in part to the bones of the wrist. This bone radiates or turns on the ulna, carrying the hand with it.

> Experiment 10. Rest the forearm on a table, with the palm up (an attitude called supination). The radius is on the outer side and parallel with the ulna If now, without moving the elbow, we turn the hand (pronation), as if to pick up something from the table, the radius may be seen and felt crossing over the ulna, while the latter has not moved.

[Illustration: Fig. 19.--Left Clavicle, or Collar Bone. (Anterior surface.)]

45. The Hand. The hand is the executive or essential part of the upper limb. Without it the arm would be almost useless. It consists of 27 separate bones, and is divided into three parts, the wrist, the palm, and the fingers.

[Illustration: Fig. 20.--Left Humerus.]

[Illustration: Fig. 21.--Left Radius and Ulna.]

The carpus, or wrist, includes 8 short bones, arranged in two rows of four each, so as to form a broad support for the hand. These bones are closely packed, and tightly bound with ligaments which admit of ample flexibility. Thus the wrist is much less liable to be broken than if it were to consist of a single bone, while the elasticity from having the eight bones movable on each other, neutralizes, to a great extent, a shock caused by falling on the hands. Although each of the wrist bones has a very limited mobility in relation to its neighbors, their combination gives the hand that freedom of action upon the wrist, which is manifest in countless examples of the most accurate and delicate manipulation.

The metacarpal bones are the five long bones of the back of the hand. They are attached to the wrist and to the finger bones, and may be easily felt by pressing the fingers of one hand over the back of the other. The metacarpal bones of the fingers have little freedom of movement, while the thumb, unlike the others, is freely movable. We are thus enabled to bring the thumb in opposition to each of the fingers, a matter of the highest importance in manipulation. For this reason the loss of the thumb disables the hand far more than the loss of either of the fingers. This very significant opposition of the thumb to the fingers, furnishing the complete grasp by the hand, is characteristic of the human race, and is wanting in the hand of the ape, chimpanzee, and ourang-outang.

The phalanges, or finger bones, are the fourteen small bones arranged in three rows to form the fingers. Each finger has three bones; each thumb, two.

The large number of bones in the hand not only affords every variety of movement, but offers great resistance to blows or shocks. These bones are united by strong but flexible ligaments. The hand is thus given strength and flexibility, and enabled to accomplish the countless movements so necessary to our well-being.

In brief, the hand is a marvel of precise and adapted mechanism, capable not only of performing every variety of work and of expressing many emotions of the mind, but of executing its orders with inconceivable rapidity.

The Bones of the Lower Limbs.

46. The Lower Limbs. The general structure and number of the bones of the lower limbs bear a striking similarity to those of the upper limbs. Thus the leg, like the arm, is arranged in three parts, the thigh, the lower leg, and the foot. The thigh bone corresponds to the humerus; the tibia and fibula to the ulna and radius; the ankle to the wrist; and the metatarsus and the phalanges of the foot, to the metacarpus and the phalanges of the hand.

The bones of the lower limbs may be thus arranged:

Thigh: Femur, or thigh bone,

Lower Leg:
- Patella, or knee cap,
- Tibia, or shin bone,
- Fibula, or splint bone,

Foot:
- 7 Tarsal or ankle bones,
- 5 Metatarsal or instep bones,
- 14 Phalanges, or toes bones,

making 30 bones in all.

[Illustration: Fig. 22.--Right Femur, or Thigh Bone.]

47. The Thigh. The longest and strongest of all the bones is the femur, or thigh bone. Its upper end has a rounded head which fits into the _acetabulum_, or the deep cup-like cavity of the hip bone, forming a perfect ball-and-socket joint. When covered with cartilage, the ball fits so accurately into its socket that it may be retained by atmospheric pressure alone (sec. 50).

The shaft of the femur is strong, and is ridged and roughened in places for the attachment of the muscles. Its lower end is broad and irregularly shaped, having two prominences called _condyles_, separated by a groove, the whole fitted for forming a hinge joint with the bones of the lower leg and the knee-cap.

48. The Lower Leg. The lower leg, like the forearm, consists of two bones. The tibia, or shin bone, is the long three-sided bone forming the front of the leg. The sharp edge of the bone is easily felt just under the skin. It articulates with the lower end of the thigh bone, forming with it a hinge joint.

The fibula, the companion bone of the tibia, is the long, slender bone on the outer side of the leg. It is firmly fixed to the tibia at each end, and is commonly spoken of as the small bone of the leg. Its lower end forms the outer projection of the ankle. In front of the knee joint, embedded in a thick, strong tendon, is an irregularly disk-shaped bone, the patella, or knee-cap. It increases the leverage of important muscles, and protects the front of the knee joint, which is, from its position, much exposed to injury.

[Illustration: Fig. 23.--Patella, or Knee-Cap.]

49. The Foot. The bones of the foot, 26 in number, consist of the tarsal bones, the metatarsal, and the phalanges. The tarsal bones are the seven small, irregular bones which make up the ankle. These bones, like those of the wrist, are compactly arranged, and are held firmly in place by ligaments which allow a considerable amount of motion.

One of the ankle bones, the _os calcis_, projects prominently backwards, forming the heel. An extensive surface is thus afforded for the attachment of the strong tendon of the calf of the leg, called the tendon of Achilles. The large bone above the heel bone, the _astragalus_, articulates with the tibia, forming a hinge joint, and receives the weight of the body.

The metatarsal bones, corresponding to the metacarpals of the hand, are five in number, and form the lower instep.

The phalanges are the fourteen bones of the toes,--three in each except the great toe, which, like the thumb, has two. They resemble in number and plan the corresponding bones in the hand. The bones of the foot form a double arch,--an arch from before backwards, and an arch from side to side. The former is supported behind by the os calcis, and in front by the ends of the metatarsal bones. The weight of the body falls perpendicularly on the astragalus, which is the key-bone or crown of the arch. The bones of the foot are kept in place by powerful ligaments, combining great strength with elasticity.

[Illustration: Fig. 24.--Right Tibia and Fibula (Anterior surface.)]

[Illustration: Fig. 25.--Bones of Right Foot. (Dorsal surface.)]

The Joints.

50. Formation of Joints. The various bones of the skeleton are connected together at different parts of their surfaces by joints, or articulations. Many different kinds of joints have been described, but the same general plan obtains for nearly all. They vary according to the kind and the amount of motion.

The principal structures which unite in the formation of a joint are: bone, cartilage, synovial membrane, and ligaments. Bones make the chief element of all the joints, and their adjoining surfaces are shaped to meet the special demands of each joint (Fig. 27). The joint-end of bones is coated with a thin layer of tough, elastic cartilage. This is also used at the edge of joint-cavities, forming a ring to deepen them. The rounded heads of bones which move in them are thus more securely held in their sockets.

Besides these structures, the muscles also help to maintain the joint-surfaces in proper relation. Another essential to the action of the joints is the pressure of the outside air. This may be sufficient to keep the articular surfaces in contact even after all the muscles are removed. Thus the hip joint is so completely surrounded by ligaments as to be air-tight; and the union is very strong. But if the ligaments be pierced and air allowed to enter the joint, the union at once becomes much less close, and the head of the thigh bone falls away as far as the ligaments will allow it.

51. Synovial Membrane. A very delicate connective tissue, called the synovial membrane, lines the capsules of the joints, and covers the ligaments connected with them. It secretes the _synovia_, or joint oil, a thick and glairy fluid, like the white of a raw egg, which thoroughly lubricates the inner surfaces of the joints. Thus the friction and heat developed by movement are reduced, and every part of a joint is enabled to act smoothly.

52. Ligaments. The bones are fastened together, held in place, and their movements controlled, to a certain extent, by bands of various forms, called ligaments. These are composed mainly of bundles of white fibrous tissue placed parallel to, or closely interlaced with, one another, and present a shining, silvery aspect. They extend from one of the articulating bones to another, strongly supporting the joint, which they sometimes completely envelope with a kind of cap (Fig. 28). This prevents the bones from being easily dislocated. It is difficult, for instance, to separate the two bones in a shoulder or leg of mutton, they are so firmly held together by tough ligaments.

While ligaments are pliable and flexible, permitting free movement, they are also wonderfully strong and inextensible. A bone may be broken, or its end torn off, before its ligaments can be ruptured. The wrist end of the radius, for instance, is often torn off by force exerted on its ligaments without their rupture.

The ligaments are so numerous and various and are in some parts so interwoven with each other, that space does not allow even mention of those that are important. At the knee joint, for instance, there are no less than fifteen distinct ligaments.

53. Imperfect Joints. It is only perfect joints that are fully equipped with the structures just mentioned. Some joints lack one or more, and are therefore called imperfect joints. Such joints allow little or no motion and have no smooth cartilages at their edges. Thus, the bones of the skull are dovetailed by joints called sutures, which are immovable. The union between the vertebrae affords a good example of imperfect joints which are partially movable.

[Illustration: Fig. 26.--Elastic Tissue from the Ligaments about Joints. (Highly magnified.)]

54. Perfect Joints. There are various forms of perfect joints, according to the nature and amount of movement permitted. They an divided into hinge joints, ball-and-socket joints and pivot joints.

The hinge joints allow forward and backward movements like a hinge. These joints are the most numerous in the body, as the elbow, the ankle, and the knee joints.

In the ball-and-socket joints--a beautiful contrivance--the rounded head of one bone fits into a socket in the other, as the hip joint and shoulder joint. These joints permit free motion in almost every direction.

In the pivot joint a kind of peg in one bone fits into a notch in another. The best example of this is the joint between the first and second vertebrae (see sec. 38). The radius moves around on the ulna by means of a pivot joint. The radius, as well as the bones of the wrist and hand, turns around, thus enabling us to turn the palm of the hand upwards and downwards. In many joints the extent of motion amounts to only a slight gliding between the ends of the bones.

55. Uses of the Bones. The bones serve many important and useful purposes. The skeleton, a general framework, affords protection, support, and leverage to the bodily tissues. Thus, the bones of the skull and of the chest protect the brain, the lungs, and the heart; the bones of the legs support the weight of the body; and the long bones of the limbs are levers to which muscles are attached.

Owing to the various duties they have to perform, the bones are constructed in many different shapes. Some are broad and flat; others, long and cylindrical; and a large number very irregular in form. Each bone is not only different from all the others, but is also curiously adapted to its particular place and use.

[Illustration: Fig. 27.--Showing how the Ends of the Bones are shaped to form the Elbow Joint. (The cut ends of a few ligaments are seen.)]

Nothing could be more admirable than the mechanism by which each one of the bones is enabled to fulfill the manifold purposes for which it was designed. We have seen how the bones of the cranium are united by sutures in a manner the better to allow the delicate brain to grow, and to afford it protection from violence. The arched arrangement of the bones of the foot has several mechanical advantages, the most important being that it gives firmness and elasticity to the foot, which thus serves as a support for the weight of the body, and as the chief instrument of locomotion.

The complicated organ of hearing is protected by a winding series of minute apartments, in the rock-like portion of the temporal bone. The socket for the eye has a jutting ridge of bone all around it, to guard the organ of vision against injury. Grooves and canals, formed in hard bone, lodge and protect minute nerves and tiny blood-vessels. The surfaces of bones are often provided with grooves, sharp edges, and rough projections, for the origin and insertion of muscles.

[Illustration: Fig. 28.--External Ligaments of the Knee.]

56. The Bones in Infancy and Childhood. The bones of the infant, consisting almost wholly of cartilage, are not stiff and hard as in after life, but flexible and elastic. As the child grows, the bones become more solid and firmer from a gradually increased deposit of lime salts. In time they become capable of supporting the body and sustaining the action of the muscles. The reason is that well-developed bones would be of no use to a child that had not muscular strength to support its body. Again, the numerous falls and tumbles that the child sustains before it is able to walk, would result in broken bones almost every day of its life. As it is, young children meet with a great variety of falls without serious injury.

But this condition of things has its dangers. The fact that a child's bones bend easily, also renders them liable to permanent change of shape. Thus, children often become bow-legged when allowed to walk too early. Moderate exercise, however, even in infancy, promotes the health of the bones as well as of the other tissues. Hence a child may be kept too long in its cradle, or wheeled about too much in a carriage, when the full use of its limbs would furnish proper exercise and enable it to walk earlier.

57. Positions at School. Great care must be exercised by teachers that children do not form the habit of taking injurious positions at school. The desks should not be too low, causing a forward stoop; or too high, throwing one shoulder up and giving a twist to the spine. If the seats are too low there will result an undue strain on the shoulder and the backbone; if too high, the feet have no proper support, the thighs may be bent by the weight of the feet and legs, and there is a prolonged strain on the hips and back. Curvature of the spine and round shoulders often result from long-continued positions at school in seats and at desks which are not adapted to the physical build of the occupant.

[Illustration: Fig. 29.--Section of the Knee Joint. (Showing its internal structure)

A, tendon of the semi-membranosus muscle cut across;
B, F, tendon of same muscle;
C, internal condyle of femur;
D, posterior crucial ligament;
E, internal interarticular fibro cartilage;
G, bursa under knee-cap;
H, ligament of knee-cap;
K, fatty mass under knee-cap;
L, anterior crucial ligament cut across;
P, patella, or knee-cap
]

A few simple rules should guide teachers and school officials in providing proper furniture for pupils. Seats should be regulated according to the size and age of the pupils, and frequent changes of seats should be made. At least three sizes of desks should be used in every schoolroom, and more in ungraded schools. The feet of each pupil should rest firmly on the floor, and the edge of the desk should be about one inch higher than the level of the elbows. A line dropped from the edge of the desk should strike the front edge of the seat. Sliding down into the seat, bending too much over the desk while writing and studying, sitting on one foot or resting on the small of the back, are all ungraceful and unhealthful positions, and are often taken by pupils old enough to know better. This topic is well worth the vigilance of every thoughtful teacher, especially of one in the lower grades.

58. The Bones in After Life. Popular impression attributes a less share of life, or a lower grade of vitality, to the bones than to any other part of the body. But really they have their own circulation and nutrition, and even nervous relations. Thus, bones are the seat of active vital processes, not only during childhood, but also in adult life, and in fact throughout life, except perhaps in extreme old age. The final knitting together of the ends of some of the bones with their shafts does not occur until somewhat late in life. For example, the upper end of the tibia and its shaft do not unite until the twenty-first year. The separate bones of the sacrum do not fully knit into one solid bone until the twenty-fifth year. Hence, the risk of subjecting the bones of young persons to undue violence from injudicious physical exercise as in rowing, baseball, football, and bicycle-riding.

The bones during life are constantly going through the process of absorption and reconstruction. They are easily modified in their growth. Thus the continued pressure of some morbid deposit, as a tumor or cancer, or an enlargement of an artery, may cause the absorption or distortion of bones as readily as of one of the softer tissues. The distortion resulting from tight lacing is a familiar illustration of the facility with which the bones may be modified by prolonged pressure.

Some savage races, not content with the natural shape of the head, take special methods to mould it by continued artificial pressure, so that it may conform in its distortion to the fashion of their tribe or race. This custom is one of the most ancient and widespread with which we are acquainted. In some cases the skull is flattened, as seen in certain Indian tribes on our Pacific coast, while with other tribes on the same coast it is compressed into a sort of conical appearance. In such cases the brain is compelled, of course, to accommodate itself to the change in the shape of the head; and this is done, it is said, without any serious result.

59. Sprains and Dislocations. A twist or strain of the ligaments and soft parts about a joint is known as a sprain, and may result from a great variety of accidents. When a person falls, the foot is frequently caught under him, and the twist comes upon the ligaments and tissues of the ankle. The ligaments cannot stretch, and so have to endure the wrench upon the joint. The result is a sprained ankle. Next to the ankle, a sprain of the wrist is most common. A person tries, by throwing out his hand, to save himself from a fall, and the weight of the body brings the strain upon the firmly fixed wrist. As a result of a sprain, the ligaments may be wrenched or torn, and even a piece of an adjacent bone may be torn off; the soft parts about the injured joint are bruised, and the neighboring muscles put to a severe stretch. A sprain may be a slight affair, needing only a brief rest, or it may be severe and painful enough to call for the most skillful treatment by a surgeon. Lack of proper care

in severe sprains often results in permanent lameness.

A fall or a blow may bring such a sudden wrench or twist upon the ligaments as to force a bone out of place. This displacement is known as a dislocation. A child may trip or fall during play and put his elbow out of joint. A fall from horseback, a carriage, or a bicycle may result in a dislocation of the shoulder joint. In playing baseball a swift ball often knocks a finger out of joint. A dislocation must be reduced at once. Any delay or carelessness may make a serious and painful affair of it, as the torn and bruised parts rapidly swell and become extremely sensitive.

60. Broken Bones. The bones, especially those of the upper limbs, are often fractured or broken. The _simple_ fracture is the most common form, the bone being broken in a single place with no opening through the skin. When properly adjusted, the bone heals rapidly. Sometimes bones are crushed into a number of fragments; this is a _comminuted_ fracture. When, besides the break, there is an opening through the soft parts and surface of the body, we have a _compound_ fracture. This is a serious injury, and calls for the best surgical treatment.

A bone may be bent, or only partly broken, or split. This is called "a green-stick fracture," from its resemblance to a half-broken green stick. This fracture is more common in the bones of children.

Fractures may be caused by direct violence, as when a bone is broken at a certain point by some powerful force, as a blow from a baseball bat or a fall from a horse. Again, a bone may be broken by indirect violence, as when a person being about to fall, throws out his hand to save himself. The force of the fall on the hand often breaks the wrist, by which is meant the fracture of the lower end of the radius, often known as the "silver-fork fracture." This accident is common in winter from a fall or slip on the ice.

Sometimes bones are broken at a distance from the point of injury, as in a fracture of the ribs by violent compression of the chest; or fracture may occur from the vibration of a blow, as when a fall or blow upon the top of the head produces fracture of the bones at the base of the brain.[6]

61. Treatment for Broken Bones. When a bone is broken a surgeon is needed to set it, that is, to bring the broken parts into their natural position, and retain them by proper appliances. Nature throws out between and around the broken ends of bones a supply of repair material known as plastic lymph, which is changed to fibrous tissue, then to cartilage, and finally to bone. This material serves as a sort of cement to hold the fractured parts together. The excess of this at the point of union can be felt under the skin for some time after the bone is healed.

With old people a broken bone is often a serious matter, and may cripple them for life or prove fatal. A trifling fall, for instance, may cause a broken hip (popularly so called, though really a fracture of the neck of the femur), from the shock of which, and the subsequent pain and exhaustion, an aged person may die in a few weeks. In young people, however, the parts of a broken bone will knit together in three or four weeks after the fracture is reduced; while in adults, six or even more may be required for firm union. After a broken bone is strong enough to be used, it is fragile for some time; and great care must be taken, especially with children, that the injured parts may not be broken again before perfect union takes place.[7]

62. The Effect of Alcohol upon the Bones. While the growth of the bones occurs, of course, mainly during the earlier years of life, yet they do not attain their full maturity until about the twenty-fifth year; and it is stated that in persons devoted to intellectual pursuits, the skull grows even after that age. It is plainly necessary that during this period of bone growth the nutrition of the body should be of the best, that the bones may be built up from pure blood, and supplied with all the materials for a large and durable framework. Else the body will be feeble and stunted, and so through life fall short of its purpose.

If this bony foundation be then laid wrong, the defect can never be remedied. This condition is seen in young persons who have been underfed and overworked. But the use of alcoholic liquors produces a similar effect, hindering bone cell-growth and preventing full development.[8] The appetite is diminished, nutrition perverted and impaired, the stature stunted, and both bodily and mental powers are enfeebled.

63. Effect of Tobacco upon the Bones. Another narcotic, the destructive influence of which is wide and serious, is tobacco. Its pernicious influence, like that of alcohol, is peculiarly hurtful to the young, as the cell development during the years of growth is easily disturbed by noxious agents. The bone growth is by cells, and a powerful narcotic like tobacco retards cell-growth, and thus hinders the building up of the bodily frame. The formation of healthy bone demands good, nutritious blood, but if instead of this, the material furnished for the production of blood is poor in quality or loaded with poisonous narcotics, the body thus defrauded of its proper building material becomes undergrown and enfeebled.

Two unfavorable facts accompany this serious drawback: one is, that owing to the insidious nature of the smoky poison[9] (cigarettes are its worst form) the cause may often be unsuspected, and so go on, unchecked; and the other, that the progress of growth once interrupted, the gap can never be fully made up. Nature does her best to repair damages and to restore defects, but never goes backwards to remedy neglects.

Additional Experiments.

Experiment 11. Take a portion of the decalcified bone obtained from Experiment 4, and wash it thoroughly in water: in this it is insoluble. Place it in a solution of carbonate of soda and wash it again. Boil it in water, and from it gelatine will be obtained.

Experiment 12. Dissolve in hydrochloric acid a small piece of the powdered bone-ash obtained from Experiment 3. Bubbles of carbon dioxid are given off, indicating the presence of a carbonate. Dilute the solution; add an excess of ammonia, and we find a white precipitate of the phosphate of lime and of magnesia.

Experiment 13. Filter the solution in the preceding experiment, and to the filtrate add oxalate of ammonia. The result is a white precipitate of the oxalate of lime, showing there is lime present, but not as a phosphate.

Experiment 14. To the solution of mineral matters obtained from Experiment 3, add acetate of soda until free acetic acid is present, recognized by the smell (like dilute vinegar); then add oxalate of ammonia. The result will be a copious white precipitate of lime salts.

Experiment 15. _To show how the cancellous structure of bone is able to support a great deal of weight_. Have the market-man saw out a cubic inch from the cancellous tissue of a fresh beef bone and place it on a table with its principal layers upright. Balance a heavy book upon it, and then gradually place upon it various articles and note how many pounds it will support before giving way.

Experiment 16. Repeat the last experiment, using a cube of the decalcified bone obtained from Experiment 4.

[NOTE. As the succeeding chapters are studied, additional experiments on bones and their relation to other parts of the body, will readily suggest themselves to the ingenious instructor or the thoughtful student. Such experiments may be utilized for review or other exercises.]

Review Analysis: The Skeleton (206 bones).

```
             /                / 1 Frontal,
            /                /  2 Parietal,
           /    I. Cranium  |   2 Temporal,
          /      (8 bones)  |   1 Occipital,
         /                   \  1 Sphenoid,
        |                     \ 1 Ethmoid.
        |
        |                     / 2 Superior Maxillary,
 The Head    |               /  2 Malar,
(28 bones).  |              /   2 Nasal,
        |      II. Face    |    2 Lachrymal Bones,
        |     (14 bones)   |    2 Palate Bones,
        |                   \   2 Turbinated,
        |                    \  1 Vomer,
        \                     \ 1 Lower Maxillary.
         \
          \              / Hammer,
           \  III. The Ear  |  Anvil,
            \   (6 bones)    \ Stirrup.

           /                     /  7 Cervical Vertebrae.
          /                     /  12 Dorsal Vertebrae,
         /     I. Spinal Column  |    5 Lumbar Vertebrae,
        |         (26 bones)      \     Sacrum,
        |                          \    Coccyx.
 The Trunk   |
(54 bones).  |                    /  7 True Ribs,
        |      II. The Ribs   |   3 False Ribs,
        |       (24 bones)     \  2 Floating Ribs.
        |
         \    III. Sternum.
          \    IV. Two Hip Bones.
           \    V. Hyoid Bone.


              /                 /   Scapula,
             /     I. Upper Arm  |    Clavicle,
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               |                    \   Humerus.
               |
 The Upper Limbs  |      II. Forearm    /    Ulna,
   (64 bones).    |                   \    Radius.
               |
               |                 /  8 Carpal Bones,
                \    III. Hand      |   5 Metacarpal Bones,
                 \                 \ 14 Phalanges.

                 /     I. Thigh           Femur.
                /
               |                  /   Patella,
 The Lower Limbs  |      II. Lower Leg  |    Tibia,
   (60 bones).    |                    \   Fibula.
               |
               |                 /  7 Tarsal Bones,
                \    III. Foot      |   5 Metatarsal Bones,
                 \                 \ 14 Phalanges.
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Chapter III.

The Muscles.

64. Motion in Animals. All motion of our bodies is produced by means of muscles. Not only the limbs are moved by them, but even the movements of the stomach and of the heart are controlled by muscles. Every part of the body which is capable of motion has its own special set of muscles.

Even when the higher animals are at rest it is possible to observe some kind of motion in them. Trees and stones never move unless acted upon by external force, while the infant and the tiniest insect can execute a great variety of movements. Even in the deepest sleep the beating of the heart and the motion of the chest never cease. In fact, the power to execute spontaneous movement is the most characteristic property of living animals.

65. Kinds of Muscles. Most of the bodily movements, such as affect the limbs and the body as a whole, are performed by muscles under our control. These muscles make up the red flesh or lean parts, which, together with the fat, clothe the bony framework, and give to it general form and proportion. We call these muscular tissues voluntary muscles, because they usually act under the control of the will.

The internal organs, as those of digestion, secretion, circulation, and respiration, perform their functions by means of muscular activity of another kind, that is, by that of muscles not under our control. This work goes on quite independently of the will, and during sleep. We call the instruments of this activity involuntary muscles. The voluntary muscles, from peculiarities revealed by the microscope, are also known as striped or striated muscles. The involuntary from their smooth, regular appearance under the microscope are called the unstriped or non-striated muscles.

The two kinds of muscles, then, are the red, voluntary, striated muscles, and the smooth, involuntary, non-striated muscles.

66. Structure of Voluntary Muscles. The main substance which clothes the bony framework of the body, and which forms about two-fifths of its weight, is the voluntary muscular tissue. These muscles do not cover and surround the bones in continuous sheets, but consist of separate bundles of flesh, varying in size and length, many of which are capable of independent movement.

Each muscle has its own set of blood-vessels, lymphatics, and nerves. It is the blood that gives the red color to the flesh. Blood-vessels and nerves on their way to other parts of the body, do not pass through the muscles, but between them. Each muscle is enveloped in its own sheath of connective tissue, known as the fascia. Muscles are not usually connected directly with bones, but by means of white, glistening cords called tendons.

[Illustration: Fig. 30.--Striated (voluntary) Muscular Fibers.

A, fiber serparating into disks;
B, fibrillae (highly magnified);
C, cross section of a disk
]

If a small piece of muscle be examined under a microscope it is found to be made up of bundles of fibers. Each fiber is enclosed within a delicate, transparent sheath, known as the sarcolemma. If one of these fibers be further examined under a microscope, it will be seen to consist of a great number of still more minute fibers called fibrillae. These fibers are also seen marked cross-wise with dark stripes, and can be separated at each stripe into disks. These cross markings account for the name _striped_ or _striated_ muscle.

The fibrillae, then, are bound together in a bundle to form a fiber, which is enveloped in its own sheath, the sarcolemma. These fibers, in turn, are further bound together to form larger bundles called fasciculi, and these, too, are enclosed in a sheath of connective tissue. The muscle itself is made up of a number of these fasciculi bound together by a denser layer of connective tissue.

Experiment 17. _To show the gross structure of muscle._ Take a small portion of a large muscle, as a strip of lean corned beef. Have it boiled until its fibers can be easily separated. Pick the bundles and fasciculi apart until the fibers are so fine as to be almost invisible to the naked eye. Continue the experiment with the help of a hand magnifying glass or a microscope.

67. The Involuntary Muscles. These muscles consist of ribbon-shaped bands which surround hollow fleshy tubes or cavities. We might compare them to India rubber rings on rolls of paper. As they are never attached to bony levers, they have no need of tendons.

[Illustration: Fig. 31.--A, Muscular Fiber, showing Stripes, and Nuclei, b and c. (Highly magnified.)]

The microscope shows these muscles to consist not of fibers, but of long spindle-shaped cells, united to form sheets or bands. They have no sarcolemma, stripes, or cross markings like those of the voluntary muscles. Hence their name of _non-striated_, or _unstriped_, and _smooth_ muscles.

The involuntary muscles respond to irritation much less rapidly than do the voluntary. The wave of contraction passes over them more slowly and more irregularly, one part contracting while another is relaxing. This may readily be seen in the muscular action of the intestines, called vermicular motion. It is the irregular and excessive contraction of the muscular walls of the bowels that produces the cramp-like pains of colic.

The smooth muscles are found in the tissues of the heart, lungs, blood-vessels, stomach, and intestines. In the stomach their contraction produces the motion by which the food is churned about; in the arteries and veins they help supply the force by which the blood is driven along, and in the intestines that by which the partly digested food is mainly kept in motion.

Thus all the great vital functions are carried on, regardless of the will of the individual, or of any outward circumstances. If it required an effort of the will to control the action of the internal organs we could not think of anything else. It would take all our time to attend to living. Hence the care of such delicate and important machinery has wisely been put beyond our control.

Thus, too, these muscles act instinctively without training; but the voluntary need long and careful education. A babe can use the muscles of swallowing on the first day of its life as well as it ever can. But as it grows up, long and patient education of its voluntary muscles is needed to achieve walking, writing, use of musical instruments, and many other acts of daily life.

[Illustration: Fig. 32.--A Spindle Cell of Involuntary Muscle. (Highly magnified.)]

Experiment 18. _To show the general appearance of the muscles._ Obtain the lower part of a sheep's or calf's leg, with the most of the lean meat and the hoof left on. One or more of the muscles with their bundles of fibers, fascia, and tendons; are readily made out with a little careful dissection. The dissection should be made a few days before it is wanted and the parts allowed to harden somewhat in dilute alcohol.

68. Properties of Muscular Tissue. The peculiar property of living muscular tissue is irritability, or the capacity of responding to a stimulus. When a muscle is irritated it responds by contracting. By this act the muscle does not diminish its bulk to any extent; it simply changes its form. The ends of the muscle are drawn nearer each other and the middle is thicker.

Muscles do not shorten themselves all at once, but the contraction passes quickly over them in the form of a wave. They are usually stimulated by nervous action. The delicate nerve fibrils which end in the fibers communicate with the brain, the center of the will power. Hence, when the brain commands, a nervous impulse, sent along the nerve fibers, becomes the exciting stimulus which acts upon the muscles and makes them shorter, harder, and more rigid.[10]

Muscles, however, will respond to other than this usual stimulus. Thus an electrical current may have a similar effect. Heat, also, may produce muscular contraction. Mechanical means, such as a sharp blow or pinching, may irritate a muscle and cause it to contract.

We must remember that this property of contraction is inherent and belongs to the muscle itself. This power of contraction is often independent of the brain. Thus, on pricking the heart of a fish an hour after removal from its body, obvious contraction will occur. In this case it is not the nerve force from the brain that supplies the energy for contraction. The power of contraction is inherent in the muscle substance, and the stimulus by irritating the nerve ganglia of the heart simply affords the opportunity for its exercise.

Contraction is not, however, the natural state of a muscle. In time it is tired, and begins to relax. Even the heart, the hardest-working muscle, has short periods of rest between its beats. Muscles are highly elastic as well as contractile. By this property muscle yields to a stretching force, and returns to its original length if the stretching has not been excessive.

[Illustration: Fig. 33.--Principal Muscles of the Body. (Anterior view.)]

69. The Object of Contraction. The object of contraction is obvious. Like rubber bands, if one end of a muscle be fixed and the other attached to some object which is free to move, the contraction of the muscle will bring the movable body nearer to the fixed point. A weight fastened to the free end of a muscle may be lifted when the muscle contracts. Thus by their contraction muscles are able to do their work. They even contract more vigorously when resistance is opposed to them than when it is not. With increased weight there is an increased amount of work to be done. The greater resistance calls forth a greater action of the muscle. This is true up to a certain point, but when the limit has been passed, the muscle quickly fails to respond.

Again, muscles work best with a certain degree of rapidity provided the irritations do not follow each other too rapidly. If, however, the contractions are too rapid, the muscles become exhausted and fatigue results. When the feeling of fatigue passes away with rest, the muscle recovers its power. While we are resting, the blood is pouring in fresh supplies of building material.

> Experiment 19. _To show how muscles relax and contract_. Lay your left forearm on a table; grasp with the right hand the mass of flesh on the front of the upper arm. Now gradually raise the forearm, keeping the elbow on the table. Note that the muscle thickens as the hand rises. This illustrates the contraction of the biceps, and is popularly called "trying your muscle" Reverse the act. Keep the elbow in position, bring the forearm slowly to the table, and the biceps appears to become softer and smaller,--it relaxes.

> Experiment 20. Repeat the same experiment with other muscles. With the right hand grasp firmly the extended left forearm. Extend and flex the fingers vigorously. Note the effect on the muscles and tendons of the forearm. Grasp with the right hand the calf of the extended right leg, and vigorously flex the leg, bringing it near to the body. Note the contractions and relaxations of the muscles.

70. Arrangement of Muscles. Muscles are not connected directly with bones. The mass of flesh tapers off towards the ends, where the fibers pass into white, glistening cords known as tendons. The place at

which a muscle is attached to a bone, generally by means of a tendon, is called its origin; the end connected with the movable bone is its insertion.

There are about 400 muscles in the human body, all necessary for its various movements. They vary greatly in shape and size, according to their position and use. Some are from one to two feet long, others only a fraction of an inch. Some are long and spindle-shaped, others thin and broad, while still others form rings. Thus some of the muscles of the arm and thigh are long and tapering, while the abdominal muscles are thin and broad because they help form walls for cavities. Again, the muscular fibers which surround and by their contraction close certain orifices, as those of the eyelids and lips, often radiate like the spokes of a wheel.

Muscles are named according to their shape, position, division of origin or insertion, and their function. Thus we have the _recti_ (straight), and the _deltoid_ ([Greek: D], delta), the _brachial_ (arm), _pectoral_ (breast), and the _intercostals_ (between the ribs), so named from their position. Again, we have the _biceps_ (two-headed), _triceps_ (three-headed), and many others with similar names, so called from the points of origin and insertion. We find other groups named after their special use. The muscles which bend the limbs are called _flexors_ while those which straighten them are known as _extensors_.

After a bone has been moved by the contraction of a muscle, it is brought back to its position by the contraction of another muscle on the opposite side, the former muscle meanwhile being relaxed. Muscles thus acting in opposition to each other are called antagonistic. Thus the biceps serves as one of the antagonists to the triceps, and the various flexors and extensors of the limbs are antagonistic to one another.

71. The Tendons. The muscles which move the bones by their contraction taper for the most part, as before mentioned, into tendons. These are commonly very strong cords, like belts or straps, made up of white, fibrous tissue.

Tendons are most numerous about the larger joints, where they permit free action and yet occupy but little space. Large and prominent muscles in these places would be clumsy and inconvenient. If we bend the arm or leg forcibly, and grasp the inside of the elbow or knee joint, we can feel the tendons beneath the skin. The numerous tendons in the palm or on the back of the hand contribute to its marvelous dexterity and flexibility. The thickest and strongest tendon in the body is the tendon of Achilles, which connects the great muscles in the calf of the leg with the heel bone (sec. 49).

When muscles contract forcibly, they pull upon the tendons which transmit the movement to the bones to which they are attached. Tendons may be compared to ropes or cords which, when pulled, are made to act upon distant objects to which one end is fastened. Sometimes the tendon runs down the middle of a muscle, and the fibers run obliquely into it, the tendon resembling the quill in a feather. Again, tendons are spread out in a flat layer on the surface of muscles, in which case they are called aponeuroses. Sometimes a tendon is found in the middle of a muscle as well as at each end of it.

[Illustration: Fig. 34.--The Biceps Muscle dissected to show its Tendons.]

72. Synovial Sheaths and Sacs. The rapid movement of the tendons

over bony surfaces and prominences would soon produce an undue amount of heat and friction unless some means existed to make the motion as easy as possible. This is supplied by sheaths which form a double lining around the tendons. The opposed surfaces are lined with synovial membrane,[11] the secretion from which oils the sheaths in which the tendons move.

Little closed sacs, called synovial sacs or bursae, similarly lined and containing fluid, are also found in special places between two surfaces where much motion is required. There are two of these bursae near the patella, one superficial, just under the skin; the other deep beneath the bone (Fig. 29). Without these, the constant motion of the knee-pan and its tendons in walking would produce undue friction and heat and consequent inflammation. Similar, though smaller, sacs are found over the point of the elbow, over the knuckles, the ankle bones, and various other prominent points. These sacs answer a very important purpose, and are liable to various forms of inflammation.

Experiment 21. Examine carefully the tendons in the parts dissected in Experiment 18. Pull on the muscles and the tendons, and note how they act to move the parts. This may be also admirably shown on the leg of a fowl or turkey from a kitchen or obtained at the market.

Obtain the hoof of a calf or sheep with one end of the tendon of Achilles still attached. Dissect it and test its strength.

73. Mechanism of Movement. The active agents of bodily movements, as we have seen, are the muscles, which by their contraction cause the bones to move one on the other. All these movements, both of motion and of locomotion, occur according to certain fixed laws of mechanics. The bones, to which a great proportion of the muscles in the body are attached, act as distinct levers. The muscles supply the power for moving the bones, and the joints act as fulcrums or points of support. The weight of the limb, the weight to be lifted, or the force to overcome, is the resistance.

74. Levers in the Body. In mechanics three classes of levers are described, according to the relative position of the power, the fulcrum, and the resistance. All the movements of the bones can be referred to one or another of these three classes.

Levers of the first class are those in which the fulcrum is between the power and the weight. The crowbar, when used to lift a weight at one end by the application of power at the other, with a block as a fulcrum, is a familiar example of this class. There are several examples of this in the human body. The head supported on the atlas is one. The joint between the atlas and the skull is the fulcrum, the weight of the head is the resistance. The power is behind, where the muscles from the neck are attached to the back of the skull. The object of this arrangement is to keep the head steady and balanced on the spinal column, and to move it backward and forward.

[Illustration: Fig. 35.--Showing how the Bones of the Arm serve as Levers.

P, power;
W, weight;
F, fulcrum.
]

Levers of the second class are those in which the weight is between the fulcrum and the power. A familiar example is the crowbar when used for lifting a weight while one end rests on the ground. This class of levers is not common in the body. Standing on tiptoe is, however, an example. Here the toes in contact with the ground are the fulcrum, the power is the action of the muscles of the calf, and between these is the weight of the body transmitted down the bones of the leg to the foot.

Levers of the third class are those in which the power is applied at a point between the fulcrum and weight. A familiar example is where a workman raises a ladder against a wall. This class of levers is common in the body. In bending the forearm on the arm, familiarly known as "trying your muscle," the power is supplied by the biceps muscle attached to the radius, the fulcrum is the elbow joint at one end of the lever, and the resistance is the weight of the forearm at the other end.

Experiment 22. _To illustrate how the muscles use the bones as levers._ First, practice with a ruler, blackboard pointer, or any other convenient object, illustrating the different kinds of levers until the principles are familiar. Next, illustrate these principles on the person, by making use of convenient muscles. Thus, lift a book on the toes, by the fingers, on the back of the hand, by the mouth, and in other ways.

These experiments, showing how the bones serve as levers, may be multiplied and varied as circumstances may require.

75. The Erect Position. The erect position is peculiar to man. No other animal naturally assumes it or is able to keep it long. It is the result of a somewhat complex arrangement of muscles which balance each other, some pulling backwards and some forwards. Although the whole skeleton is formed with reference to the erect position, yet this attitude is slowly learned in infancy.

In the erect position the center of gravity lies in the joint between the sacrum and the last lumbar vertebra. A line dropped from this point would fall between the feet, just in front of the ankle joints. We rarely stand with the feet close together, because that basis of support is too small for a firm position. Hence, in all efforts requiring vigorous muscular movements the feet are kept more or less apart to enlarge the basis of support.

Now, on account of the large number and flexibility of the joints, the body could not be kept in an upright position without the cooperation of certain groups of muscles. The muscles of the calf of the leg, acting on the thigh bone, above the knee, keep the body from falling forward, while another set in front of the thigh helps hold the leg straight. These thigh muscles also tend to pull the trunk forward, but in turn are balanced by the powerful muscles of the lower back, which help keep the body straight and braced.

The head is kept balanced on the neck partly by the central position of the joint between the atlas and axis, and partly by means of strong muscles. Thus, the combined action of these and other muscles serves to balance the body and keep it erect. A blow on the head, or a sudden shock to the nervous system, causes the body to fall in a heap, because the brain has for the time lost its power over the muscles, and they cease to contract.

[Illustration: Fig. 36.--Diagram showing the Action of the Chief Muscles which keep the Body Erect. (The arrows indicate the direction in which these muscles act, the feet serving as a fixed basis.) [After Huxley.]

Muscles which tend to keep the body from falling forward.

  A, muscles of the calf;
  B, of the back of the thigh;
  C, of the spinal column.

Muscles which tend to keep the body from falling backward.

  D, muscles of the front of the leg;
  E, of the front of the thigh;
  F, of the front of the abdomen;
  G, of the front of the neck.
]

76. Important Muscles. There are scores of tiny muscles about the head, face, and eyes, which, by their alternate contractions and relaxations, impart to the countenance those expressions which reflect the feelings and passions of the individual. Two important muscles, the temporal, near the temples, and the masseter, or chewing muscle, are the chief agents in moving the lower jaw. They are very large in the lion, tiger, and other flesh-eating animals. On the inner side of each cheek is the buccinator, or trumpeter's muscle, which is largely developed in those who play on wind instruments. Easily seen and felt under the skin in thin persons, on turning the head to one side, is the sterno-cleido-mastoid muscle, which passes obliquely down on each side of the neck to the collar bone--prominent in sculpture and painting.

The chest is supplied with numerous muscles which move the ribs up and down in the act of breathing. A great, fan-shaped muscle, called the pectoralis major, lies on the chest. It extends from the chest to the arm and helps draw the arm inward and forward. The arm is raised from the side by a large triangular muscle on the shoulder, the deltoid, so called from its resemblance to the Greek letter delta, [Greek: D]. The biceps, or two-headed muscle, forms a large part of the fleshy mass in front of the arm. Its use is to bend the forearm on the arm, an act familiarly known as "trying your muscle." Its direct antagonist is the three-headed muscle called the triceps. It forms the fleshy mass on the back of the arm, its use being to draw the flexed forearm into a right line.

On the back and outside of the forearm are the extensors, which straighten the wrist, the hand, and the fingers. On the front and inside of the forearm are the flexors, which bend the hand, the wrist, and the fingers. If these muscles are worked vigorously, their tendons can be readily seen and felt under the skin. At the back of the shoulder a large, spread-out muscle passes upward from the back to the humerus. From its wide expanse on the back it is known as the latissimus dorsi (broadest of the back). When in action it draws the arm downward and backward, or, if one hangs by the hands, it helps to raise the body. It is familiarly known as the "climbing muscle."

[Illustration: Fig. 37.--A Few of the Important Muscles of the Back.]

Passing to the lower extremity, the thigh muscles are the largest and the most powerful in the body. In front a great, four-headed muscle, quadriceps extensor, unites into a single tendon in which the knee-cap is set, and serves to straighten the knee, or when rising from a sitting posture helps elevate the body. On the back of the thigh are several large muscles which bend the knee, and whose tendons, known as the "hamstrings," are readily felt just behind the knee. On the back of the leg the most important muscles, forming what is known as the calf, are the gastrocnemius and the soleus. The first forms the largest part of the calf. The soleus, so named from resembling a sole-fish, is a muscle of broad, flattened shape, lying beneath the gastrocnemius. The tendons of these two muscles unite to form the tendon of Achilles, as that hero is said to have been invulnerable except at this point. The muscles of the calf have great power, and are constantly called into use in walking, cycling, dancing, and leaping.

77. The Effect of Alcoholic Drinks upon the Muscles. It is found that a man can do more work without alcohol than with it. After taking it there may be a momentary increase of activity, but this lasts only ten or fifteen minutes at the most. It is followed by a rapid reduction of power that more than outweighs the momentary gain, while the quality of the work is decidedly impaired from the time the alcohol is taken.

Even in the case of hard work that must be speedily done, alcohol does not help, but hinders its execution. The tired man who does not understand the effects of alcohol often supposes that it increases his strength, when in fact it only deadens his sense of fatigue by paralyzing his nerves. When put to the test he is surprised at his self-deception.

Full intoxication produces, by its peculiar depression of the brain and nervous system, an artificial and temporary paralysis of the muscles, as is obvious in the pitifully helpless condition of a man fully intoxicated. But even partial approach to intoxication involves its proportionate impairment of nervous integrity, and therefore just so much diminution of muscular force. All athletes recognize this fact, as while training for a contest, rigid abstinence is the rule, both from liquors and tobacco. This muscular weakness is shown also in the unsteady hand, the trembling limbs of the inebriate, his thick speech, wandering eye, and lolling head.

78. Destructive Effect of Alcoholic Liquors upon Muscular Tissue. Alcoholic liquors retard the natural chemical changes so essential to good health, by which is meant the oxidation of the nutritious elements of food. Careful demonstration has proved also that the amount of carbon dioxide escaping from the lungs of intoxicated persons is from thirty to fifty per cent less than normal. This shut-in carbon stifles the nervous energy, and cuts off the power that controls muscular force. This lost force is in close ratio to the retained carbon: so much perverted chemical change, so much loss of muscular power. Not only the strength but the fine delicacy of muscular action is lost, the power of nice control of the hand and fingers, as in neat penmanship, or the use of musical instruments.

To this perverted chemical action is also due the fatty degeneration so common in inebriates, affecting the muscles, the heart, and the liver. These organs are encroached upon by globules of fat (a hydrocarbon), which, while very good in their proper place and quantity, become a source of disorder and even of death when they abnormally invade vital structures. Other poisons, as phosphorus, produce this fatty decay more rapidly; but alcohol causes it in a much more general way.

This is proved by the microscope, which plainly shows the condition mentioned, and the difference between the healthy tissues and those thus diseased.

[Illustration: Fig. 38.--Principal Muscles on the Left Side of Neck.

A, buccinator;
B, masseter;
C, depressor anguli oris;
D, anterior portion of the digastric;
E, mylo-hyoid;
F, tendon of the digastric;
G, sterno-hyoid;
H, sterno-thyroid;
K, omo-hyoid;
L, sternal origin of sterno-cleido-mastoid muscle;
M, superior fibers of deltoid;
N, posterior scalenus;
O, clavicular origin of sterno-cleido-mastoid;
P, sterno-cleido-mastoid;
R, trapezius;
S, anterior constrictor;
T, splenius capitis;
V, stylo-hyoid;
W, posterior portion of the digastric;
X, fasciculi of ear muscles;
Z, occipital.
]

[NOTE. It was proposed during the Civil War to give each soldier in a certain army one gill of whiskey a day, because of great hardship and exposure. The eminent surgeon, Dr. Frank H. Hamilton of New York, thus expressed his views of the question: "It is earnestly desired that no such experiment will ever be repeated in the armies of the United States. In our own mind, the conviction is established, by the experience and observation of a life, that the regular routine employment of alcoholic stimulants by man in health is never, under any circumstances, useful. We make no exceptions in favor of cold or heat or rain."

"It seems to me to follow from these Arctic experiences that the regular use of spirits, even in moderation, under conditions of great physical hardship, continued and exhausting labor, or exposure to severe cold cannot be too strongly deprecated."

A. W. Greely, retired Brigadier General, U.S.A., and formerly leader of the Greely Expedition.]

79. Effect of Tobacco on the Muscles. That other prominent narcotic, tobacco, impairs the energy of the muscles somewhat as alcohol does, by its paralyzing effect upon the nervous system. As all muscular action depends on the integrity of the nervous system, whatever lays its deadening hand upon that, saps the vigor and growth of the entire frame, dwarfs the body, and retards mental development. This applies especially to the young, in the growing age between twelve or fourteen and twenty, the very time when the healthy body is being well knit and compacted.

Hence many public schools, as well as our national naval and military academies, rigidly prohibit the use of tobacco by their pupils. So also young men in athletic training are strictly forbidden to use it.[12] This loss of muscular vigor is shown by the unsteady condition of the muscles, the trembling hand, and the inability to do with precision and accuracy any fine work, as in drawing or nice penmanship.

Additional Experiments.

Experiment 23. _ To examine the minute structure of voluntary muscular fiber._ Tease, with two needles set in small handles, a bit of raw, lean meat, on a slip of glass, in a little water. Continue until the pieces are almost invisible to the naked eye.

Experiment 24. Place a clean, dry cover-glass of about the width of the slip, over the water containing the torn fragments. Absorb the excess of moisture at the edge of the cover, by pressing a bit of blotting-paper against it for a moment. Place it on the stage of a microscope and examine with highest obtainable power, by light reflected upward from the mirror beneath the stage. Note the apparent size of the finest fibers; the striation of the fibers, or their markings, consisting of alternate dim and bright cross bands. Note the arrangement of the fibers in bundles, each thread running parallel with its neighbor.

Experiment 25. _To examine the minute structure of involuntary muscular fiber, a tendon, or a ligament._ Obtain a very small portion of the muscular coat of a cow's or a pig's stomach. Put it to soak in a solution of one dram of bichromate of potash in a pint of water. Take out a morsel on the slip of glass, and tease as directed for the voluntary muscle. Examine with a high power of the microscope and note: (1) the isolated cells, long and spindle-shaped, that they are much flattened; (2) the arrangement of the cells, or fibers, in sheets, or layers, from the torn ends of which they project like palisades.

Experiment 26. Tease out a small portion of the tendon or ligament in water, and examine with a glass of high power. Note the large fibers in the ligament, which branch and interlace.

Experiment 27. With the head slightly bent forwards, grasp between the fingers of the right hand the edge of the left sterno-cleido-mastoid, just above the collar bone. Raise the head and turn it from left to right, and the action of this important muscle is readily seen and felt. In some persons it stands out in bold relief.

Experiment 28. The tendons which bound the space (popliteal) behind the knee can be distinctly felt when the muscles which bend the knee are in action. On the outer side note the tendons of the biceps of the leg, running down to the head of the fibula. On the inside we feel three tendons of important muscles on the back of the thigh which flex the leg upon the thigh.

Experiment 29. _To show the ligamentous action of the muscles._ Standing with the back fixed against a wall to steady the pelvis, the knee can be flexed so as to almost touch the abdomen. Take the same position and keep the knee rigid. When the heel has been but slightly raised a sharp pain in the back of the thigh follows any effort to carry it higher. Flexion of the leg to a right angle, increases the distance from the lines of insertion on the pelvic bones to the tuberosities of the tibia by two or three inches--an amount of stretching these muscle cannot undergo. Hence the knee must be flexed in flexion of the hip.

Experiment 30. A similar experiment may be tried at the wrist. Flex the wrist with the fingers extended, and again with the fingers in the fist. The first movement can be carried to 90 degrees, the second only to 30 degrees, or in some persons up to 60 degrees. Making a fist had already stretched the extensor muscles of the arm, and they can be stretched but little farther. Hence, needless pain will be avoided by working a stiff wrist with the parts loose, or the fingers extended, and not with a clenched fist.

Review Analysis: Important Muscles.

Location.
Name. Chief Function.

Head and Neck.

Occipito-frontalis. moves scalp and raises eye brow.
Orbicularis palpebrarum. shuts the eyes.
Levator palpebrarum. opens the eyes.
Temporal. raise the lower jaw.
Masseter. " " " "
Sterno-cleido-mastoid. depresses head upon neck and neck upon chest.
Platysma myoides. depresses lower jaw and lower lip.

Trunk.

Pectoralis major. draws arm across front of chest.
Pectoralis minor. depresses point of shoulder,
Latissimus dorsi. draws arm downwards and backwards.
Serratus magnus. assists in raising ribs.
Trapezius. Rhomboideus. backward movements of head and shoulder,
Intercostals. raise and depress the ribs.
External oblique. /various forward movements
Internal oblique. \ of trunk
Rectus abdominis. compresses abdominal viscera and acts upon pelvis.

Upper Limbs.

Deltoid. carries arm outwards and upwards.
Biceps. flexes elbow and raises arm.
Triceps. extends the forearm.
Brachialis anticus. flexor of elbow.
Supinator longus. flexes the forearm.
Flexor carpi radialis. flexors of wrist.
Flexor carpi ulnaris. " " "

Lower Limbs.

Gluteus maximus. adducts the thigh.
Adductors of thigh. draw the leg inwards.
Sartorius. crosses the legs.
Rectus femoris. flexes the thigh.
Vastus externus. extensor of leg.

Vastus internus.	extensor of leg upon thigh.
Biceps femoris.	flexes leg upon thigh.
Gracilis.	flexes the leg and adducts thigh.
Tibialis anticus.	draws up inner border of foot.
Peroneus longus.	raises outer edge of foot,
Gastrocnemius.	keep the body erect, and
Soleus.	aid in walking and running.

Chapter IV.

Physical Exercise.

80. Importance of Bodily Exercise. Nothing is so essential to success in life as sound physical health. It enables us to work with energy and comfort, and better to endure unusual physical and mental strains. While others suffer the penalties of feebleness, a lower standard of functional activities, and premature decay, the fortunate possessor of a sound mind in a sound body is better prepared, with proper application, to endure the hardships and win the triumphs of life[13].

This element of physical capacity is as necessary to a useful and energetic life, as are mental endowment and intellectual acquirement. Instinct impels us to seek health and pleasure in muscular exercise. A healthy and vigorous child is never still except during sleep. The restless limbs and muscles of school children pent up for several hours, feel the need of movement, as a hungry man craves food. This natural desire for exercise, although too often overlooked, is really one of the necessities of life. One must be in ill health or of an imperfect nature, when he ceases to feel this impulse. Indeed, motion within proper bounds is essential to the full development and perfect maintenance of the bodily health. Unlike other machines, the human body becomes within reasonable limits, stronger and more capable the more it is used.

As our tenure of life at best is short, it is our duty to strive to live as free as possible from bodily ills. It is, therefore, of paramount importance to rightly exercise every part of the body, and this without undue effort or injurious strain.

Strictly speaking, physical exercise refers to the functional activity of each and every tissue, and properly includes the regulation of the functions and movements of the entire body. The word exercise, however, is used usually in a narrower sense as applied to those movements that are effected by the contraction of the voluntary muscles.

Brief reference will be made in this chapter only to such natural and systematic physical training as should enter into the life of every healthy person.

81. Muscular Activity. The body, as we have learned, is built up of certain elementary tissues which are combined to make bones, muscles, nerves, and other structures. The tissues, in turn, are made up of countless minute cells, each of which has its birth, lives its brief moment to do its work in the animal economy, is separated from the tissue of which it was a part, and is in due time eliminated by the organs of

excretion,--the lungs, the skin, or the kidneys. Thus there is a continuous process of growth, of decay, and removal, among the individual cells of each tissue.

[NOTE. The Incessant Changes in Muscular Tissue. "In every tiny block of muscle there is a part which is really alive, there are parts which are becoming alive, there are parts which have been alive, and are now dying or dead; there is an upward rush from the lifeless to the living, a downward rush from the living to the dead. This is always going on, whether the muscle be quiet and at rest, or whether it be active and moving,--some of the capital of living material is being spent, changed into dead waste; some of the new food is always being raised into living capital. But when the muscle is called upon to do work, when it is put into movement, the expenditure is quickened, there is a run upon the living capital, the greater, the more urgent the call for action."--Professor Michael Foster.]

These ceaseless processes are greatly modified by the activity of the bodily functions. Every movement of a muscle, for instance, involves change in its component cells. And since the loss of every atom of the body is in direct relation to its activity, a second process is necessary to repair this constant waste; else the body would rapidly diminish in size and strength, and life itself would soon end. This process of repair is accomplished, as we shall learn in Chapters VI. and VII., by the organs of nutrition, which convert the food into blood.

[Illustration: Fig. 39.--Showing how the Muscles of the Back may be developed by a Moderate Amount of Dumb-Bell Exercise at Home. (From a photograph.)]

82. Effect of Exercise upon the Muscles. Systematic exercise influences the growth and structure of the muscles of the body in a manner somewhat remarkable. Muscular exercise makes muscular tissue; from the lack of it, muscles become soft and wasted. Muscles properly exercised not only increase in size, both as a whole and in their individual structure, but are better enabled to get rid of material which tends to hamper their movements. Thus muscular exercise helps to remove any needless accumulation of fat, as well as useless waste matters, which may exist in the tissues. As fat forms no permanent structural part of the organism, its removal is, within limits, effected with no inconvenience.

Muscular strength provides the joints with more powerful ligaments and better developed bony parts. After long confinement to the bed from disease, the joints have wasted ligaments, thin cartilages, and the bones are of smaller proportions. Duly exercised muscles influence the size of the bones upon which they act. Thus the bones of a well-developed man are stronger, firmer, and larger than those of a feeble person.

He who has been physically well trained, has both a more complete and a more intelligent use of his muscles. He has acquired the art of causing his muscles to act in concert. Movements once difficult are now carried on with ease. The power of coordination is increased, so that a desired end is attained with the least amount of physical force and nervous energy. In learning to row, play baseball, ride the bicycle, or in any other exercises, the beginner makes his movements in a stiff and awkward manner. He will use and waste more muscular force in playing one game of ball, or in riding a mile on his wheel, than an expert would in doing ten times the work. He has not yet learned to balance one set of muscles against their antagonists.

[Illustration: Fig. 40.--The Standard Special Chest Weight.

A convenient machine by means of which all the muscles of the body may be easily and pleasantly exercised with sufficient variations in the movements to relieve it of monotony.

A space 6 ft wide, 6 ft deep, and 7 ft high nearly in front of the machine is required for exercise.]

In time, however, acts which were first done only with effort and by a conscious will, become automatic. The will ceases to concern itself. By what is called reflex action, memory is developed in the spinal cord and the muscular centers (sec. 273). There is thus a great saving of actual brain work, and one important cause of fatigue is removed.

83. Effect of Exercise on Important Organs. The importance of regular exercise is best understood by noting its effects upon the principal organs of the body. As the action of the heart is increased both in force and frequency during exercise, the flow of blood throughout the body is augmented. This results from the force of the muscular contractions which play their part in pressing the blood in the veins onward towards the heart. Exercise also induces a more vigorous respiration, and under increased breathing efforts the lung capacity is increased and the size of the chest is enlarged. The amount of air inspired and expired in a given time is much larger than if the body were at rest. The blood is thus supplied with a much larger amount of oxygen from the air inhaled, and gives off to the air a corresponding excess of carbon dioxid and water.

Again, exercise stimulates and strengthens the organs of digestion. The appetite is improved, as is especially noted after exercise in the open air. The digestion is more complete, absorption becomes more rapid, the peristaltic movements of the bowels are promoted, and the circulation through the liver is more vigorous. More food is taken to supply the force necessary for the maintenance of the mechanical movements. Ample exercise also checks the tendency towards a torpid circulation in the larger digestive organs, as the stomach and the liver, so common with those who eat heartily, but lead sedentary lives. In short, exercise may be regarded as a great regulator of nutrition.

Exercise increases the flow of blood through the small vessels of the skin, and thus increases the radiation of heat from the surface. If the exercise be vigorous and the weather hot, a profuse sweat ensues, the rapid evaporation of which cools the body. The skin is thus a most important regulator of the bodily temperature, and prevents any rise above the normal which would otherwise result from vigorous exercise. (See secs. 226 and 241).

84. Effect of Exercise upon the Personal Appearance. Judicious and systematic exercise, if moderately employed, soon gives a more upright and symmetrical figure, and an easier and more graceful carriage. Rounded shoulders become square, the awkward gait disappears, and there is seen a graceful poise to the head and a bearing of the body which mark those whose muscles have been well trained. A perfectly formed skeleton and well-developed muscles give the graceful contour and perfect outline to the human body. The lean, soft limbs of those who have never had any physical education, often look as if they belonged to persons recovering from sickness. The effects of sound physical exercise are well exhibited

in the aspect of the neck, shoulders, and chest of one who has been well trained. This is noticeable in gymnasts and others who practice upon the horizontal bar, with chest weights, dumb-bells, and other apparatus which develop more especially the muscles of the upper half of the trunk.

[Illustration: Fig. 41.--Young Woman practicing at Home with the "Whitely Exerciser." (From a photograph)]

Exercise improves the condition of the tissues generally. They become more elastic, and in all respects sounder. The skin becomes firm, clear, and wholesome. Hence, every part of the surface of the body rapidly takes on a change in contour, and soon assumes that appearance of vigor and soundness which marks those of firm physical condition. The delicate, ruddy aspect of the complexion, the swing about the body and the bearing of the head and shoulders, of young women whose physical training has been efficient, are in marked contrast with those characteristics in persons whose education in this respect has been neglected.

85. Effect of Unsuitable or Excessive Exercise. But exercise, like everything else which contributes to our welfare, may be carried to excess. The words excessive and unsuitable, when applied to muscular exertion, are relative terms, and apply to the individual rather than to amount of work done. Thus what may be excessive for one person, might be suitable and beneficial to another. Then the condition of the individual, rather than the character of the muscular work, is always a most important factor.

Breathlessness is, perhaps, the most common effect of undue exertion. Let a middle-aged person, who is out of practice, run a certain distance, and he is soon troubled with his breathing. The respirations become irregular, and there is a sense of oppression in his chest. He pants, and his strength gives out. His chest, and not his legs, has failed him. He is said to be "out of breath." He might have practiced dumb-bells or rowed for some time without inconvenience.

The heart is often overstrained, and at times has been ruptured during violent exertion, as in lifting an immense weight. The various forms of heart-disease are common with those whose occupations involve severe muscular effort, as professional athletes and oarsmen. Haemorrhages of various kinds, especially from the lungs, or rupture of blood-vessels in the brain, are not uncommon results of over-exertion.

Excessive repetition of muscular movements may lead to permanent contractions of the parts involved. Thus sailors, mechanics, and others frequently develop a rigidity of the tendons of the hand which prevents the full extension of the fingers. So stenographers, telegraphers and writers occasionally suffer from permanent contractions of certain muscles of the arm, known as writer's cramp, due to their excessive use. But the accidents which now and then may result from severe physical exertion, should discourage no one from securing the benefits which accrue from moderate and reasonable exercise.

86. Muscular Fatigue. We all know how tiresome it is to hold the arm outstretched horizontally even for a few moments. A single muscle, the deltoid, in this case does most of the work. Even in a vigorous man, this muscle can act no longer than four to six minutes before the arm drops helpless. We may prolong the period by a strong effort of the will, but a time soon comes when by no possible effort are we able to hold out the arm. The muscle is said to be fatigued. It has by no means lost its

contractile power, for if we apply a strong electric stimulus to it, the fatigue seems to disappear. Thus we see the functional power of a muscle has a definite limit, and in fatigue that limit is reached.

[Illustration: Fig. 42.--A Well-Equipped Gymnasium. (From a photograph.)]

The strength of the muscle, its physical condition, the work it has done, and the mental condition of the individual, all modify the state of fatigue. In those difficult acts which involve a special effort of the will, the matter of nerve exhaustion is largely concerned. Thus, the incessant movements in St. Vitus' dance result in comparatively little fatigue, because there is no association of the brain with the muscular action. If a strong man should attempt to perform voluntarily the same movements, he would soon have to rest. None of the movements which are performed independently of the will, as the heart-beats and breathing movements, ever involve the sensation of fatigue. As a result of fatigue the normal irritability of muscular tissue becomes weakened, and its force of contraction is lessened. There is, also, often noticed in fatigue a peculiar tremor of the muscles, rendering their movements uncertain. The stiffness of the muscles which comes on during severe exercise, or the day after, are familiar results of fatigue.

This sense of fatigue should put us on guard against danger. It is a kind of regulator which serves in the ordinary actions of life to warn us not to exceed the limits of useful exercise. Fatigue summons us to rest long before all the force of the motor organs has been expended, just as the sensation of hunger warns us that we need food, long before the body has become weak from the lack of nourishment.

We should never forget that it is highly essential to maintain an unused reserve of power, just as a cautious merchant always keeps at the bank an unexpended balance of money. If he overspends his money he is bankrupt, and the person who overspends his strength is for the time physically bankrupt. In each case the process of recovery is slow and painful.

87. Rest for the Muscles. Rest is necessary for the tissues, that they may repair the losses sustained by work; that is, a period of rest must alternate with a period of activity. Even the heart, beating ceaselessly, has its periods of absolute rest to alternate with those of work. A steam-engine is always slowly, but surely, losing its fitness for work. At last it stops from the need of repair. Unlike the engine, the body is constantly renewing itself and undergoing continual repair. Were it not for this power to repair and renew its various tissues, the body would soon be worn out.

This repair is really a renovation of the structure. Rest and work are relative terms, directly opposed to each other. Work quickens the pulse and the respiration, while rest slows both. During sleep the voluntary muscles are relaxed, and those of organic life work with less energy. The pulse and the respiration are less frequent, and the temperature lower than when awake. Hence sleep, "tired Nature's sweet restorer," may be regarded as a complete rest.

The periods of rest should vary with the kind of exercise. Thus exercise which produces breathlessness requires frequent but short rests. The trained runner, finding his respiration embarrassed, stops a moment to regain his breath. Exercises of endurance cause fatigue less quickly than those of speed, but require longer rest. Thus a man not used to long distances may walk a number of hours without stopping, but while fatigue is slow to result, it is also slow to disappear. Hence a lengthy period of rest is necessary before he is able to renew his journey.

88. Amount of Physical Exercise Required. The amount of physical exercise that can be safely performed by each person, is a most important and practical question. No rule can be laid down, for what one person bears well, may prove very injurious to another. To a certain extent, each must be guided by his own judgment. If, after taking exercise, we feel fatigued and irritable, are subject to headache and sleeplessness, or find it difficult to apply the mind to its work, it is plain that we have been taxing our strength unduly, and the warnings should be heeded.

Age is an important factor in the problem, as a young man may do with ease and safety, what might be injurious to an older person. In youth, when the body is making its most active development, the judicious use of games, sports, and gymnastics is most beneficial. In advanced life, both the power and the inclination for exercise fail, but even then effort should be made to take a certain reasonable amount of exercise.

Abundant evidence shows that physical development is most active from thirteen to seventeen years of age; this manifests itself clearly by increase in weight. Hence this period of life is of great consequence. If at this age a boy or girl is subjected to undue physical strain, the development may suffer, the growth be retarded, and the foundation laid for future ill health.

[Illustration: Fig. 43.--Student exercising in the School Gymnasium on the Rowing Machine. (From a photograph.)]

The proper amount of exercise must vary greatly with circumstances. It may be laid down as a fairly safe rule, that a person of average height and weight, engaged in study or in any indoor or sedentary occupation, should take an amount of exercise equivalent to walking five or six miles a day. Growing children, as a rule, take more exercise than this, while most men working indoors take far less, and many women take less exercise than men. Exercise may be varied in many ways, the more the better; but for the most part it should always be taken in the open air.

89. Time for Exercise. It is not prudent to do hard work or take severe exercise, just before or just after a full meal. The best time is one or two hours after a meal. Vigorous exercise while the stomach is busily digesting food, may prove injurious, and is apt to result sooner or later in dyspepsia. On the other hand, severe exercise should not be taken on an empty stomach. Those who do much work or study before breakfast, should first take a light lunch, just enough to prevent any faint feeling. With this precaution, there is no better time for moderate exercise than the early morning.

In the case of children, physical exercises should not be undertaken when they are overtired or hungry. Neither is it judicious for adults to take vigorous exercise in the evening, after a long and arduous day's work.

90. Walking, Running, and Jumping. Walking is generally regarded as the simplest and most convenient mode of taking exercise. Man is essentially a walking animal. When taken with a special object in view, it is the best and most pleasant of all physical activities. It is suited for individuals of all ages and occupations, and for residents of every climate. The child, the athlete, and the aged are all able to indulge in this simple and effective means of keeping the body in health.

In walking, the muscles of the entire body are brought into action, and the movements of breathing and the circulation of the blood are increased. The body should be erect, the chest thrown out, the head and shoulders held back, and the stride long and elastic. It is an excellent custom to add to the usefulness of this fine exercise, by deep, voluntary inhalations of pure air.

Running is an excellent exercise for children and young people, but should be sparingly indulged in after the age of thirty-five. If it be accompanied with a feeling of faintness, breathlessness, and palpitation of the heart, the exercise is too severe, and its continuance may do serious harm. Running as an exercise is beneficial to those who have kept themselves in practice and in sound condition. It brings into play nearly every muscle of the body, and thus serves to develop the power of endurance, as well as strength and capacity for rapid movement.

Jumping may well be left to boys and young men under twenty, but skipping with a rope, allied to jumping, is an admirable and beneficial form of exercise. It brings into action many muscles without putting undue strain upon any particular group.

91. Skating, Swimming, and Rowing. Skating is a delightful and invigorating exercise. It calls into play a great variety of muscles, and is admirably adapted for almost all ages. It strengthens the ankles and helps give an easy and graceful carriage to the body. Skating is especially valuable, as it can be enjoyed when other out-door exercises are not convenient.

Every child above ten years of age should be taught to swim. The art, once mastered, is never forgotten. It calls into use a wide combination of muscles. This accomplishment, so easily learned, should be a part of our education, as well as baseball or bicycling, as it may chance to any one to save his own life or that of a companion.

In many respects rowing is one of the most perfect exercises at our command. It expands the chest, strengthens the body, and gives tone to the muscles of the abdomen. It is very suitable for girls and women, as no other exercise is so well adapted to remedy the muscular defects so marked in their sex. Even elderly persons can row day after day without difficulty. The degree of muscular effort required, can be regulated so that those with weak hearts and weak lungs can adjust themselves to the exercise.

92. Bicycling as an Exercise. The bicycle as a means of taking exercise has come into popular use with remarkable rapidity. Sharp competition bids fair to make the wheel more popular and less expensive than ever. Its phenomenal use by persons of all ages and in all stations of life, is proof of the enthusiasm with which this athletic exercise is employed by women as well as by men.

Mechanical skill has removed most of the risks to health and person which once existed. A good machine, used by its owner with judgment, is the most convenient, the safest, and the least expensive means of traveling for pleasure or exercise. It is doing more than any other form of exercise to improve the bodily condition of thousands whose occupations confine them all day to sedentary work. Dependent upon no one but himself, the cyclist has his means of exercise always at hand. No preparation is necessary to take a spin of ten miles or so on the road, during a summer evening or before breakfast.

Bicycling brings into active use the muscles of the legs as well as those of the trunk and arms. It seems to benefit those who suffer from dyspepsia, constipation, and functional disorders of the liver.

A special caution must be used against overdoing in cycling, for the temptation by rivalry, making a record, by social competition on the road, is stronger in this form of exercise than in any other, especially for young folks. Many cases have occurred of permanent injury, and even loss of life, from collapse simply by excessive exertion and exhaustion.

93. Outdoor Games and Physical Education. While outdoor games are not necessary to maintain health, yet we can scarcely overestimate the part that the great games of baseball, football, tennis, golf, and croquet, play in the physical development of young people. When played in moderation and under suitable conditions, they are most useful and beneficial exercises. They are played in the open air, and demand a great variety of vigorous muscular movement, with a considerable amount of skill and adroitness of action. These games not only involve healthful exercise, but develop all those manly and wholesome qualities so essential to success in life.

A vigorous body is well-nigh essential to success, but equally important are readiness of action, sound judgment, good temper, personal courage, a sense of fair play, and above all, a spirit of honor. Outdoor games, when played in a reasonable and honorable manner, are most efficient and practical means to develop these qualities in young people.

94. The School and Physical Education. The advantages to be derived, during the school period, from the proper care and development of the body, should be understood and appreciated by school officials, teachers, and parents. The school period is the best time to shape the lives of pupils, not mentally or morally alone, but physically as well. This is the time, by the use of a few daily exercises at school, to draw back the rounding shoulders, to form the habit of sitting and standing erect, to build up strong and comely arms and chests, and otherwise to train pupils to those methods which will serve to ripen them into vigorous and well-knit men and women.

Teachers can by a little effort gain the knowledge requisite properly to instruct their pupils in a few systematic exercises. Gratifying results will follow just as the teacher and pupils evince interest and judgment in the work. It is found by experience that pupils are not only quick to learn, but look forward eagerly to the physical exercises as an interesting change from the routine of school life.

There should be a stated time for these school exercises, as for any other duty. There can be practiced in the schoolroom a great variety of interesting and useful exercises, which call for little or no expense for apparatus. Such exercises should no more interfere with the children's usual games than any other study does. Under no circumstances should the play hours be curtailed.

95. Physical Exercises in School. Physical exercises of some sort, then, should be provided for pupils in our schools, especially in large towns and cities, where there is little opportunity for outdoor games, and they should form a part of the regular course of study. The object should

be the promotion of sound health rather than the development of muscle, or performing feats of agility or strength. Exercises with dumb-bells and wands, or even without any apparatus, practiced a few times a day, for five minutes at a time, do a great deal of good. They relax the tension of body and mind, and introduce an element of pleasure into the routine of school life. They increase the breathing power and quicken the action of the heart.

[Illustration: Fig. 44.--Physical Exercises as carried on in Schools. (From photographs.)]

[NOTE. "In early boyhood and youth nothing can replace the active sports so much enjoyed at this period; and while no needless restrictions should be placed upon them, consideration should be paid to the amount, and especially to the character, of the games pursued by delicate youth. For these it would be better to develop the weakened parts by means of systematic physical exercises and by lighter sports."--Dr. John M. Keating on "Physical Development" in Pepper's _Cyclopaedia of the Diseases of Children_.]

If vigorously and systematically carried out, these exercises invigorate all the tissues and organs of the body, and stimulate them to renewed activity. They serve to offset the lack of proper ventilation, faulty positions at the desks, and the prolonged inaction of the muscles. To secure the greatest benefit from physical training in school, it is important that the pupils be interested in these exercises, and consider them a recreation, and not a task[14].

96. Practical Points about Physical Exercise. The main object in undertaking systematic and graduated physical exercises is not to learn to do mere feats of strength and skill, but the better to fit the individual for the duties and the work of life. Exercises should be considered with reference to their availability from the learner's standpoint. The most beneficial exercises ordinarily are the gentle ones, in which no strain is put upon the heart and the respiration. The special aim is to secure the equal use of all the muscles, not the development of a few. The performance of feats of strength should never come within the scope of any educational scheme. Exercises which call for sustained effort, violent exertion, or sudden strain are best avoided by those who have had no preparation or training.

Regular exercise, not sudden and occasional prolonged exertion, is necessary for health. The man or woman who works in an office or store all the week, and on Sunday or a holiday indulges in a long spin on the bicycle, often receives more harm than good from the exertion. Exercise should be taken, so far as is convenient, in the open air, or in a large and well-ventilated room.[15]

After the more violent exercises, as baseball, football, a long ride on the bicycle, or even after a prolonged walk, a warm bath should be taken at the first convenient opportunity. Care should be taken to rub down thoroughly, and to change a part or all of the clothing. Exercise is comparatively valueless until the idea of taking it for health is quite forgotten in the interest and pleasure excited by the occasion. No exercise should be carried to such a degree as to cause fatigue or exhaustion. Keep warmly clad after exercise, avoid chills, and always stop exercising as soon as fatigue is felt.

Wear clothing which allows free play to all the muscles of the body. The clothing should be light, loose, and made of wool. Care should be taken not to take cold by standing about in clothes which are damp with perspiration. In brisk walking and climbing hills keep the mouth shut, especially in cold weather, and breathe through the nose, regulating the pace so that it can be done without discomfort.

97. Effect of Alcoholic Liquors and Tobacco upon Physical Culture. As a result of the unusual attention given to physical culture in the last few years, hundreds of special instructors are now employed in training young people in the theory and practice of physical exercise. These expert teachers, to do their work with thoroughness and discipline, recognize the necessity of looking after the daily living of their students. The time of rising and retiring, the hours of sleep, the dress, the care of the diet, and many other details of personal health become an important part of the training.

Recognizing the fact that alcoholic drink and tobacco are so disastrous to efficiency in any system of physical training, these instructors rigidly forbid the use of these drugs under all circumstances. While this principle is perhaps more rigorously enforced in training for athletic contests, it applies equally to those who have in view only the maintenance of health.

Books on Physical Education. There are many excellent books on physical education, which are easily obtained for reading or for reference. Among these one of the most useful and suggestive is Blackie's well-known book, "How to Get Strong and how to Stay so." This little book is full of kindly advice and practical suggestions to those who may wish to begin to practice health exercises at home with inexpensive apparatus. For more advanced work, Lagrange's "Physiology of Bodily Exercise" and the Introduction to Maclaren's "Physical Education" may be consulted. A notable article on "Physical Training" by Joseph H. Sears, an Ex-Captain of the Harvard Football Team, may be found in Roosevelt's "In Sickness and in Health."

Price lists and catalogues of all kinds of gymnastic apparatus are easily obtained on application to firms handling such goods.

Various Systems of Physical Exercises. The recent revival of popular interest in physical education has done much to call the attention of the public to the usefulness and importance of a more thorough and systematic use of physical exercises, both at home and in the schools. It is not within the scope of this book to describe the various systems of gymnastic and calisthenic exercises now in common use in this country. For the most part they have been modified and rearranged from other sources, notably from the two great systems, i.e., Swedish and German.

For a most comprehensive work on the Swedish system, the teacher is referred to the "Swedish System of Educational Gymnastics," with 264 illustrations, by Baron Nils Posse. There is also a small manual for teachers, called "Handbook of School Gymnastics of the Swedish Systems," by the same author.

Chapter V.

Food and Drink.

98. Why we need Food. The body is often compared to a steam-engine in good working order. An engine uses up fuel and water to obtain from them the energy necessary to do its work. So, we consume within our bodies certain nutritious substances to obtain from them the energy necessary for our activities. Just as the energy for the working of the engine is obtained from steam by the combustion of fuel, so the energy possessed by our bodies results from the combustion or oxidation within us of the food we eat. Unless this energy is provided for the body it will have but little power of doing work, and like an engine without steam, must soon become motionless.

99. Waste and Repair. A steam-engine from the first stroke of its piston-rod begins to wear out, and before long needs repair. All work involves waste. The engine, unless kept in thorough repair, would soon stop. So with our bodies. In their living cells chemical changes are constantly going on; energy, on the whole, is running down; complex substances are being broken up into simpler combinations. So long as life lasts, food must be brought to the tissues, and waste products carried away from them. It is impossible to move a single muscle, or even to think for one moment, without some minute part of the muscular or brain tissue becoming of no further use in the body. The transformation of dead matter into living tissue is the ever-present miracle which life presents even in its lowest forms.

In childhood the waste is small, and the amount of food taken is more than sufficient to repair the loss. Some of the extra food is used in building up the body, especially the muscles. As we shall learn in Chapter VIII., food is also required to maintain the bodily heat. Food, then, is necessary for the production of energy, for the repair of the body, for the building up of the tissues, and for the maintenance of bodily heat.

100. Nature of the Waste Material. An ordinarily healthy person passes daily, on an average, by the kidneys about 50 ounces of waste material, of which 96 per cent is water, and from the intestines, on an average, 5-1/2 ounces, a large proportion of which is water. By the skin, in the shape of sweat and insensible perspiration, there is cast out about 23 ounces, of which 99 per cent is water; and by the lungs about 34 ounces, 10 of which are water and the remainder carbon dioxid.

Now if we omit an estimate of the undigestible remains of the food, we find that the main bulk of what daily leaves the body consists of water, carbon dioxid, and certain solid matters contained in solution in the renal secretion and the sweat. The chief of these solid matters is urea, a complex product made up of four elements,--carbon, hydrogen, oxygen, and nitrogen. Water contains only two elements, hydrogen and oxygen; and carbon dioxid also has only two, carbon and oxygen. Hence, what we daily cast out of our bodies consists essentially of these four elements in the form mainly of water, carbon dioxid, and urea.

These waste products represent the oxidation that has taken place in the tissues in producing the energy necessary for the bodily activities, just as the smoke, ashes, clinkers, and steam represent the consumption of fuel and water in the engine. Plainly, therefore, if we could restore to the body a supply of these four elements equivalent to that cast out, we could make up for the waste. The object of food, then, is to restore to the body an amount of the four elements equal to that consumed. In other words, and briefly: The purpose of food is to supply the waste of the tissues and to maintain the normal composition of the blood.

101. Classification of Foods. Foods may be conveniently divided into four great classes, to which the name food-stuffs or alimentary principles has been given. They correspond to the chief "proximate principles" of which the body consists. To one or the other of these classes all available foods belong[16]. The classification of food-stuffs usually given is as follows:

I. Proteids, or Nitrogenous Foods.
II. Starches and Sugars, or Carbohydrates.
III. Fats and Oils.
IV. Inorganic or Mineral Foods,--Water, Salt.

102. Proteids; or Nitrogenous Foods. The proteids, frequently spoken of as the nitrogenous foods, are rich in one or more of the following organic substances: albumen, casein, fibrin, gelatine, myosin, gluten, and legumin.

The type of this class of foods is albumen, well known as the white of an egg. The serum of the blood is very rich in albumen, as is lean meat. The curd of milk consists mainly of casein. Fibrin exists largely in blood and flesh foods. Gelatine is obtained from the animal parts of bones and connective tissue by prolonged boiling. One of the chief constituents of muscular fiber is myosin. Gluten exists largely in the cereals wheat, barley, oats, and rye. The proteid principle of peas and beans is legumin, a substance resembling casein.

As the name implies, the proteids, or nitrogenous foods, contain nitrogen; carbohydrates and fats, on the contrary, do not contain nitrogen. The principal proteid food-stuffs are milk, eggs, flesh foods of all kinds, fish, and the cereals among vegetable foods. Peas and beans are rich in proteids. The essential use of the proteids to the tissues is to supply the material from which the new proteid tissue is made or the old proteid tissue is repaired. They are also valuable as sources of energy to the body. Now, as the proteid part of its molecule is the most important constituent of living matter, it is evident that proteid food is an absolute necessity. If our diet contained no proteids, the tissues of the body would gradually waste away, and death from starvation would result. All the food-stuffs are necessary in one way or another to the preservation of perfect health, but proteids, together with a certain proportion of water and inorganic salts, are absolutely necessary for the bare maintenance of animal life--that is, for the formation and preservation of living protoplasm.

103. Starches and Sugars. The starches, sugars, and gums, also known as carbohydrates, enter largely into the composition of foods of vegetable origin. They contain no nitrogen, but the three elements, carbon, hydrogen, and oxygen, the last two in the same proportion as in water. The starches are widely distributed throughout the vegetable kingdom. They are abundant in potatoes and the cereals, and in arrowroot, rice, sago, and tapioca. Starch probably stands first in importance among the various vegetable foods.

The sugars are also widely distributed substances, and include the cane, grape, malt, maple, and milk sugars. Here also belong the gums and cellulose found in fruit, cereals, and all vegetables which form the basis of the plant cells and fibers. Honey, molasses, and manna are included in this class.

The physiological value of the starches and sugars lies in the fact that they are oxidized in the body, and a certain amount of energy is thereby liberated. The energy of muscular work and of the heat of the body comes largely from the oxidation, or destruction, of this class of foods. Now, inasmuch as we are continually giving off energy from the body, chiefly in the form of muscular work and heat, it is evident that material for the production of this energy must be taken in the food. The carbohydrates constitute the bulk of our ordinary food.

104. Fats and Oils. These include not only the ordinary fats of meat, but many animal and vegetable oils. They are alike in chemical composition, consisting of carbon and hydrogen, with a little oxygen and no nitrogen. The principal kinds of fat used as food are the fat of meat, butter, suet, and lard; but in many parts of the world various vegetable oils are largely used, as the olive, palm, cotton seed, cocoanut, and almond.

The use of the fats in the body is essentially the same as that of the starches and sugars. Weight for weight they are more valuable than the carbohydrates as sources of energy, but the latter are more easily digested, and more easily oxidized in the body. An important use of fatty foods is for the maintenance of the bodily heat. The inhabitants of Arctic regions are thus enabled, by large use of the fat and oil from the animals they devour, to endure safely the severe cold. Then there is reason to believe that fat helps the digestion of other foods, for it is found that the body is better nourished when the fats are used as food. When more fat is consumed than is required to keep up the bodily heat and to yield working power, the excess is stored up in various parts of the body, making a sort of reserve fuel, which may be drawn upon at any future time.

105. Saline or Mineral Foods. All food contains, besides the substances having potential energy, as described, certain saline matters. Water and salts are not usually considered foods, but the results of scientific research, as well as the experience of life, show that these substances are absolutely necessary to the body. The principal mineral foods are salt, lime, iron, magnesia, phosphorus, potash, and water. Except common salt and water, these substances are usually taken only in combination with other foods.

These saline matters are essential to health, and when not present in due proportion nutrition is disturbed. If a dog be fed on food freed from all salines, but otherwise containing proper nutrients, he soon suffers from weakness, after a time amounting to paralysis, and often dies in convulsions.

About 200 grains of common salt are required daily by an adult, but a large proportion of this is in our food. Phosphate of lime is obtained from milk and meats, and carbonate of lime from the hard water we drink. Both are required for the bones and teeth. The salts of potash, which assist in purifying the blood, are obtained from vegetables and fruits. An iron salt is found in most foods, and sulphur in the yolk of eggs.

106. Water. Water is of use chiefly as a solvent, and while not strictly a food, is necessary to life. It enters into the construction of

every tissue and is constantly being removed from the body by every channel of waste[17].

As a solvent water aids digestion, and as it forms about 80 per cent of the blood, it serves as a carrier of nutrient material to all the tissues of the body.

Important Articles of Diet.

107. Milk. The value of milk as a food cannot be overestimated. It affords nourishment in a very simple, convenient, and perfect form. It is the sole food provided for the young of all animals which nourish their young. It is an ideal food containing, in excellent proportions, all the four elements necessary for growth and health in earlier youth.

[Table: Composition of Food Materials. Careful analyses have been made of the different articles of food, mostly of the raw, or uncooked foods. As might be expected, the analyses on record differ more or less in the percentages assigned to the various constituents, but the following table will give a fair idea of the fundamental nutritive value of the more common foods:

In 100 parts	Water	Proteid	Fat	Carbohydrate		Ash
				Digestible	Cellulose	
Meat	76.7	20.8	1.5	0.3	--	1.3
Eggs	73.7	12.6	12.1	--	--	1.1
Cheese	36-60	25-33	7-30	3-7	--	3.4
Cow's Milk	87.7	3.4	3.2	4.8	--	0.7
Wheat Flour	13.3	10.2	0.9	74.8	0.3	0.5
Wheat Bread	35.6	7.1	0.2	55.5	0.3	1.1
Rye Flour	13.7	11.5	2.1	69.7	1.6	1.4
Rye bread	42.3	6.1	0.4	49.2	0.5	1.5
Rice	13.1	7.0	0.9	77.4	0.6	1.0
Corn	13.1	9.9	4.6	68.4	2.5	1.5
Macaroni	10.1	9.0	0.3	79.0	0.3	0.5
Peas and Beans	12-15	23-26	1-1/2-2	49-54	4.7	2-3
Potatoes	75.5	2.0	0.2	20.6	0.7	1.0
Carrots	87.1	1.0	0.2	9.3	1.4	0.9
Cabbage	90	2.3	0.5	4-6	1-2	1.3
Fruit	84	0.5	--	10	4	0.5

]

Cheese is the nitrogenous part of milk, which has been coagulated by the use of rennet. The curd is then carefully dried, salted, and pressed. Cheese is sometimes difficult of digestion, as on account of its solid form it is not easily acted upon by the digestive fluids.

108. Meats. The flesh of animals is one of our main sources of food. Containing a large amount of proteid, it is admirably adapted for building up and repairing the tissues of the body. The proportion of water is also high, varying from 50 to 75 per cent. The most common meats used in this country are beef, mutton, veal, pork, poultry, and game.

Beef contains less fat and is more nutritious than either mutton or pork. Mutton has a fine flavor and is easily digested. Veal and lamb, though more tender, are less easily digested. Pork contains much fat, and its fiber is hard, so that it is the most difficult to digest of all the meats. Poultry and game have usually a small proportion of fat, but are rich in phosphates and are valued for their flavor.

109. Eggs. Consisting of about two-thirds water and the rest albumen and fat, eggs are often spoken of as typical natural food. The white of an egg is chiefly albumen, with traces of fat and salt; the yolk is largely fat and salts. The yellow color is due partly to sulphur. It is this which blackens a silver spoon. Eggs furnish a convenient and concentrated food, and if properly cooked are readily digested.

110. Fish. Fish forms an important and a most nutritious article of diet, as it contains almost as much nourishment as butcher's meat. The fish-eating races and classes are remarkably strong and healthy. Fish is less stimulating than meat, and is thus valuable as a food for invalids and dyspeptics. To be at its best, fish should be eaten in its season. As a rule shell-fish, except oysters, are not very digestible. Some persons are unable to eat certain kinds of fish, especially shell-fish, without eruptions on the skin and other symptoms of mild poisoning.

111. Vegetable Foods. This is a large and important group of foods, and embraces a remarkable number of different kinds of diet. Vegetable foods include the cereals, garden vegetables, the fruits, and other less important articles. These foods supply a certain quantity of albumen and fat, but their chief use is to furnish starches, sugars, acids, and salts. The vegetable foods indirectly supply the body with a large amount of water, which they absorb in cooking.

112. Proteid Vegetable Foods. The most important proteid vegetable foods are those derived from the grains of cereals and certain leguminous seeds, as peas and beans. The grains when ground make the various flours or meals. They contain a large quantity of starch, a proteid substance peculiar to them called gluten, and mineral salts, especially phosphate of lime. Peas and beans contain a smaller proportion of starch, but more proteid matter, called legumin, or vegetable casein. Of the cereal foods, wheat is that most generally useful. Wheat, and corn and oatmeal form most important articles of diet. Wheat flour has starch, sugar, and gluten--nearly everything to support life except fat.

Oatmeal is rich in proteids. In some countries, as Scotland, it forms an important article of diet, in the form of porridge or oatmeal cakes.

Corn meal is not only rich in nitrogen, but the proportion of fat is also large; hence it is a most important and nutritious article of food. Rice, on the other hand, contains less proteids than any other cereal grain, and is the least nutritious. Where used as a staple article of food, as in India, it is commonly mixed with milk, cheese, or other nutritious substances. Peas and beans, distinguished from all other vegetables by their large amount of proteids--excel in this respect even beef, mutton, and fish. They take the place of meats with those who believe in a vegetable diet.

113. Non-proteid Vegetable Foods. The common potato is the best type of non-proteid vegetable food. When properly cooked it is easily digested and makes an excellent food. It contains about 75 per cent of water, about 20 per cent of carbohydrates, chiefly starch, 2 per cent of proteids, and a little fat and saline matters. But being deficient in flesh-forming materials, it is unfit for an exclusive food, but is best

used with milk, meat, and other foods richer in proteid substances. Sweet potatoes, of late years extensively used as food, are rich in starch and sugar. Arrowroot, sago, tapioca, and similar foods are nutritious, and easily digested, and with milk furnish excellent articles of diet, especially for invalids and children.

Explanation of the Graphic Chart. The graphic chart, on the next page, presents in a succinct and easily understood form the composition of food materials as they are bought in the market, including the edible and non-edible portions. It has been condensed from Dr. W. O. Atwater's valuable monograph on "Foods and Diet." This work is known as the Yearbook of the U.S. Department of Agriculture for 1894.

KEY: 1, percentage of nutrients; 2, fuel value of 1 pound in calories. The unit of heat, called a _calorie_, or gramme-degree, is the amount of heat which is necessary to raise one gramme (15.43 grains) of water one degree centigrade (1.8 degrees Fahr.). A, round beef; B, sirloin beef; C, rib beef; D, leg of mutton; E, spare rib of pork; F, salt pork; G, smoked ham; H, fresh codfish; I, oysters; J, milk; K, butter; L, cheese; M, eggs; N, wheat bread; O, corn meal; P, oatmeal; Q, dried beans; R, rice; S, potatoes; T, sugar.

This table, among other things, shows that the flesh of fish contains more water than that of warm-blooded animals. It may also be seen that animal foods contain the most water; and vegetable foods, except potatoes, the most nutrients. Proteids and fats exist only in small proportions in most vegetables, except beans and oatmeal. Vegetable foods are rich in carbohydrates while meats contain none. The fatter the meat the less the amount of water. Thus very lean meat may be almost four-fifths water, and fat pork almost one-tenth water.

[Illustration: Fig. 45.--Graphic Chart of the Composition of Food Materials. Composition of Food Materials. Nutritive ingredients, refuse, and fuel value.]

114. Non-proteid Animal Foods. Butter is one of the most digestible of animal fats, agreeable and delicate in flavor, and is on this account much used as a wholesome food. Various substitutes have recently come into use. These are all made from animal fat, chiefly that of beef, and are known as butterine, oleomargarine, and by other trade names. These preparations, if properly made, are wholesome, and may be useful substitutes for butter, from which they differ but little in composition.

115. Garden Vegetables. Various green, fresh, and succulent vegetables form an essential part of our diet. They are of importance not so much on account of their nutritious elements, which are usually small, as for the salts they supply, especially the salts of potash. It is a well-known fact that the continued use of a diet from which fresh vegetables are excluded leads to a disease known as scurvy. They are also used for the agreeable flavor possessed by many, and the pleasant variety and relish they give to the food. The undigested residue left by all green vegetables affords a useful stimulus to intestinal contraction, and tends to promote the regular action of the bowels.

116. Fruits. A great variety of fruits, both fresh and dry, is used as food, or as luxuries. They are of little nutritive value, containing, as they do, much water and only a small amount of proteid, but are of use chiefly for the sugar, vegetable acids, and salts they contain.

In moderate quantity, fruits are a useful addition to our regular diet. They are cooling and refreshing, of agreeable flavor, and tend to prevent constipation. Their flavor and juiciness serve to stimulate a weak appetite and to give variety to an otherwise heavy diet. If eaten in excess, especially in an unripe or an overripe state, fruits may occasion a disturbance of the stomach and bowels, often of a severe form.

117. Condiments. The refinements of cookery as well as the craving of the appetite, demand many articles which cannot be classed strictly as foods. They are called condiments, and as such may be used in moderation. They give flavor and relish to food, excite appetite and promote digestion. Condiments increase the pleasure of eating, and by their stimulating properties promote secretions of the digestive fluids and excite the muscular contractions of the alimentary canal.

The well-known condiments are salt, vinegar, pepper, ginger, nutmeg, cloves, and various substances containing ethereal oils and aromatics. Their excessive use is calculated to excite irritation and disorder of the digestive organs.

118. Salt The most important and extensively used of the condiments is common salt. It exists in all ordinary articles of diet, but in quantities not sufficient to meet the wants of the bodily tissues. Hence it is added to many articles of food. It improves their flavor, promotes certain digestive secretions, and meets the nutritive demands of the body. The use of salt seems based upon an instinctive demand of the system for something necessary for the full performance of its functions. Food without salt, however nutritious in other respects, is taken with reluctance and digested with difficulty.

Salt has always played an important and picturesque part in the history of dietetics. Reference to its worth and necessity abounds in sacred and profane history. In ancient times, salt was the first thing placed on the table and the last removed. The place at the long table, above or below the salt, indicated rank. It was everywhere the emblem of hospitality. In parts of Africa it is so scarce that it is worth its weight in gold, and is actually used as money. Torture was inflicted upon prisoners of state in olden times by limiting the food to water and bread, without salt. So intense may this craving for salt become, that men have often risked their liberty and even their lives to obtain it.

119. Water. The most important natural beverage is pure water; in fact it is the only one required. Man has, however, from the earliest times preferred and daily used a variety of artificial drinks, among which are tea, coffee, and cocoa.

All beverages except certain strong alcoholic liquors, consist almost entirely of water. It is a large element of solid foods, and our bodies are made up to a great extent of water. Everything taken into the circulating fluids of the body, or eliminated from them, is done through the agency of water. As a solvent it is indispensable in all the activities of the body.

It has been estimated that an average-sized adult loses by means of the lungs, skin, and kidneys about eighty ounces of water every twenty-four hours. To restore this loss about four pints must be taken daily. About one pint of this is obtained from the food we eat, the remaining three pints being taken as drink. One of the best ways of supplying water to the body is by drinking it in its pure state, when its solvent properties can be completely utilized. The amount of water consumed depends largely upon the amount of work performed by the body, and upon the temperature.

Being one of the essential elements of the body, it is highly important that water should be free from harmful impurities. If it contain the germs of disease, sickness may follow its use. Without doubt the most important factor in the spread of disease is, with the exception of impure air, impure water. The chief agent in the spread of typhoid fever is impure water. So with cholera, the evidence is overwhelming that filthy water is an all-powerful agent in the spread of this terrible disease.

120. Tea, Coffee, and Cocoa. The active principle of tea is called theine; that of coffee, caffeine, and of cocoa, theobromine. They also contain an aromatic, volatile oil, to which they owe their distinctive flavor. Tea and coffee also contain an astringent called tannin, which gives the peculiar bitter taste to the infusions when steeped too long. In cocoa, the fat known as cocoa butter amounts to fifty per cent.

121. Tea. It has been estimated that one-half of the human race now use tea, either habitually or occasionally. Its use is a prolific source of indigestion, palpitation of the heart, persistent wakefulness, and of other disorders. When used at all it should be only in moderation. Persons who cannot use it without feeling its hurtful effects, should leave it alone. It should not be taken on an empty stomach, nor sipped after every mouthful of food.

122. Coffee. Coffee often disturbs the rhythm of the heart and causes palpitation. Taken at night, coffee often causes wakefulness. This effect is so well known that it is often employed to prevent sleep. Immoderate use of strong coffee may produce other toxic effects, such as muscular tremors, nervous anxiety, sick-headache, palpitation, and various uncomfortable feelings in the cardiac region. Some persons cannot drink even a small amount of tea or coffee without these unpleasant effects. These favorite beverages are unsuitable for young people.

123. Cocoa. The beverage known as cocoa comes from the seeds of the cocoa-tree, which are roasted like the coffee berries to develop the aroma. Chocolate is manufactured cocoa,--sugar and flavors being added to the prepared seeds. Chocolate is a convenient and palatable form of highly nutritious food. For those with whom tea and coffee disagree, it may be an agreeable beverage. The large quantity of fat which it contains, however, often causes it to be somewhat indigestible.

124. Alcoholic Beverages. There is a class of liquids which are certainly not properly food or drink, but being so commonly used as beverages, they seem to require special notice in this chapter. In view of the great variety of alcoholic beverages, the prevalence of their use, and the very remarkable deleterious effects they produce upon the bodily organism, they imperatively demand our most careful attention, both from a physiological and an hygienic point of view.

125. Nature of Alcohol. The ceaseless action of minute forms of plant life, in bringing about the decomposition of the elaborated products of organized plant or animal structures, will be described in more detail (secs. 394-398).

All such work of vegetable organisms, whether going on in the moulding cheese, in the souring of milk, in putrefying meat, in rotting fruit, or in decomposing fruit juice, is essentially one of fermentation, caused by these minute forms of plant life. There are many kinds of fermentation, each with its own special form of minute plant life or micro-organism.

In this section we are more especially concerned about that fermentation which results from the decomposition of sweet fruit, plant, or other vegetable, juices which are composed largely of water containing sugar and flavoring matters.

This special form of fermentation is known as alcoholic or vinous fermentation, and the micro-organisms that cause it are familiarly termed alcoholic ferments. The botanist classes them as _Saccharomycetes_, of which there are several varieties. Germs of _Saccharomycetes_ are found on the surfaces and stems of fruit as it is ripening. While the fruit remains whole these germs have no power to invade the juice, and even when the skins are broken the conditions are less favorable for their work than for that of the moulds,[18] which are the cause of the rotting of fruit.

But when fruit is crushed and its juice pressed out, the _Saccharomycetes_ are carried into it where they cannot get the oxygen they need from the air. They are then able to obtain oxygen by taking it from the sugar of the juice. By so doing they cause a breaking up of the sugar and a rearrangement of its elements. Two new substances are formed in this decomposition of sugar, viz., carbon dioxid, which arises from the liquid in tiny bubbles, and alcohol, a poison which remains in the fermenting fluid.

Now we must remember that fermentation entirely changes the nature of the substance fermented. For all forms of decomposition this one law holds good. Before alcoholic fermentation, the fruit juice was wholesome and beneficial; after fermentation, it becomes, by the action of the minute germs, a poisonous liquid known as alcohol, and which forms an essential part of all intoxicating beverages.

Taking advantage of this great law of fermentation which dominates the realm of nature, man has devised means to manufacture various alcoholic beverages from a great variety of plant structures, as ripe grapes, pears, apples, and other fruits, cane juices, corn, the malt of barley, rye, wheat, and other cereals.

The process differs according to the substance used and the manner in which it is treated, but the ultimate outcome is always the same, viz., the manufacture of a beverage containing a greater or less proportion of alcoholic poison. By the process of _distillation_, new and stronger liquor is made. Beverages thus distilled are known as ardent spirits. Brandy is distilled from wine, rum from fermented molasses, and commercial alcohol mostly from whiskey.

The poisonous element in all forms of intoxicating drinks, and the one so fraught with danger to the bodily tissues, is the alcohol they contain. The proportion of the alcoholic ingredient varies, being about 50 per cent in brandy, whiskey, and rum, about 20 to 15 per cent in wines, down to 5 per cent, or less, in the various beers and cider; but whether the proportion of alcohol be more or less, the same element of danger is always present.

126. Effects of Alcoholic Beverages upon the Human System. One of the most common alcoholic beverages is wine, made from the juice of grapes. As the juice flows from the crushed fruit the ferments are washed from the

skins and stems into the vat. Here they bud and multiply rapidly, producing alcohol. In a few hours the juice that was sweet and wholesome while in the grape is changed to a poisonous liquid, capable of injuring whoever drinks it. One of the gravest dangers of wine-drinking is the power which the alcohol in it has to create a thirst which demands more alcohol. The spread of alcoholism in wine-making countries is an illustration of this fact.

Another alcoholic beverage, common in apple-growing districts, is cider. Until the microscope revealed the ferment germ on the "bloom" of the apple-skin, very little was known of the changes produced in cider during the mysterious process of "working." Now, when we see the bubbles of gas in the glass of cider we know what has produced them, and we know too that a poison which we do not see is there also in corresponding amounts. We have learned, too, to trace the wrecked hopes of many a farmer's family to the alcohol in the cider which he provided so freely, supposing it harmless.

Beer and other malt liquors are made from grain. By sprouting the grain, which changes its starch to sugar, and then dissolving out the sugar with water, a sweet liquid is obtained which is fermented with yeast, one kind of alcoholic ferment. Some kinds of beer contain only a small percentage of alcohol, but these are usually drunk in proportionately large amounts. The life insurance company finds the beer drinker a precarious risk; the surgeon finds him an unpromising subject; the criminal court finds him conspicuous in its proceedings. The united testimony from all these sources is that beer is demoralizing, mentally, morally, and physically.

127. Cooking. The process through which nearly all food used by civilized man has to pass before it is eaten is known as cooking. Very few articles indeed are consumed in their natural state, the exceptions being eggs, milk, oysters, fruit and a few vegetables. Man is the only animal that cooks his food. Although there are savage races that have no knowledge of cooking, civilized man invariably cooks most of his food. It seems to be true that as nations advance in civilization they make a proportionate advance in the art of cooking.

Cooking answers most important purposes in connection with our food, especially from its influence upon health. It enables food to be more readily chewed, and more easily digested. Thus, a piece of meat when raw is tough and tenacious, but if cooked the fibers lose much of their toughness, while the connective tissues are changed into a soft and jelly-like mass. Besides, the meat is much more readily masticated and acted upon by the digestive fluids. So cooking makes vegetables and grains softer, loosens their structure, and enables the digestive juices readily to penetrate their substance.

Cooking also improves or develops flavors in food, especially in animal foods, and thus makes them attractive and pleasant to the palate. The appearance of uncooked meat, for example, is repulsive to our taste, but by the process of cooking, agreeable flavors are developed which stimulate the appetite and the flow of digestive fluids.

Another important use of cooking is that it kills any minute parasites or germs in the raw food. The safeguard of cooking thus effectually removes some important causes of disease. The warmth that cooking imparts to food is a matter of no slight importance; for warm food is more readily digested, and therefore nourishes the body more quickly.

The art of cooking plays a very important part in the matter of health, and thus of comfort and happiness. Badly cooked and ill-assorted foods are often the cause of serious disorders. Mere cooking is not enough, but good cooking is essential.

Experiments.

Experiments with the Proteids.

Experiment 31. As a type of the group of proteids we take the white of egg, egg-white or egg-albumen. Break an egg carefully, so as not to mix the white with the yolk. Drop about half a teaspoonful of the raw white of egg into half a pint of distilled water. Beat the mixture vigorously with a glass rod until it froths freely. Filter through several folds of muslin until a fairly clear solution is obtained.

Experiment 32. To a small quantity of this solution in a test tube add strong nitric acid, and boil. Note the formation of a white precipitate, which turns yellow. After cooling, add ammonia, and note that the precipitate becomes orange.

Experiment 33. Add to the solution of egg-albumen, excess of strong solution of caustic soda (or potash), and then a drop or two of very dilute solution (one per cent) of copper sulphate. A violet color is obtained which deepens on boiling.

Experiment 34. Boil a small portion of the albumen solution in a test tube, adding drop by drop dilute acetic acid (two per cent) until a flaky coagulum of insoluble albumen separates.

Experiments with Starch.

Experiment 35. Wash a potato and peel it. Grate it on a nutmeg grater into a tall cylindrical glass full of water. Allow the suspended particles to subside, and after a time note the deposit. The lowest layer consists of a white powder, or starch, and above it lie coarser fragments of cellulose and other matters.

Experiment 36. Examine under the microscope a bit of the above white deposit. Note that each starch granule shows an eccentric hilum with concentric markings. Add a few drops of very dilute solution of iodine. Each granule becomes blue, while the markings become more distinct.

Experiment 37. Examine a few of the many varieties of other kinds of starch granules, as in rice, arrowroot, etc. Press some dry starch powder between the thumb and forefinger, and note the peculiar crepitation.

Experiment 38. Rub a few bits of starch in a little cold water. Put a little of the mixture in a large test tube, and then fill with boiling water. Boil until an imperfect opalescent solution is obtained.

Experiment 39. Add powdered dry starch to cold water. It is insoluble. Filter and test the filtrate with iodine. It gives no blue color.

Experiment 40. Boil a little starch with water; if there is enough starch it sets on cooling and a paste results.

Experiment 41. Moisten some flour with water until it forms a tough, tenacious dough; tie it in a piece of cotton cloth, and knead it in a vessel containing water until all the starch is separated. There remains on the cloth a grayish white, sticky, elastic "gluten," made up of albumen, some of the ash, and fats. Draw out some of the gluten into threads, and observe its tenacious character.

Experiment 42. Shake up a little flour with ether in a test tube, with a tight-fitting cork. Allow the mixture to stand for an hour, shaking it from time to time. Filter off the ether, and place some of it on a perfectly clean watch glass. Allow the ether to evaporate, when a greasy stain will be left, thus showing the presence of fats in the flour.

Experiment 43. Secure a specimen of the various kinds of flour, and meal, peas, beans, rice, tapioca, potato, etc. Boil a small quantity of each in a test tube for some minutes. Put a bit of each thus cooked on a white plate, and pour on it two or three drops of the tincture of iodine. Note the various changes of color,--blue, greenish, orange, or yellowish.

Experiments with Milk.

Experiment 44. Use fresh cow's milk. Examine the naked-eye character of the milk. Test its reaction with litmus paper. It is usually neutral or slightly alkaline.

Experiment 45. Examine with the microscope a drop of milk, noting numerous small, highly refractive oil globules floating in a fluid.

Experiment 46. Dilute one ounce of milk with ten times its volume of water. Add cautiously dilute acetic acid until there is a copious, granular-looking precipitate of the chief proteid of milk (caseinogen), formerly regarded as a derived albumen. This action is hastened by heating.

Experiment 47. Saturate milk with Epsom salts, or common salt. The proteid and fat separate, rise to the surface, and leave a clear fluid beneath.

Experiment 48. Place some milk in a basin; heat it to about 100 degrees F., and add a few drops of acetic acid. The mass curdles and separates into a solid curd (proteid and fat) and a clear fluid (the whey), which contains the lactose.

Experiment 49. Take one or two teaspoonfuls of fresh milk in a test tube; heat it, and add a small quantity of extract of rennet. Note that the whole mass curdles in a few minutes, so that the tube can be inverted without the curd falling out. Soon the curd shrinks, and squeezes out a clear, slightly yellowish fluid, the whey.

Experiment 50. Boil the milk as before, and allow it to cool; then add rennet. No coagulation will probably take place. It is more difficult to coagulate boiled milk with rennet than unboiled milk.

Experiment 51. Test fresh milk with red litmus paper; it should turn the paper pale blue, showing that it is slightly alkaline. Place aside for a day or two, and then test with blue litmus paper; it will be found to be acid. This is due to the fact that lactose undergoes the lactic acid fermentation. The lactose is converted into lactic acid by means of a special ferment.

Experiment 52. Evaporate a small quantity of milk to dryness in an open dish. After the dry residue is obtained, continue to apply heat; observe that it chars and gives off pungent gases. Raise the temperature until it is red hot; allow the dish then to cool; a fine white ash will be left behind. This represents the _inorganic matter_ of the milk.

Experiments with the Sugars.

Experiment 53. Cane sugar is familiar as cooking and table sugar. The little white grains found with raisins are grape sugar, or glucose. Milk sugar is readily obtained of the druggist. Prepare a solution of the various sugars by dissolving a small quantity of each in water. Heat each solution with sulphuric acid, and it is seen to darken or char slowly.

Experiment 54. Place some Fehling solution (which can be readily obtained at the drug store as a solution, or tablets may be bought which answer the same purpose) in a test tube, and boil. If no yellow discoloration takes place, it is in good condition. Add a few drops of the grape sugar solution and boil, when the mixture suddenly turns to an opaque yellow or red color.

Experiment 55. Repeat same experiment with milk sugar.

Chapter VI.

Digestion.

128. The Purpose of Digestion. As we have learned, our bodies are subject to continual waste, due both to the wear and tear of their substance, and to the consumption of material for the production of their heat and energy. The waste occurs in no one part alone, but in all the tissues.

Now, the blood comes into direct contact with every one of these tissues. The ultimate cells which form the tissues are constantly being bathed by the myriads of minute blood-vessels which bring to the cells the raw material needed for their continued renewal. These cells are able to select from the nutritive fluid whatever they require to repair their waste, and to provide for their renewed activity. At the same time, the blood, as it bathes the tissues, sweeps into its current and bears away the products of waste.

Thus the waste occurs in the tissues and the means of repair are obtained from the blood. The blood is thus continually being impoverished by having its nourishment drained away. How, then, is the efficiency of the blood maintained? The answer is that while the ultimate purpose of the food is for the repair of the waste, its immediate destination is the blood.[19]

129. Absorption of Food by the Blood. How does the food pass from the cavity of the stomach and intestinal canal into the blood-vessels? There are no visible openings which permit communication. It is done by what in physics is known as _endosmotic_ and _exosmotic_ action. That is, whenever there are two solutions of different densities, separated only by an animal membrane, an interchange will take place between them through the membrane.

To illustrate: in the walls of the stomach and intestines there is a network of minute vessels filled with blood,--a liquid containing many substances in solution. The stomach and intestinal canal also contain liquid food, holding many substances in solution. A membrane, made up of the extremely thin walls of the blood-vessels and intestines, separates the liquids. An exchange takes place between the blood and the contents of the stomach and bowels, by which the dissolved substances of food pass through the separating membranes into the blood.

[Illustration: Fig. 46.--Cavities of the Mouth, Pharynx, etc. (Section in the middle line designed to show the mouth in its relations to the nasal fossae, the pharynx, and the larynx.)

A, sphenoidal sinus;
B, internal orifice of Eustachian tube;
C, velum palati;
D, anterior pillar of soft palate;
E, posterior pillar of soft palate;
F, tonsil;
H, lingual portion of the pharynx;
K, lower portion of the pharynx;
L, larynx;
M, section of hyoid bone;
N, epiglottis;
O, palatine arch
]

This change, by which food is made ready to pass into the blood, constitutes food-digestion, and the organs concerned in bringing about this change in the food are the digestive organs.

130. The General Plan of Digestion. It is evident that the digestive organs will be simple or complex, according to the amount of change which is necessary to prepare the food to be taken up by the blood. If the requisite change is slight, the digestive organs will be few, and their structure simple. But if the food is varied and complex in composition, the digestive apparatus will be complex. This condition applies to the food and the digestion of man.

[Illustration: Fig. 47.--Diagram of the Structure of Secreting Glands.

A, simple tubular gland;
B, gland with mouth shut and sac formed;
C, gland with a coiled tube;
D, plan of part of a racemose gland
]

The digestive apparatus of the human body consists of the alimentary canal and tributary organs which, although outside of this canal, communicate with it by ducts. The alimentary canal consists of the mouth, the pharynx, the oesophagus, the stomach, and the intestines. Other digestive organs which are tributary to this canal, and discharge their secretions into it, are the salivary glands,[20] the liver, and the pancreas.

The digestive process is subdivided into three steps, which take place in the mouth, in the stomach, and in the intestines.

131. The Mouth. The mouth is the cavity formed by the lips, the cheeks, the palate, and the tongue. Its bony roof is made up of the upper jawbone on each side, and the palate bones behind. This is the _hard palate_, and forms only the front portion of the roof. The continuation of the roof is called the _soft palate_, and is made up of muscular tissue covered with mucous membrane.

The mouth continues behind into the throat, the separation between the two being marked by fleshy pillars which arch up from the sides to form the soft palate. In the middle of this arch there hangs from its free edge a little lobe called the uvula. On each side where the pillars begin to arch is an almond-shaped body known as the tonsil. When we take cold, one or both of the tonsils may become inflamed, and so swollen as to obstruct the passage into the throat. The mouth is lined with mucous membrane, which is continuous with that of the throat, oesophagus, stomach, and intestines (Fig. 51).

132. Mastication, or Chewing. The first step of the process of digestion is mastication, the cutting and grinding of the food by the teeth, effected by the vertical and lateral movements of the lower jaw. While the food is thus being crushed, it is moved to and fro by the varied movements of the tongue, that every part of it may be acted upon by the teeth. The advantage of this is obvious. The more finely the food is divided, the more easily will the digestive fluids reach every part of it, and the more thoroughly and speedily will digestion ensue.

The act of chewing is simple and yet important, for if hurriedly or imperfectly done, the food is in a condition to cause disturbance in the digestive process. Thorough mastication is a necessary introduction to the more complicated changes which occur in the later digestion.

133. The Teeth. The teeth are attached to the upper and lower maxillary bones by roots which sink into the sockets of the jaws. Each tooth consists of a _crown_, the visible part, and one or more fangs, buried in the sockets. There are in adults 32 teeth, 16 in each jaw.

Teeth differ in name according to their form and the uses to which they are specially adapted. Thus, at the front of the jaws, the incisors, or cutting teeth, number eight, two on each side. They have a single root and the crown is beveled behind, presenting a chisel-like edge. The incisors divide the food, and are well developed in rodents, as squirrels, rats, and beavers.

Next come the canine teeth, or cuspids, two in each jaw, so called from their resemblance to the teeth of dogs and other flesh-eating animals. These teeth have single roots, but their crowns are more pointed than in the incisors. The upper two are often called eye teeth, and the lower two, stomach teeth. Next behind the canines follow, on each side, two bicuspids. Their crowns are broad, and they have two roots. The three hindmost teeth in each jaw are the molars, or grinders. These are broad teeth with four or five points on each, and usually each molar has three roots.

The last molars are known as the wisdom teeth, as they do not usually appear until the person has reached the "years of discretion." All animals that live on grass, hay, corn, and the cereals generally, have large grinding teeth, as the horse, ox, sheep, and elephant.

The following table shows the teeth in their order:

	Mo.	Bi.	Ca.	In.		In.	Ca.	Bi.	Mo.	
Upper	3	2	1	2	|	2	1	2	3	= 16
			|					} = 32		
Lower	3	2	1	2	|	2	1	2	3	= 16

The vertical line indicates the middle of the jaw, and shows that on each side of each jaw there are eight teeth.

134. Development of the Teeth. The teeth just described are the permanent set, which succeeds the temporary or milk teeth.
The latter are twenty in number, ten in each jaw, of which the four in the middle are incisors. The tooth beyond on each side is an eye tooth, and the next two on each side are bicuspids, or premolars.

The milk teeth appear during the first and second years, and last until about the sixth or seventh year, from which time until the twelfth or thirteenth year, they are gradually pushed out, one by one, by the permanent teeth. The roots of the milk teeth are much smaller than those of the second set.

[Illustration: Fig. 48.--Temporary and Permanent Teeth together.

Temporary teeth:
A, central incisors;
B lateral incisors;
C, canines;
D, anterior molars;
E, posterior molars

Permanent teeth:
F, central incisors;
H, lateral incisors;
K, canines;
L, first bicuspids;
M, second biscuspids;
N, first molars
]

The plan of a gradual succession of teeth is a beautiful provision of nature, permitting the jaws to increase in size, and preserving the relative position and regularity of the successive teeth.

[Illustration: Fig. 49.--Showing the Principal Organs of the Thorax and Abdomen _in situ_. (The principal muscles are seen on the left, and superficial veins on the right.)]

135. Structure of the Teeth. If we should saw a tooth down through its center we would find in the interior a cavity. This is the pulp cavity, which is filled with the dental pulp, a delicate substance richly supplied with nerves and blood-vessels, which enter the tooth by small openings at the point of the root. The teeth are thus nourished like

other parts of the body. The exposure of the delicate pulp to the air, due to the decay of the dentine, gives rise to the pain of toothache.

Surrounding the cavity on all sides is the hard substance known as the dentine, or tooth ivory. Outside the dentine of the root is a substance closely resembling bone, called cement. In fact, it is true bone, but lacks the Haversian canals. The root is held in its socket by a dense fibrous membrane which surrounds the cement as the periosteum does bone.

[Illustration: Fig. 50.--Section of Face. (Showing the parotid and submaxillary glands.)]

The crown of the tooth is not covered by cement, but by the hard enamel, which forms a strong protection for the exposed part. When the teeth are first "cut," the surface of the enamel is coated with a delicate membrane which answers to the Scriptural phrase "the skin of the teeth." This is worn off in adult life.

136. Insalivation. The thorough mixture of the saliva with the food is called insalivation. While the food is being chewed, it is moistened with a fluid called saliva, which flows into the mouth from six little glands. There are on each side of the mouth three salivary glands, which secrete the saliva from the blood. The parotid is situated on the side of the face in front of the ear. The disease, common in childhood, during which this gland becomes inflamed and swollen, is known as the "mumps." The submaxillary gland is placed below and to the inner side of the lower jaw, and the sublingual is on the floor of the mouth, between the tongue and the gums. Each gland opens into the mouth by a little duct. These glands somewhat resemble a bunch of grapes with a tube for a stalk.

The saliva is a colorless liquid without taste or smell. Its principal element, besides water, is a ferment called _ptyalin_, which has the remarkable property of being able to change starch into a form of cane-sugar, known as maltose.

Thus, while the food is being chewed, another process is going on by which starch is changed into sugar. The saliva also moistens the food into a mass for swallowing, and aids in speech by keeping the mouth moist.

The activity of the salivary glands is largely regulated by their abundant supply of nerves. Thus, the saliva flows into the mouth, even at the sight, smell, or thought of food. This is popularly known as "making the mouth water." The flow of saliva may be checked by nervous influences, as sudden terror and undue anxiety.

Experiment 56. _To show the action of saliva on starch_. Saliva for experiment may be obtained by chewing a piece of India rubber and collecting the saliva in a test tube. Observe that it is colorless and either transparent or translucent, and when poured from one vessel to another is glairy and more or less adhesive. Its reaction is alkaline to litmus paper.

Experiment 57. Make a thin paste from pure starch or arrowroot. Dilute a little of the saliva with five volumes of water, and filter it. This is best done through a filter perforated at its apex by a pin-hole. In this way all air-bubbles are avoided. Label three test tubes _A, B_, and _C_. In _A_, place starch paste; in _B_, saliva; and in _C_ one volume of saliva and three volumes of starch paste. Place them for ten minutes in a water bath at about 104 degrees Fahrenheit.

Test portions of all three for a reducing sugar, by means of Fehling's solution or tablets.[21] _A_ and _B_ give no evidence of sugar, while _C_ reduces the Fehling, giving a yellow or red deposit of cuprous oxide. Therefore, starch is converted into a reducing sugar by the saliva. This is done by the ferment ptyalin contained in saliva.

137. The Pharynx and OEsophagus. The dilated upper part of the alimentary canal is called the pharynx. It forms a blind sac above the level of the mouth. The mouth opens directly into the pharynx, and just above it are two openings leading into the posterior passages of the nose. There are also little openings, one on each side, from which begin the Eustachian tubes, which lead upward to the ear cavities.

The windpipe opens downward from the pharynx, but this communication can be shut off by a little plate or lid of cartilage, the epiglottis. During the act of swallowing, this closes down over the entrance to the windpipe, like a lid, and prevents the food from passing into the air-passages. This tiny trap-door can be seen, by the aid of a mirror, if we open the mouth wide and press down the back of the tongue with the handle of a spoon (Figs. 46, 84, and 85).

Thus, there are six openings from the pharynx; the oesophagus being the direct continuation from it to the stomach. If we open the mouth before a mirror we see through the fauces the rear wall of the pharynx. In its lining membrane is a large number of glands, the secretion from which during a severe cold may be quite troublesome.

The oesophagus, or gullet, is a tube about nine inches long, reaching from the throat to the stomach. It lies behind the windpipe, pierces the diaphragm between the chest and abdomen, and opens into the stomach. It has in its walls muscular fibers, which, by their worm-like contractions, grasp the successive masses of food swallowed, and pass them along downwards into the stomach.

138. Deglutition, or Swallowing. The food, having been well chewed and mixed with saliva, is now ready to be swallowed as a soft, pasty mass. The tongue gathers it up and forces it backwards between the pillars of the fauces into the pharynx.

If we place the fingers on the "Adam's apple," and then pretend to swallow something, we can feel the upper part of the windpipe and the closing of its lid (epiglottis), so as to cover the entrance and prevent the passage of food into the trachea.

There is only one pathway for the food to travel, and that is down the oesophagus. The slow descent of the food may be seen if a horse or dog be watched while swallowing. Even liquids do not fall or flow down the food passage. Hence, acrobats can drink while standing on their heads, or a horse with its mouth below the level of the oesophagus. The food is under the control of the will until it has entered the pharynx; all the later movements are involuntary.

[Illustration: Fig. 51.--A View into the Back Part of the Adult Mouth. (The head is represented as having been thrown back, and the tongue drawn forward.)

A, B, incisors;
C, canine;
D, E, bicuspids;
F, H, K, molars;
M, anterior pillar of the fauces;
N, tonsil;
L, uvula;
O, upper part of the pharynx;
P, tongue drawn forward;
R, linear ridge, or raphe.
]

139. The Stomach. The stomach is the most dilated portion of the alimentary canal and the principal organ of digestion. Its form is not easily described. It has been compared to a bagpipe, which it resembles somewhat, when moderately distended. When empty it is flattened, and in some parts its opposite walls are in contact.

We may describe the stomach as a pear-shaped bag, with the large end to the left and the small end to the right. It lies chiefly on the left side of the abdomen, under the diaphragm, and protected by the lower ribs. The fact that the large end of the stomach lies just beneath the diaphragm and the heart, and is sometimes greatly distended on account of indigestion or gas, may cause feelings of heaviness in the chest or palpitation of the heart. The stomach is subject to greater variations in size than any other organ of the body, depending on its contents. Just after a moderate meal it averages about twelve inches in length and four in diameter, with a capacity of about four pints.

[Illustration: Fig. 52.--The Stomach. A, cardiac end; B, pyloric end, C, lesser curvature, D, greater curvature]

The orifice by which the food enters is called the cardiac opening, because it is near the heart. The other opening, by which the food leaves the stomach, and where the small intestine begins, is the pyloric orifice, and is guarded by a kind of valve, known as the pylorus, or gatekeeper. The concave border between the two orifices is called the _small curvature_, and the convex as the _great curvature_, of the stomach.

140. Coats of Stomach. The walls of the stomach are formed by four coats, known successively from without as serous, muscular, sub-mucous, and mucous. The outer coat is the serous membrane which lines the abdomen,--the peritoneum (note, p. 135). The second coat is muscular, having three sets of involuntary muscular fibers. The outer set runs lengthwise from the cardiac orifice to the pylorus. The middle set encircles all parts of the stomach, while the inner set consists of oblique fibers. The third coat is the sub-mucous, made up of loose connective tissues, and binds the mucous to the muscular coat. Lastly there is the mucous coat, a moist, pink, inelastic membrane, which completely lines the stomach. When the stomach is not distended, the mucous layer is thrown into folds presenting a corrugated appearance.

[Illustration: Fig. 53.--Pits in the Mucous Membrane of the Stomach, and Openings of the Gastric Glands. (Magnified 20 diameters.)]

141. The Gastric Glands. If we were to examine with a hand lens the inner surface of the stomach, we would find it covered with little pits, or depressions, at the bottom of which would be seen dark dots. These dots

are the openings of the gastric glands. In the form of fine, wavy tubes, the gastric glands are buried in the mucous membrane, their mouths opening on the surface. When the stomach is empty the mucous membrane is pale, but when food enters, it at once takes on a rosy tint. This is due to the influx of blood from the large number of very minute blood-vessels which are in the tissue between the rows of glands.

The cells of the gastric glands are thrown into a state of greater activity by the increased quantity of blood supply. As a result, soon after food enters the stomach, drops of fluid collect at the mouths of the glands and trickle down its walls to mix with the food. Thus these glands produce a large quantity of gastric juice, to aid in the digestion of food.

142. Digestion in the Stomach. When the food, thoroughly mixed with saliva, reaches the stomach, the cardiac end of that organ is closed as well as the pyloric valve, and the muscular walls contract on the contents. A spiral wave of motion begins, becoming more rapid as digestion goes on. Every particle of food is thus constantly churned about in the stomach and thoroughly mixed with the gastric juice. The action of the juice is aided by the heat of the parts, a temperature of about 99 degrees Fahrenheit.

The gastric juice is a thin almost colorless fluid with a sour taste and odor. The reaction is distinctly acid, normally due to free hydrochloric acid. Its chief constituents are two ferments called pepsin and rennin, free hydrochloric acid, mineral salts, and 95 per cent of water.

[Illustration: Fig. 54.--A highly magnified view of a peptic or gastric gland, which is represented as giving off branches. It shows the columnar epithelium of the surface dipping down into the duct D of the gland, from which two tubes branch off. Each tube is lined with columnar epithelial cells, and there is a minute central passage with the "neck" at N. Here and there are seen other special cells called parietal cells, P, which are supposed to produce the acid of the gastric juice. The principal cells are represented at C.]

Pepsin the important constituent of the gastric juice, has the power, in the presence of an acid, of dissolving the proteid food-stuffs. Some of which is converted into what are called _peptones_, both soluble and capable of filtering through membranes. The gastric juice has no action on starchy foods, neither does it act on fats, except to dissolve the albuminous walls of the fat cells. The fat itself is thus set free in the form of minute globules. The whole contents of the stomach now assume the appearance and the consistency of a thick soup, usually of a grayish color, known as chyme.

It is well known that "rennet" prepared from the calf's stomach has a remarkable effect in rapidly curdling milk, and this property is utilized in the manufacture of cheese. Now, a similar ferment is abundant in the gastric juice, and may be called _rennin_. It causes milk to clot, and does this by so acting on the casein as to make the milk set into a jelly. Mothers are sometimes frightened when their children, seemingly in perfect health, vomit masses of curdled milk. This curdling of the milk is, however, a normal process, and the only noteworthy thing is its rejection, usually due to overfeeding.

Experiment 58. _To show that pepsin and acid are necessary for gastric digestion._ Take three beakers, or large test tubes; label them _A_, _B_, _C_. Put into _A_ water and a few grains of powdered pepsin. Fill _B_ two-thirds full of dilute hydrochloric acid (one teaspoonful to a pint), and fill _C_ two-thirds full of hydrochloric acid and a few grains of pepsin. Put into each a small quantity of well-washed fibrin, and place them all in a water bath at 104 degrees Fahrenheit for half an hour.

Examine them. In _A_, the fibrin is unchanged; in _B_, the fibrin is clear and swollen up; in _C_, it has disappeared, having first become swollen and clear, and completely dissolved, being finally converted into peptones. Therefore, both acid and ferment are required for gastric digestion.

Experiment 59. Half fill with dilute hydrochloric acid three large test tubes, labelled _A_, _B_, _C_. Add to each a few grains of pepsin. Boil _B_, and make _C_ faintly alkaline with sodic carbonate. The alkalinity may be noted by adding previously some neutral litmus solution. Add to each an equal amount--a few threads--of well-washed fibrin which has been previously steeped for some time in dilute hydrochloric acid, so that it is swollen and transparent. Keep the tubes in a water-bath at about 104 degrees Fahrenheit for an hour and examine them at intervals of twenty minutes.

After five to ten minutes the fibrin in _A_ is dissolved and the fluid begins to be turbid. In _B_ and _C_ there is no change. Even after long exposure to 100 degrees Fahrenheit there is no change in _B_ and _C_.

After a variable time, from one to four hours, the contents of the stomach, which are now called chyme, begin to move on in successive portions into the next part of the intestinal canal. The ring-like muscles of the pylorus relax at intervals to allow the muscles of the stomach to force the partly digested mass into the small intestines. This action is frequently repeated, until even the indigestible masses which the gastric juice cannot break down are crowded out of the stomach into the intestines. From three to four hours after a meal the stomach is again quite emptied.

A certain amount of this semi-liquid mass, especially the peptones, with any saccharine fluids, resulting from the partial conversion of starch or otherwise, is at once absorbed, making its way through the delicate vessels of the stomach into the blood current, which is flowing through the gastric veins to the portal vein of the liver.

[Illustration: Fig. 55.--A Small Portion of the Mucous Membrane of the Small Intestine. (Villi are seen surrounded with the openings of the tubular glands.) [Magnified 20 diameters.]]

143. The Small Intestine. At the pyloric end of the stomach the alimentary canal becomes again a slender tube called the small intestine. This is about twenty feet long and one inch in diameter, and is divided, for the convenience of description, into three parts.

The first 12 inches is called the duodenum. Into this portion opens the bile duct from the liver with the duct from the pancreas, these having been first united and then entering the intestine as a common duct.

The next portion of the intestine is called the jejunum, because it is usually empty after death.

The remaining portion is named the ileum, because of the many folds into which it is thrown. It is the longest part of the small intestine, and terminates in the right iliac region, opening into the large intestine. This opening is guarded by the folds of the membrane forming the ileo-caecal valve, which permits the passage of material from the small to the large intestine, but prevents its backward movement.

144. The Coats of the Small Intestine. Like the stomach, the small intestine has four coats, the serous, muscular, sub-mucous, and mucous. The serous is the peritoneum.[22] The muscular consists of an outer layer of longitudinal, and an inner layer of circular fibers, by contraction of which the food is forced along the bowel. The sub-mucous coat is made up of a loose layer of tissue in which the blood-vessels and nerves are distributed. The inner, or mucous, surface has a fine, velvety feeling, due to a countless number of tiny, thread-like projections, called villi. They stand up somewhat like the "pile" of velvet. It is through these villi that the digested food passes into the blood.

[Illustration: Fig. 56.--Sectional View of Intestinal Villi. (Black dots represent the glandular openings.)]

The inner coat of a large part of the small intestine is thrown into numerous transverse folds called _valvulae conniventes_. These seem to serve two purposes, to increase the extent of the surface of the bowels and to delay mechanically the progress of the intestinal contents. Buried in the mucous layer throughout the length, both of the small and large intestines, are other glands which secrete intestinal fluids. Thus, in the lower part of the ileum there are numerous glands in oval patches known as _Peyer's patches_. These are very prone to become inflamed and to ulcerate during the course of typhoid fever.

145. The Large Intestine. The large intestine begins in the right iliac region and is about five or six feet long. It is much larger than the small intestine, joining it obliquely at short distance from its end. A blind pouch, or dilated pocket is thus formed at the place of junction, called the caecum. A valvular arrangement called the ileo-caecal valve, which is provided with a button-hole slit, forms a kind of movable partition between this part of the large intestine and the small intestine.

[Illustration: Fig. 57.--Tubular Glands of the Small Intestines.

A, B, tubular glands seen in vertical section with their orifices at C, opening upon the membrane between the villi, D, villus (Magnified 40 diameters)]

Attached to the caecum is a worm-shaped tube, about the size of a lead pencil, and from three to four inches long, called the _vermiform appendix_. Its use is unknown. This tube is of great surgical importance, from the fact that it is subject to severe inflammation, often resulting in an internal abscess, which is always dangerous and may prove fatal. Inflammation of the appendix is known as _appendicitis_,--a name quite familiar on account of the many surgical operations performed of late years for its relief.

The large intestine passes upwards on the right side as the ascending colon, until the under side of the liver is reached, where it passes to the left side, as the transverse colon, below the stomach. It there turns downward, as the descending colon, and making an S-shaped curve, ends in the rectum. Thus the large intestine encircles, in the form of a horseshoe, the convoluted mass of small intestines.

Like the small intestine, the large has four coats. The mucous coat, however, has no folds, or villi, but numerous closely set glands, like some of those of the small intestine. The longitudinal muscular fibers of the large intestine are arranged in three bands, or bundles, which, being shorter than the canal itself, produce a series of bulgings or pouches in its walls. This sacculation of the large bowel is supposed to be designed for delaying the onward flow of its contents, thus allowing more time for the absorption of the liquid material. The blood-vessels and nerves of this part of the digestive canal are very numerous, and are derived from the same sources as those of the small intestine.

146. The Liver. The liver is a part of the digestive apparatus, since it forms the bile, one of the digestive fluids. It is a large reddish-brown organ, situated just below the diaphragm, and on the right side. The liver is the largest gland in the body, and weighs from 50 to 60 ounces. It consists of two lobes, the right and the left, the right being much the larger. The upper, convex surface of the liver is very smooth and even; but the under surface is irregular, broken by the entrance and exit of the various vessels which belong to the organ. It is held in its place by five ligaments, four of which are formed by double folds of the peritoneum.

The thin front edge of the liver reaches just below the bony edge of the ribs; but the dome-shaped diaphragm rises slightly in a horizontal position, and the liver passes up and is almost wholly covered by the ribs. In tight lacing, the liver is often forced downward out from the cover of the ribs, and thus becomes permanently displaced. As a result, other organs in the abdomen and pelvis are crowded together, and also become displaced.

147. Minute Structure of the Liver. When a small piece of the liver is examined under a microscope it is found to be made up of masses of many-sided cells, each about 1/1000 of an inch in diameter. Each group of cells is called a _lobule_. When a single lobule is examined under the microscope it appears to be of an irregular, circular shape, with its cells arranged in rows, radiating from the center to the circumference. Minute, hair-like channels separate the cells one from another, and unite in one main duct leading from the lobule. It is the lobules which give to the liver its coarse, granular appearance, when torn across.

[Illustration: Fig. 58.--Diagrammatic Section of a Villus

A, layer of columnar epithelium covering the villus;
B, central lacteal of villus;
C, unstriped muscular fibers;
D, goblet cell
]

Now there is a large vessel called the portal vein that brings to the liver blood full of nourishing material obtained from the stomach and intestines. On entering the liver this great vein conducts itself as if it were an artery. It divides and subdivides into smaller and smaller branches, until, in the form of the tiniest vessels, called capillaries, it passes inward among the cells to the very center of the hepatic lobules.

148. The Bile. We have in the liver, on a grand scale, exactly the same conditions as obtain in the smaller and simpler glands. The thin-walled liver cells take from the blood certain materials which they elaborate into an important digestive fluid, called the bile.[23] This newly manufactured fluid is carried away in little canals, called _bile ducts_. These minute ducts gradually unite and form at last one main duct, which carries the bile from the liver. This is known as the hepatic duct. It passes out on the under side of the liver, and as it approaches the intestine, it meets at an acute angle the cystic duct which proceeds from the gall bladder and forms with it the common bile duct. The common duct opens obliquely into the horseshoe bend of the duodenum.

The cystic duct leads back to the under surface of the liver, where it expands into a sac capable of holding about two ounces of fluid, and is known as the gall bladder. Thus the bile, prepared in the depths of the liver by the liver cells, is carried away by the bile ducts, and may pass directly into the intestines to mix with the food. If, however, digestion is not going on, the mouth of the bile duct is closed, and in that case the bile is carried by the cystic duct to the gall bladder. Here it remains until such time as it is needed.

149. Blood Supply of the Liver. We must not forget that the liver itself, being a large and important organ, requires constant nourishment for the work assigned to it. The blood which is brought to it by the portal vein, being venous, is not fit to nourish it. The work is done by the arterial blood brought to it by a great branch direct from the aorta, known as the hepatic artery, minute branches of which in the form of capillaries, spread themselves around the hepatic lobules.

The blood, having done its work and now laden with impurities, is picked up by minute veinlets, which unite again and again till they at last form one great trunk called the hepatic vein. This carries the impure blood from the liver, and finally empties it into one of the large veins of the body.

After the blood has been robbed of its bile-making materials, it is collected by the veinlets that surround the lobules, and finds its way with other venous blood into the hepatic vein. In brief, blood is brought to the liver and distributed through its substance by two distinct channels,--the portal vein and the hepatic artery, but it leaves the liver by one distinct channel,--the hepatic vein.

[Illustration: Fig. 59--Showing the Relations of the Duodenum and Other Intestinal Organs. (A portion of the stomach has been cut away.)]

150. Functions of the Liver. We have thus far studied the liver only as an organ of secretion, whose work is to elaborate bile for future use in the process of digestion. This is, however, only one of its functions, and perhaps not the most important. In fact, the functions of the liver are not single, but several. The bile is not wholly a digestive fluid, but it contains, also, materials which are separated from the blood to be cast out of the body before they work mischief. Thus, the liver ranks above all others as an organ of excretion, that is, it separates material of no further use to the body.

Of the various ingredients of the bile, only the bile salts are of use in the work of digestion, for they act upon the fats in the alimentary canal, and aid somehow in their emulsion and absorption. They appear to be themselves split up into other substances, and absorbed with the dissolved fats into the blood stream again.

The third function of the liver is very different from those already described. It is found that the liver of an animal well and regularly fed, when examined soon after death, contains a quantity of a carbohydrate substance not unlike starch. This substance, extracted in the form of a white powder, is really an animal starch. It is called glycogen, or liver sugar, and is easily converted into grape sugar.

The hepatic cells appear to manufacture this glycogen and to store it up from the food brought by the portal blood. It is also thought the glycogen thus deposited and stored up in the liver is little by little changed into sugar. Then, as it is wanted, the liver disposes of this stored-up material, by pouring it, in a state of solution, into the hepatic vein. It is thus steadily carried to the tissues, as their needs demand, to supply them with material to be transformed into heat and energy.

151. The Pancreas. The pancreas, or sweetbread, is much smaller than the liver. It is a tongue-like mass from six to eight inches long, weighing from three to four ounces, and is often compared in appearance to a dog's tongue. It is somewhat the shape of a hammer with the handle running to a point.

The pancreas lies behind the stomach, across the body, from right to left, with its large head embraced in the horseshoe bend of the duodenum. It closely resembles the salivary glands in structure, with its main duct running from one end to the other. This duct at last enters the duodenum in company with the common bile duct.

The pancreatic juice, the most powerful in the body, is clear, somewhat viscid, fluid. It has a decided alkaline reaction and is not unlike saliva in many respects. Combined with the bile, this juice acts upon the large drops of fat which pass from the stomach into the duodenum and emulsifies them. This process consists partly in producing a fine subdivision of the particles of fat, called an emulsion, and partly in a chemical decomposition by which a kind of soap is formed. In this way the oils and fats are divided into particles sufficiently minute to permit of their being absorbed into the blood.

Again, this most important digestive fluid produces on starch an action similar to that of saliva, but much more powerful. During its short stay in the mouth, very little starch is changed into sugar, and in the stomach, as we have seen, the action of the saliva is arrested. Now, the pancreatic juice takes up the work in the small intestine and changes the greater part of the starch into sugar. Nor is this all, for it also acts powerfully upon the proteids not acted upon in the stomach, and changes them into peptones that do not differ materially from those resulting from gastric digestion. The remarkable power which the pancreatic juice possesses of acting on all the food-stuffs appears to be due mainly to the presence of a specific element or ferment, known as _trypsin_.

Experiment 60. _To show the action of pancreatic juice upon oils or fats._ Put two grains of Fairchild's extract of pancreas into a four-ounce bottle. Add half a teaspoonful of warm water, and shake well for a few minutes; then add a tablespoonful of cod liver oil; shake vigorously.

A creamy, opaque mixture of the oil and water, called an emulsion, will result. This will gradually separate upon standing, the pancreatic extract settling in the water at the bottom. When shaken it will again form an emulsion.

Experiment 61. _To show the action of pancreatic juice on starch_. Put two tablespoonfuls of _smooth_ starch paste into a goblet, and while still so warm as just to be borne by the mouth, stir into it two grains of the extract of pancreas. The starch paste will rapidly become thinner, and gradually change into soluble starch, in a perfectly fluid solution. Within a few minutes some of the starch is converted through intermediary stages into maltose. Use the Fehling test for sugar.

152. Digestion in the Small Intestines. After digestion in the stomach has been going on for some time, successive portions of the semi-digested food begin to pass into the duodenum. The pancreas now takes on new activity, and a copious flow of pancreatic juice is poured along its duct into the intestines. As the food is pushed along over the common opening of the bile and pancreatic ducts, a great quantity of bile from this reservoir, the gall bladder, is poured into the intestines. These two digestive fluids are now mixed with the chyme, and act upon it in the remarkable manner just described.

[Illustration: Fig. 60.--Diagrammatic Scheme of Intestinal Absorption.

A, mesentery;
B, lacteals and mesentery glands;
C, veins of intestines;
R.C, receptacle of the chyle (receptaculum chyli);
P V, portal vein;
H V, hepatic veins;
S.V.C, superior vena cava;
R.A, right auricle of the heart;
I.V.C, inferior vena cava.
]

The inner surface of the small intestine also secretes a liquid called intestinal juice, the precise functions of which are not known. The chyme, thus acted upon by the different digestive fluids, resembles a thick cream, and is now called chyle. The chyle is propelled along the intestine by the worm-like contractions of its muscular walls. A function of the bile, not yet mentioned, is to stimulate these movements, and at the same time by its antiseptic properties to prevent putrefaction of the contents of the intestine.

153. Digestion in the Large Intestines. Digestion does not occur to any great extent in the large intestines. The food enters this portion of the digestive canal through the ileo-caecal valve, and travels through it slowly. Time is thus given for the fluid materials to be taken up by the blood-vessels of the mucous membrane. The remains of the food now become less fluid, and consist of undigested matter which has escaped the action of the several digestive juices, or withstood their influence. Driven onward by the contractions of the muscular walls, the refuse materials at last reach the rectum, from which they are voluntarily expelled from the body.

Absorption.

154. Absorption. While food remains within the alimentary canal it is as much outside of the body, so far as nutrition is concerned, as if it had never been taken inside. To be of any service the food must enter the blood; it must be absorbed. The efficient agents in absorption are the blood-vessels, the lacteals, and the lymphatics. The process through which the nutritious material is fitted to enter the blood, is called absorption. It is a process not confined, as we shall see, simply to the alimentary canal, but one that is going on in every tissue.

The vessels by which the process of absorption is carried on are called absorbents. The story, briefly told, is this: certain food materials that have been prepared to enter the blood, filter through the mucous membrane of the intestinal canal, and also the thin walls of minute blood-vessels and lymphatics, and are carried by these to larger vessels, and at last reach the heart, thence to be distributed to the tissues.

155. Absorption from the Mouth and Stomach. The lining of the mouth and oesophagus is not well adapted for absorption. That this does occur is shown by the fact that certain poisonous chemicals, like cyanide of potash, if kept in the mouth for a few moments will cause death. While we are chewing and swallowing our food, no doubt a certain amount of water and common salt, together with sugar which has been changed from starch by the action of the saliva, gains entrance to the blood.

In the stomach, however, absorption takes place with great activity. The semi-liquid food is separated from the enormous supply of blood-vessels in the mucous membrane only by a thin porous partition. There is, therefore, nothing to prevent the exchange taking place between the blood and the food. Water, along with any substances in the food that have become dissolved, will pass through the partition and enter the blood-current. Thus it is that a certain amount of starch that has been changed into sugar, of salts in solution, of proteids converted into peptones, is taken up directly by the blood-vessels of the stomach.

156. Absorption by the Intestines. Absorption by the intestines is a most active and complicated process. The stomach is really an organ more for the digestion than the absorption of food, while the small intestines are especially constructed for absorption. In fact, the greatest part of absorption is accomplished by the small intestines. They have not only a very large area of absorbing surface, but also structures especially adapted to do this work.

157. The Lacteals. We have learned in Section 144 that the mucous lining of the small intestines is crowded with millions of little appendages called villi, meaning "tufts of hair." These are only about 1/30 of an inch long, and a dime will cover more than five hundred of them. Each villus contains a loop of blood-vessels, and another vessel, the lacteal, so called from the Latin word _lac_, milk, because of the milky appearance of the fluid it contains. The villi are adapted especially for the absorption of fat. They dip like the tiniest fingers into the chyle, and the minute particles of fat pass through their cellular covering and gain entrance to the lacteals. The milky material sucked up by the lacteals is not in a proper condition to be poured at once into the blood current. It is, as it were, in too crude a state, and needs some special preparation.

The intestines are suspended to the posterior wall of the abdomen by a double fold of peritoneum called the mesentery. In this membrane are some 150 glands about the size of an almond, called mesenteric glands. Now the lacteals join these glands and pour in their fluid contents to undergo some important changes. It is not unlikely that the mesenteric glands may intercept, like a filter, material which, if allowed to enter the blood, would disturb the whole body. Thus, while the glands might suffer, the rest of the body might escape. This may account for the fact that these glands and the lymphatics may be easily irritated and inflamed, thus becoming enlarged and sensitive, as often occurs in the axilla.

Having been acted upon by the mesenteric glands, and passed through them, the chyle flows onward until it is poured into a dilated reservoir for the chyle, known as the receptaculum chyli. This is a sac-like expansion of the lower end of the thoracic duct. Into this receptacle, situated at the level of the upper lumbar vertebrae, in front of the spinal column, are poured, not only the contents of the lacteals, but also of the lymphatic vessels of the lower limbs.

158. The Thoracic Duct. This duct is a tube from fifteen to eighteen inches long, which passes upwards in front of the spine to reach the base of the neck, where it opens at the junction of the great veins of the left side of the head with those of the left arm. Thus the thoracic duct acts as a kind of feeding pipe to carry along the nutritive material obtained from the food and to pour it into the blood current. It is to be remembered that the lacteals are in reality lymphatics--the lymphatics of the intestines.

[Illustration: Fig. 61.--Section of a Lymphatic Gland.

A, strong fibrous capsule sending partitions into the gland;
B, partitions between the follicles or pouches of the _cortical_ or outer portion;
C, partitions of the _medullary_ or central portion;
D, E, masses of protoplasmic matter in the pouches of the gland;
F, lymph-vessels which bring lymph _to_ the gland, passing into its center;
G, confluence of those leading to the efferent vessel;
H, vessel which carries the lymph away _from_ the gland.
]

159. The Lymphatics. In nearly every tissue and organ of the body there is a marvelous network of vessels, precisely like the lacteals, called the lymphatics. These are busily at work taking up and making over anew waste fluids or surplus materials derived from the blood and tissues generally. It is estimated that the quantity of fluid picked up from the tissues by the lymphatics and restored daily to the circulation is equal to the bulk of the blood in the body. The lymphatics seem to start out from the part in which they are found, like the rootlets of a plant in the soil. They carry a turbid, slightly yellowish fluid, called lymph, very much like blood without the red corpuscles.

Now, just as the chyle was not fit to be immediately taken up by the blood, but was passed through the mesenteric glands to be properly worked over, so the lymph is carried to the lymphatic glands, where it undergoes certain changes to fit it for being poured into the blood. Nature, like a careful housekeeper, allows nothing to be wasted that can be of any further service in the animal economy (Figs. 63 and 64).

The lymphatics unite to form larger and larger vessels, and at last join the thoracic duct, except the lymphatics of the right side of the head and chest and right arm. These open by the right lymphatic duct into the venous system on the right side of the neck.

The whole lymphatic system may be regarded as a necessary appendage to the vascular system (Chapter VII.). It is convenient, however, to treat it under the general topic of absorption, in order to complete the history of food digestion.

160. The Spleen and Other Ductless Glands. With the lymphatics may be classified, for convenience, a number of organs called ductless or blood glands. Although they apparently prepare materials for use in the body, they have no ducts or canals along which may be carried the result of their work. Again, they are called blood glands because it is supposed they serve some purpose in preparing material for the blood.

The spleen is the largest of these glands. It lies beneath the diaphragm, and upon the left side of the stomach. It is of a deep red color, full of blood, and is about the size and shape of the palm of the hand.

The spleen has a fibrous capsule from which partitions pass inwards, dividing it into spaces by a framework of elastic tissue, with plain muscular fibers. These spaces are filled with what is called the spleen pulp, through which the blood filters from its artery, just as a fluid would pass through a sponge. The functions of the spleen are not known. It appears to take some part in the formation of blood corpuscles. In certain diseases, like malarial fever, it may become remarkably enlarged. It may be wholly removed from an animal without apparent injury. During digestion it seems to act as a muscular pump, drawing the blood onwards with increased vigor along its large vein to the liver.

The thyroid is another ductless gland. It is situated beneath the muscles of the neck on the sides of "Adam's apple" and below it. It undergoes great enlargement in the disease called goitre.

The thymus is also a blood gland. It is situated around the windpipe, behind the upper part of the breastbone. Until about the end of the second year it increases in size, and then it begins gradually to shrivel away. Like the spleen, the thyroid and thymus glands are supposed to work some change in the blood, but what is not clearly known.

The suprarenal capsules are two little bodies, one perched on the top of each kidney, in shape not unlike that of a conical hat. Of their functions nothing definite is known.

Experiments.

The action produced by the tendency of fluids to mix, or become equally diffused in contact with each other, is known as _osmosis_, a form of molecular attraction allied to that of adhesion. The various physical processes by which the products of digestion are transferred from the digestive canal to the blood may be illustrated in a general way by the following simple experiments.

The student must, however, understand that the necessarily crude experiments of the classroom may not conform in certain essentials to these great processes conducted in the living body, which they are intended to illustrate and explain.

[Illustration: Fig. 62.]

Experiment 62. _Simple Apparatus for Illustrating Endosmotic Action._ "Remove carefully a circular portion, about an inch in diameter, of the shell from one end of an egg, which may be done without injuring the membranes, by cracking the shell in small pieces, which are picked off with forceps. A small glass tube is then introduced through an opening in the shell and membranes of the other end of the egg, and is secured in a vertical position by wax or plaster of Paris, the tube penetrating the yelk. The egg is then placed in a wine-glass partly filled with water. In the course of a few minutes, the water will have penetrated the exposed membrane, and the yelk will rise in the tube."--Flint's _Human Physiology_, page 293.

Experiment 63. Stretch a piece of moist bladder across a glass tube,--a common lamp-chimney will do. Into this put a strong saline solution. Now suspend the tube in a wide mouthed vessel of water. After a short time it will be found that a part of the salt solution has passed through into the water, while a larger amount of water has passed into the tube and raised the height of the liquid within it.

161. The Quantity of Food as Affected by Age. The quantity of food required to keep the body in proper condition is modified to a great extent by circumstances. Age, occupation, place of residence, climate, and season, as well as individual conditions of health and disease, are always important factors in the problem. In youth the body is not only growing, but the tissue changes are active. The restless energy and necessary growth at this time of life cannot be maintained without an abundance of wholesome food. This food supply for young people should be ample enough to answer the demands of their keen appetite and vigorous digestion.

In adult life, when the processes of digestion and assimilation are active, the amount of food may without harm, be in excess of the actual needs of the body. This is true, however, only so long as active muscular exercise is taken.

In advanced life the tissue changes are slow, digestion is less active, and the ability to assimilate food is greatly diminished. Growth has ceased, the energy which induced activity is gone, and the proteids are no longer required to build up worn-out tissues. Hence, as old age approaches, the quantity of nitrogenous foods should be steadily diminished.

Experiment 64. Obtain a sheep's bladder and pour into it a heavy solution of sugar or some colored simple elixir, found at any drug store. Tie the bladder carefully and place it in a vessel containing water. After a while it will be found that an interchange has occurred, water having passed into the bladder and the water outside having become sweet.

Experiment 65. Make a hole about as big as a five-cent piece in the large end of an egg. That is, break the shell carefully and snip the outer shell membrane, thus opening the space between the outer and inner membranes. Now put the egg into a glass of water, keeping it in an upright position by resting on a napkin-ring. There is only the inner shell membrane between the liquid white of the egg (albumen) and the water.

An interchange takes place, and the water passes towards the albumen. As the albumen does not pass out freely towards the water, the membrane becomes distended, like a little bag at the top of the egg.

162. Ill Effects of a too Generous Diet. A generous diet, even of those who take active muscular exercise, should be indulged in only with vigilance and discretion. Frequent sick or nervous headaches, a sense of fullness, bilious attacks, and dyspepsia are some of the after-effects of eating more food than the body actually requires. The excess of food is not properly acted upon by the digestive juices, and is liable to undergo fermentation, and thus to become a source of irritation to the stomach and the intestines. If too much and too rich food be persistently indulged in, the complexion is apt to become muddy, the skin, especially of the face, pale and sallow, and more or less covered with blotches and pimples; the breath has an unpleasant odor, and the general appearance of the body is unwholesome.

An excess of any one of the different classes of foods may lead to serious results. Thus a diet habitually too rich in proteids, as with those who eat meat in excess, often over-taxes the kidneys to get rid of the excess of nitrogenous waste, and the organs of excretion are not able to rid the tissues of waste products which accumulate in the system. From the blood, thus imperfectly purified, may result kidney troubles and various diseases of the liver and the stomach.

163. Effect of Occupation. Occupation has an important influence upon the quantity of food demanded for the bodily support. Those who work long and hard at physical labor, need a generous amount of nutritious food. A liberal diet of the cereals and lean meat, especially beef, gives that vigor to the muscles which enables one to undergo laborious and prolonged physical exertion. On the other hand, those who follow a sedentary occupation do not need so large a quantity of food. Brain-workers who would work well and live long, should not indulge in too generous a diet. The digestion of heavy meals involves a great expenditure of nervous force. Hence, the forces of the brain-worker, being required for mental exertion, should not be expended to an unwarranted extent on the task of digestion.

164. Effect of Climate. Climate also has a marked influence on the quantity of food demanded by the system. Much more food of all kinds is consumed in cold than in warm climates. The accounts by travelers of the quantity of food used by the inhabitants of the frigid zone are almost beyond belief. A Russian admiral gives an instance of a man who, in his presence, ate at a single meal 28 pounds of rice and butter. Dr. Hayes, the Arctic traveler, states from personal observation that the daily ration of the Eskimos is 12 to 15 pounds of meat. With the thermometer ranging from 60 to 70 degrees F. below zero, there was a persistent craving for strong animal diet, especially fatty foods.[24]

[Illustration: Fig. 63.--Lymphatics and Lymphatic Glands of the Axilla.]

The intense cold makes such a drain upon the heat-producing power of the body that only food containing the largest proportion of carbon is capable of making up for the loss. In tropical countries, on the other hand, the natives crave and subsist mainly upon fruits and vegetables.

165. The Kinds of Food Required. An appetite for plain, well-cooked food is a safe guide to follow. Every person in good health, taking a moderate amount of daily exercise, should have a keen appetite for three meals a day and enjoy them. Food should be both nutritious and digestible. It is nutritious in proportion to the amount of material it furnishes for the nourishment of the tissues. It is digestible in a greater or less degree in respect to the readiness with which it yields to the action of the digestive fluids, and is prepared to be taken up by the blood. This digestibility depends partly upon the nature of the food in its raw state, partly upon the effect produced upon it by cooking, and to some extent upon its admixture with other foods. Certain foods, as the vegetable albumens, are both nutritious and digestible. A hard-working man may grow strong and maintain vigorous health on most of them, even if deprived of animal food.

While it is true that the vegetable albumens furnish all that is really needed for the bodily health, animal food of some kind is an economical and useful addition to the diet. Races of men who endure prolonged physical exertion have discovered for themselves, without the teaching of science, the great value of meat. Hence the common custom of eating meat with bread and vegetables is a sound one. It is undoubtedly true that the people of this country, as a rule, eat meat too often and too much at a time. The judicious admixture of different classes of foods greatly aids their digestibility.

The great abundance and variety of food in this country, permit this principle to be put into practice. A variety of mixed foods, as milk, eggs, bread, and meat, are almost invariably associated to a greater or less extent at every meal.

Oftentimes where there is of necessity a sameness of diet, there arises a craving for special articles of food. Thus on long voyages, and during long campaigns in war, there is an almost universal craving for onions, raw potatoes, and other vegetables.

166. Hints about Meals. On an average, three meals each day, from five to six hours apart, is the proper number for adults. Five hours is by no means too long a time to intervene between consecutive meals, for it is not desirable to introduce new food into the stomach, until the gastric digestion of the preceding meal has been completed, and until the stomach has had time to rest, and is in condition to receive fresh material. The stomach, like other organs, does its work best at regular periods.[25]

Eating out of mealtimes should be strictly avoided, for it robs the stomach of its needed rest. Food eaten when the body and mind are wearied is not well digested. Rest, even for a few minutes, should be taken before eating a full meal. It is well to lie down, or sit quietly and read, fifteen minutes before eating, and directly afterwards, if possible.

Severe exercise and hard study just after a full meal, are very apt to delay or actually arrest digestion, for after eating heartily, the vital forces of the body are called upon to help the stomach digest its food. If our bodily energies are compelled, in addition to this, to help the muscles or brain, digestion is retarded, and a feeling of dullness and heaviness follows. Fermentative changes, instead of the normal digestive changes, are apt to take place in the food.

167. Practical Points about Eating. We should not eat for at least

two or three hours before going to bed. When we are asleep, the vital forces are at a low ebb, the process of digestion is for the time nearly suspended, and the retention of incompletely digested food in the stomach may cause bad dreams and troubled sleep. But in many cases of sleeplessness, a trifle of some simple food, especially if the stomach seems to feel exhausted, often appears to promote sleep and rest.

[NOTE. The table on the next page shows the results of many experiments to illustrate the time taken for the gastric digestion of a number of the more common solid foods. There are a good many factors of which the table takes no account, such as the interval since the last meal, state of the appetite, amount of work and exercise, method of cooking, and especially the quantity of food.]

Table Showing the Digestibility of the More Common Solid Foods.

Food	How Cooked	Time in Stomach, Hours
Apples, sweet and mellow	Raw	1-1/2
Apples, sour and hard	"	2-1/2
Apple Dumpling	Boiled	3
Bass, striped, fresh	Broiled	3
Beans, pod	Boiled	2-1/2
Beef, with salt only	"	2-3/4
" fresh, lean	Raw	3
" " "	Fried	4
" " "	Roasted	3-1/2
" old, hard, salted	Boiled	4-1/4
Beefsteak	Broiled	3
Beets	Boiled	3-3/4
Bread, corn	Baked	3-1/4
" wheat, fresh	"	3-1/2
Butter	Melted	3-1/2
Cabbage, with vinegar	Raw	2
" " "	Boiled	4-1/2
" heads	Raw	2-1/2
Carrots	Boiled	3-1/4
Cheese, old, strong	Raw	3-1/2
Chicken, full-grown	Fricassee	2-3/4
" soup	Boiled	3
Codfish, cured, dried	"	2
Corncake	Baked	2-3/4
Custard	"	2-3/4
Duck, domestic	Roasted	4
" wild	"	4-1/2
Eggs, fresh, whipped	Raw	1-1/2
"	"	2
" soft-boiled	Boiled	3
" hard-boiled	"	3-1/2
"	Fried	3-1/2
Fowl, domestic	Boiled	4
" "	Roasted	4
Gelatin	Boiled	2-1/2
Goose	Roasted	2-1/2
Green corn and beans	Boiled	3-3/4
Hash, meat and vegetables	Warmed	2-1/2
Lamb	Broiled	2-1/2

Liver	"	2
Milk	Boiled	2
"	Raw	2-1/4
Mutton, fresh	Broiled	3
" "	Boiled	3
" "	Roasted	3-1/4
Oysters, fresh	Raw	2-1/2
" "	Roasted	3-1/4
" "	Stewed	3-1/2
Parsnips	Boiled	2-1/2
Pig	Roasted	2-1/2
Pig's feet, soused	Boiled	1
Pork, recently salted	"	4-1/2
"	Fried	4-1/4
"	Raw	3
" steaks	Fried	3-1/4
"	Stewed	3
" fat or lean	Roasted	5-1/4
Potatoes	Baked	2-1/2
"	Boiled	3-1/2
"	Roasted	2-1/2
Rice	Boiled	1
Sago	"	1-3/4
Salmon, salted	"	4
Soup, barley	"	1-1/2
" beans	"	3
" beef, vegetables, bread	"	4
" marrow bone	"	4-1/2
" mutton	"	3-1/2
Sponge Cake	Baked	2-1/2
Suet, beef, fresh	Boiled	5-1/3
" mutton	"	4-1/2
Tapioca	"	2
Tripe, soused	"	1
Trout, salmon, fresh	"	1-1/2
" " "	Fried	1-1/2
Turkey, wild	Roasted	2-1/4
" domestic	Boiled	2-1/4
" "	Roasted	2-1/2
Turnips	Boiled	3-1/2
Veal	Roasted	4
"	Fried	4-1/2
Venison, steaks	Broiled	1-1/2

The state of mind has much to do with digestion. Sudden fear or joy, or unexpected news, may destroy the appetite at once. Let a hungry person be anxiously awaiting a hearty meal, when suddenly a disastrous telegram is brought him; all appetite instantly disappears, and the tempting food is refused. Hence we should laugh and talk at our meals, and drive away anxious thoughts and unpleasant topics of discussion.

The proper chewing of the food is an important element in digestion. Hence, eat slowly, and do not "bolt" large fragments of food. If imperfectly chewed, it is not readily acted upon by the gastric juice, and often undergoes fermentative changes which result in sour stomach, gastric pain, and other digestive disturbance.

If we take too much drink with our meals, the flow of the saliva is checked, and digestion is hindered. It is not desireable to dilute the gastric juice, nor to chill the stomach with large amount of cold liquid.

Do not take food and drink too hot or too cold. If they are taken too cold, the stomach is chilled, and digestion delayed. If we drink freely of ice-water, it may require half an hour or more for the stomach to regain its natural heat.

It is a poor plan to stimulate a flagging appetite with highly spiced food and bitter drinks. An undue amount of pepper, mustard, horseradish, pickles, and highly seasoned meat-sauces may stimulate digestion for the time, but they soon impair it.

[NOTE. The process of gastric digestion was studied many years ago by Dr. Beaumont and others, in the remarkable case of Alexis St. Martin, a French-Canadian, who met with a gun-shot wound which left a permanent opening into his stomach, guarded by a little valve of mucous membrane. Through this opening the lining of the stomach could be seen, the temperature ascertained, and numerous experiments made as to the digestibility of various kinds of food.

It was by these careful and convincing experiments that the foundation of our exact knowledge of the composition and action of gastric juice was laid. The modest book in which Dr. Beaumont published his results is still counted among the classics of physiology. The production of artificial fistulae in animals, a method that has since proved so fruitful, was first suggested by his work.]

It cannot be too strongly stated that food of a simple character, well cooked and neatly served, is more productive of healthful living than a great variety of fancy dishes which unduly stimulate the digestive organs, and create a craving for food in excess of the bodily needs.

168. The Proper Care of the Teeth. It is our duty not only to take the very best care of our teeth, but to retain them as long as possible. Teeth, as we well know, are prone to decay. We may inherit poor and soft teeth: our mode of living may make bad teeth worse. If an ounce of prevention is ever worth a pound of cure, it is in keeping the teeth in good order. Bad teeth and toothless gums mean imperfect chewing of the food and, hence, impaired digestion. To attain a healthful old age, the power of vigorous mastication must be preserved.

One of the most frequent causes of decay of the teeth is the retention of fragments of food between and around them. The warmth and moisture of the mouth make these matters decompose quickly. The acid thus generated attacks the enamel of the teeth, causing decay of the dentine. Decayed teeth are often the cause of an offensive breath and a foul stomach.

[Illustration: Fig. 64.--Lymphatics on the Inside of the Right Hand.]

To keep the teeth clean and wholesome, they should be thoroughly cleansed at bedtime and in the morning with a soft brush and warm water. Castile soap, and some prepared tooth-powder without grit, should be used, and the brush should be applied on both sides of the teeth.

The enamel, once broken through, is never renewed. The tooth decays, slowly but surely: hence we must guard against certain habits which injure the enamel, as picking the teeth with pins and needles. We should never crack nuts, crush hard candy, or bite off stout thread with the teeth. Stiff tooth-brushes, gritty and cheap tooth-powders, and hot food and drink, often injure the enamel.

To remove fragments of food which have lodged between adjacent teeth, a quill or wooden toothpick should be used. Even better than these is the use of surgeon's floss, or silk, which when drawn between the teeth, effectually dislodges retained particles. If the teeth are not regularly cleansed they become discolored, and a hard coating known as _tartar_ accumulates on them and tends to loosen them. It is said that after the age of thirty more teeth are lost from this deposit than from all other causes combined. In fact decay and tartar are the two great agents that furnish work for the dentist.[26]

169. Hints about Saving Teeth. We should exercise the greatest care in saving the teeth. The last resort of all is to lose a tooth by extraction. The skilled dentist will save almost anything in the shape of a tooth.

People are often urged and consent to have a number of teeth extracted which, with but little trouble and expense, might be kept and do good service for years. The object is to replace the teeth with an artificial set. Very few plates, either partial or entire, are worn with real comfort. They should always be removed before going to sleep, as there is danger of their being swallowed.

The great majority of drugs have no injurious effect upon the teeth. Some medicines, however, must be used with great care. The acids used in the tincture of iron have a great affinity for the lime salts of the teeth. As this form of iron is often used, it is not unusual to see teeth very badly stained or decayed from the effects of this drug. The acid used in the liquid preparations of quinine may destroy the teeth in a comparatively short time. After taking such medicines the mouth should be thoroughly rinsed with a weak solution of common soda, and the teeth cleansed.

170. Alcohol and Digestion. The influence of alcoholic drinks upon digestion is of the utmost importance. Alcohol is not, and cannot be regarded from a physiological point of view as a true food. The reception given to it by the stomach proves this very plainly. It is obviously an unwelcome intruder. It cannot, like proper foods, be transformed into any element or component of the human body, but passes on, innutritious and for the most part unappropriated. Taken even into the mouth, by any person not hardened to its use, its effect is so pungent and burning as at once to demand its rejection. But if allowed to pass into the stomach, that organ immediately rebels against its intrusion, and not unfrequently ejects it with indignant emphasis. The burning sensation it produces there, is only an appeal for water to dilute it.

The stomach meanwhile, in response to this fiery invitation, secretes from its myriad pores its juices and watery fluids, to protect itself as much as possible from the invading liquid. It does not digest alcoholic drinks; we might say it does not attempt to, because they are not material suitable for digestion, and also because no organ can perform its normal work while smarting under an unnatural irritation.

Even if the stomach does not at once eject the poison, it refuses to adopt it as food, for it does not pass along with the other food material, as chyme, into the intestines, but is seized by the absorbents, borne into the veins, which convey it to the heart, whence the pulmonary artery conveys it to the lungs, where its presence is announced in the breath. But wherever alcohol is carried in the tissues, it is always an irritant, every organ in turn endeavoring to rid itself of the noxious material.

171. Effect of Alcoholic Liquor upon the Stomach. The methods by which intoxicating drinks impair and often ruin digestion are various. We know that a piece of animal food, as beef, if soaked in alcohol for a few hours, becomes hard and tough, the fibers having been compacted together because of the abstraction of their moisture by the alcohol, which has a marvelous affinity for water. In the same way alcohol hardens and toughens animal food in the stomach, condensing its fibers, and rendering it indigestible, thus preventing the healthful nutrition of the body. So, if alcohol be added to the clear, liquid white of an egg, it is instantly coagulated and transformed into hard albumen. As a result of this hardening action, animal food in contact with alcoholic liquids in the stomach remains undigested, and must either be detained there so long as to become a source of gastric disturbance, or else be allowed to pass undigested through the pyloric gate, and then may become a cause of serious intestinal disturbance.[27]

This peculiar property of alcohol, its greedy absorption of water from objects in contact with it, acts also by absorbing liquids from the surface of the stomach itself, thus hardening the delicate glands, impairing their ability to absorb the food-liquids, and so inducing gastric dyspepsia. This local injury inflicted upon the stomach by all forms of intoxicants, is serious and protracted. This organ is, with admirable wisdom, so constructed as to endure a surprising amount of abuse, but it was plainly not intended to thrive on alcoholic liquids. The application of fiery drinks to its tender surface produces at first a marked congestion of its blood-vessels, changing the natural pink color, as in the mouth, to a bright or deep red.

If the irritation be not repeated, the lining membrane soon recovers its natural appearance. But if repeated and continued, the congestion becomes more intense, the red color deeper and darker; the entire surface is the subject of chronic inflammation, its walls are thickened, and sometimes ulcerated. In this deplorable state, the organ is quite unable to perform its normal work of digestion.[28]

172. Alcohol and the Gastric Juice. But still another destructive influence upon digestion appears in the singular fact that alcohol diminishes the power of the gastric juice to do its proper work. Alcohol coagulates the pepsin, which is the dissolving element in this important gastric fluid. A very simple experiment will prove this. Obtain a small quantity of gastric juice from the fresh stomach of a calf or pig, by gently pressing it in a very little water. Pour the milky juice into a clear glass vessel, add a little alcohol, and a white deposit will presently settle to the bottom. This deposit contains the pepsin of the gastric juice, the potent element by which it does its special work of digestion. The ill effect of alcohol upon it is one of the prime factors in the long series of evil results from the use of intoxicants.

173. The Final Results upon Digestion. We have thus explained three different methods by which alcoholic drinks exercise a terrible power for harm; they act upon the food so as to render it less digestible; they injure the stomach so as seriously to impair its power of digestion; and they deprive the gastric juice of the one principal ingredient essential to its usefulness.

Alcoholic drinks forced upon the stomach are a foreign substance; the stomach treats them as such, and refuses to go on with the process of digestion till it first gets rid of the poison. This irritating presence and delay weaken the stomach, so that when proper food follows, the enfeebled organ is ill prepared for its work. After intoxication, there occurs an obvious reaction of the stomach, and digestive organs, against the violent and unnatural disturbance. The appetite is extinguished or depraved, and intense headache racks the frame, the whole system is prostrated, as from a partial paralysis (all these results being the voice of Nature's sharp warning of this great wrong), and a rest of some days is needed before the system fully recovers from the injury inflicted.

It is altogether an error to suppose the use of intoxicants is necessary or even desirable to promote appetite or digestion. In health, good food and a stomach undisturbed by artificial interference furnish all the conditions required. More than these is harmful. If it may sometimes seem as if alcoholic drinks arouse the appetite and invigorate digestion, we must not shut our eyes to the fact that this is only a seeming, and that their continued use will inevitably ruin both. In brief, there is no more sure foe to good appetite and normal digestion than the habitual use of alcoholic liquors.

174. Effect of Alcoholic Drinks upon the Liver. It is to be noted that the circulation of the liver is peculiar; that the capillaries of the hepatic artery unite in the lobule with those of the portal vein, and thus the blood from both sources is combined; and that the portal vein brings to the liver the blood from the stomach, the intestines, and the spleen. From the fact that alcohol absorbed from the stomach enters the portal vein, and is borne directly to the liver, we would expect to find this organ suffering the full effects of its presence. And all the more would this be true, because we have just learned that the liver acts as a sort of filter to strain from the blood its impurities. So the liver is especially liable to diseases produced by alcoholics. Post mortems of those who have died while intoxicated show a larger amount of alcohol in the liver than in any other organ. Next to the stomach the liver is an early and late sufferer, and this is especially the case with hard drinkers, and even more moderate drinkers in hot climates. Yellow fever occurring in inebriates is always fatal.

The effects produced in the liver are not so much functional as organic; that is, not merely a disturbed mode of action, but a destruction of the fabric of the organ itself. From the use of intoxicants, the liver becomes at first irritated, then inflamed, and finally seriously diseased. The fine bands, or septa, which serve as partitions between the hepatic lobules, and so maintain the form and consistency of the organ, are the special subjects of the inflammation. Though the liver is at first enlarged, it soon becomes contracted; the secreting cells are compressed, and are quite unable to perform their proper work, which indeed is a very important one in the round of the digestion of food and the purification of the blood. This contraction of the septa in time gives the whole organ an irregularly puckered appearance, called from this fact a hob-nail liver or, popularly, gin liver. The yellowish discoloration, usually from retained or perverted bile, gives the disease the medical name of cirrhosis.[29] It is usually accompanied with dropsy in the lower extremities, caused by obstruction to the return of the circulation from the parts below the liver. This disease is always fatal.

175. Fatty Degeneration Due to Alcohol. Another form of destructive disease often occurs. There is an increase of fat globules deposited in the liver, causing notable enlargement and destroying its function. This

is called fatty degeneration, and is not limited to the liver, but other organs are likely to be similarly affected. In truth, this deposition of fat is a most significant occurrence, as it means actual destruction of the liver tissues,--nothing less than progressive death of the organ. This condition always leads to a fatal issue. Still other forms of alcoholic disease of the liver are produced, one being the excessive formation of sugar, constituting what is known as a form of diabetes.

176. Effect of Tobacco on Digestion. The noxious influence of tobacco upon the process of digestion is nearly parallel to the effects of alcohol, which it resembles in its irritant and narcotic character. Locally, it stimulates the secretion of saliva to an unnatural extent, and this excess of secretion diminishes the amount available for normal digestion.

Tobacco also poisons the saliva furnished for the digestion of food, and thus at the very outset impairs, in both of these particulars, the general digestion, and especially the digestion of the starchy portions of the food. For this reason the amount of food taken, fails to nourish as it should, and either more food must be taken, or the body becomes gradually impoverished.

The poisonous _nicotine_, the active element of tobacco, exerts a destructive influence upon the stomach digestion, enfeebling the vigor of the muscular walls of that organ. These effects combined produce dyspepsia, with its weary train of baneful results.

The tobacco tongue never presents the natural, clear, pink color, but rather a dirty yellow, and is usually heavily coated, showing a disordered stomach and impaired digestion. Then, too, there is dryness of the mouth, an unnatural thirst that demands drink. But pure water is stale and flat to such a mouth: something more emphatic is needed. Thus comes the unnatural craving for alcoholic liquors, and thus are taken the first steps on the downward grade.

"There is no doubt that tobacco predisposes to neuralgia, vertigo, indigestion, and other affections of the nervous, circulatory and digestive organs."--W. H. Hammond, the eminent surgeon of New York city and formerly Surgeon General, U.S.A.

Drs. Seaver of Yale University and Hitchcock of Amherst College, instructors of physical education in these two colleges, have clearly demonstrated by personal examination and recorded statistics that the use of tobacco among college students checks growth in weight, height, chest-girth, and, most of all, in lung capacity.

Additional Experiments.

Experiment 66. Test a portion of _C_ (Experiment 57) with solution of iodine; no blue color is obtained, as all the starch has disappeared, having been converted into a reducing sugar, or maltose.

Experiment 67. Make a thick starch paste; place some in test tubes, labeled _A_ and _B_. Keep _A_ for comparison, and to _B_ add saliva, and expose both to about 104 degrees F. _A_ is unaffected, while _B_ soon becomes fluid--within two minutes--and loses its opalescence; this liquefaction is a process quite antecedent to the saccharifying process which follows.

Experiment 68. _To show the action of gastric juice on milk_. Mix two teaspoonfuls of fresh milk in a test tube with a few drops of neutral artificial gastric juice;[30] keep at about 100 degrees F. In a short time the milk curdles, so that the tube can be inverted without the curd falling out. By and by _whey_ is squeezed out of the clot. The curdling of milk by the rennet ferment present in the gastric juice, is quite different from that produced by the "souring of milk," or by the precipitation of caseinogen by acids. Here the casein (carrying with it most of the fats) is precipitated in a neutral fluid.

Experiment 69. To the test tube in the preceding experiment, add two teaspoonfuls of dilute hydrochloric acid, and keep at 100 degrees F. for two hours. The pepsin in the presence of the acid digests the casein, gradually dissolving it, forming a straw-colored fluid containing peptones. The peptonized milk has a peculiar odor and bitter taste.

Experiment 70. _To show the action of rennet on milk_. Place milk in a test tube, add a drop or two of commercial rennet, and place the tube in a water-bath at about 100 degrees F. The milk becomes solid in a few minutes, forming a _curd_, and by and by the curd of casein contracts, and presses out a fluid,--the _whey_.

Experiment 71. Repeat the experiment, but previously boil the rennet. No such result is obtained as in the preceding experiment, because the rennet ferment is destroyed by heat.

Experiment 72. _To show the effect of the pancreatic ferment (trypsin) upon albuminous matter_. Half fill three test tubes, _A, B, C_, with one-per-cent solution of sodium carbonate, and add 5 drops of liquor pancreaticus, or a few grains of Fairchild's extract of pancreas, in each. Boil _B_, and make _C_ acid with dilute hydrochloric acid. Place in each tube an equal amount of well-washed fibrin, plug the tubes with absorbent cotton, and place all in a water-bath at about 100 degrees F.

Experiment 73. Examine from time to time the three test tubes in the preceding experiment. At the end of one, two, or three hours, there is no change in _B_ and _C_, while in _A_ the fibrin is gradually being eroded, and finally disappears; but it does not swell up, and the solution at the same time becomes slightly turbid. After three hours, still no change is observable in _B_ and _C_.

Experiment 74. Filter _A_, and carefully neutralize the filtrate with very dilute hydrochloric or acetic acid, equal to a precipitate of alkali-albumen. Filter off the precipitate, and on testing the filtrate, peptones are found. The intermediate bodies, the albumoses, are not nearly so readily obtained from pancreatic as from gastric digests.

Experiment 75. Filter _B_ and _C_, and carefully neutralize the filtrates. They give no precipitate. No peptones are found.

Experiment 76. _To show the action of pancreatic juice upon the albuminous ingredients (casein) of milk_. Into a four-ounce bottle put two tablespoonfuls of cold water; add one grain of Fairchild's extract of pancreas, and as much baking soda as can be taken up on the point of a penknife. Shake well, and add four tablespoonfuls of cold, fresh milk. Shake again.

Now set the bottle into a basin of hot water (as hot as one can bear the hand in), and let it stand for about forty-five minutes. While the milk is digesting, take a small quantity of milk in a goblet, and stir in ten drops or more of vinegar. A thick curd of casein will be seen.

Upon applying the same test to the digested milk, no curd will be made. This is because the pancreatic ferment (trypsin) has digested the casein into "peptone," which does not curdle. This digested milk is therefore called "peptonized milk."

Experiment 77. _To show the action of bile_. Obtain from the butcher some ox bile. Note its bitter taste, peculiar odor, and greenish color. It is alkaline or neutral to litmus paper. Pour it from one vessel to another, and note that strings of mucin (from the lining membrane of the gall bladder) connect one vessel with the other. It is best to precipitate the mucin by acetic acid before making experiments; and to dilute the clear liquid with a little distilled water.

Experiment 78. _Test for bile pigments_. Place a few drops of bile on a white porcelain slab. With a glass rod place a drop or two of strong nitric acid containing nitrous acid near the drop of bile; bring the acid and bile into contact. Notice the succession of colors, beginning with green and passing into blue, red, and yellow.

Experiment 79. _To show the action of bile on fats_. Mix three teaspoonfuls of bile with one-half a teaspoonful of almond oil, to which some oleic acid is added. Shake well, and keep the tube in a water-bath at about 100 degrees F. A very good emulsion is obtained.

Experiment 80. _To show that bile favors filtration and the absorption of fats_. Place two small funnels of exactly the same size in a filter stand, and under each a beaker. Into each funnel put a filter paper; moisten the one with water (_A_) and the other with bile (_B_). Pour into each an equal volume of almond oil; cover with a slip of glass to prevent evaporation. Set aside for twelve hours, and note that the oil passes through _B_, but scarcely any through _A_. The oil filters much more readily through the one moistened with bile, than through the one moistened with water.

Experiments with the Fats.

Experiment 81. Use olive oil or lard. Show by experiment that they are soluble in ether, chloroform and hot water, but insoluble in water alone.

Experiment 82. Dissolve a few drops of oil or fat in a teaspoonful of ether. Let a drop of the solution fall on a piece of tissue or rice paper. Note the greasy stain, which does not disappear with the heat.

Experiment 83. Pour a little cod-liver oil into a test tube; add a few drops of a dilute solution of sodium carbonate. The whole mass becomes white, making an emulsion.

Experiment 84. Shake up olive oil with a solution of albumen in a test tube. Note that an emulsion is formed.

Chapter VII.

The Blood and Its Circulation.

177. The Circulation. All the tissues of the body are traversed by exceedingly minute tubes called capillaries, which receive the blood from the arteries, and convey it to the veins. These capillaries form a great system of networks, the meshes of which are filled with the elements of the various tissues. That is, the capillaries are closed vessels, and the tissues lie outside of them, as asbestos packing may be used to envelop hot-water pipes. The space between the walls of the capillaries and the cells of the tissues is filled with lymph. As the blood flows along the capillaries, certain parts of the plasma of the blood filter through their walls into the lymph, and certain parts of the lymph filter through the cell walls of the tissues and mingle with the blood current. The lymph thus acts as a medium of exchange, in which a transfer of material takes place between the blood in the capillaries and the lymph around them. A similar exchange of material is constantly going on between the lymph and the tissues themselves.

This, then, we must remember,--that in every tissue, so long as the blood flows, and life lasts, this exchange takes place between the blood within the capillaries and the tissues without.

The stream of blood _to_ the tissues carries to them the material, including the all-important oxygen, with which they build themselves up and do their work. The stream _from_ the tissues carries into the blood the products of certain chemical changes which have taken place in these tissues. These products may represent simple waste matter to be cast out or material which may be of use to some other tissue.

In brief, the tissues by the help of the lymph live on the blood. Just as our bodies, as a whole, live on the things around us, the food and the air, so do the bodily tissues live on the blood which bathes them in an unceasing current, and which is their immediate air and food.

178. Physical Properties of Blood. The blood has been called the life of the body from the fact that upon it depends our bodily existence. The blood is so essentially the nutrient element that it is called sometimes very aptly "liquid flesh." It is a red, warm, heavy, alkaline fluid, slightly salt in taste, and has a somewhat fetid odor. Its color varies from bright red in the arteries and when exposed to the air, to various tints from dark purple to red in the veins. The color of the blood is due to the coloring constituent of the red corpuscles, _haemoglobin_, which is brighter or darker as it contains more or less oxygen.

[Illustration: Fig. 65.--Blood Corpuscles of Various Animals. (Magnified to the same scale.)

A, from proteus, a kind of newt;
B, salamander;
C, frog;
D, frog after addition of acetic acid, showing the central nucleus;
E, bird;
F, camel;

G, fish;
H, crab or other invertebrate animal
]

The temperature of the blood varies slightly in different parts of the circulation. Its average heat near the surface is in health about the same, _viz_. 98-1/2 degrees F. Blood is alkaline, but outside of the body it soon becomes neutral, then acid. The chloride of sodium, or common salt, which the blood contains, gives it a salty taste. In a hemorrhage from the lungs, the sufferer is quick to notice in the mouth the warm and saltish taste. The total amount of the blood in the body was formerly greatly overestimated. It is about 1/13 of the total weight of the body, and in a person weighing 156 pounds would amount to about 12 pounds.

179. Blood Corpuscles. If we put a drop of blood upon a glass slide, and place upon it a cover of thin glass, we can flatten it out until the color almost disappears. If we examine this thin film with a microscope, we see that the blood is not altogether fluid. We find that the liquid part, or plasma, is of a light straw color, and has floating in it a multitude of very minute bodies, called corpuscles. These are of two kinds, the red and the colorless. The former are much more numerous, and have been compared somewhat fancifully to countless myriads of tiny fishes in a swiftly flowing stream.

180. Red Corpuscles. The red corpuscles are circular disks about 1/3200 of an inch in diameter, and double concave in shape. They tend to adhere in long rolls like piles of coins. They are soft, flexible, and elastic, readily squeezing through openings and passages narrower than their own diameter, then at once resuming their own shape.

The red corpuscles are so very small, that rather more than ten millions of them will lie on a surface one inch square. Their number is so enormous that, if all the red corpuscles in a healthy person could be arranged in a continuous line, it is estimated that they would reach four times around the earth! The principal constituent of these corpuscles, next to water, and that which gives them color is _haemoglobin_, a compound containing iron. As all the tissues are constantly absorbing oxygen, and giving off carbon dioxid, a very important office of the red corpuscles is to carry oxygen to all parts of the body.

181. Colorless Corpuscles. The colorless corpuscles are larger than the red, their average diameter being about 1/2500 of an inch. While the red corpuscles are regular in shape, and float about, and tumble freely over one another, the colorless are of irregular shape, and stick close to the glass slide on which they are placed. Again, while the red corpuscles are changed only by some influence from without, as pressure and the like, the colorless corpuscles spontaneously undergo active and very curious changes of form, resembling those of the amoeba, a very minute organism found in stagnant water (Fig. 2).

The number of both red and colorless corpuscles varies a great deal from time to time. For instance, the number of the latter increases after meals, and quickly diminishes. There is reason to think both kinds of corpuscles are continually being destroyed, their place being supplied by new ones. While the action of the colorless corpuscles is important to the lymph and the chyle, and in the coagulation of the blood, their real function has not been ascertained.

[Illustration: Fig. 66.--Blood Corpuscles of Man.

A, red corpuscles;
B, the same seen edgeways;
C, the same arranged in rows;
D, white corpuscles with nuclei.
]

Experiment 85. _To show the blood corpuscles_. A moderately powerful microscope is necessary to examine blood corpuscles. Let a small drop of blood (easily obtained by pricking the finger with a needle) be placed upon a clean slip of glass, and covered with thin glass, such as is ordinarily used for microscopic purposes.

The blood is thus spread out into a film and may be readily examined. At first the red corpuscles will be seen as pale, disk-like bodies floating in the clear fluid. Soon they will be observed to stick to each other by their flattened faces, so as to form rows. The colorless corpuscles are to be seen among the red ones, but are much less numerous.

182. The Coagulation of the Blood. Blood when shed from the living body is as fluid as water. But it soon becomes viscid, and flows less readily from one vessel to another. Soon the whole mass becomes a nearly solid jelly called a clot. The vessel containing it even can be turned upside down, without a drop of blood being spilled. If carefully shaken out, the mass will form a complete mould of the vessel.

At first the clot includes the whole mass of blood, takes the shape of the vessel in which it is contained, and is of a uniform color. But in a short time a pale yellowish fluid begins to ooze out, and to collect on the surface. The clot gradually shrinks, until at the end of a few hours it is much firmer, and floats in the yellowish fluid. The white corpuscles become entangled in the upper portion of clot, giving it a pale yellow look on the top, known as the _buffy coat_. As the clot is attached to the sides of the vessel, the shrinkage is more pronounced toward the center, and thus the surface of the clot is hollowed or _cupped_, as it is called. This remarkable process is known as coagulation, or the clotting of blood; and the liquid which separates from the clot is called serum. The serum is almost entirely free from corpuscles, these being entangled in the fibrin.

[Illustration: Fig. 67.--Diagram of Clot with Buffy Coat.

A, serum;
B, cupped upper surface of clot;
C, white corpuscles in upper layer of clot;
D, lower portion of clot with red corpuscles.
]

This clotting of the blood is due to the formation in the blood, after it is withdrawn from the living body, of a substance called fibrin.[31] It is made up of a network of fine white threads, running in every direction through the plasma, and is a proteid substance. The coagulation of the blood may be retarded, and even prevented, by a temperature below 40 degrees F., or a temperature above 120 degrees F. The addition of common salt also prevents coagulation. The clotting of the blood may be hastened by free access to air, by contact with roughened surfaces, or by keeping it at perfect rest.

This power of coagulation is of the most vital importance. But for this, a very small cut might cause bleeding sufficient to empty the blood-vessels, and death would speedily follow. In slight cuts, Nature plugs up the wound with clots of blood, and thus prevents excessive bleeding. The unfavorable effects of the want of clotting are illustrated in some persons in whom bleeding from even the slightest wounds continues till life is in danger. Such persons are called "bleeders," and surgeons hesitate to perform on them any operation, however trivial, even the extraction of a tooth being often followed by an alarming loss of blood.

Experiment 86. A few drops of fresh blood may be easily obtained to illustrate important points in the physiology of blood, by tying a string tight around the finger, and piercing it with a clean needle. The blood runs freely, is red and opaque. Put two or three drops of fresh blood on a sheet of white paper, and observe that it looks yellowish.

Experiment 87. Put two or three drops of fresh blood on a white individual butter plate inverted in a saucer of water. Cover it with an inverted goblet. Take off the cover in five minutes, and the drop has set into a jelly-like mass. Take it off in half an hour, and a little clot will be seen in the watery serum.

Experiment 88. _To show the blood-clot._ Carry to the slaughter house a clean, six or eight ounce, wide-mouthed bottle. Fill it with fresh blood. Carry it home with great care, and let it stand over night. The next day the clot will be seen floating in the nearly colorless serum.

Experiment 89. Obtain a pint of fresh blood; put it into a bowl, and whip it briskly for five minutes, with a bunch of dry twigs. Fine white threads of fibrin collect on the twigs, the blood remaining fluid. This is "whipped" or defibrinated blood, which has lost the power of coagulating spontaneously.

183. General Plan of Circulation. All the tissues of the body depend upon the blood for their nourishment. It is evident then that this vital fluid must be continually renewed, else it would speedily lose all of its life-giving material. Some provision, then, is necessary not only to have the blood renewed in quantity and quality, but also to enable it to carry away impurities.

So we must have an apparatus of circulation. We need first a central pump from which branch off large pipes, which divide into smaller and smaller branches until they reach the remotest tissues. Through these pipes the blood must be pumped and distributed to the whole body. Then we must have a set of return pipes by which the blood, after it has carried nourishment to the tissues, and received waste matters from them, shall be brought back to the central pumping station, to be used again. We must have also some apparatus to purify the blood from the waste matter it has collected.

[Illustration: Fig. 68.--Anterior View of the Heart.

A, superior vena cava;
B, right auricle;
C, right ventricle;
D, left ventricle;
E, left auricle;
F, pulmonary vein;
H, pulmonary artery;

K, aorta;
L, right subclavian artery;
M, right common carotid artery;
N, left common carotid artery.
]

This central pump is the heart. The pipes leading from it and gradually growing smaller and smaller are the arteries. The very minute vessels into which they are at last subdivided are capillaries. The pipes which convey the blood back to the heart are the veins. Thus, the arteries end in the tissues in fine, hair-like vessels, the capillaries; and the veins begin in the tissues in exceedingly small tubes,--the capillaries. Of course, there can be no break in the continuity between the arteries and the vein. The apparatus of circulation is thus formed by the heart, the arteries, the capillaries, and the veins.

184. The Heart. The heart is a pear-shaped, muscular organ roughly estimated as about the size of the persons closed fist. It lies in the chest behind the breastbone, and is, lodged between the lobes of the lungs, which partly cover it. In shape the heart resembles a cone, the base of which is directed upwards, a little backwards, and to the right side, while the apex is pointed downwards, forwards, and to the left side. During life, the apex of the heart beats against the chest wall in the space between the fifth and sixth ribs, and about an inch and a half to the left of the middle line of the body. The beating of the heart can be readily felt, heard, and often seen moving the chest wall as it strikes against it.

[Illustration: Fig. 69.--Diagram illustrating the Structure of a Serous Membrane.

A, the viscus, or organ, enveloped by serous membrane;
B, layer of membrane lining cavity;
C, membrane reflected to envelop viscus;
D, outer layer of viscus, with blood-vessels at
E communicating with the general circulation.
]

The heart does not hang free in the chest, but is suspended and kept in position to some extent by the great vessels connected with it. It is enclosed in a bell-shaped covering called the pericardium. This is really double, with two layers, one over another. The inner or serous layer covers the external surface of the heart, and is reflected back upon itself in order to form, like all membranes of this kind, a sac without an opening.[32] The heart is thus covered by the pericardial sac, but is not contained inside its cavity. The space between the two membranes is filled with serous fluid. This fluid permits the heart and the pericardium to glide upon one another with the least possible amount of friction.[33]

The heart is a hollow organ, but the cavity is divided into two parts by a muscular partition forming a left and a right side, between which there is no communication. These two cavities are each divided by a horizontal partition into an upper and a lower chamber. These partitions, however, include a set of valves which open like folding doors between the two rooms. If these doors are closed there are two separate rooms, but if open there is practically only one room. The heart thus has four chambers, two on each side. The two upper chambers are called auricles from their supposed resemblance to the ear. The two lower chambers are called ventricles, and their walls form the chief portion of the muscular substance of the organ. There are, therefore, the right and left auricles, with their thin, soft walls, and the right and left ventricles, with their thick and strong walls.

185. The Valves of the Heart. The heart is a valvular pump, which works on mechanical principles, the motive power being supplied by the contraction of its muscular fibers. Regarding the heart as a pump, its valves assume great importance. They consist of thin, but strong, triangular folds of tough membrane which hang down from the edges of the passages into the ventricles. They may be compared to swinging curtains which, by opening only one way, allow the blood to flow from the auricles to the ventricles, but by instantly folding back prevent its return.

[Illustration: Fig. 70.--Lateral Section of the Right Chest. (Showing the relative position of the heart and its great vessels, the oesophagus and trachea.)

A, inferior constrictor muscle (aids in conveying food down the oesophagus);
B, oesophagus;
C, section of the right bronchus;
D, two right pulmonary veins;
E, great azygos vein crossing oesophagus and right bronchus to empty into the superior vena cava;
F, thoracic duct;
H, thoracic aorta;
K, lower portion of oesophagus passing through the diaphragm;
L, diaphragm as it appears in sectional view, enveloping the heart;
M, inferior vena cava passing through diaphragm and emptying into auricle;
N, right auricle;
O, section of right branch of the pulmonary artery;
P, aorta;
R, superior vena cava;
S, trachea.
]

The valve on the right side is called the tricuspid, because it consists of three little folds which fall over the opening and close it, being kept from falling too far by a number of slender threads called chordae tendinae. The valve on the left side, called the mitral, from its fancied resemblance to a bishop's mitre, consists of two folds which close together as do those of the tricuspid valve.

The slender cords which regulate the valves are only just long enough to allow the folds to close together, and no force of the blood pushing against the valves can send them farther back, as the cords will not stretch The harder the blood in the ventricles pushes back against the valves, the tighter the cords become and the closer the folds are brought together, until the way is completely closed.

From the right ventricle a large vessel called the pulmonary artery passes to the lungs, and from the left ventricle a large vessel called the aorta arches out to the general circulation of the body. The openings from the ventricles into these vessels are guarded by the semilunar valves. Each valve has three folds, each half-moon-shaped, hence the name semilunar. These valves, when shut, prevent any backward flow of the blood on the right side between the pulmonary artery and the right ventricle, and on the left side between the aorta and the left ventricle.

[Illustration: Fig. 71.--Right Cavities of the Heart.

A, aorta;
B, superior vena cava;
C, C, right pulmonary veins;
D, inferior vena cava;
E, section of coronary vein;
F, right ventricular cavity;
H, posterior curtain of the tricuspid valve;
K, right auricular cavity;
M, fossa ovalis, oval depression, partition between the auricles formed after birth.
]

186. General Plan of the Blood-vessels Connected with the Heart. There are numerous blood-vessels connected with the heart, the relative position and the use of which must be understood. The two largest veins in the body, the superior vena cava and the inferior vena cava, open into the right auricle. These two veins bring venous blood from all parts of the body, and pour it into the right auricle, whence it passes into the right ventricle.

From the right ventricle arises one large vessel, the pulmonary artery, which soon divides into two branches of nearly equal size, one for the right lung, the other for the left. Each branch, having reached its lung, divides and subdivides again and again, until it ends in hair-like capillaries, which form a very fine network in every part of the lung. Thus the blood is pumped from the right ventricle into the pulmonary artery and distributed throughout the two lungs (Figs. 86 and 88).

We will now turn to the left side of the heart, and notice the general arrangement of its great vessels. Four veins, called the pulmonary veins, open into the left auricle, two from each lung. These veins start from very minute vessels the continuation of the capillaries of the pulmonary artery. They form larger and larger vessels until they become two large veins in each lung, and pour their contents into the left auricle. Thus the pulmonary artery carries venous blood from the right ventricle _to_ the lungs, as the pulmonary veins carry arterial blood _from_ the lungs to the left auricle.

From the left ventricle springs the largest arterial trunk in the body, over one-half of an inch in diameter, called the aorta. From the aorta other arteries branch off to carry the blood to all parts of the body, only to be again brought back by the veins to the right side, through the cavities of the ventricles. We shall learn in Chapter VIII. that the main object of pumping the blood into the lungs is to have it purified from certain waste matters which it has taken up in its course through the body, before it is again sent on its journey from the left ventricle.

187. The Arteries. The blood-vessels are flexible tubes through which the blood is borne through the body. There are three kinds,--the arteries, the veins, and the capillaries, and these differ from one another in various ways.

The arteries are the highly elastic and extensible tubes which carry the pure, fresh blood outwards from the heart to all parts of the body. They may all be regarded as branches of the aorta. After the aorta leaves the left ventricle it rises towards the neck, but soon turns downwards, making a curve known as the arch of the aorta.

From the arch are given off the arteries which supply the head and arms with blood. These are the two carotid arteries, which run up on each side of the neck to the head, and the two subclavian arteries, which pass beneath the collar bone to the arms. This great arterial trunk now passes down in front of the spine to the pelvis, where it divides into two main branches, which supply the pelvis and the lower limbs.

The descending aorta, while passing downwards, gives off arteries to the different tissues and organs. Of these branches the chief are the coeliac artery, which subdivides into three great branches,--one each to supply the stomach, the liver, and the spleen; then the renal arteries, one to each kidney; and next two others, the mesenteric arteries, to the intestines. The aorta at last divides into two main branches, the common iliac arteries, which, by their subdivisions, furnish the arterial vessels for the pelvis and the lower limbs.

[Illustration: Fig. 72.--Left Cavities of the Heart.

A, B, right pulmonary veins;
with S, openings of the veins;
E, D, C, aortic valves;
R, aorta;
P, pulmonary artery;
O, pulmonic valves;
H, mitral valve;
K, columnae carnoeae;
M, right ventricular cavity;
N, interventricular septum.
]

The flow of blood in the arteries is caused by the muscular force of the heart, aided by the elastic tissues and muscular fibers of the arterial walls, and to a certain extent by the muscles themselves. Most of the great arterial trunks lie deep in the fleshy parts of the body; but their branches are so numerous and become so minute that, with a few exceptions, they penetrate all the tissues of the body,--so much so, that the point of the finest needle cannot be thrust into the flesh anywhere without wounding one or more little arteries and thus drawing blood.

188. The Veins. The veins are the blood-vessels which carry the impure blood from the various tissues of the body to the heart. They begin in the minute capillaries at the extremities of the four limbs, and everywhere throughout the body, and passing onwards toward the heart, receive constantly fresh accessions on the way from myriad other veins bringing blood from other wayside capillaries, till the central veins gradually unite into larger and larger vessels until at length they form the two great vessels which open into the right auricle of the heart.

These two great venous trunks are the inferior vena cava, bringing the blood from the trunk and the lower limbs, and the superior vena cava, bringing the blood from the head and the upper limbs. These two large trunks meet as they enter the right auricle. The four pulmonary veins, as we have learned, carry the arterial blood from the lungs to the left auricle.

[Illustration: Fig. 73.

A, part of a vein laid open, with two pairs of valves;
B, longitudinal section of a vein, showing the valves closed.
]

A large vein generally accompanies its corresponding artery, but most veins lie near the surface of the body, just beneath the skin. They may be easily seen under the skin of the hand and forearm, especially in aged persons. If the arm of a young person is allowed to hang down a few moments, and then tightly bandaged above the elbow to retard the return of the blood, the veins become large and prominent.

The walls of the larger veins, unlike arteries, contain but little of either elastic or muscular tissue; hence they are thin, and when empty collapse. The inner surfaces of many of the veins are supplied with pouch-like folds, or pockets, which act as valves to impede the backward flow of the blood, while they do not obstruct blood flowing forward toward the heart. These valves can be shown by letting the forearm hang down, and sliding the finger upwards over the veins (Fig. 73).

The veins have no force-pump, like the arteries, to propel their contents towards their destination. The onward flow of the blood in them is due to various causes, the chief being the pressure behind of the blood pumped into the capillaries. Then as the pocket-like valves prevent the backward flow of the blood, the pressure of the various muscles of the body urges along the blood, and thus promotes the onward flow.

The forces which drive the blood through the arteries are sufficient to carry the blood on through the capillaries. It is calculated that the onward flow in the capillaries is about 1/50 to 1/33 of an inch in a second, while in the arteries the blood current flows about 16 inches in a second, and in the great veins about 4 inches every second.

[Illustration: Fig. 74.--The Structure of Capillaries.

Capillaries of various sizes, showing cells with nuclei]

189. The Capillaries. The capillaries are the minute, hair-like tubes, with very thin walls, which form the connection between the ending of the finest arteries and the beginning of the smallest veins. They are distributed through every tissue of the body, except the epidermis and its products, the epithelium, the cartilages, and the substance of the teeth. In fact, the capillaries form a network of the tiniest blood-vessels, so minute as to be quite invisible, at least one-fourth smaller than the finest line visible to the naked eye.

The capillaries serve as a medium to transmit the blood from the arteries to the veins; and it is through them that the blood brings nourishment to the surrounding tissues. In brief, we may regard the whole body as consisting of countless groups of little islands surrounded by ever-flowing streams of blood. The walls of the capillaries are of the most delicate structure, consisting of a single layer of cells loosely connected. Thus there is allowed the most free interchange between the blood and the tissues, through the medium of the lymph.

The number of the capillaries is inconceivable. Those in the lungs alone, placed in a continuous line, would reach thousands of miles. The thin walls of the capillaries are admirably adapted for the important interchanges that take place between the blood and the tissues.

190. The Circulation of the Blood. It is now well to study the circulation as a whole, tracing the course of the blood from a certain point until it returns to the same point. We may conveniently begin with the portion of blood contained at any moment in the right auricle. The superior and inferior venae cavae are busily filling the auricle with dark, impure blood. When it is full, it contracts. The passage leading to the right ventricle lies open, and through it the blood pours till the ventricle is full. Instantly this begins, in its turn, to contract. The tricuspid valve at once closes, and blocks the way backward. The blood is now forced through the open semilunar valves into the pulmonary artery.

The pulmonary artery, bringing venous blood, by its alternate expansion and recoil, draws the blood along until it reaches the pulmonary capillaries. These tiny tubes surround the air cells of the lungs, and here an exchange takes place. The impure, venous blood here gives up its _debris_ in the shape of carbon dioxid and water, and in return takes up a large amount of oxygen. Thus the blood brought to the lungs by the pulmonary arteries leaves the lungs entirely different in character and appearance. This part of the circulation is often called the lesser or pulmonic circulation.

The four pulmonary veins bring back bright, scarlet blood, and pour it into the left auricle of the heart, whence it passes through the mitral valve into the left ventricle. As soon as the left ventricle is full, it contracts. The mitral valve instantly closes and blocks the passage backward into the auricle; the blood, having no other way open, is forced through the semilunar valves into the aorta. Now red in color from its fresh oxygen, and laden with nutritive materials, it is distributed by the arteries to the various tissues of the body. Here it gives up its oxygen, and certain nutritive materials to build up the tissues, and receives certain products of waste, and, changed to a purple color, passes from the capillaries into the veins.

[Illustration: Fig. 75.--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.
]

All the veins of the body, except those from the lungs and the heart itself, unite into two large veins, as already described, which pour their contents into the right auricle of the heart, and thus the grand round of circulation is continually maintained. This is called the systemic circulation. The whole circuit of the blood is thus divided into two portions, very distinct from each other.

191. The Portal Circulation. A certain part of the systemic or greater circulation is often called the portal circulation, which consists of the flow of the blood from the abdominal viscera through the portal vein and liver to the hepatic vein. The blood brought to the capillaries of the stomach, intestines, spleen, and pancreas is gathered into veins which unite into a single trunk called the portal vein. The blood, thus laden with certain products of digestion, is carried to the liver by the portal vein, mingling with that supplied to the capillaries of the same organ by the hepatic artery. From these capillaries the blood is carried by small veins which unite into a large trunk, the hepatic vein, which opens into the inferior vena cava. The portal circulation is thus not an independent system, but forms a kind of loop on the systemic circulation.

The lymph-current is in a sense a slow and stagnant side stream of the blood circulation; for substances are constantly passing from the blood-vessels into the lymph spaces, and returning, although after a comparatively long interval, into the blood by the great lymphatic trunks.

Experiment 90. _To illustrate the action of the heart, and how it pumps the blood in only one direction_. Take a Davidson or Household rubber syringe. Sink the suction end into water, and press the bulb. As you let the bulb expand, it fills with water; as you press it again, a valve prevents the water from flowing back, and it is driven out in a jet along the other pipe. The suction pipe represents the veins; the bulb, the heart; and the tube end, out of which the water flows, the arteries.

[NOTE. The heart is not nourished by the blood which passes through it. The muscular substance of the heart itself is supplied with nourishment by two little arteries called the _coronary arteries_, which start from the aorta just above two of the semilunar valves. The blood is returned to the right auricle (not to either of the venae cavae) by the _coronary vein_.]

The longest route a portion of blood may take from the moment it leaves the left ventricle to the moment it returns to it, is through the portal circulation. The shortest possible route is through the substance of the heart itself. The mean time which the blood requires to make a complete circuit is about 23 seconds.

192. The Rhythmic Action of the Heart. To maintain a steady flow of blood throughout the body the action of the heart must be regular and methodical. The heart does not contract as a whole. The two auricles contract at the same time, and this is followed at once by the contraction of the two ventricles. While the ventricles are contracting, the auricles begin to relax, and after the ventricles contract they also relax. Now comes a pause, or rest, after which the auricles and ventricles contract again in the same order as before, and their contractions are followed by the same pause as before. These contractions and relaxations of the various parts of the heart follow one another so regularly that the result is called the rhythmic action of the heart.

The average number of beats of the heart, under normal conditions, is from 65 to 75 per minute. Now the time occupied from the instant the auricles begin to contract until after the contraction of the ventricles and the pause, is less than a second. Of this time one-fifth is occupied by the contraction of the auricles, two-fifths by the contraction of the ventricles, and the time during which the whole heart is at rest is two-fifths of the period.

193. Impulse and Sounds of the Heart. The rhythmic action of the heart is attended with various occurrences worthy of note. If the hand be laid flat over the chest wall on the left, between the fifth and sixth ribs, the heart will be felt beating. This movement is known as the beat or impulse of the heart, and can be both seen and felt on the left side. The heart-beat is unusually strong during active bodily exertion, and under mental excitement.

The impulse of the heart is due to the striking of the lower, tense part of the ventricles--the apex of the heart--against the chest wall at the moment of their vigorous contraction. It is important for the physician to know the exact place where the heart-beat should be felt, for the heart may be displaced by disease, and its impulse would indicate its new position.

Sounds also accompany the heart's action. If the ear be applied over the region of the heart, two distinct sounds will be heard following one another with perfect regularity. Their character may be tolerably imitated by pronouncing the syllables _lubb_, _dup_. One sound is heard immediately after the other, then there is a pause, then come the two sounds again. The first is a dull, muffled sound, known as the "first sound," followed at once by a short and sharper sound, known as the "second sound" of the heart.

The precise cause of the first sound is still doubtful, but it is made at the moment the ventricles contract. The second sound is, without doubt, caused by the sudden closure of the semilunar valves of the pulmonary artery and the aorta, at the moment when the contraction of the ventricles is completed.

[Illustration: Fig. 76.--Muscular Fibers of the Ventricles.

A, superficial fibers common to both ventricles;
B, fibers of the left ventricle;
C, deep fibers passing upwards toward the base of the heart;
D, fibers penetrating the left ventricle
]

The sounds of the heart are modified or masked by blowing "murmurs" when the cardiac orifices or valves are roughened, dilated, or otherwise affected as the result of disease. Hence these new sounds may often afford indications of the greatest importance to physicians in the diagnosis of heart-disease.

194. The Nervous Control of the Heart. The regular, rhythmic movement of the heart is maintained by the action of certain nerves. In various places in the substance of the heart are masses of nerve matter, called ganglia. From these ganglia there proceed, at regular intervals, discharges of nerve energy, some of which excite movement, while others seem to restrain it. The heart would quickly become exhausted if the exciting ganglia had it all their own way, while it would stand still if

the restraining ganglia had full sway. The influence of one, however, modifies the other, and the result is a moderate and regular activity of the heart.

The heart is also subject to other nerve influences, but from outside of itself. Two nerves are connected with the heart, the pneumogastric and the sympathetic (secs. 271 and 265). The former appears to be connected with the restraining ganglia; the latter with the exciting ganglia. Thus, if a person were the subject of some emotion which caused fainting, the explanation would be that the impression had been conveyed to the brain, and from the brain to the heart by the pneumogastric nerves. The result would be that the heart for an instant ceases to beat. Death would be the result if the nerve influence were so great as to restrain the movements of the heart for any appreciable time.

Again, if the person were the subject of some emotion by which the heart were beating faster than usual, it would mean that there was sent from the brain to the heart by the sympathetic nerves the impression which stimulated it to increased activity.

195. The Nervous Control of the Blood-vessels. The tone and caliber of the blood-vessels are controlled by certain vaso-motor nerves, which are distributed among the muscular fibers of the walls. These nerves are governed from a center in the medulla oblongata, a part of the brain (sec. 270). If the nerves are stimulated more than usual, the muscular walls contract, and the quantity of the blood flowing through them and the supply to the part are diminished. Again, if the stimulus is less than usual, the vessels dilate, and the supply to the part is increased.

Now the vaso-motor center may be excited to increased activity by influences reaching it from various parts of the body, or even from the brain itself. As a result, the nerves are stimulated, and the vessels contract. Again, the normal influence of the vaso-motor center may be suspended for a time by what is known as the inhibitory or restraining effect. The result is that the tone of the blood-vessels becomes diminished, and their channels widen.

The effect of this power of the nervous system is to give it a certain control over the circulation in particular parts. Thus, though the force of the heart and the general average blood-pressure remain the same, the state of the circulation may be very different in different parts of the body. The importance of this local control over the circulation is of the utmost significance. Thus an organ at work needs to be more richly supplied with blood than when at rest. For example, when the salivary glands need to secrete saliva, and the stomach to pour out gastric juice, the arteries that supply these organs are dilated, and so the parts are flushed with an extra supply of blood, and thus are aroused to greater activity.

Again, the ordinary supply of blood to a part may be lessened, so that the organ is reduced to a state of inactivity, as occurs in the case of the brain during sleep. We have in the act of blushing a visible example of sudden enlargement of the smaller arteries of the face and neck, called forth by some mental emotion which acts on the vaso-motor center and diminishes its activity. The reverse condition occurs in the act of turning pale. Then the result of the mental emotion is to cause the vaso-motor nerves to exercise a more powerful control over the capillaries, thereby closing them, and thus shutting off the flow of blood.

Experiment 91. Hold up the ear of a white rabbit against the light while the animal is kept quiet and not alarmed. The red central artery can be seen coursing along the translucent organ, giving off branches which by subdivision become too small to be separately visible, and the whole ear has a pink color and is warm from the abundant blood flowing through it. Attentive observation will show also that the caliber of the main artery is not constant; at somewhat irregular periods of a minute or more it dilates and contracts a little.

[Illustration: Fig. 77.--Some of the Principal Organs of the Chest and Abdomen. (Blood vessels on the left, muscles on the right.)]

In brief, all over the body, the nervous system, by its vaso-motor centers, is always supervising and regulating the distribution of blood in the body, sending now more and now less to this or that part.

[Illustration: Fig. 78.--Capillary Blood-Vessels in the Web of a Frog's Foot, as seen with the Microscope.]

196. The Pulse. When the finger is placed on any part of the body where an artery is located near the surface, as, for example, on the radial artery near the wrist, there is felt an intermittent pressure, throbbing with every beat of the heart. This movement, frequently visible to the eye, is the result of the alternate expansion of the artery by the wave of blood, and the recoil of the arterial walls by their elasticity. In other words, it is the wave produced by throwing a mass of blood into the arteries already full. The blood-wave strikes upon the elastic walls of the arteries, causing an increased distention, followed at once by contraction. This regular dilatation and rigidity of the elastic artery answering to the beats of the heart, is known as the pulse.

The pulse may be easily found at the wrist, the temple, and the inner side of the ankle. The throb of the two carotid arteries may be plainly felt by pressing the thumb and finger backwards on each side of the larynx. The progress of the pulse-wave must not be confused with the actual current of the blood itself. For instance, the pulse-wave travels at the rate of about 30 feet a second, and takes about 1/10 of a second to reach the wrist, while the blood itself is from 3 to 5 seconds in reaching the same place.

The pulse-wave may be compared to the wave produced by a stiff breeze on the surface of a slowly moving stream, or the jerking throb sent along a rope when shaken. The rate of the pulse is modified by age, fatigue, posture, exercise, stimulants, disease, and many other circumstances. At birth the rate is about 140 times a minute, in early infancy, 120 or upwards, in the healthy adult between 65 and 75, the most common number being 72. In the same individual, the pulse is quicker when standing than when lying down, is quickened by excitement, is faster in the morning, and is slowest at midnight. In old age the pulse is faster than in middle life; in children it is quicker than in adults.

[Illustration: Fig. 79.--Circulation in the Capillaries, as seen with the Microscope.]

As the pulse varies much in its rate and character in disease, it is to the skilled touch of the physician an invaluable help in the diagnosis of the physical condition of his patient.

Experiment 92. _To find the pulse_. Grasp the wrist of a friend, pressing with three fingers over the radius. Press three fingers over the radius in your own wrist, to feel the pulse.

Count by a watch the rate of your pulse per minute, and do the same with a friend's pulse. Compare its characters with your own pulse.

Observe how the character and frequency of the pulse are altered by posture, muscular exercise, a prolonged, sustained, deep inspiration, prolonged expiration, and other conditions.

197. Effect of Alcoholic Liquors upon the Organs of Circulation. Alcoholic drinks exercise a destructive influence upon the heart, the circulation, and the blood itself. These vicious liquids can reach the heart only indirectly, either from the stomach by the portal vein to the liver, and thence to the heart, or else by way of the lacteals, and so to the blood through the thoracic duct. But by either course the route is direct enough, and speedy enough to accomplish a vast amount of ruinous work.

The influence of alcohol upon the heart and circulation is produced mainly through the nervous system. The inhibitory nerves, as we have seen, hold the heart in check, exercise a restraining control over it, very much as the reins control an active horse. In health this inhibitory influence is protective and sustaining. But now comes the narcotic invasion of alcoholic drinks, which paralyze the inhibitory nerves, with the others, and at once the uncontrolled heart, like the unchecked steed, plunges on to violent and often destructive results.

[Illustration: Fig. 80.--Two Principal Arteries of the Front of the Leg (Anterior Tibial and Dorsalis Pedis).]

This action, because it is quicker, has been considered also a stronger action, and the alcohol has therefore been supposed to produce a stimulating effect. But later researches lead to the conclusion that the effect of alcoholic liquors is not properly that of a stimulant, but of a narcotic paralyzant, and that while it indeed quickens, it also really weakens the heart's action. This view would seem sustained by the fact that the more the intoxicants are pushed, the deeper are the narcotic and paralyzing effects. After having obstructed the nutritive and reparative functions of the vital fluid for many years, their effects at last may become fatal.

This relaxing effect involves not only the heart, but also the capillary system, as is shown in the complexion of the face and the color of the hands. In moderate drinkers the face is only flushed, but in drunkards it is purplish. The flush attending the early stages of drinking is, of course, not the flush of health, but an indication of disease.[34]

198. Effect upon the Heart. This forced overworking of the heart which drives it at a reckless rate, cuts short its periods of rest and inevitably produces serious heart-exhaustion. If repeated and continued, it involves grave changes of the structure of the heart. The heart muscle, endeavoring to compensate for the over-exertion, may become much thickened, making the ventricles smaller, and so fail to do its duty in properly pumping forward the blood which rushes in from the auricle. Or the heart wall may by exhaustion become thinner, making the ventricles much too large, and unable to send on the current. In still other cases, the heart degenerates with minute particles of fat deposited in its

structures, and thus loses its power to propel the nutritive fluid. All three of these conditions involve organic disease of the valves, and all three often produce fatal results.

199. Effect of Alcohol on the Blood-vessels. Alcoholic liquors injure not only the heart, but often destroy the blood-vessels, chiefly the larger arteries, as the arch of the aorta or the basilar artery of the brain. In the walls of these vessels may be gradually deposited a morbid product, the result of disordered nutrition, sometimes chalky, sometimes bony, with usually a dangerous dilatation of the tube.

In other cases the vessels are weakened by an unnatural fatty deposit. Though these disordered conditions differ somewhat, the morbid results in all are the same. The weakened and stiffened arterial walls lose the elastic spring of the pulsing current. The blood fails to sweep on with its accustomed vigor. At last, owing perhaps to the pressure, against the obstruction of a clot of blood, or perhaps to some unusual strain of work or passion, the enfeebled vessel bursts, and death speedily ensues from a form of apoplexy.

[Illustration: Fig. 81.--Showing the Carotid Artery and Jugular Vein on the Right Side, with Some of their Main Branches. (Some branches of the cervical plexus, and the hypoglossal nerve are also shown.)]

[NOTE. "An alcoholic heart loses its contractile and resisting power, both through morbid changes in its nerve ganglia and in its muscle fibers. In typhoid fever, muscle changes are evidently the cause of the heart-enfeeblement; while in diphtheria, disturbances in innervation cause the heart insufficiency. 'If the habitual use of alcohol causes the loss of contractile and resisting power by impairment of both the nerve ganglia and muscle fibers of the heart, how can it act as a heart tonic?'"--Dr. Alfred L. Loomis, Professor of Medicine in the Medical Department of the University of the City of New York.]

200. Other Results from the Use of Intoxicants. Other disastrous consequences follow the use of intoxicants, and these upon the blood. When any alcohol is present in the circulation, its greed for water induces the absorption of moisture from the red globules of the blood, the oxygen-carriers. In consequence they contract and harden, thus becoming unable to absorb, as theretofore, the oxygen in the lungs. Then, in turn, the oxidation of the waste matter in the tissues is prevented; thus the corpuscles cannot convey carbon dioxid from the capillaries, and this fact means that some portion of refuse material, not being thus changed and eliminated, must remain in the blood, rendering it impure and unfit for its proper use in nutrition. Thus, step by step, the use of alcoholics impairs the functions of the blood corpuscles, perverts nutrition, and slowly poisons the blood.

[Illustration: Fig. 82.--The Right Axillary and Brachial Arteries, with Some of their Main Branches.]

[NOTE. "Destroy or paralyze the inhibitory nerve center, and instantly its controlling effect on the heart mechanism is lost, and the accelerating agent, being no longer under its normal restraint, runs riot. The heart's action is increased, the pulse is quickened, an excess of blood is forced into the vessels, and from their becoming engorged and dilated the face gets flushed, all the usual concomitants of a general engorgement of the circulation being the result."--Dr.

George Harley, F.R.S., an eminent English medical author.

"The habitual use of alcohol produces a deleterious influence upon the whole economy. The digestive powers are weakened, the appetite is impaired, and the muscular system is enfeebled. The blood is impoverished, and nutrition is imperfect and disordered, as shown by the flabbiness of the skin and muscles, emaciation, or an abnormal accumulation of fat."--Dr. Austin Flint, Senior, formerly Professor of the Practice of Medicine in Bellevue Medical College, and author of many standard medical works.

"The immoderate use of the strong kind of tobacco, which soldiers affect, is often very injurious to them, especially to very young soldiers. It renders them nervous and shaky, gives rise to palpitation, and is a factor in the production of the irritable or so-called "trotting-heart" and tends to impair the appetite and digestion."--London _Lancet_.

"I never smoke because I have seen the most efficient proofs of the injurious effects of tobacco on the nervous system."--Dr. Brown-Sequard, the eminent French physiologist.

"Tobacco, and especially cigarettes, being a depressant upon the heart, should be positively forbidden."--Dr. J. M. Keating, on "Physical Development," in _Cyclopoedia of the Diseases of Children_.]

201. Effect of Tobacco upon the Heart. While tobacco poisons more or less almost every organ of the body, it is upon the heart that it works its most serious wrong. Upon this most important organ its destructive effect is to depress and paralyze. Especially does this apply to the young, whose bodies are not yet knit into the vigor that can brave invasion.

The _nicotine_ of tobacco acts through the nerves that control the heart's action. Under its baneful influence the motions of the heart are irregular, now feeble and fluttering, now thumping with apparently much force: but both these forms of disturbed action indicate an abnormal condition. Frequently there is severe pain in the heart, often dizziness with gasping breath, extreme pallor, and fainting.

The condition of the pulse is a guide to this state of the heart. In this the physician reads plainly the existence of the "tobacco heart," an affection as clearly known among medical men as croup or measles. There are few conditions more distressing than the constant and impending suffering attending a tumultuous and fluttering heart. It is stated that one in every four of tobacco-users is subject, in some degree, to this disturbance. Test examinations of a large number of lads who had used cigarettes showed that only a very small percentage escaped cardiac trouble. Of older tobacco-users there are very few but have some warning of the hazard they invoke. Generally they suffer more or less from the tobacco heart, and if the nervous system or the heart be naturally feeble, they suffer all the more speedily and intensely.

Additional Experiments.

Experiment 93. Touch a few drops of blood fresh from the finger, with a strip of dry, smooth, neutral litmus paper, highly glazed to prevent the red corpuscles from penetrating into the test paper. Allow the blood to remain a short time; then wash it off with a stream of distilled water, when a blue spot upon a red or violet ground will be seen, indicating its _alkaline_ reaction, due chiefly to the sodium phosphate and sodium carbonate.

Experiment 94. Place on a glass slide a thin layer of defibrinated blood; try to read printed matter through it. This cannot be done.

Experiment 95. _To make blood transparent or laky_. Place in each of three test tubes two or three teaspoonfuls of defibrinated blood, obtained from Experiment 89, labeled _A, B_, and _C. A_ is for comparison. To _B_ add five volumes of water, and warm slightly, noting the change of color by reflected and transmitted light. By reflected light it is much darker,--it looks almost black; but by transmitted light it is transparent. Test this by looking at printed matter as in Experiment 94.

Experiment 96. To fifteen or twenty drops of defibrinated blood in a test tube (labeled _D_) add five volumes of a 10-per-cent solution of common salt. It changes to a very bright, florid, brick-red color. Compare its color with _A, B_, and _C_. It is opaque.

Experiment 97. Wash away the coloring matter from the twigs (see Experiment 89) with a stream of water until the fibrin becomes quite white. It is white, fibrous, and elastic. Stretch some of the fibers to show their extensibility; on freeing them, they regain their elasticity.

Experiment 98. Take some of the serum saved from Experiment 88 and note that it does not coagulate spontaneously. Boil a little in a test tube over a spirit lamp, and the albumen will coagulate.

Experiment 99. _To illustrate in a general way that blood is really a mass of red bodies which give the red color to the fluid in which they float._ Fill a clean white glass bottle two-thirds full of little red beads, and then fill the bottle full of water. At a short distance the bottle appears to be rilled with a uniformly red liquid.

Experiment 100. _To show how blood holds a mineral substance in solution_. Put an egg-shell crushed fine, into a glass of water made acid by a teaspoonful of muriatic acid. After an hour or so the egg-shell will disappear, having been dissolved in the acid water. In like manner the blood holds various minerals in solution.

Experiment 101. _To hear the sounds of the heart_. Locate the heart exactly. Note its beat. Borrow a stethoscope from some physician. Listen to the heart-beat of some friend. Note the sounds of your own heart in the same way.

Experiment 102. _To show how the pulse may be studied_. "The movements of the artery in the human body as the pulse-wave passes through it may be shown to consist in a sudden dilatation, followed by a slow contraction, interrupted by one or more secondary dilatations. This demonstration may be made by pressing a small piece of looking-glass about one centimeter square (2/3 of an inch) upon the wrist over the radial artery, in such a way that with each pulse beat the mirror may be slightly tilted. If the wrist be now held in such a position that sunlight will fall upon the mirror, a spot of light will be reflected on the opposite side of the room, and its motion upon the wall will show that the expansion of the artery is a sudden movement, while the subsequent contraction is slow and interrupted."--Bowditch's _Hints for Teachers of Physiology_.

[Illustration: Fig. 83.--How the Pulse may be studied by Pressing a Mirror over the Radial Artery.]

Experiment 103. _To illustrate the effect of muscular exercise in quickening the pulse_. Run up and down stairs several times. Count the pulse both before and after. Note the effect upon the rate.

Experiment 104. _To show the action of the elastic walls of the arteries._ Take a long glass or metal tube of small caliber. Fasten one end to the faucet of a water-pipe (one in a set bowl preferred) by a very short piece of rubber tube. Turn the water on and off alternately and rapidly, to imitate the intermittent discharge of the ventricles. The water will flow from the other end of the rubber pipe in jets, each jet ceasing the moment the water is shut off.

The experiment will be more successful if the rubber bulb attached to an ordinary medicine-dropper be removed, and the tapering glass tube be slipped on to the outer end of the rubber tube attached to the faucet.

Experiment 105. Substitute a piece of rubber tube for the glass tube, and repeat the preceding experiment. Now it will be found that a continuous stream flows from the tube. The pressure of water stretches the elastic tube, and when the stream is turned off, the rubber recoils on the water, and the intermittent flow is changed into a continuous stream.

Experiment 106. _To illustrate some of the phenomena of circulation._ Take a common rubber bulb syringe, of the Davidson, Household, or any other standard make. Attach a piece of rubber tube about six or eight feet long to the delivery end of the syringe.

To represent the resistance made by the capillaries to the flow of blood, slip the large end of a common glass medicine-dropper into the outer end of the rubber tube. This dropper has one end tapered to a fine point.

Place the syringe flat, without kinks or bends, on a desk or table. Press the bulb slowly and regularly. The water is thus pumped into the tube in an intermittent manner, and yet it is forced out of the tapering end of the glass tube in a steady flow.

Experiment 107. Take off the tapering glass tube, or, in the place of one long piece of rubber tube, substitute several pieces of glass tubing connected together by short pieces of rubber tubes. The obstacle to the flow has thus been greatly lessened, and the water flows out in intermittent jets to correspond to the compression of the bulb.

Chapter VIII.

Respiration.

202. Nature and Object of Respiration. The blood, as we have learned, not only provides material for the growth and activity of all the tissues of the body, but also serves as a means of removing from them the products of their activity. These are waste products, which if allowed to remain, would impair the health of the tissues. Thus the blood becomes impoverished both by the addition of waste material, and from the loss of its nutritive matter.

We have shown, in the preceding chapter, how the blood carries to the tissues the nourishment it has absorbed from the food. We have now to consider a new source of nourishment to the blood, _viz._, that which it receives from the oxygen of the air. We are also to learn one of the methods by which the blood gets rid of poisonous waste matters. In brief, we are to study the set of processes known as respiration, by which oxygen is supplied to the various tissues, and by which the principal waste matters, or chief products of oxidation, are removed.

Now, the tissues are continually feeding on the life-giving oxygen, and at the same time are continually producing carbon dioxid and other waste products. In fact, the life of the tissues is dependent upon a continual succession of oxidations and deoxidations. When the blood leaves the tissues, it is poorer in oxygen, is burdened with carbon dioxid, and has had its color changed from bright scarlet to purple red. This is the change from the arterial to venous conditions which has been described in the preceding chapter.

Now, as we have seen, the change from venous to arterial blood occurs in the capillaries of the lungs, the only means of communication between the pulmonary arteries and the pulmonary veins. The blood in the pulmonary capillaries is separated from the air only by a delicate tissue formed of its own wall and the pulmonary membrane. Hence a gaseous interchange, the essential step in respiration, very readily takes place between the blood and the air, by which the latter gains moisture and carbon dioxid, and loses its oxygen. These changes in the lungs also restore to the dark blood its rosy tint.

The only condition absolutely necessary to the purification of the blood is an organ having a delicate membrane, on one side of which is a thin sheet of blood, while the other side is in such contact with the air that an interchange of gases can readily take place. The demand for oxygen is, however, so incessant, and the accumulation of carbon dioxid is so rapid in every tissue of the human body, that an All-Wise Creator has provided a most perfect but complicated set of machinery to effect this wonderful purification of the blood.

We are now ready to begin the study of the arrangement and working of the respiratory apparatus. With its consideration, we complete our view of the sources of supply to the blood, and begin our study of its purification.

[Illustration: Fig. 84.--The Epiglottis.]

203. The Trachea, or Windpipe. If we look into the mouth of a friend, or into our own with a mirror, we see at the back part an arch which is the boundary line of the mouth proper. There is just behind this a similar limit for the back part of the nostrils. The funnel-shaped cavity beyond, into which both the mouth and the posterior nasal passages open, is called the pharynx. In its lower part are two openings; the

trachea, or windpipe, in front, and the oesophagus behind.

The trachea is surmounted by a box-like structure of cartilage, about four and one-half inches long, called the larynx. The upper end of the larynx opens into the pharynx or throat, and is provided with a lid,--the epiglottis,--which closes under certain circumstances (secs. 137 and 349). The larynx contains the organ of voice, and is more fully described in Chapter XII.

The continuation of the larynx is the trachea, a tube about three-fourths of an inch in diameter, and about four inches long. It extends downwards along the middle line of the neck, where it may readily be felt in front, below the Adam's apple.

[Illustration: Fig. 85.--Larynx, Trachea, and the Bronchi. (Front view.)

A, epiglottis;
B, thyroid cartilage;
C, cricoid-thyroid membrane, connecting with the cricoid cartilage below, all forming the larynx;
D, one of the rings of the trachea.
]

The walls of the windpipe are strengthened by a series of cartilaginous rings, each somewhat the shape of a horseshoe or like the letter C, being incomplete behind, where they come in contact with the oesophagus. Thus the trachea, while always open for the passage of air, admits of the distention of the food-passage.

204. The Bronchial Tubes. The lower end of the windpipe is just behind the upper part of the sternum, and there it divides into two branches, called bronchi. Each branch enters the lung of its own side, and breaks up into a great number of smaller branches, called bronchial tubes. These divide into smaller tubes, which continue subdividing till the whole lung is penetrated by the branches, the extremities of which are extremely minute. To all these branches the general name of bronchial tubes is given. The smallest are only about one-fiftieth of an inch in diameter.

[Illustration: Fig. 86.--Relative Position of the Lungs, Heart, and its Great Vessels.

A, left ventricle;
B, right ventricle;
C, left auricle;
D, right auricle;
E, superior vena cava;
F, pulmonary artery;
G, aorta;
H, arch of the aorta;
K, innominate artery;
L, right common carotid artery;
M, right subclavian artery;
N, thyroid cartilage forming upper portion of the larynx;
O, trachea.
]

Now the walls of the windpipe, and of the larger bronchial tubes would readily collapse, and close the passage for air, but for a wise precaution. The horseshoe-shaped rings of cartilage in the trachea and the plates of cartilage in the bronchial tubes keep these passages open. Again, these air passages have elastic fibers running the length of the tubes, which allow them to stretch and bend readily with the movements of the neck.

205. The Cilia of the Air Passages. The inner surfaces of the windpipe and bronchial tubes are lined with mucous membrane, continuous with that of the throat, the mouth, and the nostrils, the secretion from which serves to keep the parts moist.

Delicate, hair-like filaments, not unlike the pile on velvet, called cilia, spring from the epithelial lining of the air tubes. Their constant wavy movement is always upwards and outwards, towards the mouth. Thus any excessive secretion, as of bronchitis or catarrh, is carried upwards, and finally expelled by coughing. In this way, the lungs are kept quite free from particles of foreign matter derived from the air. Otherwise we should suffer, and often be in danger from the accumulation of mucus and dust in the air passages. Thus these tiny cilia act as dusters which Nature uses to keep the air tubes free and clean (Fig. 5).

[Illustration: Fig. 87.--Bronchial tube, with its Divisions and Subdivisions. (Showing groups of air cells at the termination of minute bronchial tubes.)]

206. The Lungs. The lungs, the organs of respiration, are two pinkish gray structures of a light, spongy appearance, that fill the chest cavity, except the space taken up by the heart and large vessels. Between the lungs are situated the large bronchi, the oesophagus, the heart in its pericardium, and the great blood-vessels. The base of the lungs rests on the dome-like diaphragm, which separates the chest from the abdomen. This partly muscular and partly tendinous partition is a most important factor in breathing.

Each lung is covered, except at one point, with an elastic serous membrane in a double layer, called the pleura. One layer closely envelops the lung, at the apex of which it is reflected to the wall of the chest cavity of its own side, which it lines. The two layers thus form between them a Closed Sac a serous cavity (see Fig. 69, also note, p. 176).

[Illustration: Fig. 88.--The Lungs with the Trachea, Bronchi, and Larger Bronchial Tubes exposed. (Posterior view.)

A, division of left bronchus to upper lobe;
B, left branch of the Pulmonary artery;
C, left bronchus;
D, left superior pulmonary vein;
E, left inferior pulmonary vein;
F, left auricle;
K, inferior vena cava;
L, division of right bronchus to lower lobe;
M, right inferior pulmonary vein;
N, right superior pulmonary vein;
O, right branch of the pulmonary artery;
P, division of right bronchus to upper lobe;
R, left ventricle;
S, right ventricle.
]

In health the two pleural surfaces of the lungs are always in contact, and they secrete just enough serous fluid to allow the surfaces to glide smoothly upon each other. Inflammation of this membrane is called _pleurisy_. In this disease the breathing becomes very painful, as the secretion of glairy serum is suspended, and the dry and inflamed surfaces rub harshly upon each other.

The root of the lung, as it is called, is formed by the bronchi, two pulmonary arteries, and two pulmonary veins. The nerves and lymphatic vessels of the lung also enter at the root. If we only remember that all the bronchial tubes, great and small, are hollow, we may compare the whole system to a short bush or tree growing upside down in the chest, of which the trachea is the trunk, and the bronchial tubes the branches of various sizes.

207. Minute Structure of the Lungs. If one of the smallest bronchial tubes be traced in its tree-like ramifications, it will be found to end in an irregular funnel-shaped passage wider than itself. Around this passage are grouped a number of honeycomb-like sacs, the air cells[35] or alveoli of the lungs. These communicate freely with the passage, and through it with the bronchial branches, but have no other openings. The whole arrangement of passages and air cells springing from the end of a bronchial tube, is called an ultimate lobule. Now each lobule is a very small miniature of a whole lung, for by the grouping together of these lobules another set of larger lobules is formed.

[Illustration: Fig. 89.

A, diagrammatic representation of the ending of a bronchial tube in air sacs or alveoli;
B, termination of two bronchial tubes in enlargement beset with air sacs (_Huxley_);
C, diagrammatic view of an air sac.

a lies within sac and points to epithelium lining wall;
b, partition between two adjacent sacs, in which run capillaries;
c, elastic connective tissue (_Huxley_).
]

In like manner countless numbers of these lobules, bound together by connective tissue, are grouped after the same fashion to form by their aggregation the lobes of the lung. The right lung has three such lobes; and the left, two. Each lobule has a branch of the pulmonary artery entering it, and a similar rootlet of the pulmonary vein leaving it. It also receives lymphatic vessels, and minute twigs of the pulmonary plexus of nerves.

[Illustration: Fig. 90.--Diagram to illustrate the Amounts of Air contained by the Lungs in Various Phases of Ordinary and of Forced Respiration.]

The walls of the air cells are of extreme thinness, consisting of delicate elastic and connective tissue, and lined inside by a single layer of thin epithelial cells. In the connective tissue run capillary vessels belonging to the pulmonary artery and veins. Now these delicate vessels running in the connective tissue are surrounded on all sides by air cells. It is evident, then, that the blood flowing through these capillaries is separated from the air within the cells only by the thin walls of the vessels, and the delicate tissues of the air cells.

This arrangement is perfectly adapted for an interchange between the blood in the capillaries and the air in the air cells. This will be more fully explained in sec. 214.

208. Capacity of the Lungs. In breathing we alternately take into and expel from the lungs a certain quantity of air. With each quiet inspiration about 30 cubic inches of air enter the lungs, and 30 cubic inches pass out with each expiration. The air thus passing into and out of the lungs is called tidal air. After an ordinary inspiration, the lungs contain about 230 cubic inches of air. By taking a deep inspiration, about 100 cubic inches more can be taken in. This extra amount is called complemental air.

After an ordinary expiration, about 200 cubic inches are left in the lungs, but by forced expiration about one-half of this may be driven out. This is known as supplemental air. The lungs can never be entirely emptied of air, about 75 to 100 cubic inches always remaining. This is known as the residual air.

The air that the lungs of an adult man are capable of containing is thus composed:

Complemental air	100	cubic inches.
Tidal "	30	" "
Supplemental "	100	" "
Residual "	100	" "

Total capacity of lungs	330	" "

If, then, a person proceeds, after taking the deepest possible breath, to breath out as much as he can, he expels:

Complemental air	100	cubic inches.
Tidal "	30	" "
Supplemental "	100	" "

	230	

This total of 230 cubic inches forms what is called the vital capacity of the chest (Fig. 90).

209. The Movements of Breathing. The act of breathing consists of a series of rhythmical movements, succeeding one another in regular order. In the first movement, inspiration, the chest rises, and there is an inrush of fresh air; this is at once followed by expiration, the falling of the chest walls, and the output of air. A pause now occurs, and the same breathing movements are repeated.

The entrance and the exit of air into the respiratory passages are accompanied with peculiar sounds which are readily heard on placing the ear at the chest wall. These sounds are greatly modified in various pulmonary diseases, and hence are of great value to the physician in making a correct diagnosis.

In a healthy adult, the number of respirations should be from 16 to 18 per minute, but they vary with age, that of a newly born child being 44 for the same time. Exercise increases the number, while rest diminishes it. In standing, the rate is more than when lying at rest. Mental emotion and excitement quicken the rate. The number is smallest during sleep. Disease has a notable effect upon the frequency of respirations. In diseases involving the lungs, bronchial tubes, and the pleura, the rate may be alarmingly increased, and the pulse is quickened in proportion.

210. The Mechanism of Breathing. The chest is a chamber with bony walls, the ribs connecting in front with the breastbone, and behind with the spine. The spaces between the ribs are occupied by the intercostal muscles, while large muscles clothe the entire chest. The diaphragm serves as a movable floor to the chest, which is an air-tight chamber with movable walls and floor. In this chamber are suspended the lungs, the air cells of which communicate with the outside through the bronchial passages, but have no connection with the chest cavity. The thin space between the lungs and the rib walls, called the pleural cavity, is in health a vacuum.

Now, when the diaphragm contracts, it descends and thus increases the depth of the chest cavity. A quantity of air is now drawn into the lungs and causes them to expand, thus filling up the increased space. As soon as the diaphragm relaxes, returning to its arched position and reducing the size of the chest cavity, the air is driven from the lungs, which then diminish in size. After a short pause, the diaphragm again contracts, and the same round of operation is constantly repeated.

The walls of the chest being movable, by the contractions of the intercostals and other muscles, the ribs are raised and the breastbone pushed forward. The chest cavity is thus enlarged from side to side and from behind forwards. Thus, by the simultaneous descent of the diaphragm and the elevation of the ribs, the cavity of the chest is increased in three directions,--downwards, side-ways, and from behind forwards.

It is thus evident that inspiration is due to a series of muscular contractions. As soon as the contractions cease, the elastic lung tissue resumes its original position, just as an extended rubber band recovers itself. As a result, the original size of the chest cavity is restored, and the inhaled air is driven from the lungs. Expiration may then be regarded as the result of an elastic recoil, and not of active muscular contractions.

[Illustration: Fig. 91.--Diagrammatic Section of the Trunk. (Showing the expansion of the chest and the movement of the ribs by action of the lungs.) [The dotted lines indicate the position during inspiration.]]

211. Varieties of Breathing. This is the mechanism of quiet, normal respiration. When the respiration is difficult, additional forces are brought into play. Thus when the windpipe and bronchial tubes are obstructed, as in croup, asthma, or consumption, many additional muscles are made use of to help the lungs to expand. The position which asthmatics often assume, with arms raised to grasp something for support, is from the need of the sufferer to get a fixed point from which the muscles of the arm and chest may act forcibly in raising the ribs, and thus securing more comfortable breathing.

The visible movements of breathing vary according to circumstances. In infants the action of the diaphragm is marked, and the movements of the abdomen are especially obvious. This is called abdominal breathing. In women the action of the ribs as they rise and fall, is emphasized more than in men, and this we call costal breathing. In young persons and in men, the respiration not usually being impeded by tight clothing, the breathing is normal, being deep and abdominal.

Disease has a marked effect upon the mode of breathing. Thus, when children suffer from some serious chest disease, the increased movements of the abdominal walls seem distressing. So in fracture of the ribs, the surgeon envelops the overlying part of the chest with long strips of firm adhesive plaster to restrain the motions of chest respiration, that they may not disturb the jagged ends of the broken bones. Again, in painful diseases of the abdomen, the sufferer instinctively suspends the abdominal action and relies upon the chest breathing. These deviations from the natural movements of respiration are useful to the physician in ascertaining the seat of disease.

212. The Nervous Control of Respiration. It is a matter of common experience that one's breath may be held for a short time, but the need of fresh air speedily gets the mastery, and a long, deep breath is drawn. Hence the efforts of criminals to commit suicide by persistent restraint of their breathing, are always a failure. At the very worst, unconsciousness ensues, and then respiration is automatically resumed. Thus a wise Providence defeats the purpose of crime. The movements of breathing go on without our attention. In sleep the regularity of respiration is even greater than when awake. There is a particular part of the nervous system that presides over the breathing function. It is situated in that part of the brain called the medulla oblongata, and is fancifully called the "vital knot" (sec. 270). It is injury to this respiratory center which proves fatal in cases of broken neck.

From this nerve center there is sent out to the nerves that supply the diaphragm and other muscles of breathing, a force which stimulates them to regular contraction. This breathing center is affected by the condition of the blood. It is stimulated by an excess of carbon dioxid in the blood, and is quieted by the presence of oxygen.

Experiment 108. _To locate the lungs_. Mark out the boundaries of the lungs by "sounding" them; that is, by _percussion_, as it is called. This means to put the forefinger of the left hand across the chest or back, and to give it a quick, sharp rap with two or three fingers. Note where it sounds hollow, resonant. This experiment can be done by the student with only imperfect success, until practice brings some skill.

Experiment 109. Borrow a stethoscope, and listen to the respiration over the chest on the right side. This is known as _auscultation_. Note the difference of the sounds in inspiration and in expiration. Do not confuse the heart sounds with those of respiration. The respiratory murmurs may be heard fairly well by applying the ear flat to the chest, with only one garment interposed.

Experiment 110. Get a sheep's lungs, with the windpipe attached. Ask for the heart and lungs all in one mass. Take pains to examine the specimen first, and accept only a good one. Parts are apt to be hastily snipped or mangled. Examine the windpipe. Note the horseshoe-shaped rings of cartilage in front, which serve to keep it open.

Experiment 111. Examine one bronchus, carefully dissecting away the lung tissue with curved scissors. Follow along until small branches of the bronchial tubes are reached. Take time for the dissection, and save the specimen in dilute alcohol. Put pieces of the lung tissue in a basin of water, and note that they float.

The labored breathing of suffocation and of lung diseases is due to the excessive stimulation of this center, caused by the excess of carbon dioxid in the blood. Various mental influences from the brain itself, as the emotions of alarm or joy or distress, modify the action of the respiratory center.

Again, nerves of sensation on the surface of the body convey influences to this nerve center and lead to its stimulation, resulting in a vigorous breathing movement. Thus a dash of cold water on the face or neck of a fainting person instantly produces a deep, long-drawn breath. Certain drugs, as opium, act to reduce the activity of this nerve center. Hence, in opium poisoning, special attention should be paid to keeping up the respiration. The condition of the lungs themselves is made known to the breathing center, by messages sent along the branches of the great pneumogastric nerve (page 276), leading from the lungs to the medulla oblongata.

213. Effects of Respiration upon the Blood. The blood contains three gases, partly dissolved in it and partly in chemical union with certain of its constituents. These are oxygen, carbon dioxid, and nitrogen. The latter need not be taken into account. The oxygen is the nourishing material which the tissues require to carry on their work. The carbon dioxid is a waste substance which the tissues produce by their activity, and which the blood carries away from them.

As before shown, the blood as it flows through the tissues loses most of its oxygen, and carbon dioxid takes its place. Now if the blood is to maintain its efficiency in this respect, it must always be receiving new supplies of oxygen, and also have some mode of throwing off its excess of carbon dioxid. This, then, is the double function of the process of respiration. Again, the blood sent out from the left side of the heart is of a bright scarlet color. After its work is done, and the blood returns to the right side of the heart, it is of a dark purple color. This change in color takes place in the capillaries, and is due to the fact that there the blood gives up most of its oxygen to the tissues and receives from them a great deal of carbon dioxid.

In brief, while passing through the capillaries of the lungs the blood has been changed from the venous to the arterial blood. That is to say, the blood in its progress through the lungs has rid itself of its excess of carbon dioxid and obtained a fresh supply of oxygen.[36]

214. Effects of Respiration upon the Air in the Lungs. It is well known that if two different liquids be placed in a vessel in contact with each other and left undisturbed, they do not remain separate, but gradually mix, and in time will be perfectly combined. This is called diffusion of liquids. The same thing occurs with gases, though the process is not visible. This is known as the diffusion of gases. It is also true that two liquids will mingle when separated from each other by a membrane (sec. 129). In a similar manner two gases, especially if of different densities, may mingle even when separated from each other by a membrane.

In a general way this explains the respiratory changes that occur in the blood in the lungs. Blood containing oxygen and carbon dioxid is flowing in countless tiny streams through the walls of the air cells of the lungs. The air cells themselves contain a mixture of the same two gases. A thin, moist membrane, well adapted to allow gaseous diffusion, separates the blood from the air. This membrane is the delicate wall of the capillaries and the epithelium of the air cells. By experiment it has been found that the pressure of oxygen in the blood is less than that in the air cells, and that the pressure of carbon dioxid gas in the blood is greater than that in the air cells. As a result, a diffusion of gases ensues. The blood gains oxygen and loses carbon dioxid, while the air cells lose oxygen and gain the latter gas.

[Illustration: Fig. 92.--Capillary Network of the Air Cells and Origin of the Pulmonary Veins.

A, small branch of pulmonary artery;
B, twigs of the pulmonary artery anastomosing to form peripheral network of the primitive air cells;
C, capillary network around the walls of the air sacs;
D, branches of network converging for form the veinlets of the pulmonary veins.
]

The blood thus becomes purified and reinvigorated, and at the same time is changed in color from purple to scarlet, from venous to arterial. It is now evident that if this interchange is to continue, the air in the cells must be constantly renewed, its oxygen restored, and its excess of carbon dioxid removed. Otherwise the process just described would be reversed, making the blood still more unfit to nourish the tissues, and more poisonous to them than before.

215. Change in the Air in Breathing. The air which we exhale during respiration differs in several important particulars from the air we inhale. Both contain chiefly the three gases, though in different quantities, as the following table shows.

	Oxygen.	Nitrogen.	Carbon Dioxid.
Inspired air contains	20.81	79.15	.04
Expired air contains	16.03	79.58	4.38

That is, expired air contains about five per cent less oxygen and five per cent more carbon dioxid than inspired air.

The temperature of expired air is variable, but generally is higher than that of inspired air, it having been in contact with the warm air passages. It is also loaded with aqueous vapor, imparted to it like the heat, not in the depth of the lungs, but in the upper air passages.

Expired air contains, besides carbon dioxid, various impurities, many of an unknown nature, and all in small amounts. When the expired air is condensed in a cold receiver, the aqueous product is found to contain organic matter, which, from the presence of _micro-organisms_, introduced in the inspired air, is apt to putrefy rapidly. Some of these organic substances are probably poisonous, either so in themselves, as produced in some manner in the breathing apparatus, or poisonous as being the products of decomposition. For it is known that various animal substances give rise, by decomposition, to distinct poisonous products known as _ptomaines_. It is possible that some of the constituents of the expired air are of an allied nature. See under "Bacteria" (Chapter XIV).

At all events, these substances have an injurious action, for an atmosphere containing simply one per cent of pure carbon dioxid has very little hurtful effect on the animal economy, but an atmosphere in which the carbon dioxid has been raised one per cent by breathing is highly injurious.

The quantity of oxygen removed from the air by the breathing of an adult person at rest amounts daily to about 18 cubic feet. About the same amount of carbon dioxid is expelled, and this could be represented by a piece of pure charcoal weighing 9 ounces. The quantity of carbon dioxid, however, varies with the age, and is increased also by external cold and by exercise, and is affected by the kind of food. The amount of water, exhaled as vapor, varies from 6 to 20 ounces daily. The average daily quantity is about one-half a pint.

216. Modified Respiratory Movements. The respiratory column of air is often used in a mechanical way to expel bodies from the upper air passages. There are also, in order to secure special ends, a number of modified movements not distinctly respiratory. The following peculiar respiratory acts call for a few words of explanation.

A sigh is a rapid and generally audible expiration, due to the elastic recoil of the lungs and chest walls. It is often caused by depressing emotions. Yawning is a deep inspiration with a stretching of the muscles of the face and mouth, and is usually excited by fatigue or drowsiness, but often occurs from a sort of contagion.

Hiccough is a sudden jerking inspiration due to the spasmodic contraction of the diaphragm and of the glottis, causing the air to rush suddenly through the larynx, and produce this peculiar sound. Snoring is caused by vibration of the soft palate during sleep, and is habitual with some, although it occurs with many when the system is unusually exhausted and relaxed.

Laughing consists of a series of short, rapid, spasmodic expirations which cause the peculiar sounds, with characteristic movements of the facial muscles. Crying, caused by emotional states, consists of sudden jerky expirations with long inspirations, with facial movements indicative of distress. In sobbing, which often follows long-continued crying, there is a rapid series of convulsive inspirations, with sudden involuntary contractions of the diaphragm. Laughter, and sometimes sobbing, like yawning, may be the result of involuntary imitation.

Experiment 112. _Simple Apparatus to Illustrate the Movements of the Lungs in the Chest_.--T is a bottle from which the bottom has been removed; D, a flexible and elastic membrane tied on the bottle, and capable of being pulled out by the string S, so as to increase the capacity of the bottle. L is a thin elastic bag representing the lungs. It communicates with the external air by a glass tube fitted air-tight through a cork in the neck of the bottle. When D is drawn down, the pressure of the external air causes L to expand. When the string is let go, L contracts again, by virtue of its elasticity.

[Illustration: Fig. 93.]

Coughing is produced by irritation in the upper part of the windpipe and larynx. A deep breath is drawn, the opening of the windpipe is closed, and immediately is burst open with a violent effort which sends a blast of air through the upper air passages. The object is to dislodge and expel any mucus or foreign matter that is irritating the air passages.

Sneezing is like coughing; the tongue is raised against the soft palate, so the air is forced through the nasal passages. It is caused by an irritation of the nostrils or eyes. In the beginning of a cold in the head, for instance, the cold air irritates the inflamed mucous membrane of the nose, and causes repeated attacks of sneezing.

217. How the Atmosphere is Made Impure. The air around us is constantly being made impure in a great variety of ways. The combustion of fuel, the respiration of men and animals, the exhalations from their bodies, the noxious gases and effluvia of the various industries, together with the changes of fermentation and decomposition to which all organized matter is liable,--all tend to pollute the atmosphere.

The necessity of external ventilation has been foreseen for us. The forces of nature,--the winds, sunlight, rain, and growing vegetation,--all of great power and universal distribution and application, restore the balance, and purify the air. As to the principal gases, the air of the city does not differ materially from that of rural sections. There is, however, a vastly greater quantity of dust and smoke in the air of towns. The breathing of this dust, to a greater or less extent laden with bacteria, fungi, and the germs of disease, is an ever-present and most potent menace to public and personal health. It is one of the main causes of the excess of mortality in towns and cities over that of country districts.

This is best shown in the overcrowded streets and houses of great cities, which are deprived of the purifying influence of sun and air. The fatal effect of living in vitiated air is especially marked in the mortality among infants and children living in the squalid and overcrowded sections of our great cities. The salutary effect of sunshine is shown by the fact that mortality is usually greater on the shady side of the street.

218. How the Air is Made Impure by Breathing. It is not the carbon dioxid alone that causes injurious results to health, it is more especially the organic matter thrown off in the expired air. The carbon dioxid which accompanies the organic matter is only the index. In testing the purity of air it is not difficult to ascertain the amount of carbon dioxid present, but it is no easy problem to measure the amount of organic matter. Hence it is the former that is looked for in factories, churches, schoolrooms, and when it is found to exceed .07 per cent it is known that there is a hurtful amount of organic matter present.

The air as expelled from the lungs contains, not only a certain amount of organic matter in the form of vapor, but minute solid particles of _debris_ and bacterial micro-organisms (Chap. XIV). The air thus already vitiated, after it leaves the mouth, putrefies very rapidly. It is at once absorbed by clothing, curtains, carpets, porous walls, and by many other objects. It is difficult to dislodge these enemies of health even by free ventilation. The close and disagreeable odor of a filthy or overcrowded room is due to these organic exhalations from the lungs, the skin, and the unclean clothing of the occupants.

The necessity of having a proper supply of fresh air in enclosed places, and the need of removal of impure air are thus evident. If a man were shut up in a tightly sealed room containing 425 cubic feet of air, he would be found dead or nearly so at the end of twenty-four hours. Long before this time he would have suffered from nausea, headache, dizziness, and other proofs of blood-poisoning. These symptoms are often felt by those who are confined for an hour or more in a room where the atmosphere has been polluted by a crowd of people. The unpleasant effects rapidly disappear on breathing fresh air.

219. The Effect on the Health of Breathing Foul Air. People are often compelled to remain indoors for many hours, day after day, in shops, factories, or offices, breathing air perhaps only slightly vitiated, but still recognized as "stuffy." Such persons often suffer from ill health. The exact form of the disturbance of health depends much upon the hereditary proclivity and physical make-up of the individual. Loss of appetite, dull headache, fretfulness, persistent weariness, despondency, followed by a general weakness and an impoverished state of blood, often result.

Persons in this lowered state of health are much more prone to surfer from colds, catarrhs, bronchitis, and pneumonia than if they were living in the open air, or breathing only pure air. Thus, in the Crimean War, the soldiers who lived in tents in the coldest weather were far more free from colds and lung troubles than those who lived in tight and ill-ventilated huts. In the early fall when typhoid fever is prevalent, the grounds of large hospitals are dotted with canvas tents, in which patients suffering from this fever do much better than in the wards.

This tendency to inflammatory diseases of the air passages is aggravated by the overheated and overdried condition of the air in the room occupied. This may result from burning gas, from overheated furnaces and stoves, hot-water pipes, and other causes. Serious lung diseases, such as consumption, are more common among those who live in damp, overcrowded, or poorly ventilated homes.

220. The Danger from Pulmonary Infection. The germ of pulmonary consumption, known as the bacillus tuberculosis, is contained in the breath and the sputa from the lungs of its victims. It is not difficult to understand how these bacilli may be conveyed through the air from the lungs of the sick to those of apparently healthy people. Such persons may, however, be predisposed, either constitutionally or by defective hygienic surroundings, to fall victims to this dreaded disease. Overcrowding, poor ventilation, and dampness all tend to increase the risk of pulmonary infection.

It must not be supposed that the tubercle bacillus is necessarily transmitted directly through the air from the lungs of the sick to be implanted in the lungs of the healthy. The germs may remain for a time in the dust turn and _debris_ of damp, filthy, and overcrowded houses. In this congenial soil they retain their vitality for a long time, and possibly may take on more virulent infective properties than they possessed when expelled from the diseased lungs.[37]

[Illustration: Fig. 94. Example of a Micro-Organism--Bacillus Tuberculosis in Spotum. (Magnified about 500 diameters.)]

221. Ventilation. The question of a practicable and economical system of ventilation for our homes, schoolrooms, workshops, and public places presents many difficult and perplexing problems. It is perhaps due to the complex nature of the subject, that ventilation, as an ordinary condition of daily health, has been so much neglected. The matter is practically ignored in building ordinary houses. The continuous renewal of air receives little if any consideration, compared with the provision made to furnish our homes with heat, light, and water. When the windows are closed we usually depend for ventilation upon mere chance,--on the chimney, the fireplace, and the crevices of doors and windows. The proper ventilation of a house and its surroundings should form as prominent a

consideration in the plans of builders and architects as do the grading of the land, the size of the rooms, and the cost of heating.

The object of ventilation is twofold: First, to provide for the removal of the impure air; second, for a supply of pure air. This must include a plan to provide fresh air in such a manner that there shall be no draughts or exposure of the occupants of the rooms to undue temperature. Hence, what at first might seem an easy thing to do, is, in fact, one of the most difficult of sanitary problems.

222. Conditions of Efficient Ventilation. To secure proper ventilation certain conditions must be observed. The pure air introduced should not be far below the temperature of the room, or if so, the entering current should be introduced towards the ceiling, that it may mix with the warm air.

Draughts must be avoided. If the circuit from entrance to exit is short, draughts are likely to be produced, and impure air has less chance of mixing by diffusion with the pure air. The current of air introduced should be constant, otherwise the balance may occasionally be in favor of vitiated air. If a mode of ventilation prove successful, it should not be interfered with by other means of entrance. Thus, an open door may prevent the incoming air from passing through its proper channels. It is desirable that the inlet be so arranged that it can be diminished in size or closed altogether. For instance, when the outer air is very cold, or the wind blows directly into the inlet, the amount of cold air entering it may lower the temperature of the room to an undesirable degree.

In brief, it is necessary to have a thorough mixing of pure and impure air, so that the combination at different parts of the room may be fairly uniform. To secure these results, the inlets and outlets should be arranged upon principles of ventilation generally accepted by authorities on public health. It seems hardly necessary to say that due attention must be paid to the source from which the introduced air is drawn. If it be taken from foul cellars, or from dirty streets, it may be as impure as that which it is designed to replace.

Animal Heat.

223. Animal or Vital Heat. If a thermometer, made for the purpose, be placed for five minutes in the armpit, or under the tongue, it will indicate a temperature of about 98-1/2 degrees F., whether the surrounding atmosphere be warm or cold. This is the natural heat of a healthy person, and in health it rarely varies more than a degree or two. But as the body is constantly losing heat by radiation and conduction, it is evident that if the standard temperature be maintained, a certain amount of heat must be generated within the body to make up for the loss externally. The heat thus produced is known as animal or vital heat.

This generation of heat is common to all living organisms. When the mass of the body is large, its heat is readily perceptible to the touch and by its effect upon the thermometer. In mammals and birds the heat-production is more active than in fishes and reptiles, and their temperatures differ in degree even in different species of the same class, according to the special organization of the animal and the general activity of its functions. The temperature of the frog may be 85 degrees F. in June and 41 degrees F. in January. The structure of its tissues is unaltered and their vitality unimpaired by such violent fluctuations. But in man it is necessary not only for health, but even for life, that the temperature should vary only within narrow limits around the mean of 98-1/2 degrees F.

We are ignorant of the precise significance of this constancy of temperature in warm-blooded animals, which is as important and peculiar as their average height, Man, undoubtedly, must possess a superior delicacy of organization, hardly revealed by structure, which makes it necessary that he should be shielded from the shocks and jars of varying temperature, that less highly endowed organisms endure with impunity.

224. Sources of Bodily Heat. The heat of the body is generated by the chemical changes, generally spoken of as those of oxidation, which are constantly going on in the tissues. Indeed, whenever protoplasmic materials are being oxidized (the process referred to in sec. 15 as katabolism) heat is being set free. These chemical changes are of various kinds, but the great source of heat is the katabolic process, known as oxidation.

The vital part of the tissues, built up from the complex classes of food, is oxidized by means of the oxygen carried by the arterial blood, and broken down into simpler bodies which at last result in urea, carbon dioxid, and water. Wherever there is life, this process of oxidation is going on, but more energetically in some tissues and organs than in others. In other words, the minutest tissue in the body is a source of heat in proportion to the activity of its chemical changes. The more active the changes, the greater is the heat produced, and the greater the amount of urea, carbon dioxid, and water eliminated. The waste caused by this oxidation must be made good by a due supply of food to be built up into protoplasmic material. For the production of heat, therefore, food is necessary. But the oxidation process is not as simple and direct as the statement of it might seem to indicate. Though complicated in its various stages, the ultimate result is as simple as in ordinary combustion outside of the body, and the products are the same.

The continual chemical changes, then, chiefly by oxidation of combustible materials in the tissues, produce an amount of heat which is efficient to maintain the temperature of the living body at about 98-1/2 degrees F. This process of oxidation provides not only for the heat of the body, but also for the energy required to carry on the muscular work of the animal organism.

225. Regulation of the Bodily Temperature. While bodily heat is being continually produced, it is also as continually being lost by the lungs, by the skin, and to some extent, by certain excretions. The blood, in its swiftly flowing current, carries warmth from the tissues where heat is being rapidly generated, to the tissues or organs in which it is being lost by radiation, conduction, or evaporation. Were there no arrangement by which heat could be distributed and regulated, the temperature of the body would be very unequal in different parts, and would vary at different times.

The normal temperature is maintained with slight variations throughout life. Indeed a change of more than a degree above or below the average, indicates some failure in the organism, or some unusual influence. It is evident, then, that the mechanisms which regulate the temperature of the body must be exceedingly sensitive.

The two chief means of regulating the temperature of the body are the lungs and the skin. As a means of lowering the temperature, the lungs and air passages are very inferior to the skin; although, by giving heat to the air we breathe, they stand next to the skin in importance. As a regulating power they are altogether subordinate to the skin.

Experiment 113. _To show the natural temperature of the body_. Borrow a physician's clinical thermometer, and take your own temperature, and that of several friends, by placing the instrument under the tongue, closing the mouth, and holding it there for five minutes. It should be thoroughly cleansed after each use.

226. The Skin as a Heat-regulator. The great regulator of the bodily temperature is, undoubtedly, the skin, which performs this function by means of a self-regulating apparatus with a more or less double action. First, the skin regulates the loss of heat by means of the vaso-motor mechanism. The more blood passes through the skin, the greater will be the loss of heat by conduction, radiation, and evaporation. Hence, any action of the vaso-motor mechanism which causes dilatation of the cutaneous capillaries, leads to a larger flow of blood through the skin, and will tend to cool the body. On the other hand, when by the same mechanism the cutaneous vessels are constricted, there will be a smaller flow of blood through the skin, which will serve to check the loss of heat from the body (secs. 195 and 270).

Again, the special nerves of perspiration act directly as regulators of temperature. They increase the loss of heat when they promote the secretion of the skin, and diminish the loss when they cease to promote it.

The practical working of this heat-regulating mechanism is well shown by exercise. The bodily temperature rarely rises so much as a degree during vigorous exercise. The respiration is increased, the cutaneous capillaries become dilated from the quickened circulation, and a larger amount of blood is circulating through the skin. Besides this, the skin perspires freely. A large amount of heat is thus lost to the body, sufficient to offset the addition caused by the muscular contractions.

It is owing to the wonderful elasticity of the sweat-secreting mechanism, and to the increase in respiratory activity, and the consequent increase in the amount of watery vapor given off by the lungs, that men are able to endure for days an atmosphere warmer than the blood, and even for a short time at a temperature above that of boiling water. The temperature of a Turkish bath may be as high as 150 degrees to 175 degrees F. But an atmospheric temperature may be considerably below this, and yet if long continued becomes dangerous to life. In August, 1896, for instance, hundreds of persons died in this country, within a few days, from the effects of the excessive heat.

A much higher temperature may be borne in dry air than in humid air, or that which is saturated with watery vapor. Thus, a shade temperature of 100 degrees F. in the dry air of a high plain may be quite tolerable, while a temperature of 80 degrees F. in the moisture-laden atmosphere of less elevated regions, is oppressive. The reason is that in dry air the sweat evaporates freely, and cools the skin. In saturated air at the bodily temperature there is little loss of heat by perspiration, or by evaporation from the bodily surface.

This topic is again discussed in the description of the skin as a regulator of the bodily temperature (sec. 241).

227. Voluntary Means of Regulating the Temperature. The voluntary factor, as a means of regulating the heat loss in man, is one of great importance. Clothing retards the loss of heat by keeping in contact with it a layer of still air, which is an exceedingly bad conductor. When a man feels too warm and throws off his coat, he removes one of the badly conducting layers of air, and increases the heat loss by radiation and conduction. The vapor next the skin is thus allowed a freer access to the surface, and the loss of heat by evaporation of the sweat becomes greater. This voluntary factor by which the equilibrium is maintained must be regarded as of great importance. This power also exists in the lower animals, but to a much smaller extent. Thus a dog, on a hot day, runs out his tongue and stretches his limbs so as to increase the surface from which heat is radiated and conducted.

The production, like the loss, of heat is to a certain extent under the control of the will. Work increases the production of heat, and rest, especially sleep, lessens it. Thus the inhabitants of very hot countries seek relief during the hottest part of the day by a siesta. The quantity and quality of food also influence the production of heat. A larger quantity of food is taken in winter than in summer. Among the inhabitants of the northern and Arctic regions, the daily consumption of food is far greater than in temperate and tropical climates.

228. Effect of Alcohol upon the Lungs. It is a well recognized fact that alcohol when taken into the stomach is carried from that organ to the liver, where, by the baneful directness of its presence, it produces a speedy and often disastrous effect. But the trail of its malign power does not disappear there. From the liver it passes to the right side of the heart, and thence to the lungs, where its influence is still for harm.

In the lungs, alcohol tends to check and diminish the breathing capacity of these organs. This effect follows from the partial paralyzing influence of the stupefying agent upon the sympathetic nervous system, diminishing its sensibility to the impulse of healthful respiration. This diminished capacity for respiration is clearly shown by the use of the _spirometer_, a simple instrument which accurately records the cubic measure of the lungs, and proves beyond denial the decrease of the lung space.

> "Most familiar and most dangerous is the drinking man's inability to resist lung diseases."--Dr. Adoph Frick, the eminent German physiologist of Zurich.

> "Alcohol, instead of preventing consumption, as was once believed, reduces the vitality so much as to render the system unusually susceptible to that fatal disease."--R. S. Tracy, M.D., Sanitary Inspector of the N. Y. City Health Dept.

> "In thirty cases in which alcoholic phthisis was present a dense, fibroid, pigmented change was almost invariably present in some portion of the lung far more frequently than in other cases of phthisis."--_Annual of Medical Sciences_.

> "There is no form of consumption so fatal as that from alcohol. Medicines affect the disease but little, the most judicious diet fails, and change of air accomplishes but slight real good.... In plain terms, there is no remedy whatever for alcoholic phthisis. It may be delayed in its course, but it is never stopped; and not infrequently, instead of

being delayed, it runs on to a fatal termination more rapidly than is common in any other type of the disorder."--Dr. B. W. Richardson in _Diseases of Modern Life_.

229. Other Results of Intoxicants upon the Lungs. But a more potent injury to the lungs comes from another cause. The lungs are the arena where is carried on the ceaseless interchange of elements that is necessary to the processes of life. Here the dark venous blood, loaded with effete material, lays down its carbon burden and, with the brightening company of oxygen, begins again its circuit. But the enemy intrudes, and the use of alcohol tends to prevent this benign interchange.

The continued congestion of the lung tissue results in its becoming thickened and hardened, thus obstructing the absorption of oxygen, and the escape of carbon dioxid. Besides this, alcohol destroys the integrity of the red globules, causing them to shrink and harden, and impairing their power to receive oxygen. Thus the blood that leaves the lungs conveys an excess of the poisonous carbon dioxid, and a deficiency of the needful oxygen. This is plainly shown in the purplish countenance of the inebriate, crowded with enlarged veins. This discoloration of the face is in a measure reproduced upon the congested mucous membrane of the lungs. It is also proved beyond question by the decreased amount of carbon dioxid thrown off in the expired breath of any person who has used alcoholics.

The enfeebled respiration explains (though it is only one of the reasons) why inebriates cannot endure vigorous and prolonged exertion as can a healthy person. The hurried circulation produced by intoxicants involves in turn quickened respiration, which means more rapid exhaustion of the life forces. The use of intoxicants involves a repeated dilatation of the capillaries, which steadily diminishes their defensive power, rendering the person more liable to yield to the invasion of pulmonary diseases.[38]

230. Effect of Alcoholics upon Disease. A theory has prevailed, to a limited extent, that the use of intoxicants may act as a preventive of consumption. The records of medical science fail to show any proof whatever to support this impression. No error could be more serious or more misleading, for the truth is in precisely the opposite direction. Instead of preventing, alcohol tends to develop consumption. Many physicians of large experience record the existence of a distinctly recognized alcoholic consumption, attacking those constitutions broken down by dissipation. This form of consumption is steadily progressive, and always fatal.

The constitutional debility produced by the habit of using alcoholic beverages tends to render one a prompt victim to the more severe diseases, as pneumonia, and especially epidemical diseases, which sweep away vast numbers of victims every year.

231. Effect of Tobacco upon the Respiratory Passages. The effects of tobacco upon the throat and lungs are frequently very marked and persistent. The hot smoke must very naturally be an irritant, as the mouth and nostrils were not made as a chimney for heated and narcotic vapors. The smoke is an irritant, both by its temperature and from its destructive ingredients, the carbon soot and the ammonia which it conveys. It irritates and dries the mucous membrane of the mouth and throat, producing an unnatural thirst which becomes an enticement to the use of intoxicating liquors. The inflammation of the mouth and throat is apt to extend up the Eustachian tube, thus impairing the sense of hearing.

But even these are not all the bad effects of tobacco. The inhalation of the poisonous smoke produces unhealthful effects upon the delicate mucous membrane of the bronchial tubes and of the lungs. Upon the former the effect is to produce an irritating cough, with short breath and chronic bronchial catarrh. The pulmonary membrane is congested, taking cold becomes easy, and recovery from it tedious. Frequently the respiration is seriously disturbed, thus the blood is imperfectly aerated, and so in turn the nutrition of the entire system is impaired. The cigarette is the defiling medium through which these direful results frequently invade the system, and the easily moulded condition of youth yields readily to the destructive snare.

"The first effect of a cigar upon any one demonstrates that tobacco can poison by its smoke and through the lungs."--London _Lancet_.

"The action of the heart and lungs is impaired by the influence of the narcotic on the nervous system, but a morbid state of the larynx, trachea, and lungs results from the direct action of the smoke."--Dr. Laycock, Professor of Medicine in the University of Edinburgh.

Additional Experiments.

Experiment 114. _To illustrate the arrangement of the lungs and the two pleurae._ Place a large sponge which will represent the lungs in a thin paper bag which just fits it; this will represent the pulmonary layer of the pleura. Place the sponge and paper bag inside a second paper bag, which will represent the parietal layer of the pleura. Join the mouths of the two bags. The two surfaces of the bags which are now in contact will represent the two moistened surfaces of the pleurae, which rub together in breathing.

Experiment 115. _To show how the lungs may be filled with air._ Take one of the lungs saved from Experiment 110. Tie a glass tube six inches long into the larynx. Attach a piece of rubber to one end of the glass tube. Now inflate the lung several times, and let it collapse. When distended, examine every part of it.

Experiment 116. _To take your own bodily temperature or that of a friend._ If you cannot obtain the use of a physician's clinical thermometer, unfasten one of the little thermometers found on so many calendars and advertising sheets. Hold it for five minutes under the tongue with the lips closed. Read it while in position or the instant it is removed. The natural temperature of the mouth is about 98-1/2 degrees F.

Experiment 117. _To show the vocal cords._ Get a pig's windpipe in perfect order, from the butcher, to show the vocal cords. Once secured, it can be kept for an indefinite time in glycerine and water or dilute alcohol.

Experiment 118. _To show that the air we expire is warm._ Breathe on a thermometer for a few minutes. The mercury will rise rapidly.

Experiment 119. _To show that expired air is moist_. Breathe on a mirror, or a knife blade, or any polished metallic surface, and note the deposit of moisture.

Experiment 120. _To show that the expired air contains carbon dioxid_. Put a glass tube into a bottle of lime water and breathe through the tube. The A liquid will soon become cloudy, because the carbon dioxid of the expired air throws down the lime held in solution.

Experiment 121. "A substitute for a clinical thermometer may be readily contrived by taking an ordinary house thermometer from its tin case, and cutting off the lower part of the scale so that the bulb may project freely. With this instrument the pupils may take their own and each other's temperatures, and it will be found that whatever the season of the year or the temperature of the room, the thermometer in the mouth will record about 99 degrees F. Care must, of course, be taken to keep the thermometer in the mouth till it ceases to rise, and to read while it is still in position."--Professor H. P. Bowditch.

Experiment 122. _To illustrate the manner in which the movements of inspiration cause the air to enter the lungs._ Fit up an apparatus, as represented in Fig. 95, in which a stout glass tube is provided with a sound cork, B, and also an air-tight piston, D, resembling that of an ordinary syringe. A short tube, A, passing through the cork, has a small India-rubber bag, C, tied to it. Fit the cork in the tube while the piston is near the top. Now, by lowering the piston we increase the capacity of the cavity containing the bag. The pressure outside the bag is thus lowered, and air rushes into it through the tube, A, till a balance is restored. The bag is thus stretched. As soon as we let go the piston, the elasticity of the bag, being free to act, Movements of drives out the air just taken in, and the piston returns to its former place.

[Illustration: Fig. 95. Apparatus for Illustrating the Movements of Respiration.]

It will be noticed that in this experiment the elastic bag and its tube represent the lungs and trachea; and the glass vessel enclosing it, the thorax.

For additional experiments on the mechanics of respiration, see Chapter XV.

Chapter IX.

The Skin and the Kidneys.

232. The Elimination of Waste Products. We have traced the food from the alimentary canal into the blood. We have learned that various food materials, prepared by the digestive processes, are taken up by the branches of the portal vein, or by the lymphatics, and carried into the blood current. The nutritive material thus absorbed is conveyed by the blood plasma and the lymph to the various tissues to provide them with nourishment.

We have learned also that oxygen, taken up in the air cells of the lungs, is being continually carried to the tissues, and that the blood is purified by being deprived in the lungs of its excess of carbon dioxid.

From this tissue activity, which is mainly oxidation, are formed certain waste products which, as we have seen, are absorbed by the capillaries and lymphatics and carried into the venous circulation.

In their passage through the blood and tissues, the albumens, sugars, starches, and fats are converted into carbon dioxid, water, and urea, or some closely allied body. Certain articles of food also contain small amounts of sulphur and phosphorus, which undergo oxidation into sulphates and phosphates. We speak, then, of carbon dioxid, salts, and water as waste products of the animal economy. These leave the body by one of the three main channels,--the lungs, the skin, or the kidneys.

The elimination of these products is brought about by a special apparatus called organs of excretion. The worn-out substances themselves are called excretions, as opposed to secretions, which are elaborated for use in the body. (See note, p. 121.) As already shown, the lungs are the main channels for the elimination of carbon dioxid, and of a portion of water as vapor. By the skin the body gets rid of a small portion of salts, a little carbon dioxid, and a large amount of water in the form of perspiration. From the kidneys are eliminated nearly all the urea and allied bodies, the main portion of the salts, and a large amount of water. In fact, practically all the nitrogenous waste leaves the body by the kidneys.

[Illustration: Fig. 96.--Diagrammatic Scheme to illustrate in a very General Way Absorption and Excretion.

A, represents the alimentary canal;
L, the pulmonary surface;
K, the surface of the renal epithelium;
S, the skin;
o, oxygen;
h, hydrogen,;
n, nitrogen.
]

233. The Skin. The skin is an important and unique organ of the body. It is a blood-purifying organ as truly as are the lungs and the kidneys, while it also performs other and complex duties. It is not merely a protective covering for the surface of the body. This is indeed the most apparent, but in some respectes, the lest important, of its functions. This protective duty is necessary and efficient, as is proved by the familiar experience of the pain when a portion of the outer skin has been removed.

The skin, being richly supplied with nerves, is an important organ of sensibility and touch. In some parts it is closely attached to the structures beneath, while in others it is less firmly adherent and rests upon a variable amount of fatty tissue. It thus assists in relieving the abrupt projections and depressions of the general surface, and in giving roundness and symmetry to the entire body. The thickness of the skin varies in different parts of the body. Where exposed to pressure and friction, as on the soles of the feet and in the palms of the hands, it is much thickened.

The true skin is 1/12 to 1/8 of an inch in thickness, but in certain parts, as in the lips and ear passages, it is often not more than 1/100 of an inch thick. At the orifices of the body, as at the mouth, ears, and nose, the skin gradually passes into mucous membrane, the structure of the two being practically identical. As the skin is an outside covering, so is the mucous membrane a more delicate inside lining for all cavities into which the apertures open, as the alimentary canal and the lungs.

[Illustration: Fig. 97.--A Layer of the Cuticle from the Palm of the Hand. (Detached by maceration.)]

The skin ranks as an important organ of excretion, its product being sweat, excreted by the sweat glands. The amount of this excretion evaporated from the general surface is very considerable, and is modified as becomes necessary from the varied conditions of the temperature. The skin also plays an important part in regulating the bodily temperature(sec. 241).

234. The Cutis Vera, or True Skin. The skin is remarkably complex in its structure, and is divided into two distinct layers, which may be readily separated: the deeper layer,--the true skin, dermis, or corium; and the superficial layer, or outer skin,--the epidermis, cuticle, or scarf skin.

The true skin consists of elastic and white fibrous tissue, the bundles of which interlace in every direction. Throughout this feltwork structure which gradually passes into areolar tissue are numerous muscular fibers, as about the hair-follicles and the oil glands. When these tiny muscles contract from cold or by mental emotion, the follicles project upon the surface, producing what is called "goose flesh."

The true skin is richly supplied with blood-vessels and nerves, as when cut it bleeds freely, and is very sensitive. The surface of the true skin is thrown into a series of minute elevations called the papillae, upon which the outer skin is moulded. These abound in blood-vessels, lymphatics, and peculiar nerve-endings, which will be described in connection with the organ of touch (sec. 314). The papillae are large and numerous in sensitive places, as the palms of the hands, the soles of the feet, and the fingers. They are arranged in parallel curved lines, and form the elevated ridges seen on the surface of the outer skin (Fig. 103).

235. The Epidermis, or Cuticle. Above the true skin is the epidermis. It is semi-transparent, and under the microscope resembles the scales of a fish. It is this layer that is raised by a blister.

As the epidermis has neither blood-vessels, nerves, nor lymphatics, it may be cut without bleeding or pain. Its outer surface is marked with shallow grooves which correspond to the deep furrows between the papillae of the true skin. The inner surface is applied directly to the papillary layer of the true skin, and follows closely its inequalities. The outer skin is made up of several layers of cells, which next to the true skin are soft and active, but gradually become harder towards the surface, where they are flattened and scale-like. The upper scales are continually being rubbed off, and are replaced by deeper cells from beneath. There are new cells continually being produced in the deeper layer, which push upward the cells already existing, then gradually become dry, and are cast off as fine, white dust. Rubbing with a coarse towel after a hot bath removes countless numbers of these dead cells of the outer skin. During and after an attack of scarlet fever the patient "peels," that is, sheds an unusual amount of the seal; cells of the cuticle.

The deeper and more active layer of the epidermis, the _mucosum_, is made up of cells some of which contain minute granules of pigment, or coloring matter, that give color to the skin. The differences in the tint, as brunette, fair, and blond, are due mainly to the amount of coloring matter in these pigment cells. In the European this amount is generally small, while in other peoples the color cells may be brown, yellow, or even black. The pinkish tint of healthy skin, and the rosy-red after a bath are due, not to the pigment cells, but to the pressure of capillaries in the true skin, the color of the blood being seen through the semi-transparent outer skin.

[Illustration: Fig. 98.--Surface of the Palm of the Hand, showing the Openings of the Sweat Glands and the Grooves between the Papillae of the Skin. (Magnified 4 diameters.) [In the smaller figure the same epidermal surface is shown, as seen with the naked eye.]]

Experiment 123. Of course the living skin can be examined only in a general way. Stretch and pull it, and notice that it is elastic. Note any liver spots, white scars, moles, warts, etc. Examine the outer skin carefully with a strong magnifying glass. Study the papillae on the palms. Scrape off with a sharp knife a few bits of the scarf skin, and examine them with the microscope.

236. The Hair. Hairs varying in size cover nearly the entire body, except a few portions, as the upper eyelids, the palms of the hands, and the soles of the feet.

The length and diameter of the hairs vary in different persons, especially in the long, soft hairs of the head and beard. The average number of hairs upon a square inch of the scalp is about 1000, and the number upon the entire head is estimated as about 120,000.

Healthy hair is quite elastic, and may be stretched from one-fifth to one-third more than its original length. An ordinary hair from the head will support a weight of six to seven ounces. The hair may become strongly electrified by friction, especially when brushed vigorously in cold, dry weather. Another peculiarity of the hair is that it readily absorbs moisture.

237. Structure of the Hair. The hair and the nails are structures connected with the skin, being modified forms of the epidermis. A hair is formed by a depression, or furrow, the inner walls of which consist of the infolded outer skin. This depression takes the form of a sac and is called the hair-follicle, in which the roots of the hair are embedded. At the bottom of the follicle there is an upward projection of the true skin, a papilla, which contains blood-vessels and nerves. It is covered with epidermic cells which multiply rapidly, thus accounting for the rapid growth of the hair. Around each papilla is a bulbous expansion, the hair bulb, from which the hair begins to grow.

[Illustration: Fig. 99.--Epidermis of the Foot.

It will be noticed that there are only a few orifices of the sweat glands in this region. (Magnified 8 diameters.)]

The cells on the papillae are the means by which the hairs grow. As these are pushed upwards by new ones formed beneath, they are compressed, and the shape of the follicle determines their cylindrical growth, the shaft of the hair. So closely are these cells welded to form the cylinder, that even under a microscope the hair presents only a fibrous appearance, except in the center, where the cells are larger, forming the medulla, or pith (Fig. 106).

The medulla of the hair contains the pigment granules or coloring matter, which may be of any shade between a light yellow and an intense black. It is this that gives the great variety in color. Generally with old people the pigment is absent, the cells being occupied by air; hence the hair becomes gray or white. The thin, flat scales on the surface of the hair overlap like shingles. Connected with the hair-follicles are small bundles of muscular fibers, which run obliquely in the skin and which, on shortening, may cause the hairs to become more upright, and thus are made to "stand on end." The bristling back of an angry cat furnishes a familiar illustration of this muscular action.

[Illustration: Fig. 100.--Hair and Hair-Follicle.

A, root of hair;
B, bulb of the hair;
C, internal root sheath;
D, external root sheath;
E, external membrane of follicle;
F, muscular fibers attached to the follicle;
H, compound sebaceous gland with its duct;
K, L, simple sebaceous gland;
M, opening of the hair-follicle.
]

Opening into each hair-follicle are usually one or more sebaceous, or oil, glands. These consist of groups of minute pouches lined with cells producing an oily material which serves to oil the hair and keep the skin moist and pliant.

238. The Nails. The nails are also formed of epidermis cells which have undergone compression, much like those forming the shaft of a hair. In other words, a nail is simply a thick layer of horny scales built from the outer part of the scarf skin. The nail lies upon very fine and closely set papillae, forming its matrix, or bed. It is covered at its base with a fold of the true skin, called its root, from beneath which it seems to grow.

The growth of the nail, like that of the hair and the outer skin, is effected by the production of new cells at the root and under surface. The growth of each hair is limited; in time it falls out and is replaced by a new one. But the nail is kept of proper size simply by the removal of its free edge.

239. The Sweat Glands. Deep in the substance of the true skin, or in the fatty tissue beneath it, are the sweat glands. Each gland consists of a single tube with a blind end, coiled in a sort of ball about 1/60 of an inch in diameter. From this coil the tube passes upwards through the dermis in a wavy course until it reaches the cuticle, which it penetrates with a number of spiral turns, at last opening on the surface. The tubes consist of delicate walls of membrane lined with cells. The coil of the gland is enveloped by minute blood-vessels. The cells of the glands are separated from the blood only by a fine partition, and draw from it whatever supplies they need for their special work.

[Illustration: Fig. 101.--Concave or Adherent Surface of the Nail.

A, border of the root;
B, whitish portion of semilunar shape (the lunula);
C, body of nail. The continuous line around border represents the free edge.
]

[Illustration: Fig. 102.--Nail in Position.

A, section of cutaneous fold (B) turned back to show the root of the nail;
B, cutaneous fold covering the root of the nail;
C, semi lunar whitish portion (lunula);
D, free border.
]

With few exceptions every portion of the skin is provided with sweat glands, but they are not equally distributed over the body. They are fewest in the back and neck, where it is estimated they average 400 to the square inch. They are thickest in the palms of the hands, where they amount to nearly 3000 to each square inch. These minute openings occur in the ridges of the skin, and may be easily seen with a hand lens. The length of a tube when straightened is about 1/4 of an inch. The total number in the body is estimated at about 2,500,000, thus making the entire length of the tubes devoted to the secretion of sweat about 10 miles.

240. Nature and Properties of Sweat. The sweat is a turbid, saltish fluid with a feeble but characteristic odor due to certain volatile fatty acids. Urea is always present in small quantities, and its proportion may be largely increased when there is deficiency of elimination by the kidneys. Thus it is often observed that the sweat is more abundant when the kidneys are inactive, and the reverse is true. This explains the increased excretion of the kidneys in cold weather. Of the inorganic constituents of sweat, common salt is the largest and most important. Some carbon dioxid passes out through the skin, but not more than 1/50 as much as escapes by the lungs.

The sweat ordinarily passes off as vapor. If there is no obvious perspiration we must not infer that the skin is inactive, since sweat is continually passing from the surface, though often it may not be apparent. On an average from 1-1/2 to 4 pounds of sweat are eliminated daily from the skin in the form of vapor. This is double the amount excreted by the lungs, and averages about 1/67 of the weight of the body.

The visible sweat, or sensible perspiration, becomes abundant during active exercise, after copious drinking of cold water, on taking certain drugs, and when the body is exposed to excessive warmth. Forming more rapidly than it evaporates it collects in drops on the surface. The disagreeable sensations produced by humid weather result from the fact that the atmosphere is so loaded with vapor that the moisture of the skin is slowly removed by evaporation.

Experiment 124. Study the openings of the sweat glands with the aid of a strong magnifying glass. They are conveniently examined on the palms.

A man's weight may be considerably reduced within a short time by loss through the perspiration alone. This may explain to some extent the weakening effect of profuse perspiration, as from night sweats of consumption, convalescence from typhoid fever, or the artificial sweating from taking certain drugs.

241. The Skin as a Regulator of the Temperature of the Body. We thus learn that the skin covers and protects the more delicate structures beneath it; and that it also serves as an important organ of excretion. By means of the sweat the skin performs a third and a most important function, _viz_., that of regulating the temperature of the body.

The blood-vessels of the skin, like those of other parts of the body, are under the control of the nervous system, which regulates their diameter. If the nervous control be relaxed, the blood-vessels dilate, more blood flows through them, and more material is brought to the glands of the skin to be acted upon. External warmth relaxes the skin and its blood-vessels. There results an increased flow of blood to the skin, with increased perspiration. External cold, on the other hand, contracts the skin and its blood-vessels, producing a diminished supply of blood and a diminished amount of sweat.

Now, it is a law of physics that the change from liquid to vapor involves a loss of heat. A few drops of ether or of any volatile liquid placed on the skin, produce a marked sense of coldness, because the heat necessary to change the liquid into vapor has been drawn rapidly from the skin. This principle holds good for every particle of sweat that reaches the mouth of a sweat gland. As the sweat evaporates, it absorbs a certain amount of heat, and cools the body to that extent.

242. How the Action of the Skin may be Modified. After profuse sweating we feel chilly from the evaporation of a large amount of moisture, which rapidly cools the surface. When the weather is very warm the evaporation tends to prevent the bodily temperature from rising. On the other hand, if the weather be cold, much less sweat is produced, the loss of heat from the body is greatly lessened, and its temperature prevented from falling. Thus it is plain why medicine is given and other efforts are made to sweat the fever patient. The increased activity of the skin helps to reduce the bodily heat.

The sweat glands are under the control of certain nerve fibers originating in the spinal cord, and are not necessarily excited to action by an increased flow of blood through the skin. In other words, the sweat glands may be stimulated to increased action both by an increased flow of blood, and also by reflex action upon the vaso-dilator nerves of the parts. These two agencies, while working in harmony through the vaso-dilators, produce phenomena which are essentially independent of each other. Thus a strong emotion, like fear, may cause a profuse sweat to break out, with cold, pallid skin. During a fever the skin may be hot, and its vessels full of blood, and yet there may be no perspiration.

[Illustration: Fig. 103.--Papillae of the Skin of the Palm of the Hand.

In each papilla are seen vascular loops (dark lines) running up from the vascular network below, the tactile corpuscles with their nerve branches (white lines) which supply the papillae.]

The skin may have important uses with which we are not yet acquainted. Death ensues when the heat of the body has been reduced to about 70 degrees F., and suppression of the action of the skin always produces a lowering of the temperature. Warm-blooded animals usually die when more than half of the general surface has been varnished. Superficial burns which involve a large part of the surface of the body, generally have a fatal result due to shock.

If the skin be covered with some air-tight substance like a coating of varnish, its functions are completely arrested. The bodily heat falls very rapidly. Symptoms of blood-poisoning arise, and death soon ensues. The reason is not clearly known, unless it be from the sudden retention of poisonous exhalations.

243. The Skin and the Kidneys. There is a close relationship between the skin and the kidneys, as both excrete organic and saline matter. In hot weather, or in conditions producing great activity of the skin, the amount of water excreted by the kidneys is diminished. This is shown in the case of firemen, stokers, bakers, and others who are exposed to great heat, and drink heavily and sweat profusely, but do not have a relative increase in the functions of the kidneys. In cool weather, when the skin is less active, a large amount of water is excreted by the kidneys, as is shown by the experience of those who drive a long distance in severe weather, or who have caught a sudden cold.

[Illustration: Fig. 104.--Magnified View of a Sweat Gland with its Duct.

The convoluted gland is seen surrounded with big fat-cells, and may be traced through the dermis to its outlet in the horny layers of the epidermis.]

244. Absorbent Powers of the Skin. The skin serves to some extent as an organ for absorption. It is capable of absorbing certain substances to which it is freely exposed. Ointments rubbed in, are absorbed by the lymphatics in those parts where the skin is thin, as in the bend of the elbow or knee, and in the armpits. Physicians use medicated ointments in this way, when they wish to secure prompt and efficient results. Feeble infants often grow more vigorous by having their skin rubbed vigorously daily with olive oil.

A slight amount of water is absorbed in bathing. Sailors deprived of fresh water have been able to allay partially their intense thirst by soaking their clothing in salt water. The extent to which absorption occurs through the healthy skin is, however, quite limited. If the outer skin be removed from parts of the body, the exposed surface absorbs rapidly. Various substances may thus be absorbed, and rapidly passed into the blood. When the physician wishes remedies to act through the skin, he sometimes raises a small blister, and dusts over the surface some drug, a fine powder, like morphine.

The part played by the skin as an organ of touch will be considered in sections 314 and 315.

Experiment 125. _To illustrate the sense of temperature_. Ask the person to close his eyes. Use two test tubes, one filled with cold and the other with hot water, or two spoons, one hot and one cold. Apply each to different parts of the surface, and ask the person whether the touching body is hot or cold. Test roughly the sensibility of different parts of the body with cold and warm metallic-pointed rods.

Experiment 126. Touch fur, wood, and metal. The metal feels coldest, although all the objects are at the same temperature. Why?

Experiment 127. Plunge the hand into water at about 97 degrees F. One experiences a feeling of heat. Then plunge it into water at about 86 degrees F.; at first it feels cold, because heat is abstracted from the hand. Plunge the other hand direct into water at 86 degrees F. without previously placing it in water at 97 degrees F.,--it will feel pleasantly warm.

Experiment 128. _To illustrate warm and cold spots_. With a blunt metallic point, touch different parts of the skin. Certain points excite the sensation of warmth, others of cold, although the temperatures of the skin and of the instrument remain constant.

245. Necessity for Personal Cleanliness. It is evident that the skin, with its myriads of blood-vessels, nerves, and sweat and oil glands, is an exceedingly complicated and important structure. The surface is continually casting off perspiration, oily material, and dead scales. By friction and regular bathing we get rid of these waste materials. If this be not thoroughly done, the oily secretion holds the particles of waste substances to the surface of the body, while dust and dirt collect, and form a layer upon the skin. When we remember that this dirt consists of a great variety of dust particles, poisonous matters, and sometimes germs of disease, we may well be impressed with the necessity of personal cleanliness.

This layer of foreign matter on the skin is in several ways injurious to health. It clogs the pores and retards perspiration, thus checking the proper action of the skin as one of the chief means of getting rid of the waste matters of the body. Hence additional work is thrown upon other organs, chiefly the lungs and the kidneys, which already have enough to do. This extra work they can do for only a short time. Sooner or later they become disordered, and illness follows. Moreover, as this unwholesome layer is a fertile soil in which bacteria may develop, many skin diseases may result from this neglect. It is also highly probable that germs of disease thus adherent to the skin may then be absorbed into the system. Parasitic skin diseases are thus greatly favored by the presence of an unclean skin. It is also a fact that uncleanly people are more liable to take cold than those who bathe often.

The importance of cleanliness would thus seem too apparent to need special mention, were it not that the habit is so much neglected. The old and excellent definition that dirt is suitable matter, but in the wrong place, suggests that the place should be changed. This can be done only by regular habits of personal cleanliness, not only of the skin, the hair, the teeth, the nails, and the clothing, but also by the rigid observance of a proper system in daily living.

246. Baths and Bathing. In bathing we have two distinct objects in view,--to keep the skin clean and to impart vigor. These are closely related, for to remove from the body worn-out material, which tends to injure it, is a direct means of giving vigor to all the tissues. Thus a cold bath acts upon the nervous system, and calls out, in response to the temporary abstraction of heat, a freer play of the general vital powers. Bathing is so useful, both locally and constitutionally, that it should be practiced to such an extent as experience proves to be beneficial. For the general surface, the use of hot water once a week fulfills the demands of cleanliness, unless in special occupations. Whether we should bathe in hot or cold water depends upon circumstances. Most persons, especially the young and vigorous, soon become accustomed to cool, and even cold water baths, at all seasons of the year.

The hot bath should be taken at night before going to bed, as in the morning there is usually more risk of taking cold. The body is readily chilled, if exposed to cold when the blood-vessels of the skin have been relaxed by heat. Hot baths, besides their use for the purposes of cleanliness, have a sedative influence upon the nervous system, tending to allay restlessness and weariness. They are excellent after severe physical or mental work, and give a feeling of restful comfort like that of sleep.

[Illustration: Fig. 105.--Epithelial Cells from the Sweat Glands. The cells are very distinct, with nuclei enclosing pigmentary granulations (Magnified 350 times)]

Cold baths are less cleansing than hot, but serve as an excellent tonic and stimulant to the bodily functions. The best and most convenient time for a cold bath is in the morning, immediately after rising. To the healthy and vigorous, it is, if taken at this time, with proper precautions, a most agreeable and healthful luxury. The sensation of chilliness first felt is caused by the contraction of the skin and its blood-vessels, so that the blood is forced back, as it were, into the deeper parts of the body. This stimulates the nervous system, the breathing becomes quicker and deeper, the heart beats more vigorously, and, as a consequence, the warm blood is sent back to the skin with increased force. This is known as the stage of reaction, which is best increased by friction with a rough towel. This should produce the pleasant feeling of a warm glow all over the body.

A cold bath which is not followed by reaction is likely to do more harm than good. The lack of this reaction may be due to the water being too cold, the bath too prolonged, or to the bather being in a low condition of health. In brief, the ruddy glow which follows a cold bath is the main secret of its favorable influence.

The temperature of the water should be adapted to the age and strength of the bather. The young and robust can safely endure cold baths, that would be of no benefit but indeed an injury to those of greater age or of less vigorous conditions of health. After taking a bath the skin should be rapidly and vigorously rubbed dry with a rough towel, and the clothing at once put on.

247. Rules and Precautions in Bathing. Bathing in cold water should not be indulged in after severe exercise or great fatigue, whether we are heated or not. Serious results have ensued from cold baths when the body is in a state of exhaustion or of profuse perspiration. A daily cold bath when the body is comfortably warm, is a safe tonic for almost all persons during the summer months, and tends especially to restore the appetite. Cold baths, taken regularly, render persons who are susceptible to colds much less liable to them, and less likely to be disturbed by sudden changes of temperature. Persons suffering from heart disease or from chronic disease of an important organ should not indulge in frequent cold bathing except by medical advice. Owing to the relaxing nature of hot baths, persons with weak hearts or suffering from debility may faint while taking them.

Outdoor bathing should not be taken for at least an hour after a full meal, and except for the robust it is not prudent to bathe with the stomach empty, especially before breakfast. It is a wise rule, in outdoor or sea bathing, to come out of the water as soon as the glow of reaction is felt. It is often advisable not to apply cold water very freely to the head. Tepid or even hot water is preferable, especially by those subject to severe mental strain. But it is often a source of great relief during mental strain to bathe the face, neck, and chest freely at bedtime with cold water. It often proves efficient at night in calming the sleeplessness which results from mental labor.

Hot baths, if taken at bedtime, are often serviceable in preventing a threatened cold or cutting it short, the patient going immediately to bed, with extra clothing and hot drinks. The free perspiration induced helps to break up the cold.

Salt water acts more as a stimulant to the skin than fresh water. Salt-water bathing is refreshing and invigorating for those who are healthy, but the bather should come out of the water the moment there is the slightest feeling of chilliness. The practice of bathing in salt water more than once a day is unhealthful, and even dangerous. Only the strongest can sustain so severe a tax on their power of endurance. Sea bathing is beneficial in many ways for children, as their skin reacts well after it. In all cases, brisk rubbing with a rough towel should be had afterwards.

[Illustration: Fig. 106.--Magnified Section of the Lower Portion of a Hair and Hair-Follicle.

A, membrane of the hair-follicle, cells with nuclei and pigmentary granules;
B, external lining of the root sheath;
C, internal lining of the root sheath;
D, cortical or fibrous portion of the hair shaft;
E, medullary portion (pith) of shaft;
F, hair-bulb, showing its development from cells from A.
]

The golden rule of all bathing is that it must never be followed by a chill. If even a chilliness occur after bathing, it must immediately be broken up by some appropriate methods, as lively exercise, brisk friction, hot drinks, and the application of heat.

Swimming is a most valuable accomplishment, combining bathing and exercise. Bathing of the feet should never be neglected. Cleanliness of the hair is also another matter requiring strict attention, especially in children.

248. Care of the Hair and Nails. The hair brush should not be too stiff, as this increases the tendency towards scurfiness of the head. If, however, the hair is brushed too long or too hard, the scalp is greatly stimulated, and an increased production of scurf may result. If the head be washed too often with soap its natural secretion is checked, and the scalp becomes dry and scaly. The various hair pomades are as a rule undesirable and unnecessary.

The nails should be kept in proper condition, else they are not only unsightly, but may serve as carriers of germs of disease. The nails are often injured by too much interference, and should never be trimmed to the quick. The upper surfaces should on no account be scraped. The nail-brush is sufficient to cleanse them without impairing their smooth and polished surfaces.

[Illustration: Fig. 107.--Longitudinal Section of a Finger-Nail.

A, last phalanx of the fingers;
B, true skin on the dorsal surface of the finger;
C, epidermis;
D, true skin;
E, bed of the nail;
F, superficial layer of the nail;
H, true skin of the pulp of the finger.
]

249. Use of Clothing. The chief use of clothing, from a hygienic point of view, is to assist in keeping the body at a uniform temperature. It also serves for protection against injury, and for personal adornment. The heat of the body, as we have learned, is normally about 98-1/2 degrees F. This varies but slightly in health. A rise of temperature of more than one degree is a symptom of disturbance. The normal temperature does not vary with the season. In summer it is kept down by the perspiration and its rapid evaporation. In winter it is maintained by more active oxidation, by extra clothing, and by artificial heat.

The whole matter of clothing is modified to a great extent by climatic conditions and local environments,--topics which do not come within the scope of this book.

250. Material Used for Clothing. It is evident that if clothing is to do double duty in preventing the loss of heat by radiation, and in protecting us from the hot rays of the sun, some material must be used that will allow the passage of heat in either direction. The ideal clothing should be both a bad conductor and a radiator of heat. At the same time it must not interfere with the free evaporation of the perspiration, otherwise chills may result from the accumulation of moisture on the surface of the body.

Wool is a bad conductor, and should be worn next the skin, both in summer and winter, especially in variable climates. It prevents, better than any other material, the loss of heat from the body, and allows free ventilation and evaporation. Its fibers are so lightly woven that they make innumerable meshes enclosing air, which is one of the best of non-conductors.

Silk ranks next to wool in warmth and porosity. It is much softer and less irritating than flannel or merino, and is very useful for summer wear. The practical objection to its general use is the expense. Fur ranks with wool as a bad conductor of heat. It does not, however, like wool, allow of free evaporation. Its use in cold countries is universal, but in milder climates it is not much worn.

Cotton and linen are good conductors of heat, but are not absorbents of moisture, and should not be worn next the skin. They are, however, very durable and easily cleansed. As an intermediate clothing they may be worn at all seasons, especially over wool or silk. Waterproof clothing is also useful as a protection, but should not be worn a longer time than necessary, as it shuts in the perspiration, and causes a sense of great heat and discomfort.

The color of clothing is of some importance, especially if exposed directly to the sun's rays. The best reflectors, such as white and light gray clothing, absorb comparatively little heat and are the coolest, while black or dark-colored materials, being poor reflectors and good absorbents, become very warm.

251. Suggestions for the Use of Clothing. Prudence and good sense should guide us in the spring, in changing winter flannels or clothing for fabrics of lighter weight. With the fickle climate in most sections of this country, there are great risks of severe colds, pneumonia, and other pulmonary diseases from carelessness or neglect in this matter. A change from heavy to lighter clothing should be made first in the outer garments, the underclothing being changed very cautiously.

The two essentials of healthful clothing are cleanliness and dryness. To wear garments that are daily being soiled by perspiration and other cutaneous excretions, is a most uncleanly and unhealthful practice. Clothing, especially woolen underclothing, should be frequently changed. One of the objections to the use of this clothing is that it does not show soiling to the same extent as do cotton and linen.

Infectious and contagious diseases may be conveyed by the clothing. Hence, special care must be taken that all clothing in contact with sick people is burned or properly disinfected. Children especially are susceptible to scarlet fever, diphtheria, and measles, and the greatest care must be exercised to prevent their exposure to infection through the clothing.

We should never sleep in a damp bed, or between damp sheets. The vital powers are enfeebled during sleep, and there is always risk of pneumonia or rheumatism. The practice of sitting with wet feet and damp clothing is highly injurious to health. The surface of the body thus chilled may be small, yet there is a grave risk of serious, if not of fatal, disease. No harm may be done, even with clothing wet with water or damp with perspiration, so long as exercise is maintained, but the failure or inability to change into dry garments as soon as the body is at rest is fraught with danger.

Woolen comforters, scarfs, and fur mufflers, so commonly worn around the neck, are more likely to produce throat troubles and local chill than to have any useful effect. Harm ensues from the fact that the extra covering induces local perspiration, which enfeebles the natural defensive power of the parts; and when the warmer covering is removed, the perspiring surface is readily chilled. Those who never bundle their throats are least liable to suffer from throat ailments.

252. Ill Effects of Wearing Tightly Fitting Clothing. The injury to health caused by tight lacing, when carried to an extreme, is due to the compression and displacement of various organs by the pressure exerted on them. Thus the lungs and the heart may be compressed, causing short breath on exertion, palpitation of the heart, and other painful and dangerous symptoms. The stomach, the liver, and other abdominal organs are often displaced, causing dyspepsia and all its attendant evils. The improper use of corsets, especially by young women, is injurious, as they interfere with the proper development of the chest and abdominal organs. The use of tight elastics below the knee is often injurious. They obstruct the local venous circulation and are a fruitful source of cold feet and of enlarged or varicose veins.

Tightly fitting boots and shoes often cause corns, bunions, and ingrowing nails; on the other hand, if too loosely worn, they cause corns from friction. Boots too narrow in front crowd the toes together, make them overlap, and render walking difficult and painful. High-heeled boots throw the weight of the body forwards, so that the body rests too much on the toes instead of on the heels, as it should, thus placing an undue strain upon certain groups of muscles of the leg, in order to maintain the balance, while other groups are not sufficiently exercised. Locomotion is never easy and graceful, and a firm, even tread cannot be expected.

The compression of the scalp by a tight-fitting hat interferes with the local circulation, and may cause headaches, neuralgia, or baldness, the nutrition of the hair-follicles being diminished by the impaired circulation. The compression of the chest and abdomen by a tight belt and various binders interferes with the action of the diaphragm,--the most important muscle of respiration.

253. Miscellaneous Hints on the Use of Clothing. Children and old people are less able to resist the extreme changes of temperature than are adults of an average age. Special care should be taken to provide children with woolen underclothing, and to keep them warm and in well-ventilated rooms. Neither the chest nor limbs of young children should be unduly exposed, as is often done, to the cold blasts of winter or the fickle weather of early spring. Very young children should not be taken out in extremely cold weather, unless quite warmly clad and able to run about. The absurd notion is often entertained that children should be hardened by exposure to the cold. Judicious "hardening" means ample exposure of well-fed and well-clothed children. Exposure of children not thus cared for is simple cruelty. The many sicknesses of children, especially diseases of the throat and lungs, may often be traced directly to gross carelessness, ignorance, or neglect with reference to undue exposure. The delicate feet of children should not be injured by wearing ill-fitting or clumsy boots or shoes. Many deformities of the feet, which cause much vexation and trouble in after years, are acquired in early life.

No one should sleep in any of the clothes worn during the day, not even in the same underclothing. All bed clothing should be properly aired, by free exposure to the light and air every morning. Never wear wet or damp clothing one moment longer than necessary. After it is removed rub the body thoroughly, put on at once dry, warm clothing, and then exercise vigorously for a few minutes, until a genial glow is felt. Neglect of these precautions often results in rheumatism, neuralgia, and diseases of the chest, especially among delicate people and young women.

Pupils should not be allowed to sit in the schoolroom with any outer garments on. A person who has become heated in a warm room should not expose himself to cold without extra clothing. We must not be in a hurry to put on heavy clothes for winter, but having once worn them, they must not be left off until milder weather renders the change safe. The cheaper articles of clothing are often dyed with lead or arsenic. Hence such garments, like stockings and colored underclothing, worn next the skin have been known to produce severe symptoms of poisoning. As a precaution, all such articles should be carefully washed and thoroughly rinsed before they are worn.

The Kidneys.

254. The Kidneys. The kidneys are two important organs in the abdomen, one on each side of the spine. They are of a reddish-brown color, and are enveloped by a transparent capsule made up of a fold of the peritoneum. Embedded in fat, the kidneys lie between the upper lumbar

vertebrae, and the crest of the hip bone. The liver is above the right kidney, and the spleen above the left, while both lie close against the rear wall of the abdomen, with the intestines in front of them. The human kidneys, though somewhat larger, are exactly of the same shape, color, and general appearance as those of the sheep, so commonly seen in the markets.

The kidneys are about four inches long, two inches across, one inch thick, and weigh from 41/2 to 51/2 ounces each. The hollow or concave side of the kidneys is turned inwards, and the deep fissure of this side, known as the hilus, widens out to form the pelvis. Through the hilus the renal artery passes into each kidney, and from each hilus passes outwards the renal vein, a branch of the inferior vena cava.

A tube, called the ureter, passes out from the concave border of each kidney, turns downwards, and enters the bladder in the basin of the pelvis. This tube is from 12 to 14 inches long, about as large as a goose quill, and conveys the secretion of the kidneys to the bladder.

255. Structure of the Kidneys. The pelvis is surrounded by reddish cones, about twelve in number, projecting into it, called the pyramids of Malpighi. The apices of these cones, known as the _papillae_, are crowded with minute openings, the mouths of the uriniferous tubules, which form the substance of the kidney. These lie parallel in the medullary or central structure, but On reaching the cortical or outer layer, they wind about and interlace, ending, at last, in dilated closed sacs called Malpighian capsules.

[Illustration: Fig. 108.--Vertical Section of the Kidney.

A, pyramids of Malpighi;
B, apices, or papillae, of the pyramids, surrounded by subdivisions of the pelvis known as cups or calices;
C, pelvis of the kidney;
D, upper end of ureter.
]

256. Function of the Kidneys. The Malpighian capsules are really the beginning of the tubules, for here the work of excretion begins. The thin wall of the capillaries within each capsule separates the blood from the cavity of the tubule. The blood-pressure on the delicate capillary walls causes the exudation of the watery portions of the blood through the cell walls into the capsule. The epithelial cell membrane allows the water of the blood with certain salts in solution to pass, but rejects the albumen. From the capsules, the excretion passes through the tubules into the pelvis, and on through the ureters to the bladder. But the delicate epithelial walls of the tubules through which it passes permit the inflow of urea and other waste products from the surrounding capillaries. By this twofold process are separated from the blood the fluid portions of the renal secretion with soluble salts, and the urea with other waste material.

257. How the Action of the Kidneys may be Modified. The action of the kidneys is subject to very marked and sudden modifications, especially those operating through the nervous system. Thus whatever raises the blood-pressure in the capillaries of the capsules, will increase the quantity of fluid filtering through them. That is, the watery portion of the secretion will be increased without necessarily adding to its solids. So anything which lowers the blood-pressure will diminish the watery portion of the secretion, that is, the secretion will be scanty, but

concentrated.

The Renal Secretion.--The function of the kidneys is to secrete a fluid commonly known as the urine. The average quantity passed in 24 hours by an adult varies from 40 to 60 fluid ounces. Normal urine consists of about 96 per cent of water and 4 per cent of solids. The latter consist chiefly of certain nitrogenous substances known as urea and uric acid, a considerable quantity of mineral salts, and some coloring matter. Urea, the most important and most abundant constituent of urine, contains the four elements, but nitrogen forms one-half its weight. While, therefore, the lungs expel carbon dioxid chiefly, the kidneys expel nitrogen. Both of these substances express the result of oxidations going on in the body. The urea and uric acids represent the final result of the breaking down in the body of nitrogenous substances, of which albumen is the type.

Unusual constituents of the urine are _albumen, sugar_, and _bile_. When albumen is present in urine, it often indicates some disease of the kidneys, to which the term _albuminuria_ or Bright's Disease is applied. The presence of grape sugar or glucose indicates the disease known as diabetes. Bile is another unusual constituent of the urine, appearing in _jaundice_.

The bladder is situated in the pelvic cavity or in the lowest part of the abdomen. When full, the bladder is pear-shaped; when empty, it is collapsed and lies low in the pelvis. The functions of the bladder are to collect and retain the urine, which has reached it drop by drop from the kidneys through the ureters, until a certain quantity accumulates, and then to expel it from the body.

[Illustration: Fig. 109.--Vertical Section of the Back. (Showing kidneys _in situ_ and the relative position of adjacent organs and vessels.) [Posterior view.]

  A, 12th dorsal vertebra;
  B, diaphragm;
  C, receptaculum chyli;
  D, small intestines
]

In the kidneys, as elsewhere, the vaso-motor nerves are distributed to the walls of the blood-vessels, and modify the quantity and the pressure of blood in these organs. Thus, some strong emotion, like fear or undue anxiety, increases the blood-pressure, drives more blood to the kidneys, and causes a larger flow of watery secretion. When the atmosphere is hot, there is a relaxation of the vessels of the skin, with a more than ordinary flow of blood, which is thus withdrawn from the deeper organs. The blood-pressure in the kidneys is not only diminished, but the total quantity passing through them in a given time is much lessened. As a result, the secretion of the kidneys is scanty, but it contains an unusual percentage of solids.

When the atmosphere is cold, the reverse is true. The cutaneous vessels contract, the blood is driven to the deeper organs with increased pressure, and there is a less amount of sweat, but an increased renal secretion, containing a smaller proportion of solids. Certain drugs have the power of increasing or diminishing the renal secretion. As the waste matters eliminated by the kidneys are being constantly produced in the tissues, the action of the renal organs is continuous, in marked contrast with the intermittent flow of most of the secretions proper, as distinguished from the excretions.

258. Effects of Alcoholic Drinks upon the Kidneys. The kidneys differ from some of the other organs in this: those can rest a while without any harm to themselves, or to the body. We can keep the eyes closed for a few days, if necessary, without injury, and in fact often with benefit; or, we can abstain from food for some days, if need be, and let the stomach rest. But the kidneys cannot, with safety, cease their work. Their duty in ridding the blood of waste products, and of any foreign or poisonous material introduced, must be done not only faithfully, but continually, or the whole body at once suffers from the evil effects of the retained waste matters.

This vital fact is the key to the injurious results developed in the kidneys by the use of alcoholic drinks. These two organs have large blood-vessels conveying full amounts of blood to and from their structures, and they feel very quickly the presence of alcohol. Alcoholic liquors excite and irritate the delicate renal membranes, and speedily disturb and eventually destroy their capacity to excrete the proper materials from the blood.

The continued congestion of the minute structure of the kidney cuts off the needed nutrition of the organ, and forms the primary step in the series of disasters. Sometimes from this continued irritation, with the resulting inflammation, and sometimes from change of structure of the kidney by fatty degeneration, comes the failure to perform its proper function. Then, with this two-edged sword of disaster, the urea, which becomes a poisonous element, and should be removed, is retained in the system, while the albumen, which is essential to healthy blood, is filtered away through the diseased kidney.

259. Alcoholic Liquors as a Cause of Bright's Disease. The unfortunate presence of albumen in the urine is often a symptom of that insidious and fatal malady known as _albuminuria_ or Bright's disease, often accompanied with dropsy and convulsions. One of the most constant causes of this disease is the use of intoxicants. It is not at all necessary to this fatal result that a person be a heavy drinker. Steady, moderate drinking will often accomplish the work. Kidney diseases produced by alcoholic drinks, are less responsive to medical treatment and more fatal than those arising from any other known cause.[39]

Experiment 129. Obtain a sheep's kidney in good order. Observe that its shape is something like that of a bean, and note that the concave part (hilus), when in its normal position, is turned towards the backbone. Notice that all the vessels leave and enter the kidney at the hilus. Observe a small thick-walled vessel with open mouth from which may be pressed a few drops of blood. This is the renal artery. Pass a bristle down it. With the forceps, or even with a penknife, lift from the kidney the fine membrane enclosing it. This is the kidney capsule.

Divide the kidney in halves by a section from its outer to near its inner border. Do not cut directly through the hilus. Note on the cut surfaces, on the outer side, the darker cortical portion, and on the inner side, the smooth, pale, medullary portion. Note also the pyramids of Malpighi.

Chapter X.

The Nervous System.

260. General View of the Nervous System. Thus far we have learned something of the various organs and the manner in which they do their work. Regarding our bodily structure as a kind of living machine, we have studied its various parts, and found that each is designed to perform some special work essential to the well-being of the whole. As yet we have learned of no means by which these organs are enabled to adjust their activities to the needs of other tissues and other organs. We are now prepared to study a higher, a more wonderful and complex agency,--the nervous system, the master tissue, which controls, regulates, and directs every other tissue of the human body.

The nervous system, in its properties and mode of action, is distinct from all the other systems and organs, and it shares with no other organ or tissue the power to do its special work. It is the medium through which all impressions are received. It connects all the parts of the body into an organism in which each acts in harmony with every other part for the good of the whole. It animates and governs all movements, voluntary or involuntary,--secretion, excretion, nutrition; in fact all the processes of organic life are subject to its regulating power. The different organs of the body are united by a common sympathy which regulates their action: this harmonious result is secured by means of the nervous system.

This system, in certain of its parts, receives impressions, and generates a force peculiar to itself. We shall learn that there can be no physical communication between or cooerdination of the various parts of organs, or harmonious acts for a desire result, without the nerves. General impressions, as in ordinary sensation, or special impressions, as in sight, smell, taste, or hearing,--every instinct, every act of the will, and every thought are possible only through the action of the nerve centers.

261. Nerve Cells. However complicated the structure of nerve tissue in man seems to be, it is found to consist of only two different elements, nerve cells and nerve fibers. These are associated and combined in many ways. They are arranged in distinct masses called nerve centers, or in the form of cords known as nerves. The former are made up of nerve fibers; the latter of both cells and fibers.

[Illustration: Fig. 110. Nerve Cells from the Spinal Cord.]

Nerve cells, which may be regarded as the central organs of the nerve fibers, consist of masses of cell protoplasm, with a large _nucleus_ and _nucleolus_. They bear a general resemblance to other cells, but vary much in size and shape. Nerve cells grow, become active, and die, as do other cells. A number of processes branch off from them, some cells giving one or two, others many. The various kinds of nerve cells differ much in the shape and number of processes. One of the processes is a strand which becomes continuous with the axis cylinder of the nerve fibers; that is, the axis cylinders of all nerve fibers are joined in one place or another with at least one cell.

Each part of this system has its own characteristic cell. Thus we have in the spinal cord the large, irregular cells with many processes, and in the brain proper the three-sided cells with a process jutting out from each corner. So characteristic are these forms of cells, that any particular part of nerve structure may be identified by the kind of cells seen under the microscope. Nerve cells and nerve fibers are often arranged in groups, the various cells of the groups communicating with one another. This clustered arrangement is called a nerve center.

262. Nerve Fibers. The nerve fibers, the essential elements of the nerves, somewhat resemble tubes filled with a clear, jelly-like substance. They consist of a rod, or central core, continuous throughout the whole length of the nerve, called the axis cylinder. This core is surrounded by the white substance of Schwann, or medullary sheath, which gives the nerve its characteristic ivory-white appearance. The whole is enclosed in a thin, delicate sheath, known as neurilemma.

[Illustration: Fig. 111.--Nerve Cells from the Gray Matter of the Brain.]

The axis cylinder generally passes without any break from the nerve centers to the end of the fibers.[40] The outer sheath (neurilemma) is also continuous throughout the length of the fibers. The medullary sheath, on the other hand, is broken at intervals of about 1/25 of an inch, and at the same intervals nuclei are found along the fiber, around each of which is a minute protoplasmic mass. Between each pair of nuclei the sheath is interrupted. This point is known as the _node of Ranvier_.

Some nerve fibers have no inner sheath (medullary), the outer alone protecting the axis cylinder. These are known as the non-medullary fibers. They are gray, while the ordinary medullary fibers are white in appearance. The white nerve fibers form the white part of the brain and of the spinal cord, and the greater part of the cerebro-spinal nerves. The gray fibers occur chiefly in branches from the sympathetic ganglia, though found to some extent in the nerves of the cerebro-spinal system.

In a general way, the nerve fibers resemble an electric cable wire with its central rod of copper, and its outer non-conducting layer of silk or gutta percha. Like the copper rod, the axis cylinder along which the nerve impulse travels is the essential part of a nerve fiber. In a cut nerve this cylinder projects like the wick of a candle. It is really the continuation of a process of a nerve cell. Thus the nerve cells and nerve fibers are related, in that the process of one is the axis cylinder and essential part of the other.

The separate microscopic threads or fibers, bound together in cords of variable size, form the nerves. Each strand or cord is surrounded and protected by its own sheath of connective tissue, made up of nerves. According to its size a nerve may have one or many of these strands. The whole nerve, not unlike a minute tendon in appearance, is covered by a dense sheath of fibrous tissue, in which the blood-vessels and lymphatics are distributed to the nerve fibers.

[Illustration: Fig. 112.--Medullated Nerve Fibers.

A, a medullated nerve fiber, showing the subdivision of the medullary sheath into cylindrical sections imbricated with their ends, a nerve corpuscle with an oval nucleus is seen between the neurilemma and the medullary sheath;
B, a medullated nerve fiber at a node or constriction of Ranvier, the

axis cylinder passes uninterruptedly from one segment into the other, but the medullary sheath is interrupted.
]

263. The Functions of the Nerve Cells and Nerve Fibers. The nerve cells are a highly active mass of living material. They find their nourishment in the blood, which is supplied to them in abundance. The blood not only serves as nourishment, but also supplies new material, as it were, for the cells to work over for their own force or energy. Thus we may think of the nerve cells as a sort of a miniature manufactory, deriving their material from the blood, and developing from it nervous energy.

The nerve fibers, on the other hand, are conductors of nervous energy. They furnish a pathway along which the nerve energy generated by the cells may travel. Made up as they are of living nerve substance, the fibers can also generate energy, yet it is their special function to conduct influences to and from the cells.

[Illustration: Fig. 113.--Non-Medullated Fibers.

Two nerve fibers, showing the nodes or constrictions of Ranvier and the axis cylinder. The medullary sheath has been dissolved away. The deeply stained oblong nuclei indicate the nerve corpuscles within the neurilemma.]

264. The Nervous System Compared to a Telegraphic System. In men and other highly organized animals, nerves are found in nearly every tissue and organ of the body. They penetrate the most minute muscular fibers; they are closely connected with the cells of the glands, and are found in the coats of even the smallest blood-vessels. They are among the chief factors of the structure of the sense organs, and ramify through the skin. Thus the nervous system is the system of organs through the functions of which we are brought into relation with the world around us. When we hear, our ears are bringing us into relation with the outer world. So sight opens up to us another gateway of knowledge.

It will help us the better to understand the complicated functions of the nervous system, if we compare it to a telegraph line. The brain is the main office, and the multitudes of nerve fibers branching off to all parts of the body are the wires. By means of these, nerve messages are constantly being sent to the brain to inform it of what is going on in various parts of the body, and asking what is to be done in each case. The brain, on receiving the intelligence, at once sends back the required instructions. Countless messages are sent to and fro with unerring accuracy and marvelous rapidity.

Thus, when we accidentally pick up something hot, it is instantly dropped. A nerve impulse passes from the nerves of touch in the fingers to the brain, which at once hurries off its order along another set of nerves for the hand to drop the burning object. These examples, so common in daily life, may be multiplied to any extent. Almost every voluntary act we perform is executed under the direction of the nervous system, although the time occupied is so small that it is beyond our power to estimate it. The very frequency with which the nerves act tends to make us forget their beneficent work.

265. Divisions of the Nervous System. This system in man consists of two great divisions. The first is the great nerve center of the body, the

cerebro-spinal system, which rules the organs of animal life. This includes the brain, the spinal cord, and the cerebro-spinal nerves. Nerves are given off from the brain and the cord, and form the mediums of communication between the external parts of the body, the muscles or the sense organs, and the brain.

The second part is the sympathetic system, which regulates the organic life. This consists of numerous small nerve centers arranged in oval masses varying greatly in size, called ganglia or knots. These are either scattered irregularly through the body, or arranged in a double chain of knots lying on the front of the spine, within the chest and abdomen. From this chain large numbers of nerves are given off, which end chiefly in the organs of digestion, circulation, and respiration. The sympathetic system serves to bring all portions of the animal economy into direct sympathy with one another.

266. The Brain as a Whole. The brain is the seat of the intellect, the will, the affections, the emotions, the memory, and sensation. It has also many other and complex functions. In it are established many reflex, automatic, and coordinating centers, which are as independent of consciousness as are those of the spinal cord.

The brain is the largest and most complex mass of nerve tissue in the body, made up of an enormous collection of gray cells and nerve fibers. This organ consists of a vast number of distinct ganglia, or separate masses of nerve matter, each capable of performing separate functions, but united through the cerebral action into a harmonious whole.

[Illustration: Fig. 114.--The Upper Surface of the Cerebrum. (Showing its division into two hemispheres, and also the convolutions)]

The average weight of the adult human brain is about 50 ounces for men and 45 ounces for women. Other things being equal, the size and weight of the brain bear a general relation to the mental power of the individual. As a rule, a large, healthy brain stands for a vigorous and superior intellect. The brains of many eminent men have been found to be 8 to 12 ounces above the average weight, but there are notable exceptions. The brains of idiots are small; indeed, any weight under a certain size, about 30 ounces, seems to be invariably associated with an imbecile mind.

The human brain is absolutely heavier than that of any other animal, except the whale and elephant. Comparing the size of these animals with that of man, it is instructive to notice how much larger in proportion to the body is man's brain. The average proportion of the weight of the brain to the weight of the body is greater in man than in most animals, being about 1 to 36. In some small birds, in the smaller monkeys, and in some rodents, the proportional weight of the brain to that of the body is even greater than in man.

267. The Cerebrum. The three principal masses which make up the brain when viewed as a whole are:

1. The cerebrum, or brain proper.
2. The cerebellum, or lesser brain.
3. The medulla oblongata.

The cerebrum comprises nearly seven-eighths of the entire mass, and fills the upper part of the skull. It consists of two halves, the right and left cerebral hemispheres. These are almost separated from each other by a deep median fissure. The hemispheres are united at the bottom of the fissure by a mass of white fibers passing from side to side. Each of these hemispheres is subdivided into three lobes, so that the entire cerebrum is made up of six distinct lobes.

The cerebrum has a peculiar convoluted appearance, its deep folds being separated by fissures, some of them nearly an inch in depth.

It is composed of both white and gray matter. The former comprises the greater part of the mass, while the latter is spread over the surface in a layer of about 1/8 of an inch thick. The gray matter is the portion having the highest functions, and its apparent quantity is largely increased by being formed in convolutions.

The convolutions of the cerebrum are without doubt associated with all those higher actions which distinguish man's life; but all the convolutions are not of equal importance. Thus it is probable that only the frontal part of the brain is the intellectual region, while certain convolutions are devoted to the service of the senses.

The cerebrum is the chief seat of the sensations, the intellect, the will, and the emotions. A study of cerebral injuries and diseases, and experiments upon the lower animals, prove that the hemispheres, and more especially the gray matter, are connected with mental states. The convolutions in the human brain are more prominent than in that of the higher animals, most nearly allied to man, although some species of animals, not especially intelligent, have marked cerebral convolutions. The higher races of men have more marked convolutions than those less civilized.

A view of the under surface of the brain, which rests on the floor of the skull, shows the origin of important nerves, called the cranial nerves, the cerebellum, the structure connecting the optic nerves (optic commissure), the bridge of nervous matter (pons Varolii) connecting the two hemispheres of the cerebellum, and lastly numerous and well-marked convolutions.

268. The Cerebellum. The cerebellum, or lesser brain, lies in the back of the cranium, and is covered over in man by the posterior lobe of the cerebrum. It is, at it were, astride of the back of the cerebro-spinal axis, and consists of two hemispheres joined by a central mass. On its under surface is a depression which receives the medulla oblongata. The cerebellum is separated from the cerebrum by a horizontal partition of membrane, a portion of the dura mater. In some animals, as in the cat, this partition is partly bone.

The cerebellum is connected with other parts of the nervous system by strands of white matter on each side, radiating from the center and divided into numerous branches. Around these branches the gray matter is arranged in a beautiful manner, suggesting the leaves of a tree: hence its name, arbor vitae, or the tree of life.

The functions of the cerebellum are not certainly known. It appears to influence the muscles of the body so as to regulate their movements; that is, it serves to bring the various muscular movements into harmonious action. The mechanism by which it does this has not yet been clearly explained. In an animal from which the cerebellum has been removed, the functions of life do not appear to be destroyed, but all power of either walking or flying straight is lost.

[Illustration: Fig. 115.--A Vertical Section of the Brain.

A, frontal lobe of the cerebrum;
B, parietal lobe;
C, parieto occipital lobe with fissure between this lobe and
D, the occipital lobe;
E, cerebellum;
F, arbor vitae;
H, pons Varolu;
K, medulla oblongata;
L, portion of lobe on the opposite side of brain.

The white curved band above H represents the corpus callosum.]

Disease or injury of the cerebellum usually produces blindness, giddiness, a tendency to move backwards, a staggering, irregular gait, and a feeling of insecurity in maintaining various positions. There is no loss of consciousness, or other disturbance of the mental functions.

269. The Membranes of the Brain. The brain and spinal cord are protected by three important membranes, known as the meninges,--the dura mater, the arachnoid, and the pia mater.

The outer membrane, the dura mater, is much thicker and stronger than the others, and is composed of white fibrous and elastic connective tissue. It closely lines the inner surface of the skull, and forms a protective covering for the brain. Folds of it pass between the several divisions of the brain and serve to protect them.

The arachnoid is a thin membrane which lies beneath the dura mater. It secretes a serous fluid which keeps the inner surfaces moist.

The pia mater is a very delicate, vascular membrane which covers the convolutions, dips into all the fissures, and even penetrates into the interior of the brain. It is crowded with blood-vessels, which divide and subdivide very minutely before they penetrate the brain. The membranes of the brain are sometimes the seat of inflammation, a serious and painful disease, commonly known as brain fever.

270. The Medulla Oblongata. This is the thick upper part of the spinal cord, lying within the cavity of the skull. It is immediately under the cerebellum, and forms the connecting link between the brain and the spinal cord. It is about an inch and a quarter long, and from one-half to three-fourths of an inch wide at its upper part. The medulla oblongata consists, like the spinal cord, of columns of white fibers and masses of gray matter, but differently arranged. The gray matter is broken up into masses which serve as centers of origin for various nerves. The functions of the medulla oblongata are closely connected with the vital processes. It is a great nerve tract for transmitting sensory and motor impressions, and also the seat of a number of centers for reflex actions of the highest importance to life. Through the posterior part of the medulla the sensory impressions pass, that is, impressions from below upwards to the brain resulting in sensation or feeling. In the anterior part of the medulla, pass the nerves for motor transmission, that is, nerve influences from above downwards that shall result in muscular contractions in some part of the body.

The medulla is also the seat of a number of reflex centers connected with the influence of the nervous system on the blood-vessels, the movements of the heart, of respiration, and of swallowing, and on the secretion of saliva. This spot has been called the "vital knot." In the medulla also are centers for coughing, vomiting, swallowing, and the dilatation of the pupil of the eye. It is also in part the deep origin of many of the 'important cranial nerves.

[Illustration: Fig. 116.--Illustrating the General Arrangement of the Nervous System. (Posterior view.)]

271. The Cranial Nerves. The cranial or cerebral nerves consist of twelve pairs of nerves which pass from the brain through different openings in the base of the skull, and are distributed over the head and face, also to some parts of the trunk and certain internal organs. These nerves proceed in pairs from the corresponding parts of each side of the brain, chiefly to the organs of smell, taste, hearing, and sight.

The cranial nerves are of three kinds: sensory, motor, and both combined, _viz_., mixed.

Distribution and Functions of the Cranial Nerves. The cranial nerves are thus arranged in pairs:

The first pair are the olfactory nerves, which pass down through the ethmoid bone into the nasal cavities, and are spread over the inner surface of the nose. They are sensory, and are the special nerves of smell.

The second pair are the optic nerves, which, under the name of the _optic tracts_, run down to the base of the brain, from which an optic nerve passes to each eyeball. These are sensory nerves, and are devoted to sight.

The third, fourth, and sixth pairs proceed to the muscles of the eyes and control their movements. These are motor nerves, the movers of the eye.

Each of the fifth pair of nerves is in three branches, and proceeds mainly to the face. They are called tri-facial, and are mixed nerves, partly sensory and partly motor. The first branch is purely sensory, and gives sensibility to the eyeball. The second gives sensibility to the nose, gums, and cheeks. The third (mixed) gives the special sensation of taste on the front part of the tongue, and ordinary sensation on the inner side of the cheek, on the teeth, and also on the scalp in front of the ear. The motor branches supply the chewing muscles.

The seventh pair, the facial, proceed to the face, where they spread over the facial muscles and control their movements. The eighth pair are the auditory, or nerves of hearing, and are distributed to the special organs of hearing.

The next three pairs of nerves all arise from the medulla, and escape from the cavity of the skull through the same foramen. They are sometimes described as one pair, namely, the eighth, but it is more convenient to consider them separately.

The ninth pair, the glosso-pharyngeal, are partly sensory and partly motor. Each nerve contains two roots: one a nerve of taste, which spreads over the back part of the tongue; the other a motor nerve, which controls the muscles engaged in swallowing.

The tenth pair, the pneumogastric, also known as the vagus or wandering nerves, are the longest and most complex of all the cranial nerves. They are both motor and sensory, and are some of the most important nerves in the body. Passing from the medulla they descend near the oesophagus to the stomach, sending off, on their way, branches to the throat, the larynx, the lungs, and the heart. Some of their branches restrain the movements of the heart, others convey impressions to the brain, which result in quickening or slowing the movements of breathing. Other branches pass to the stomach, and convey to the brain impressions which inform us of the condition of that organ. These are the nerves by which we experience the feelings of pain in the stomach, hunger, nausea, and many other vague impressions which we often associate with that organ.

[Illustration: Fig. 117.--Anterior View of the Medulla Oblongata.

A, chiasm of the optic nerves;
B, optic tracts;
C, motor oculi communis;
D, fifth nerve;
E, motor oculi externus;
F, facial nerve;
H, auditory nerve;
I, glosso-pharyngeal nerve;
K, pneumogastric;
L, spinal accessory;
M, cervical nerves;
N, upper extremity of spinal cord;
O, decussation of the anterior pyramids;
R, anterior pyramids of the medulla oblongata;
S, pons Varolii.
]

The eleventh pair, the spinal accessory, are strictly motor, and supply the muscles of the neck and the back.

The twelfth pair, the hypoglossal, are also motor, pass to the muscles of the tongue, and help control the delicate movements in the act of speech.

272. The Spinal Cord. This is a long, rod-like mass of white nerve fibers, surrounding a central mass of gray matter. It is a continuation of the medulla oblongata, and is lodged in the canal of the spinal column. It extends from the base of the skull to the lower border of the first lumbar vertebra, where it narrows off to a slender filament of gray substance.

The spinal cord is from 16 to 18 inches long, and has about the thickness of one's little finger, weighing about 1-1/2 ounces. Like the brain, it is enclosed in three membranes, which in fact are the continuation of those within the skull. They protect the delicate cord, and convey vessels for its nourishment. The space between the two inner membranes contains a small quantity of fluid, supporting the cord, as it were in a water-bath. It is thus guarded against shocks.

The cord is suspended and kept in position in the canal by delicate ligaments at regular intervals between the inner and outer membranes. Finally, between the canal, enclosed by its three membranes, and the bony walls of the spinal canal, there is considerable fatty tissue, a sort of packing material, imbedded in which are some large blood-vessels.

273. Structure of the Spinal Cord. The arrangement of the parts of the spinal cord is best understood by a transverse section. Two fissures, one behind, the other in front, penetrate deeply into the cord, very nearly dividing it into lateral halves. In the middle of the isthmus which joins the two halves, is a very minute opening, the _central canal_ of the cord. This tiny channel, just visible to the naked eye, is connected with one of the openings of the medulla oblongata, and extends, as do the anterior and posterior fissures, the entire length of the cord.

The spinal cord, like the brain, consists of gray and white matter, but the arrangement differs. In the brain the white matter is within, and the gray matter is on the surface. In the cord the gray matter is arranged in two half-moon-shaped masses, the backs of which are connected at the central part. The white matter, consisting mainly of fibers, running for the most part in the direction of the length of the cord, is outside of and surrounds the gray crescents. Thus each half or side of the cord has its own gray crescent, the horns of which point one forwards and the other backwards, called respectively the anterior and posterior cornua or horns.

It will also be seen that the white substance itself, in each half of the cord, is divided by the horns of the gray matter and by fibers passing from them into three parts, which are known as the anterior, posterior, and lateral columns.

Experiment 130. Procure at the market an uninjured piece of the spinal cord from the loin of mutton or the sirloin or the rib of beef. After noting its general character while fresh, put it to soak in dilute alcohol, until it is sufficiently hard to be cut in sections.

274. The Spinal Nerves. From the gray matter on each side of the spinal cord 31 spinal nerves are given off and distributed chiefly to the muscles and the skin. They pass out at regular intervals on each side of the canal, by small openings between the vertebrae. Having escaped from the spine, they pass backwards and forwards, ramifying in the soft parts of the body. The first pair pass out between the skull and the atlas, the next between the atlas and the axis, and so on down the canal. The eighth pair, called _cervical_, pass out in the region of the neck; twelve, called _dorsal_, in the region of the ribs; five are _lumbar_, and five _sacral_, while the last pair leave the cord near the coccyx.

Each spinal nerve has two roots, one from the anterior, the other from the posterior portion of the cord. These unite and run side by side, forming as they pass between the vertebrae one silvery thread, or nerve trunk. Although bound up in one bundle, the nerve fibers of the two roots remain quite distinct, and perform two entirely different functions.

After leaving the spinal cord, each nerve divides again and again into finer and finer threads. These minute branches are distributed through the muscles, and terminate on the surface of the body. The anterior roots become motor nerves, their branches being distributed to certain muscles of the body, to control their movements. The posterior roots develop into sensory nerves, their branches being distributed through the skin and over the surface of the body to become nerves of touch. In brief, the spinal nerves divide and subdivide, to reach with their twigs all parts of the body, and provide every tissue with a nerve center, a station from which messages may be sent to the brain.

[Illustration: Fig. 118.--Side View of the Spinal Cord. (Showing the fissures and columns.)

A, anterior median fissure;
B, posterior median fissure;
C, anterior lateral fissure;
D, posterior lateral fissure;
E, lateral column;
F, anterior column;
G, posterior column;
H, posterior median column;
K, anterior root;
L, posterior root;
M, ganglion of
N, a spinal nerve.
]

275. The Functions of the Spinal Nerves. The messages which pass along the spinal nerves to and from the brain are transmitted mostly through the gray matter of the cord, but some pass along the white matter on the outer part. As in the brain, however, all the active powers of the cord are confined to the gray matter. The spinal nerves themselves have nothing to do with sensation or will. They are merely conductors to carry messages to and fro. They neither issue commands nor feel a sensation. Hence, they consist entirely of white matter.

276. Functions of the Spinal Cord. The spinal cord is the principal channel through which all impulses from the trunk and extremities pass to the brain, and all impulses to the trunk and extremities pass from the brain. That is, the spinal cord receives from various parts of the body by means of its sensory nerves certain impressions, and conveys them to the brain, where they are interpreted.

The cord also transmits by means of its motor nerves the commands of the brain to the voluntary muscles, and so causes movement. Thus, when the cord is divided at any point, compressed, as by a tumor or broken bone, or disorganized by disease, the result is a complete loss of sensation and voluntary movement below the point of injury. If by accident a man has his spinal cord injured at some point, he finds he has lost all sensation and power of motion below that spot. The impulse to movement started in his brain by the will does not reach the muscles he wishes to move, because traveling _down_ the spinal cord, it cannot pass the seat of injury.

So the impression produced by pricking the leg with a pin, which, before pain can be felt, must travel up the spinal cord to the brain, cannot reach the brain because the injury obstructs the path. The telegraph wire has been cut, and the current can no longer pass.

277. The Spinal Cord as a Conductor of Impulses. The identity in structure of the spinal nerves, whether motor or sensory, and the vast number of nerves in the cord make it impossible to trace for any distance with the eye, even aided by the microscope and the most skillful dissection, the course of nerve fibers. The paths by which the motor impulses travel down the cord are fairly well known. These impulses originate in the brain, and passing down keep to the same side of the cord, and go out by nerves to the same side of the body.

The sensory impulses, however, soon after they enter the cord by the nerve of one side, cross in the cord to the opposite side, up which they travel to the brain. Thus the destruction of one lateral half of the cord causes paralysis of motion on the _same side_ as the injury, but loss of sensation on the _opposite side_, because the posterior portion destroyed consists of fibers which have crossed from the opposite side.

Experiment proves that if both roots of a spinal nerve be cut, all those parts of the body to which they send branches become paralyzed, and have neither sense of pain nor power of voluntary movement. The parts might even be cut or burned without pain. It is precisely like cutting a telegraph wire and stopping the current.

[Illustration: Fig. 119.--The Base of the Brain.

A, anterior lobe of the cerebrum;
B, olfactory nerve;
C, sphenoid portion of the posterior lobe;
D, optic chiasm;
E, optic tract;
F, abducens;
H, M, hemispheres of the cerebellum;
K, occipital portion of the occipital lobe;
L, fissure separating the hemispheres;
N, medulla oblongata;
O, olivary body;
P, antenor pyramids;
R, pons Valoru;
S, section of olfactory nerve, with the trunk removed to show sulcus in which it is lodged;
T, anterior extremity of median fissure
]

Experiment also proves that if only the posterior root of a spinal nerve be cut, all sensation is lost in the parts to which the nerve passes, but the power of moving these parts is retained. But if the anterior root alone be divided, all power of motion in the parts supplied by that nerve is lost, but sensation remains. From these and many other experiments, it is evident that those fibers of a nerve which are derived from the anterior root are motor, and those from the posterior root sensory, fibers. Impulses sent _from_ the brain and spinal cord to muscles will, therefore, pass along the anterior roots through those fibers of the nerves which are derived from these (motor) roots. On the other hand, impressions or sensations passing _to_ the brain will enter the spinal cord and reach the brain through the posterior or sensory roots.

278. The Spinal Cord as a Reflex Center. Besides this function of the spinal cord as a great nerve conductor to carry sensations to the brain, and bring back its orders, it is also an independent center for what is called reflex action. By means of its sensory nerves it receives impressions from certain parts of the body, and on its own authority sends back instructions to the muscles by its motor nerves, without consulting the brain. This constitutes reflex action, so called because the impulse sent to the spinal cord by certain sensory nerves is at once reflected or sent back as a motor impulse to the muscles.

This reflex action is a most important function of the spinal cord. This power is possessed only by the gray matter of the cord, the white substance being simply a conductor.

The cells of gray matter are found all along the cord, but are grouped together in certain parts, notably in the cervical and lumbar regions. The cells of the anterior horns are in relation with the muscles by means of nerve fibers, and are also brought into connection with the skin and other sensory surfaces, by means of nerve fibers running in the posterior part of the cord. Thus there is established in the spinal cord, without reference to the brain at all, a reflex mechanism.

279. Reflex Centers. For the purpose of illustration, we might consider the body as made up of so many segments piled one on another, each segment presided over by a similar segment of spinal cord. Each bodily segment would have sensory and motor nerves corresponding to its connection with the spinal cord. The group of cells in each spinal segment is intimately connected with the cells of the segments above and below. Thus an impression reaching the cells of one spinal segment might be so strong as to overflow into the cells of other segments, and thus cause other parts of the body to be affected.

Take as an example the case of a child who has eaten improper food, which irritates its bowels. Sensory nerves of the bowels are disturbed, and powerful impressions are carried up to a center in the spinal cord. These impressions may now overflow into other centers, from which spasmodic discharges of nerve energy may be liberated, which passing to the muscles, throw them into violent and spasmodic contraction. In other words, the child has a fit, or convulsion. All this disturbance being the result of reflex action (the spasmodic motions being quite involuntary, as the brain takes no part in them), the child meanwhile is, of course, entirely unconscious and, however it may seem to be distressed, really suffers no pain.

Scattered along the entire length of the spinal cord, especially in the upper part, are groups of nerve cells which preside over certain specific functions of animal life; that is, definite collections of cells which control definite functions. Thus there are certain centers for maintaining the action of the heart, and the movements of breathing; and low down in the cord, in the lumbar regions, are centers for the control of the various abdominal organs.

Numerous other reflex centers are described by physiologists, but enough has been said to emphasize the great importance of the spinal cord as an independent nerve center, besides its function as a conductor of nervous impulses to and from the brain.

280. The Brain as a Reflex Center. The brain, as we have just stated, is the seat of consciousness and intelligence. It is also the seat of many reflex, automatic, and coordinating centers. These give rise to certain reflex actions which are as entirely independent of consciousness as are those of the spinal cord. These acts take place independently of the will, and often without the consciousness of the individual. Thus, a sudden flash of light causes the eyes to blink, as the result of reflex action. The optic nerves serve as the sensory, and the facial nerves as the motor, conductors. The sudden start of the whole body at some loud noise, the instinctive dodging a threatened blow, and the springing back from sudden danger, are the results of reflex action. The result ensues in these and in many other instances, without the consciousness of the individual, and indeed beyond his power of control.

281. The Importance of Reflex Action. Reflex action is thus a marvelous provision of nature for our comfort, health, and safety. Its

vast influence is not realized, as its numberless acts are so continually going on without our knowledge. In fact, the greater part of nerve power is expended to produce reflex action. The brain is thus relieved of a vast amount of work. It would be impossible for the brain to serve as a "thinking center" to control every act of our daily life. If we had to plan and to will every heart-beat or every respiration, the struggle for life would soon be given up.

The fact that the gray cells of the spinal cord can originate a countless number of reflex and automatic activities is not only of great importance in protecting the body from injury, but increases vastly the range of the activities of our daily life.

Even walking, riding the bicycle, playing on a piano, and numberless other such acts may be reflex movements. To learn how, requires, of course, the action of the brain, but with frequent repetition the muscles become so accustomed to certain successive movements, that they are continued by the cord without the control of the brain. Thus we may acquire a sort of artificial reflex action, which in time becomes in a way a part of our organization, and is carried on without will power or even consciousness.

So, while the hands are busily doing one thing, the brain can be intently thinking of another. In fact, any attempt to control reflex action is more apt to hinder than to help. In coming rapidly down stairs, the descent will be made with ease and safety if the spinal cord is allowed entire charge of the act, but the chances of stumbling or of tripping are very much increased if each step be taken as the result of the will power. The reflex action of the cord may be diminished, or inhibited as it is called, but this power is limited. Thus, we can by an effort of the will stop breathing for a certain time, but beyond that the reflex mechanism overcomes our will and we could not, if we would, commit suicide by holding our breath. When we are asleep, if the palm of the hand be tickled, it closes; when we are awake we can prevent it.

[Illustration: Fig. 120.--Dr. Waller's Diagrammatic Illustration of the Reflex Process.

From the sentient surface (1) an afferent impulse passes along (2) to the posterior root of the spinal cord, the nerve fibers of the posterior root ending in minute filaments among the small cells of this part of the cord (3). In some unknown way this impulse passes across the gray part of the cord to the large cells of the anterior root (5), the cells of this part being connected by their axis-cylinder with the efferent fibers (6). These convey the stimulus to the fibers of the muscle (7), which accordingly contract. Where the brain is concerned in the action the circuit is longer through S and M.]

Experiment 131. _To illustrate reflex action by what is called knee-jerk._ Sit on a chair, and cross the right leg over the left one. With the tips of the fingers or the back of a book, strike the right ligamentum patellae. The right leg will be raised and thrown forward with a jerk, owing to the contraction of the quadriceps muscles. An appreciable time elapses between the striking of the tendon and the jerk. The presence or absence of the knee-jerk may be a most significant symptom to the physician.

282. The Sympathetic System. Running along each side of the spine, from the base of the skull to the coccyx, is a chain of nerve knots, or ganglia. These ganglia, twenty-four on each side, and their branches

form the sympathetic system, as distinguished from the cerebro-spinal system consisting of the brain and spinal cord and the nerves springing from them. The ganglia of the sympathetic system are connected with each other and with the sensory roots of the spinal nerves by a network of gray nerve fibers.

At the upper end the chain of each side passes up into the cranium and is closely connected with the cranial nerves. In the neck, branches pass to the lungs and the heart. From the ganglia in the chest three nerves form a complicated network of fibers, from which branches pass to the stomach, the liver, the intestines, the kidneys, and other abdominal organs. A similar network of fibers is situated lower down in the pelvis, from which branches are distributed to the pelvic organs. At the coccyx the two chains unite into a single ganglion.

Thus, in general, the sympathetic system, while intimately connected with the cerebro-spinal, forms a close network of nerves which specially accompany the minute blood-vessels, and are distributed to the muscles of the heart, the lungs, the stomach, the liver, the intestines, and the kidneys--that is, the hollow organs of the body.

283. The Functions of the Sympathetic System. This system exercises a superintending influence over the greater part of the internal organs of the body, controlling to a certain extent the functions of digestion, nutrition, circulation, and respiration. The influence thus especially connected with the processes of organic life is generally different from, or even opposed to, that conveyed to the same organs by fibers running in the spinal or cranial nerves. These impulses are beyond the control of the will.

[Illustration: Fig. 121.--The Cervical and Thoracic Portion of the Sympathetic Nerve and its Main Branches.

A, right pneumogastric;
B, spinal accessory;
C, glosso-pharyngeal;
D, right bronchus;
E, right branch of pulmonary artery;
F, one of the intercostal nerves;
H, great splanchnic nerve;
K, solar plexus;
L, left pneumogastric;
M, stomach branches of right pneumogastric;
N, right ventricle;
O, right auricle;
P, trunk of pulmonary artery;
R, aorta; S, cardiac nerves;
T, recurrent laryngeal nerve;
U, superior laryngeal nerve;
V, submaxillary ganglion;
W, lingual branch of the 5th nerve;
X, ophthalmic ganglion;
Y, motor oculi externus.
]

Hence, all these actions of the internal organs just mentioned that are necessary to the maintenance of the animal life, and of the harmony which must exist between them, are controlled by the sympathetic system. But for this control, the heart would stop beating during sleep, digestion would cease, and breathing would be suspended. Gentle irritation of these nerves, induced by contact of food in the stomach, causes that organ to begin the churning motion needed for digestion. Various mental emotions also have a reflex action upon the sympathetic system. Thus, terror dilates the pupils, fear acts upon the nerves of the small blood-vessels of the face to produce pallor, and the sight of an accident, or even the emotions produced by hearing of one, may excite nausea and vomiting.

The control of the blood-vessels, as has been stated (sec. 195), is one of the special functions of the sympathetic system. Through the nerves distributed to the muscular coats of the arteries, the caliber of these vessels can be varied, so that at one moment they permit a large quantity of blood to pass, and at another will contract so as to diminish the supply. This, too, is beyond the control of the will, and is brought about by the vaso-motor nerves of the sympathetic system through a reflex arrangement, the center for which is the medulla oblongata.

284. Need of Rest. The life of the body, as has been emphasized in the preceding chapters, is subject to constant waste going on every moment, from the first breath of infancy to the last hour of old age. We should speedily exhaust our life from this continual loss, but for its constant renewal with fresh material. This exhaustion of life is increased by exertion, and the process of repair is vastly promoted by rest. Thus, while exercise is a duty, rest is equally imperative.

The eye, when exactingly used in fine work, should have frequent intervals of rest in a few moments of darkness by closing the lids. The brain, when urged by strenuous study, should have occasional seasons of rest by a dash of cold water upon the forehead, and a brief walk with slow and deep inspirations of fresh air. The muscles, long cramped in a painful attitude, should be rested as often as may be, by change of posture or by a few steps around the room.

It is not entirely the amount of work done, but the continuity of strain that wears upon the body. Even a brief rest interrupts this strain; it unclogs the wheels of action. Our bodies are not designed for continuous toil. An alternation of labor and rest diminishes the waste of life. The benign process of repair cannot go on, to any extent, during strenuous labor, but by interposing frequent though brief periods of rest, we lessen the amount of exhaustion, refresh the jaded nerves, and the remaining labor is more easily endured.

285. Benefits of Rest. There is too little repose in our American nature and in our modes of life. A sense of fatigue is the mute appeal of the body for a brief respite from labor, and the appeal should, if possible, be heeded. If this appeal be not met, the future exertion exhausts far more than if the body had been even slightly refreshed. If the appeal be met, the brief mid-labor rest eases the friction of toil, and the remaining labor is more easily borne. The feeling that a five-minute rest is so much time lost is quite an error. It is a gain of physical strength, of mental vigor, and of the total amount of work done.

The merchant burdened with the cares of business life, the soldier on the long march, the ambitious student over-anxious to win success in his studies, the housewife wearied with her many hours of exacting toil, each would make the task lighter, and would get through it with less loss of vital force, by occasionally devoting a few minutes to absolute rest in entire relaxation of the strained muscles and overtaxed nerves.

286. The Sabbath as a Day of Physiological Rest. The divine institution of a Sabbath of rest, one day in seven, is based upon the highest needs of our nature. Rest, to be most effective, should alternate in brief periods with labor.

It is sound physiology, as well as good morals and manners, to cease from the usual routine of six days of mental or physical work, and rest both the mind and the body on the seventh. Those who have succeeded best in what they have undertaken, and who have enjoyed sound health during a long and useful life, have studiously lived up to the mandates of this great physiological law. It is by no means certain that the tendency nowadays to devote the Sabbath to long trips on the bicycle, tiresome excursions by land and sea, and sight-seeing generally, affords that real rest from a physiological point of view which nature demands after six days of well-directed manual or mental labor.

287. The Significance of Sleep as a Periodical Rest. Of the chief characteristics of all living beings none is so significant as their periodicity. Plants as well as animals exhibit this periodic character. Thus plants have their annual as well as daily periods of activity and inactivity. Hibernating animals pass the winter in a condition of unconsciousness only to have their functions of activity restored in early spring. Human beings also present many instances of a periodic character, many of which have been mentioned in the preceding pages. Thus we have learned that the heart has its regular alternating periods of work and rest. After every expiration from the lungs there is a pause before the next inspiration begins.

Now sleep is just another manifestation of this periodic and physiological rest by which Nature refreshes us. It is during the periods of sleep that the energy expended in the activities of the waking hours is mainly renewed. In our waking moments the mind is kept incessantly active by the demands made on it through the senses. There is a never-ceasing expenditure of energy and a consequent waste which must be repaired. A time soon comes when the brain cells fail to respond to the demand, and sleep must supervene. However resolutely we may resist this demand, Nature, in her relentless way, puts us to sleep, no matter what objects are brought before the mind with a view to retain its attention.[41]

288. Effect of Sleep upon the Bodily Functions. In all the higher animals, the central nervous system enters once at least in the twenty-four hours into the condition of rest which we call sleep. Inasmuch as the most important modifications of this function are observed in connection with the cerebro-spinal system, a brief consideration of the subject is properly studied in this chapter. In Chapter IV. we learned that repose was as necessary as exercise to maintain muscular vigor. So after prolonged mental exertion, or in fact any effort which involves an expenditure of what is often called nerve-force, sleep becomes a necessity. The need of such a rest is self-evident, and the loss of it is a common cause of the impairment of health. While we are awake and active, the waste of the body exceeds the repair; but when asleep, the waste is diminished, and the cells are more actively rebuilding the structure for to-morrow's labor. The organic functions, such as are under the direct control of the sympathetic nervous system,--circulation, respiration, and digestion,--are diminished in activity during sleep. The pulsations of the heart and the respiratory movements are less frequent, and the circulation is slower. The bodily temperature is reduced, and the cerebral circulation is diminished. The eyes are turned upward and inward, and the pupils are contracted.

The senses do not all fall to sleep at once, but drop off successively: first the sight, then the smell, the taste, the hearing and lastly the touch. The sleep ended, they awake in an inverse order, touch, hearing, taste, smell, and sight.

289. The Amount of Sleep Required. No precise rule can be laid down concerning the amount of sleep required. It varies with age, occupation, temperament, and climate to a certain extent. An infant whose main business it is to grow spends the greater part of its time in sound sleep. Adults of average age who work hard with their hands or brain, under perfectly normal physiological conditions, usually require at least eight hours of sleep. Some need less, but few require more. Personal peculiarities, and perhaps habit to a great extent, exert a marked influence. Some of the greatest men, as Napoleon I., have been very sparing sleepers. Throughout his long and active life, Frederick the Great never slept more than five or six hours in the twenty-four. On the other hand, some of the busiest brain-workers who lived to old age, as William Cullen Bryant and Henry Ward Beecher, required and took care to secure at least eight or nine hours of sound sleep every night.

In old age, less sleep is usually required than in adult life, while the aged may pass much of their time in sleep. In fact, each person learns by experience how much sleep is necessary. There is no one thing which more unfits one for prolonged mental or physical effort than the loss of natural rest.

290. Practical Rules about Sleep. Children should not be played with boisterously just before the bedtime hour, nor their minds excited with weird goblin stories, or a long time may pass before the wide-open eyes and agitated nerves become composed to slumber. Disturbed or insufficient sleep is a potent factor towards producing a fretful, irritable child.

At all ages the last hour before sleep should, if possible, be spent quietly, to smooth the way towards sound and refreshing rest. The sleep induced by medicine is very often troubled and unsatisfactory. Medicines of this sort should not be taken except on the advice of a physician.

While a hearty meal should not usually be taken just before bedtime, it is not well to go to bed with a sense of positive faintness and hunger. Rather, one should take a very light lunch of quite simple food as a support for the next eight hours.

[Illustration: Fig. 122.--Trunk of the Left Pneumogastric.

(Showing its distribution by its branches and ganglia to the larynx, pharynx, heart, lungs, and other parts.)]

It is better, as a rule, not to engage in severe study during the hours just before bedtime. Neither body nor mind being at its best after the fatigues of the day, study at that time wears upon the system more, and the progress is less than at earlier hours. One hour of morning or day study is worth a much longer time late at night. It is, therefore, an economy both of time and of nerve force to use the day hours and the early evening for study.

The so-called "cat naps" should never be made to serve as a substitute for a full night's sleep. They are largely a matter of habit, and are detrimental to some as well as beneficial to others. Late hours are usually associated with exposure, excitement, and various other drains upon the nerve force, and hence are injurious.

It is better to sleep on one or other side than on the back. The head should be somewhat raised, and a mattress is better than a feather bed. The bedclothes should be sufficient, but not too heavy. Light tends to prevent sleep, as do loud or abrupt sounds, but monotonous sounds aid it.

291. Alcohol and the Brain. The unfortunate effects which alcoholic drinks produce upon the brain and nervous system differ from the destructive results upon other parts of the body in this respect, that elsewhere the consequences are usually both less speedy and less obvious. The stomach, the liver, and even the heart may endure for a while the trespass of the narcotic poison, and not betray the invasion. But the nervous system cannot, like them, suffer in silence.

In the other parts of the body the victim may (to a certain extent) conceal from others the suffering of which he himself is painfully conscious. But the tortured brain instantly reveals the calamity and the shame, while the only one who may not fully realize it is the victim himself. Besides this, the injuries inflicted upon other organs affect only the body, but here they drag down the mind, ruin the morals, and destroy the character.

The brain is indeed the most important organ of the body, as it presides over all the others. It is the lofty seat of power and authority. Here the king is on his throne. But if, by this malignant adversary, the king himself be dethroned, his whole empire falls to ruins.

292. How Alcohol Injures the Brain. The brain, the nerve centers, and the nerves are all made up of nerve pulp, the softest and most delicate tissue in the whole bodily structure. Wherever this fragile material occurs in our bodies,--in the skull, the spine, the trunk, or the limbs,--the all-wise Architect has carefully protected it from violence, for a rough touch would injure it, or even tender pressure would disturb its function.

It is a further indication of the supreme importance of the brain, that about one-fifth of the entire blood of the body is furnished to it. Manifestly, then, this vital organ must be tenderly cared for. It must indeed be well nourished, and therefore the blood sent to it must be highly nutrient, capable of supplying oxygen freely. This condition is essential to successful brain action. But intoxicants bring to it blood surcharged with a poisonous liquid, and bearing only a limited supply of oxygen.

Another condition of a healthy brain is that the supply of blood to it shall be equable and uniform. But under the influence of strong drink, the blood pours into the paralyzed arteries a surging tide that floods the head, and hinders and may destroy the use of the brain and the senses. Still another requirement is that whatever is introduced into the cerebral tissues, having first passed through the stomach walls and thence into the blood, shall be bland, not irritating. But in the brain of the inebriate are found not only the distinct odor but the actual presence of alcohol. Thus we plainly see how all these three vital conditions of a healthy brain are grossly violated by the use of intoxicants.

> "I think there is a great deal of injury being done by the use of alcohol in what is supposed by the consumer to be a most moderate

quantity, to persons who are not in the least intemperate, and to people supposed to be fairly well. It leads to degeneration of the tissues; it damages the health; it injures the intellect. Short of drunkenness, that is, in those effects of it which stop short of drunkenness, I should say from my experience that alcohol is the most destructive agent we are aware of in this country."--Sir William Gull, the most eminent English physician of our time.

293. Why the Brain Suffers from the Alcoholic Habit. We do not find that the alcoholic habit has produced in the brain the same coarse injuries that we see in other organs, as in the stomach, the liver, or the heart. Nor should we expect to find them; for so delicate and so sensitive is the structure of this organ, that a very slight injury here goes a great way,--a disturbance may be overwhelming to the brain that would be only a trifle to some of the less delicate organs.

Alcohol has different degrees of affinity for different organs of the body, but much the strongest for the cerebral tissues. Therefore the brain feels more keenly the presence of alcohol than does any other organ. Almost the moment that the poison is brought into the stomach, the nerves send up the alarm that an invading foe has come. At once there follows a shock to the brain, and very soon its paralyzed blood-vessels are distended with the rush of blood. This first effect is, in a certain sense, exhilarating, and from this arousing influence alcohol has been erroneously considered a stimulant; but the falsity of this view is pointed out elsewhere in this book.

294. Alcohol, the Enemy of Brain Work. The healthy brain contains a larger proportion of water than does any other organ. Now alcohol, with its intense affinity for water, absorbs it from the brain, and thus condenses and hardens its structure. One of the important elements of the brain is its albumen; this also is contracted by alcohol. The nerve cells and fibers gradually become shriveled and their activity is lowered, the elasticity of the arteries is diminished, the membranes enveloping the brain are thickened, and thus all proper brain nutrition is impaired. The entire organ is slowly hardened, and becomes unfitted for the proper performance of its delicate duties. In brief, alcohol in any and every form is the enemy of successful and long-continued brain work.

[Illustration: Fig. 123.--Nerve Trunks of the Right Arm.]

295. Other Physical Results of Intoxicants. What are some of the physical results observed? First, we note the failure of the vaso-motor nerves to maintain the proper tone of the blood-vessels, as in the turgid face and the congested cornea of the eye. Again, we observe the loss of muscular control, as is shown by the drop of the lower lip, the thickened speech, and the wandering eye. The spinal cord, too, is often affected and becomes unable to respond to the demand for reflex action, as appears from the trembling hands, the staggering legs, the swaying body, and the general muscular uncertainty. All these are varied results of the temporary paralysis of the great nerve centers.

Besides, the sensibility of the nerves is deadened. The inebriate may seize a hot iron and hardly know it, or wound his hand painfully and never feel the injury. The numbness is not of the skin, but of the brain, for the drunken man may be frozen or burned to death without pain. The senses, too, are invaded and dulled. Double vision is produced, the eyes not being so controlled as to bring the image upon corresponding points of the retina.

296. Diseases Produced by Alcohol. The diseases that follow in the train of the alcoholic habit are numerous and fatal. It lays its paralyzing hand upon the brain itself, and soon permanently destroys the integrity of its functions. In some the paralysis is local only, perhaps in one of the limbs, or on one side of the body; in others there is a general muscular failure. The vitality of the nerve centers is so thoroughly impaired that general paralysis often ensues. A condition of insomnia, or sleeplessness, often follows, or when sleep does come, it is in fragments, and is far from refreshing to the jaded body.

In time follows another and a terrible disease known as _delirium tremens_; and this may occur in those who claim to be only moderate drinkers, rarely if ever intoxicated. It accompanies an utter breakdown of the nervous system. Here reason is for the time dethroned, while at some times wild and frantic, or at others a low, mumbling delirium occurs, with a marked trembling from terror and exhaustion.

There is still another depth of ruin in this downward course, and that is _insanity_. In fact, every instance of complete intoxication is a case of temporary insanity, that is, of mental unsoundness with loss of self-control. Permanent insanity may be one of the last results of intemperance. Alcoholism sends to our insane asylums a large proportion of their inmates, as ample records testify.

297. Mental and Moral Ruin Caused by Alcoholism. Alcoholism, the evil prince of destroyers, also hastens to lay waste man's mental and moral nature. Just as the inebriate's senses, sight, hearing, and touch, fail to report correctly of the outer world, so the mind fails to preside properly over the inner realm. Mental perceptions are dulled. The stupefied faculties can hardly be aroused by any appeal. Memory fails. Thus the man is disqualified for any responsible labor. No railroad company, no mercantile house, will employ any one addicted to drinking. The mind of the drunkard is unable to retain a single chain of thought, but gropes about with idle questionings. The intellect is debased. Judgment is impossible, for the unstable mind cannot think, compare, or decide.

The once active power of the will is prostrate, and the victim can no longer resist the feeblest impulse of temptation. The grand faculty of self-control is lost; and as a result, the baser instincts of our lower nature are now uppermost; greed and appetite rule unrestrained.

But the moral power is also dragged down to the lowest depths. All the finer sensibilities of character are deadened; all pride of personal appearance, all nice self-respect and proper regard for the good opinion of others, every sense of decorum, and at last every pretence of decency. Dignity of behavior yields to clownish silliness, and the person lately respected is now an object of pity and loathing. The great central convictions of right and wrong now find no place in his nature; conscience is quenched, dishonesty prevails. This is true both as to the solemn promises, which prove mere idle tales, and also as to property, for he resorts to any form of fraud or theft to feed the consuming craving for more drink.

298. Evil Results of Alcoholism Inherited. But the calamity does not end with the offender. It may follow down the family line, and fasten itself upon the unoffending children. These often inherit the craving for drink, with the enfeebled nature that cannot resist the craving, and so are almost inevitably doomed to follow the appalling career of their

parents before them.

Nor does this cruel taint stop with the children. Even their descendants are often prone to become perverse. As one example, careful statistics of a large number of families, more than two hundred descended from drunkards, show that a very large portion of them gave undoubted proof of well-marked degeneration. This was plain in the unusual prevalence of infant mortality, convulsions, epilepsy, hysteria, fatal brain diseases, and actual imbecility.[42]

It is found that the long-continued habitual user of alcoholic drinks, the man who is never intoxicated, but who will tell you that he has drunk whiskey all his life without being harmed by it, is more likely to transmit the evil effects to his children than the man who has occasional drunken outbreaks with intervals of perfect sobriety between. By his frequently repeated small drams he keeps his tissues constantly "alcoholized" to such an extent that they are seldom free from some of the more or less serious consequences. His children are born with organisms which have received a certain bias from which they cannot escape; they are freighted with some heredity, or predisposition to particular forms of degeneration, to some morbid tendency, to an enfeebled constitution, to various defective conditions of mind and body. Let the children of such a man attempt to imitate the drinking habits of the father and they quickly show the effects. Moderate drinking brings them down.

Among other consequences of an alcoholic inheritance which have been traced by careful observers are: Morbid changes in the nerve centers, consisting of inflammatory lesions, which vary according to the age in which they occur; alcoholic insanity; congenital malformations; and a much higher infant death rate, owing to lack of vitality, than among the children of normal parents.

Where the alcoholic inheritance does not manifest itself in some definite disease or disorder, it can still be traced in the limitations to be found in the drinking man's descendants. They seem to reach a level from which they cannot ascend, and where from slight causes they deteriorate. The parents, by alcoholic poisoning, have lowered the race stock of vitality beyond the power of ascent or possibility to rise above or overcome the downward tendency.

Of course these effects of alcoholics differ widely according to the degree of intoxication. Yet, we must not forget that the real nature of inebriety is always the same. The end differs from the beginning only in degree. He who would avoid a life of sorrow, disgrace, and shame must carefully shun the very first glass of intoxicants.

299. Opium. Opium is a gum-like substance, the dried juice of the unripe capsule of the poppy. The head of the plant is slit with fine incisions, and the exuding white juice is collected. When it thickens and is moulded in mass, it becomes dark with exposure. _Morphine_, a white powder, is a very condensed form of opiate; _laudanum_, an alcoholic solution of marked strength; and _paregoric_, a diluted and flavored form of alcoholic tincture.

300. Poisonous Effects of Opium. Some persons are drawn into the use of opium, solely for its narcotic and intoxicating influence.
Every early consent to its use involves a lurking pledge to repeat the poison, till soon strong cords of the intoxicant appetite bind the now yielding victim.

Opium thus used lays its benumbing hand upon the brain, the mind is befogged, thought and reasoning are impossible. The secretions of the stomach are suspended, digestion is notably impaired, and the gastric nerves are so deadened that the body is rendered unconscious of its needs.

The moral sense is extinguished, persons once honest resort to fraud and theft, if need be, to obtain the drug, till at last health, character, and life itself all become a pitiful wreck.

301. The Use of Opium in Patent Medicines. Some forms of this drug are found in nearly all the various patent medicines so freely sold as a cure-all for every mortal disease. Opiates are an ingredient in different forms and proportions in almost all the soothing-syrups, cough medicines, cholera mixtures, pain cures, and consumption remedies, so widely and unwisely used. Many deaths occur from the use of these opiates, which at first seem indeed to bring relief, but really only smother the prominent symptoms, while the disease goes on unchecked, and at last proves fatal.

These patent medicines may appear to help one person and be fraught with danger to the next, so widely different are the effects of opiates upon different ages and temperaments. But it is upon children that these fatal results oftenest fall. Beyond doubt, thousands of children have been soothed and soothed out of existence.[43]

302. The Victim of the Opium Habit. Occasionally persons convalescing from serious sickness where anodynes were taken, unwisely cling to them long after recovery. Other persons, jaded with business or with worry, and unable to sleep, unwisely resort to some narcotic mixture to procure rest. In these and other similar cases, the use of opiates is always most pernicious. The amount must be steadily increased to obtain the elusive repose, and at best the phantom too often escapes.

Even if the desired sleep is procured, it is hardly the coveted rest, but a troubled and dreamy slumber, leaving in the morning the body quite unrefreshed, the head aching, the mouth dry, and the stomach utterly devoid of appetite. But far worse than even this condition is the slavish yielding to the habit, which soon becomes a bondage in which life is shorn of its wholesome pleasures, and existence becomes a burden.

303. Chloral. There are other preparations which have become instruments of direful and often fatal injury. Chloral is a powerful drug that has been much resorted to by unthinking persons to produce sleep. Others, yielding to a morbid reluctance to face the problems of life, have timidly sought shelter in artificial forgetfulness. To all such it is a false friend. Its promises are treason. It degrades the mind, tramples upon the morals, overpowers the will, and destroys life itself.

304. Cocaine, Ether, Chloroform, and Other Powerful Drugs. Another dangerous drug is Cocaine. Ether and chloroform, those priceless blessings to the human race if properly controlled, become instruments of death when carelessly trifled with. Persons who have been accustomed to inhale the vapor in slight whiffs for neuralgia or similar troubles do so at imminent hazard, especially if lying down. They are liable to become slowly unconscious, and so to continue the inhalation till life is ended.

There is still another class of drugs often carelessly used, whose effect, while less directly serious than those mentioned, is yet far from harmless. These drugs, which have sprung into popular use since the disease _la grippe_ began its dreaded career, include _phenacetine_, _antipyrine_, _antifebrine_, and other similar preparations. These drugs have been seized by the public and taken freely and carelessly for all sorts and conditions of trouble. The random arrow may yet do serious harm. These drugs, products of coal-oil distillation, are powerful depressants. They lower the action of the heart and the tone of the nervous centers. Thus the effect of their continued use is to so diminish the vigor of the system as to aggravate the very disorder they are taken to relieve.

305. Effect of Tobacco on the Nervous System. That the use of tobacco produces a pernicious effect upon the nervous system is obvious from the indignant protest of the entire body against it when it is first used. Its poisonous character is amply shown by the distressing prostration and pallor, the dizziness and faintness, with extreme nausea and vomiting, which follow its employment by a novice.

The morbid effects of tobacco upon the nervous system of those who habitually use it are shown in the irregular and enfeebled action of the heart, with dizziness and muscular tremor. The character of the pulse shows plainly the unsteady heart action, caused by partial paralysis of the nerves controlling this organ. Old, habitual smokers often show an irritable and nervous condition, with sleeplessness, due doubtless to lack of proper brain nutrition.

All these results tend to prove that tobacco is really a nerve poison, and there is reason to suspect that the nervous breakdown of many men in mature life is often due to the continued use of this depressing agent. This is shown more especially in men of sedentary life and habits, as men of active habits and out-door life, experience less of the ill effects of tobacco.

Few, if any, habitual users of tobacco ever themselves approve of it. They all regret the habit, and many lament they are so enslaved to it that they cannot throw it off. They very rarely advise any one to follow their example.

306. Effects of Tobacco on the Mind. With this continuously depressing effect of tobacco upon the brain, it is little wonder that the mind may become enfeebled and lose its capacity for study or successful effort. This is especially true of the young. The growth and development of the brain having been once retarded, the youthful user of tobacco (especially the foolish cigarette-smoker) has established a permanent drawback which may hamper him all his life.

The young man addicted to the use of tobacco is often through its use retarded in his career by mental languor or weakening will power, and by mental incapacity. The keenness of mental perception is dulled, and the ability to seize and hold an abstract thought is impaired. True, these effects are not sharply obvious, as it would be impossible to contrast the present condition of any one person with what it might have been. But the comparison of large numbers conveys an instructive lesson. Scholars who start well and give promise of a good future fail by the way. The honors of the great schools, academies, and colleges are very largely taken by the tobacco abstainers. This is proved by the result of repeated and extensive comparisons of the advanced classes in a great number of institutions in this country and in Europe. So true is this that any young man who aspires to a noble career should bid farewell either to his honorable ambition or to his tobacco, for the two very rarely travel together. Consequently our military and naval academies and very many seminaries and colleges prohibit the use of tobacco by their students. For the same reasons the laws of many states very properly forbid the sale to boys of tobacco, and especially of cigarettes.

307. Effect of Tobacco upon Character. Nor does tobacco spare the morals. The tobacco-user is apt to manifest a selfish disregard of the courtesies due to others. He brings to the presence of others a repulsive breath, and clothing tainted with offensive odors. He poisons the atmosphere that others must inhale, and disputes their rights to breathe a pure, untainted air. The free use of tobacco by young people dulls the acuteness of the moral senses, often leads to prevarication and deceit in the indulgence, and is apt to draw one downward to bad associates. It is not the speed but the direction that tells on the future character and destiny of young men.

Additional Experiments.

Experiment 132. _To illustrate the cooperation of certain parts of the body._ Tickle the inside of the nose with a feather. This does not interfere with the muscles of breathing, but they come to the help of the irritated part, and provoke sneezing to clear and protect the nose.

Experiment 133. Pretend to aim a blow at a person's eye. Even if he is warned beforehand, the lids will close in spite of his effort to prevent them.

Experiment 134. _To illustrate how sensations are referred to the ends of the nerves_. Strike the elbow end of the ulna against anything hard (commonly called "hitting the crazy bone") where the ulna nerve is exposed, and the little finger and the ring finger will tingle and become numb.

Experiment 135. _To show that every nerve is independent of any other._ Press two fingers closely together. Let the point of the finest needle be carried ever so lightly across from one finger to another, and we can easily tell just when the needle leaves one finger and touches the other.

Experiment 136. _To paralyze a nerve temporarily_. Throw one arm over the sharp edge of a chair-back, bringing the inner edge of the biceps directly over the edge of the chair. Press deep and hard for a few minutes. The deep pressure on the nerve of the arm will put the arm "asleep," causing numbness and tingling. The leg and foot often "get asleep" by deep pressure on the nerves of the thigh.

Experiment 137. Press the ulnar nerve at the elbow, the prickling sensation is referred to the skin on the ulnar side of the hand.

Experiment 138. Dip the elbow in ice-cold water; at first one feels the sensation of cold, owing to the effect on the cutaneous nerve-endings. Afterwards, when the trunk of the ulnar nerve is affected, pain is felt in the skin of the ulnar side of the hand, where the nerve terminates.

Chapter XI.

The Special Senses.

308. The Special Senses. In man certain special organs are set apart the particular duty of which is to give information of the nature of the relations which he sustains to the great world of things, and of which he is but a mere speck. The special senses are the avenues by which we obtain this information as to our bodily condition, the world around us, and the manner in which it affects us.

Animals high in the scale are affected in so many different ways, and by so many agencies, that a subdivision of labor becomes necessary that the sense avenues may be rigidly guarded. One person alone may be a sufficient watch on the deck of a sloop, but an ocean steamer needs a score or more on guard, each with his special duty and at his own post. Or the senses are like a series of disciplined picket-guards, along the outposts of the mind, to take note of events, and to report to headquarters any information which may be within the range of their duty.

Thus it is that we are provided with a number of special senses, by means of which information is supplied regarding outward forces and objects. These are touch, taste, smell, seeing, and hearing, to which may be added the muscular sense and a sense of temperature.

309. General Sensations. The body, as we have learned, is made up of a great number of complicated organs, each doing its own part of the general work required for the life and vigor of the human organism. These organs should all work in harmony for the good of the whole. We must have some means of knowing whether this harmony is maintained, and of receiving timely warning if any organ fails to do its particular duty.

Such information is supplied by the common or general sensations. Thus we have a feeling of hunger or thirst indicating the need of food, and a feeling of discomfort when imperfectly clad, informing us of the need of more clothing.

To these may be added the sensation of pain, tickling, itching, and so on, the needs of which arise from the complicated structure of the human body. The great majority of sensations result from some stimulus or outward agency; and yet some sensations, such as those of faintness, restlessness, and fatigue seem to spring up within us in some mysterious way, without any obvious cause.

310. Essentials of a Sense Organ. Certain essentials are necessary for a sensation. First, there is a special structure adapted to a particular kind of influence. Thus the ear is formed specially for being stimulated by the waves of sound, while the eye is not influenced by sound, but responds to the action of light. These special structures are called terminal organs.

Again, a nerve proceeds from the special structure, which is in direct communication with nerve cells in the brain at the region of consciousness. This last point is important to remember, for if on some account the impression is arrested in the connecting nerve, no sensation will result. Thus a man whose spine has been injured may not feel a severe pinch on either leg. The impression may be quite sufficient to stimulate a nerve center in a healthy cord, so as to produce a marked reflex act, but he has no sensation, because the injury has prevented the impression from being carried up the cord to the higher centers in the brain.

311. The Condition of Sensation. It is thus evident that while an impression may be made upon a terminal organ, it cannot strictly be called a sensation until the person becomes conscious of it. The consciousness of an impression is, therefore, the essential element of a sensation.

It follows that sensation may be prevented in various ways. In the sense of sight, for example, one person may be blind because the terminal organ, or eye, is defective or diseased. Another may have perfect eyes and yet have no sight, because a tumor presses on the nerve between the eye and the brain. In this case, the impression fails because of the break in the communication. Once more, the eye may be perfect and the nerve connection unbroken, and yet the person cannot see, because the center in the brain itself is injured from disease or accident, and cannot receive the impression.

312. The Functions of the Brain Center in the Perception of an Impression. Sensation is really the result of a change which occurs in a nerve center in the brain, and yet we refer impressions to the various terminal organs. Thus, when the skin is pinched, the sensation is referred to the skin, although the perception is in the brain. We may think it is the eyes that see objects; in reality, it is only the brain that takes note of them.

This is largely the result of education and habit. From a blow on the head one sees flashes of light as vividly as if torches actually dance before the eyes. Impressions have reached the seeing-center in the brain from irritation of the optic nerve, producing the same effect as real lights would cause. In this case, however, knowing the cause of the colors, the person is able to correct the erroneous conclusion.

As a result of a depraved condition of blood, the seeing-center itself may be unduly stimulated, and a person may see objects which appear real. Thus in an attack of delirium tremens, the victim of alcoholic poisoning sees horrible and fantastic creatures. The diseased brain refers them as usual to the external world; hence they appear real. As the sufferer's judgment is warped by the alcoholic liquor, he cannot correct the impressions, and is therefore deceived by them.

313. Organs of Special Sense. The organs of special sense, the means by which we are brought into relation with surrounding objects, are usually classed as five in number. They are sometimes fancifully called "the five gateways of knowledge"--the skin, the organ of touch; the tongue, of taste; the nose, of smell; the eye, of sight; and the ear, of hearing.

[Illustration: Fig. 124.--Magnified View of a Papilla of the Skin, with a Touch Corpuscle.]

314. The Organ of Touch. The organ of touch, or tactile sensibility, is the most widely extended of all the special senses, and perhaps the simplest. It is certainly the most precise and certain in its results. It is this sense to which we instinctively appeal to escape from the illusions into which the other senses may mislead us. It has its seat in the skin all over the body, and in the mucous membrane of the nostrils. All parts of the body, however, do not have this sense in an equal degree.

In Chapter IX. we learned that the superficial layers of the skin covers and dips in between the papillae. We also learned that these papillae are richly provided with blood-vessels and sensory nerve fibers (sec. 234). Now these nerve fibers terminate in a peculiar way in those parts of the body which are endowed with a very delicate sense of touch. In every papilla are oval-shaped bodies about 1/300 of an inch long, around which the nerve fibers wind, and which they finally enter. These are called touch-bodies, or tactile corpuscles, and are found in great numbers on the feet and toes, and more scantily in other places, as on the edges of the eyelids.

Again, many of the nerve fibers terminate in corpuscles, the largest about 1/20 of an inch long, called Pacinian corpuscles. These are most numerous in the palm of the hand and the sole of the foot. In the papillae of the red border of the lips the nerves end in capsules which enclose one or more fibers, and are called end-bulbs.

The great majority of the nerve fibers which supply the skin do not end in such well-defined organs. They oftener divide into exceedingly delicate filaments, the terminations of which are traced with the greatest difficulty.

315. The Sense of Touch. Touch is a sensation of contact referred to the surface of the body. It includes three things,--the sense of contact, the sense of pressure, and the sense of heat and cold.

The sense of contact is the most important element in touch. By it we learn of the form, size, and other properties of objects, as their smoothness and hardness. As we all know, the sense of touch varies in different parts of the skin. It is most acute where the outer skin is thinnest. The tips of the fingers, the edges of the lips, and the tip of the tongue are the most sensitive parts.

Even the nails, the teeth, and the hair have the sense of touch in a slight degree. When the scarf skin is removed, the part is not more sensitive to sense of contact. In fact, direct contact with the unprotected true skin occasions pain, which effectually masks the feeling of touch. The sense of touch is capable of education, and is generally developed to an extraordinary degree in persons who are deprived of some other special sense, as sight or hearing. We read of the famous blind sculptor who was said to model excellent likenesses, guided entirely by the sense of touch. An eminent authority on botany was a blind man, able to distinguish rare plants by the fingers, and by the tip of the tongue. The blind learn to read with facility by passing their fingers over raised letters of a coarse type. It is impossible to contemplate, even for a moment, the prominence assigned to the sense of touch in the physical organism, without being impressed with the manifestations of design--the work of an all-wise Creator.

316. Muscular Sense; Sense of Temperature; Pain. When a heavy object is laid upon certain parts of the body, it produces a sensation of pressure. By it we are enabled to estimate differences of weight. If an attempt be made to raise this object, it offers resistance which the muscles must overcome. This is known as the muscular sense. It depends on sensory nerves originating in the muscles and carrying impressions from them to the nerve centers.

The skin also judges, to a certain extent, of heat and cold. These sensations can be felt only by the skin. Direct irritation of a nerve does not give rise to them. Thus, the exposed pulp of a diseased tooth, when irritated by cold fluids, gives rise to pain, and not to a sensation of temperature. Various portions of the body have different degrees of sensibility in this respect. The hand will bear a degree of heat which would cause pain to some other parts of the body. Then, again, the sensibility of the outer skin seems to affect the sensibility to heat, for parts with a thin skin can bear less heat than portions with a thick cuticle.

Experiment 139. _To illustrate how the sense of touch is a matter of habit or education_. Shut both eyes, and let a friend run the tips of your fingers first lightly over a hard plane surface; then press hard, then lightly again, and the surface will seem to be concave.

Experiment 140. Cross the middle over the index finger, roll a small marble between the fingers; one has a distinct impression of two marbles. Cross the fingers in the same way, and rub them against the point of the nose. A similar illusion is experienced.

Experiment 141. _To test the sense of locality_. Ask a person to shut his eyes, touch some part of his body lightly with the point of a pin, and ask him to indicate the part touched.

As to the general temperature, this sense is relative and is much modified by habit, for what is cold to an inhabitant of the torrid zone would be warm to one accustomed to a very cold climate.

Pain is an excessive stimulation of the sensory nerves, and in it all finer sensations are lost. Thus, when a piece of hot iron burns the hand, the sensation is the same as when the iron is very cold, and extreme cold feels like intense heat.

317. The Organ of Taste. The sense of taste is located chiefly in the tongue, but may also be referred even to the regions of the fauces. Taste, like touch, consists in a particular mode of nerve termination.

The tongue is a muscular organ covered with mucous membrane, and is richly supplied with blood-vessels and nerves. By its complicated movements it is an important factor in chewing, in swallowing, and in articulate speech. The surface of the tongue is covered with irregular projections, called papillae,--fine hair-like processes, about 1/12 of an inch high. Interspersed with these are the fungiform papillae. These are shaped something like a mushroom, and may often be detected by their bright red points when the rest of the tongue is coated.

Towards the root of the tongue is another kind of papillae, the circumvallate, eight to fifteen in number, arranged in the form of the letter V, with the apex directed backwards. These are so called because they consist of a fungiform papilla surrounded by a fold of mucous membrane, presenting the appearance of being walled around.

In many of the fungiform and most of the circumvallate papillae are peculiar structures called taste buds or taste goblets. These exist in great numbers, and are believed to be connected with nerve fibers. These taste buds are readily excited by savory substances, and transmit the impression along the connected nerve.

The tongue is supplied with sensory fibers by branches from the fifth and eighth pairs of cranial nerves. The former confers taste on the front part of the tongue, and the latter on the back part. Branches of the latter also pass to the soft palate and neighboring parts and confer taste on them. The motor nerve of the tongue is the ninth pair, the hypoglossal.

[Illustration: Fig. 125.--The Tongue.

A, epiglottis;
B, glands at the base of tongue;
C, tonsil;
D, median circumvallate papilla,
E, circumvallate papillae;
F, filiform papillae;
H, furrows on border of the tongue;
K, fungiform papillae.
]

318. The Sense of Taste. The sense of taste is excited by stimulation of the mucous membrane of the tongue and of the palate, affecting the ends of the nerve fibers. Taste is most acute in or near the circumvallate papillae. The middle of the tongue is scarcely sensitive to taste, while the edges and the tip are, as a rule, highly sensitive.

Certain conditions are necessary that the sense of taste may be exercised. First, the substance to be tasted must be in _solution_, or be soluble in the fluids of the mouth. Insoluble substances are tasteless. If we touch our tongue to a piece of rock crystal, there is a sensation of contact or cold, but no sense of taste. On the other hand, when we bring the tongue in contact with a piece of rock salt, we experience the sensations of contact, coolness, and saline taste.

Again, the mucous membrane of the mouth must be _moist_. When the mouth is dry, and receives substances not already in solution, there is no saliva ready to dissolve them; hence, they are tasteless. This absence of taste is common with the parched mouth during a fever.

The tongue assists in bringing the food in contact with the nerves, by pressing it against the roof of the mouth and the soft palate, and thus is produced the fullest sense of taste.

319. Physiological Conditions of Taste. The tongue is the seat of sensations which are quite unlike each other. Thus, besides the sense of taste, there is the sensation of touch, pressure, heat and cold, burning or acrid feelings, and those produced by the application of the tongue to an interrupted electric current. These are distinct sensations, due to some chemical action excited probably in the touch cells, although the true tastes may be excited by causes not strictly chemical. Thus a smart tap on the tongue may excite the sensation of taste.

In the majority of persons the back of the tongue is most sensitive to bitters, and the tip to sweets. Saline matters are perceived most distinctly at the tip, and acid substances at the sides. The nerves of taste are sensitive in an extraordinary degree to some articles of food and certain drugs. For example, the taste of the various preparations of quinine, peppermint, and wild cherry is got rid of with difficulty.

Like the other special senses, that of taste may become fatigued. The repeated tasting of one substance rapidly deadens the sensibility, probably by over-stimulation. Some savors so impress the nerves of taste that others fail to make any impression. This principle is used to make disagreeable medicine somewhat tasteless. Thus a few cloves, or grains of coffee, or a bit of pepper, eaten before a dose of castor oil, renders it less nauseous.

Flavor is something more than taste. It is in reality a mixed sensation, in which smell and taste are both concerned, as is shown by the common observation that one suffering from a cold in the head, which blunts his sense of smell, loses the proper flavor of his food. So if a person be blindfolded, and the nose pinched, he will be unable to distinguish between an apple and an onion, if one be rubbed on the tongue after the other. As soon as the nostrils are opened the difference is at once perceived.

Experiment 142. Put a drop of vinegar on a friend's tongue, or on your own. Notice how the papillae of the tongue start up.

Experiment 143. Rub different parts of the tongue with the pointed end of a piece of salt or gum-aloes, to show that the _back_ of the tongue is most sensitive to salt and bitter substances.

Experiment 144. Repeat the same with some sweet or sour substances, to show that the _edges_ of the tongue are the most sensitive to these substances.

Experiment 145. We often fail to distinguish between the sense of taste and that of smell. Chew some pure, roasted coffee, and it seems to have a distinct taste. Pinch the nose hard, and there is little taste. Coffee has a powerful odor, but only a feeble taste. The same is true of garlic, onions, and various spices.

Experiment 146. Light helps the sense of taste. Shut the eyes, and palatable foods taste insipid. Pinch the nose, close the eyes, and see how palatable one half of a teaspoonful of cod-liver oil becomes.

Experiment 147. Close the nostrils, shut the eyes, and attempt to distinguish by taste alone between a slice of an apple and one of a potato.

320. Modifications of the Sense of Taste. Taste is modified to a great extent by habit, education, and other circumstances. Articles of food that are unpleasant in early life often become agreeable in later years. There is occasionally a craving, especially with people of a peculiar nervous organization, for certain unnatural articles (as chalk and laundry starch) which are eaten without the least repugnance. Again, the most savory dishes may excite disgust, while the simplest articles may have a delicious flavor to one long deprived of them. The taste for certain articles is certainly acquired. This is often true of raw tomatoes, olives, and especially of tobacco.

The organs of taste and smell may be regarded as necessary accessories of the general apparatus of nutrition, and are, therefore, more or less essential to the maintenance of animal life. While taste and smell are generally maintained until the close of life, sight and hearing are often impaired by time, and may be altogether destroyed, the other vital functions remaining unimpaired.

321. Effect of Tobacco and Alcohol upon Taste. It would be remarkable if tobacco should fail to injure the sense of taste. The effect produced upon the tender papillae of the tongue by the nicotine-loaded juices and the acrid smoke tends to impair the delicate sensibility of the entire surface. The keen appreciation of fine flavors is destroyed. The once clear and enjoyable tastes of simple objects become dull and vapid; thus highly spiced and seasoned articles of food are in demand, and then follows continued indigestion, with all its suffering.

Again, the burning, almost caustic effect of the stronger alcoholic drinks, and the acrid pungency of tobacco smoke, are disastrous to the finer perceptions of both taste and odors.

322. Smell. The sense of smell is lodged in the delicate membrane which lines the nasal cavities. The floor, sides, and roof of these cavities are formed by certain bones of the cranium and the face. Man, in common with all air-breathing animals, has two nasal cavities. They communicate with the outer air by two nostrils opening in front, while two other passages open into the pharynx behind.

To increase the area of the air passages, the two light, spongy turbinated bones, one on each side, form narrow, winding channels. The mucous membrane, with the branches of the olfactory nerve, lines the dividing wall and the inner surfaces of these winding passages. Below all these bones the lower turbinated bones may be said to divide the olfactory chamber above from the ordinary air passages.

[Illustration: Fig. 126.--Distribution of Nerves over the Interior of the Nostrils. (Outer wall.)

A, branches of the nerves of smell--olfactory nerve, or ganglion;
B, nerves of common sensation to the nostril;
E, F, G, nerves to the, palate springing from a ganglion at C;
H, vidian nerve, from which branches
D, I, and J spring to be distributed to the nostrils.
]

The nerves which supply the nasal mucous membrane are derived from the branches of the fifth and the first pair of cranial nerves,--the olfactory. The latter, however, are the nerves of smell proper, and are spread out in a kind of thick brush of minute nerve filaments. It is in the mucous membrane of the uppermost part of the cavity of the nostril that the nerve endings of smell proper reside. The other nerves which supply the nostrils are those of common sensation (sec. 271).

323. The Sense of Smell. The sense of smell is excited by the contact of odorous particles contained in the air, with the fibers of the olfactory nerves, which are distributed over the delicate surface of the upper parts of the nasal cavities. In the lower parts are the endings

of nerves of ordinary sensation. These latter nerves may be irritated by some substance like ammonia, resulting in a powerfully pungent sensation. This is not a true sensation of smell, but merely an irritation of a nerve of general sensation.

In ordinary quiet breathing, the air simply flows along the lower nasal passages into the pharynx, scarcely entering the olfactory chamber at all. This is the reason why, when we wish to perceive a faint odor, we sniff up the air sharply. By so doing, the air which is forcibly drawn into the nostrils passes up even into the higher olfactory chamber, where some of the floating particles of the odorous material come into contact with the nerves of smell.

One of the most essential conditions of the sense of smell is that the nasal passages be kept well bathed in the fluid secreted by the lining membrane. At the beginning of a cold in the head, this membrane becomes dry and swollen, thus preventing the entrance of air into the upper chamber, deadening the sensibility of the nerves, and thus the sense of smell is greatly diminished.

The delicacy of the sense of smell varies greatly in different individuals and in different animals. It is generally more acute in savage races. It is highly developed in both the carnivora and the herbivora. Many animals are more highly endowed with this sense than is man. The dog, for example, appears to depend on the sense of smell almost as much as on sight. It is well known, also, that fishes have a sense of smell. Fragments of bait thrown into the water soon attract them to a fishing ground, and at depths which little or no light can penetrate. Deer, wild horses, and antelopes probably surpass all other animals in having a vivid sense of smell.

Smell has been defined as "taste at a distance," and it is obvious that these two senses not only form a natural group, but are clearly associated in their physical action, especially in connection with the perception of the flavor of food. The sense of odor gives us information as to the quality of food and drink, and more especially as to the quality of the air we breathe. Taste is at the gateway of the alimentary canal, while smell acts as the sentinel of the respiratory tract. Just as taste and flavor influence nutrition by affecting the digestive process, so the agreeable odors about us, even those of the perfumes, play an important part in the economy of life.

324. The Sense of Sight. The sight is well regarded as the highest and the most perfect of all our senses. It plays so common and so beneficent a part in the animal economy that we scarcely appreciate this marvelous gift. Sight is essential not only to the simplest matters of daily comfort and necessity, but is also of prime importance in the culture of the mind and in the higher forms of pleasure. It opens to us the widest and the most varied range of observation and enjoyment. The pleasures and advantages it affords, directly and indirectly, have neither cessation nor bounds.

Apart from its uses, the eye itself is an interesting and instructive object of study. It presents beyond comparison the most beautiful example of design and artistic workmanship to be found in the bodily structure. It is the watchful sentinel and investigator of the external world. Unlike the senses of taste and smell we seem, by the sense of vision, to become aware of the existence of objects which are entirely apart from us, and which have no direct or material link connecting them with our bodies. And yet we are told that in vision the eye is affected by something which is as material as any substance we taste or smell.

[NOTE. "The higher intelligence of man is intimately associated with the perfection of the eye. Crystalline in its transparency, sensitive in receptivity, delicate in its adjustments, quick in its motions, the eye is a fitting servant for the eager soul, and, at times, the truest interpreter between man and man of the spirit's inmost workings. The rainbow's vivid hues and the pallor of the lily, the fair creations of art and the glance of mutual affection, all are pictured in its translucent depths, and transformed and glorified by the mind within. Banish vision, and the material universe shrinks for us to that which we may touch; sight alone sets us free to pierce the limitless abyss of space."--M'Kendrick and Snodgrass's _Physiology of the Senses_.]

Physicists tell us that this material, known as the _luminiferous ether_, permeates the universe, and by its vibrations transmits movements which affect the eye, giving rise to the sensation of light, and the perception of even the most distant objects. Our eyes are so constructed as to respond to the vibrations of this medium for the transmission of light.

325. The Eye. The eye, the outer instrument of vision, is a most beautiful and ingenious machine. All its parts are arranged with such a delicate adjustment to one another, and such an exquisite adaptation of every part to the great object of the whole, that the eye is properly regarded as one of the wonders of nature.

The eyeball is nearly spherical in shape, but is slightly elongated from before backwards. The front part is clear and transparent, and bulges somewhat prominently to allow the entrance of the rays of light. The eye rests in a bowl-shaped socket, called the orbit, formed by parts of various bones of the head and face. The margins of this cavity are formed of strong bone which can withstand heavy blows. The socket is padded with loose, fatty tissue, and certain membranes, which serve as a soft and yielding bed in which the eyeball can rest and move without injury. In a severe sickness this fatty tissue is absorbed, and this fact explains the sunken appearance of the eyes.

The orbit is pierced through its posterior surface by an opening through which the nerve of sight, the optic, passes to the eyeball. We may think of the optic nerve holding the eyeball much as the stem holds the apple. It is the function of this most important nerve to transmit retinal impressions to the seat of consciousness in the brain, where they are interpreted.

The eye is bathed with a watery fluid, and protected by the eyelids and the eyebrows; it is moved in various directions, by muscles, all of which will soon be described.

[Illustration: Fig. 127.--Section of the Human Eye.]

326. The Coats of the Eyeball. The eyeball proper is elastic but firm, and is composed of three coats, or layers, each of which performs important functions. These coats are the sclerotic, the choroid, and the retina.

The sclerotic coat is the outside layer and enclosing membrane of the eyeball. It is a tough, fibrous coat for the protection and maintenance of the shape of the eye. It is white and glistening in appearance, and is in part visible, to which the phrase, "the white of the eye," is applied. To this coat, which serves as a kind of framework for the eye, are attached the muscles which move the eyeball. In front of the globe, the sclerotic passes into a transparent circular portion forming a window through which one can see into the interior. This is the cornea.

The cornea, a clear, transparent, circular disk, fits into the sclerotic, somewhat as the crystal fits into the metallic case of a watch, forming a covering for its dial. It projects from the general contour of the eyeball, not unlike a rounded bay-window, and is often spoken of as the "window of the eye."

Lining the inner surface of the sclerotic is the second coat, the choroid. It is dark in color and fragile in structure, and is made up almost entirely of blood-vessels and nerves. As the choroid approaches the front part of the eyeball, its parts become folded upon themselves into a series of ridges, called ciliary processes. These folds gradually become larger, and at last merge into the ciliary or accommodation muscle of the eye. The circular space thus left in front by the termination of the choroid is occupied by the iris, a thin, circular curtain, suspended in the aqueous humor behind the cornea and in front of the crystalline lens. In its center is a round opening for the admission of light.

This is the pupil, which appears as if it were a black spot. The back of the iris is lined with dark pigment, and as the coloring matter is more or less abundant, we may have a variety of colors. This pigment layer and that of the choroid and retina absorb the light entering the eye, so that little is reflected.

The pupil appears black, just as the open doorway to a dark closet seems black. The margin of the iris is firmly connected with the eyeball all round, at the junction of the sclerotic and the cornea.

327. The Retina. The third and innermost coat of the eyeball is the retina. This is the perceptive coat, without which it would be impossible to see, and upon which the images of external objects are received. It lines nearly the whole of the inner surface of the posterior chamber, resting on the inner surface of the choroid. It is with the retina, therefore, that the vitreous humor is in contact.

The retina is a very thin, delicate membrane. Although very thin, it is made up of ten distinct layers, and is so complicated in structure that not even a general description will be attempted in this book. It does not extend quite to the front limits of the posterior chamber, but stops short in a scalloped border, a little behind the ciliary processes. This is the nerve coat of the eye, and forms the terminal organ of vision. It is really an expansion of the ultimate fibers of the optic nerve, by means of which impressions are sent to the brain.

The retina contains curious structures which can be seen only with the aid of the microscope. For instance, a layer near the choroid is made up of nerve cells arranged in innumerable cylinders called "rods and cones," and packed together not unlike the seeds of a sunflower. These rods and cones are to be regarded as the peculiar modes of termination of the nerve filaments of the eye, just as the taste buds are the modes of termination of the nerve of taste in the tongue, and just as the touch corpuscles are the terminations of the nerves in the skin.

Experiment 148. Close one eye and look steadily at the small a in the figure below. The other letters will also be visible at the same time. If now the page be brought slowly nearer to the eye while the eye is kept steadily looking at the small a, the large A will disappear at a certain point, reappearing when the book is brought still nearer.

[Illustration: a oAx]

On the reappearance of the A it will be noted that it comes into view from the inner side, the x being seen before it. If now we move the book towards its original place, the A will again disappear, coming again into view from the outer side when the o is seen before it.

328. Inner Structure of the Eye. Let us imagine an eyeball divided through the middle from above downwards. Let us now start in front and observe its parts (Fig. 127). We come first to the cornea, which has just been described. The iris forms a sort of vertical partition, dividing the cavity of the eyeball into two chambers.

[Illustration: Fig. 128.--Diagram illustrating the Manner in which the Image of an Object is brought to a Focus on the Retina.]

The anterior chamber occupies the space between the cornea and the iris, and is filled with a thin, watery fluid called the aqueous humor.

The portion behind the iris forms the posterior chamber, and contains the crystalline lens and a transparent, jelly-like fluid, the vitreous humor. This fluid is never renewed, and its loss is popularly described by the phrase, "when the eye runs out."

Experiment 149. The retina is not sensitive where the optic nerve enters the eyeball. This is called the "blind spot." Put two ink-bottles about two feet apart, on a table covered with white paper. Close the left eye, and fix the right steadily on the left-hand inkstand, gradually varying the distance from the eye to the ink-bottle. At a certain distance the right-hand bottle will disappear; but nearer or farther than that, it will be plainly seen.

The vitreous humor fills about four-fifths of the eyeball and prevents it from falling into a shapeless mass. It also serves to hold the choroid and the retina in position, and to maintain the proper relations of the inner structures of the eye.

The iris consists of a framework of connective tissue, the surface of which is lined by cells containing pigment, which gives color to the eye.

Bundles of involuntary muscular fibers are found in the substance of the iris. Some are arranged in a ring round the margin of the pupil; others radiate from it like the spokes of a wheel. When the circular fibers contract, the pupil is made smaller, but if these fibers relax, the radiating fibers cause the pupil to dilate more or less widely.

329. The Crystalline Lens. Just behind the pupil and close to the iris is a semi-solid, double-convex body, called the crystalline lens. It is shaped like a magnifying glass, convex on each side, but with the posterior surface more convex than the anterior. In health it is perfectly clear and transparent, and highly elastic. When the lens becomes opaque,

from change in old age, or from ulcers or wounds, we have the disease known as _cataract_.

[Illustration: Fig. 129.--Diagram showing the Change in the Lens during Accommodation.

On the right the lens is arranged for distant vision, the ciliary muscle is relaxed and the ligament D is tense, so flattening by its compression the front of the lens C; on the left the muscle A is acting, and this relaxes the ligament and allows the lens B to become more convex, and so fitted for the vision of near objects.]

The lens is not placed loosely in the eyeball, but is enclosed in a transparent and elastic capsule suspended throughout its circumference by a ligament called the suspensory ligament. This ligament not only retains the lens in place, but is capable of altering its shape. In ordinary conditions of the eye, this ligament is kept tense so that the front part of the lens is flattened somewhat by the pressure on it.

All around the edge, where the cornea, sclerotic, and choroid meet, is a ring of involuntary muscular fibers, forming the ciliary muscle. When these fibers contract, they draw forwards the attachment of the suspensory ligament of the lens, the pressure of which on the lens is consequently diminished. The elasticity of the lens causes it at once to bulge forwards, and it becomes more convex.

The ciliary muscle is thus known as the muscle of accommodation, because it has the power to accommodate the eye to near and distant objects. In this respect it corresponds in its use to the adjusting screw in the opera-glass and the microscope.

330. The Eye Compared to the Photographic Camera. As an optical instrument, the eye may be aptly compared, in many particulars, to the photographic camera. The latter, of course, is much simpler in structure. The eyelid forms the cap, which being removed, the light from the object streams through the eye and passes across the dark chamber to the retina behind, which corresponds to the sensitive plate of the camera. The transparent structures through which the rays of light pass represent the lenses. To prevent any reflected light from striking the plate and interfering with the sharpness of the picture, the interior of the photographic camera box is darkened. The pigmented layer of the choroid coat represents this blackened lining.

In the camera, the artist uses a thumb-screw to bring to a focus on the sensitive plate the rays of light coming from objects at different distances. Thus the lens of the camera may be moved nearer to or farther from the object. In order to obtain clear images, the same result must be accomplished by the eye. When the eye is focused for near objects, those at a distance are blurred, and when focused for distant objects, those near at hand are indistinct. Now, in the eye there is no arrangement to alter the position of the lenses, as in the camera, but the same result is obtained by what is called "accommodation."

Again, every camera has an arrangement of diaphragms regulating the amount of light. This is a rude contrivance compared with the iris, which by means of its muscular fibers can in a moment alter the size of the pupil, thus serving a similar purpose.

[Illustration: Fig. 130.--Illustrating the manner in which the Image of an Object is brought to a Focus in a Photographer's Camera.]

331. The Refractive Media of the Eye. The eye is a closed chamber into which no light can pass but through the cornea. All the rays that enter the eye must also pass through the crystalline lens, which brings them to a focus, as any ordinary lens would do.

Now, if the media through which the light from an object passes to reach the retina were all of the same density as the air, and were also plane surfaces, an impression would be produced, but the image would not be distinct. The action of the lens is aided by several refractive media in the eye. These media are the cornea, the aqueous humor, and the vitreous humor. By reason of their shape and density these media refract the rays of light, and bring them to a focus upon the retina, thus aiding in producing a sharp and distinct image of the object. Each point of the image being the focus or meeting-place of a vast number of rays coming from the corresponding point of the object is sufficiently bright to stimulate the retina to action.[44]

Thus, the moment rays of light enter the eye they are bent out of their course. By the action of the crystalline lens, aided by the refractive media, the rays of light that are parallel when they fall upon the normal eye are brought to a focus on the retina.

If the entire optical apparatus of the eye were rigid and immovable, one of three things would be necessary, in order to obtain a clear image of an object; for only parallel rays (that is, rays coming from objects distant about thirty feet or more), are brought to a focus in the average normal eye, unless some change is brought about in the refractive media. First, the posterior wall of the eye must be moved further back, or the lens would have to be capable of movement, or there must be some way of increasing the focusing power of the lens. In the eye it is the convexity of the lens that is altered so that the eye is capable of adjusting itself to different distances.[45]

[Illustration: Fig. 131.--The Actual Size of the Test-Type, which should be seen by the Normal Eye at a Distance of Twenty Feet.]

332. The More Common Defects of Vision. The eye may be free from disease and perfectly sound, and yet vision be indistinct, because the rays of light are not accurately brought to a focus on the retina. "Old sight," known as presbyopia, is a common defect of vision in advancing years. This is a partial loss of the power to accommodate the eye to different distances. This defect is caused by an increase in the density of the crystalline lens, and an accompanying diminution in the ability to change its form. The far point of vision is not changed, but the near point is removed so far from the eye, that small objects are no longer visible.

[Illustration: Fig. 132.--Diagram illustrating the Hypermetropic (far-sighted) Eye.

The image P' of a point P falls behind the retina in the unaccommodated eye. By means of a convex lens it may be focused on the retina without accommodation (dotted lines). (To save space P is placed much too near the eye.)]

Hence, when a person about forty-five years of age complains of dim light, poor print, and tired eyes, the time has come to seek the advice of an optician. A convex lens may be needed to aid the failing power to increase the convexity of the lens, and to assist it in bringing the divergent rays of light to a focus.

In "long sight," or hypermetropia both the near and far point of vision are concerned, and there is no distinct vision at any distance without a strain. It is a defect in the focus, dependent upon the form of the eyes, and exists in childhood. The axis of the eyeball is too short, and the focus falls beyond the retina, which is too near the cornea. In childhood this strain may pass unnoticed, but, sooner or later it manifests itself by a sense of fatigue, dizziness, and a blurred and indistinct vision. The remedy is in the use of convex glasses to converge parallel rays of light before they enter the eye. The muscles of accommodation are thus relieved of their extra work.

"Short sight," known as myopia, is one of the commonest defects of vision. In this defect the axis of the eye, or the distance between the cornea and the retina, is too long and the rays of light are brought to a focus in front of the retina. The tendency to short-sightedness exists in many cases at birth, and is largely hereditary. It is alarmingly common with those who make a severe demand upon the eyes. During childhood there is a marked increase of near-sightedness. The results of imprudence and abuse, in matters of eyesight, are so disastrous, especially during school life, that the question of short sight becomes one of paramount importance.

Experiment 150. With a hand-mirror reflect the sunlight on a white wall. Look steadily at the spot for a full minute, and then let the mirror suddenly be removed. The "complementary" color--a dark spot--will appear.

Experiment 151. _To show that impressions made upon the retina do not disappear at once_. Look steadily at a bright light for a moment or two, and then turn away suddenly, or shut the eyes. A gleam of light will be seen for a second or two.

Look steadily at a well-lighted window for a few seconds, and then turn the eyes suddenly to a darkened wall. The window frame may be plainly seen for a moment.

Glance at the sun for a moment, close the eyes and the image of the sun may be seen for a few seconds.

Experiment 152. Take a round piece of white cardboard the size of a saucer, and paint it in alternate rings of red and yellow,--two primary colors. Thrust a pin through the center and rotate it rapidly. The eye perceives neither color, but orange,--the secondary color.

Experiment 153. To note the shadows cast upon the retina by opaque matters in the vitreous humor (popularly known as floating specks, or gossamer threads), look through a small pin-hole in a card at a bright light covered by a ground-glass shade.

Experiment 154. _To illustrate accommodation_. Standing near a source of light, close one eye, hold up both forefingers not quite in a line, keeping one finger about six or seven inches from the other eye, and the other forefinger about sixteen to eighteen inches from the eye. Look at the _near_ finger; a distinct image is obtained of it, while the far one is blurred or indistinct. Look at the far image; it becomes distinct, while the near one becomes blurred. Observe that in accommodating for the near object, one is conscious of a distinct effort.

In many cases near-sightedness becomes a serious matter and demands skillful advice and careful treatment. To remedy this defect, something must be done to throw farther back the rays proceeding from an object so that they will come to a focus exactly on the retina. This is done by means of concave glasses, properly adjusted to meet the conditions of the eyes. The selection of suitable glasses calls for great care, as much harm may be done by using glasses not properly fitted to the eye.

[Illustration: Fig. 133.--Diagram illustrating the Myopic (near-sighted) Eye.

The image P' of a distant object P falls in front of the retina even without accommodation. By means of a concave lens (L) the image may be made to fall on the retina (dotted lines). (To save space P is placed much too near the eye).]

There is an optical condition of the eye known as astigmatism, in which the cornea is usually at fault. In this defect of vision the curvature of the cornea is greater in one meridian than in another. As a result the rays from an object are not all brought to the same focus. Objects appear distorted or are seen with unequal clearness. Glasses of a peculiar shape are required to counteract this defect.

333. The Movements of the Eyes. In order that our eyes may be efficient instruments of vision, it is necessary that they have the power of moving independently of the head. The mechanical arrangement by which the eyeballs are moved in different directions is quite simple. It is done by six little muscles, arranged in three pairs, which, with one exception, originate in the back of the cavity in which the eye rests. Four of these muscles run a straight course and are called the _recti_. The remaining two muscles bend in their course and are called _oblique_. The cooerdination of these tiny muscles is marvellous in its delicacy, accuracy, and rapidity of action.

When, for any cause, the cooerdination is faulty, "cross eye," technically called strabismus, is produced. Thus, if the internal rectus is shortened, the eye turns in; if the external rectus, the eye turns out, producing what is known as "wall eye." It is thus evident that the beauty of the internal mechanism of the eye has its fitting complement in the precision, delicacy, and range of movement conferred upon it by its muscles.

334. The Eyelids and Eyebrows. The eye is adorned and protected by the eyelids, eyelashes, and eyebrows.

[Illustration: Fig. 134.--Muscles of the Eyeball.

A, attachment of tendon connected with the three recti muscles;
B, external rectus, divided and turned downward, to expose the internus rectus;
C, inferior rectus;
D, internal rectus;
E, superior rectus;

F, superior oblique;
H, pulley and reflected portion of the superior oblique;
K, inferior oblique; L, levator palpebri superioris;
M, middle portion of the same muscle (L);
N, optic nerve.
]

The eyelids, two in number, move over the front of the eyeball and protect it from injury. They consist of folds of skin lined with mucous membrane, kept in shape by a layer of fibrous material. Near the inner surface of the lids is a row of twenty or thirty glands, known as the _Meibomian glands_, which open on the free edges of each lid. When one of these glands is blocked by its own secretion, the inflammation which results is called a "sty."

The inner lining membrane of the eyelids is known as the conjunctiva; it is richly supplied with blood-vessels and nerves. After lining the lids it is reflected on to the eyeballs. It is this membrane which is occasionally inflamed from taking cold.

The free edges of the lids are bordered with two or more rows of hairs called the eyelashes, which serve both for ornament and for use. They help to protect the eyes from dust, and to a certain extent to shade them. Their loss gives a peculiar, unsightly look to the face.

The upper border of the orbit is provided with a fringe of short, stiff hairs, the eyebrows. They help to shade the eyes from excessive light, and to protect the eyelids from perspiration, which would otherwise cause serious discomfort.

335. The Lacrymal Apparatus. Nature provides a special secretion, the tears, to moisten and protect the eye. The apparatus producing this secretion consists of the lacrymal or tear gland and lacrymal canals or tear passages (Fig. 136).

Outside of the eyeball, in the loose, fatty tissue of the orbit, in the upper and outer corner is the lacrymal or tear gland. It is about the size of a small almond and from it lead several little canals which open on the inner surface of the upper lid. The fluid from the gland flows out by these openings over the eyeball, and is collected at the inner or nasal corner. Here in each lid is a little reddish elevation, or _lacrymal caruncle_, in which is an opening, communicating with a small canal in the lid which joins the lacrymal sac, lodged between the orbit and the bridge of the nose (Fig. 137).

From this sac there passes a channel, the nasal duct, about one-half of an inch long, leading into the lower portion of the nostril. The fluid which has flowed over the eye is drained off by these canals into the nose. During sleep this secretion is much diminished. When the eyes are open the quantity is sufficient to moisten the eyeball, the excess being carried into the nose so gradually that the attention is not attracted to it.

The lacrymal canals are at times blocked by inflammation of the nasal duct, and the fluid collects in the corners of the eyelids and overflows down the cheeks, producing much inconvenience. The lining membrane of the eyelids through these canals is continuous with that of the nostrils. Hence, when the lining membrane of the eye is red and swollen, as during a cold, the nasal passages are also irritated, and when the nasal membrane is inflamed, the irritation is apt to pass upwards and affect the eyelids.

336. The Tears. The lacrymal or tear gland is under the control of the nervous system. Thus, if anything irritates the eyelids, the sensory nerves are stimulated and the impression is carried to the brain. Thence the nerve impulses travel to the lacrymal glands, leading to an increased flow of their secretion. The irritation of the sensory nerves in the nasal passages by smelling such substances as onions, or pungent salts, often causes a copious flow of tears.

[Illustration: Fig. 135.--Lacrymal Gland and Ducts.

A, lachrymal gland, the size of a small almond lodged in a shallow depression in the bones of the orbit;
B, lachrymal ducts (usually seven), which form a row of openings into the conjunctival fold.
]

Various mental emotions, as joy and grief, may produce similar results. In these cases the glands secrete the fluid in such quantities that it cannot escape by the lacrymal canals, and the excess rolls over the cheeks as tears. Excessive grief sometimes acts on the nerve centers in exactly the opposite manner, so that the activity of the glands is arrested and less fluid is secreted. This explains why some people do not shed tears in times of deep grief.

Experiment 155. Gently turn the inner part of your lower eyelid down. Look in a mirror, and the small lacrymal point, or opening into the nasal duct, may be observed.

337. Color-blindness. There is an abnormal condition of vision called color-blindness, in which the power of discrimination between different colors is impaired. Experiment shows that ninety-six out of every one hundred men agree as to the identity or the difference of color, while the remaining four show a defective perception of color.

The first may be said to have _normal vision_; the second are called _color-blind_. It is a curious fact that ten times more men than women are color-blind.

In its true sense, color-blindness is always congenital, often hereditary. This condition of abnormal vision is totally incurable. A person may be color-blind and not know it until the defect is accidentally revealed. The common form of defective color-vision is the inability to distinguish between _red_ and _green_. As green lights mean safety, and red lights danger, on railroads, on shipboard, and elsewhere, it becomes of paramount importance that no one who is color-blind should be employed in such service. Various tests are now required by statute law in many states to be used for the detection of such defects of vision among employees in certain occupations.

338. School Life and the Eyesight. The eyes of children need more care than those of adults, because their eyes are still in the course of development. The eyes, like any other organ which is yet to attain its full growth, require more care in their use than one which has already reached its full size. They are peculiarly liable to be affected by improper or defective light. Hence the care of the eyes during school life

is a matter of the most practical importance.

In no matter of health can the teacher do a more distinct service than in looking after the eyesight of the pupils. Children suffering from defective vision are sometimes punished by teachers for supposed stupidity. Such pupils, as well as the deaf, are peculiarly sensitive to their defects. Every schoolroom should have plenty of light; it should come from either side or the rear, and should be regulated with suitable shades and curtains.

Pupils should not be allowed to form the bad habit of reading with the book held close to the eyes. The long search on maps for obscure names printed in letters of bad and trying type should be discouraged. Straining the eyes in trying to read from slates and blackboards, in the last hour of the afternoon session, or in cloudy weather, may do a lifelong injury to the eyesight. Avoid the use, so far as possible, especially in a defective light, of text-books which are printed on battered type and worn plates.

The seat and desk of each scholar should be carefully arranged to suit the eyesight, as well as the bones and muscles. Special pains should be taken with the near-sighted pupils, and those who return to school after an attack of scarlet fever, measles, or diphtheria.

Experiment 156. _To test color-blindness._ On no account is the person being tested to be asked to name a color. In a large class of students one is pretty sure to find some who are more or less color-blind. The common defects are for red and green.

Place worsteds on a white background in a good light. Select, as a test color, a skein of light green color, such as would be obtained by mixing a pure green with white. Ask the examinee to select and pick out from the heap all those skeins which appear to him to be of the same color, whether of lighter or darker shades. A color-blind person will select amongst others some of the confusion-colors, _e.g._, pink, yellow. A colored plate showing these should be hung up in the room. Any one who selects all the greens and no confusion-colors has normal color vision. If, however, one or more confusion-colors be selected, proceed as follows: select as a test color a skein of pale rose. If the person be red-blind, he will choose blue and violet; if green-blind, gray and green.

Select a bright red skein. The red-blind will select green and brown; the green-blind picks out reds or lighter brown.

339. Practical Hints on the Care of the Eyes. The eye is an exceedingly delicate and sensitive organ. While it is long-suffering, its endurance has a limit. Like all the other organs of the body, the eyes are better for moderate and rational use. More than any other organ they require attention to the general health, as the condition of the skin, exercise in the open air, good food, and proper habits of daily living.

The tissues of the eyes are peculiarly sensitive to any general influence. Certain constitutional diseases, like rheumatism, lead-poisoning, diphtheria, and measles often affect the eyes. Special care should be taken with children's eyes during and after an attack of measles and scarlet fever. The eyes of young infants should not be exposed to glaring lights or to the direct rays of the sun, as when taken out in baby carriages.

[Illustration: Fig. 136.--Showing the Relative Position of the Lacrymal Apparatus, the Eyeball, and the Eyelids.

A, lacrymal canals, with the minute orifices represented as two black dots (puncta lacrymalia) to the right;
B, tendon of the orbicularis palpebrarum muscle; apparently under B is seen the lacrymal sac. The minute openings of the Meibomian glands are seen on the free margins of the eyelids.

Below A is seen a small conical elevation, with black dots (the lacrymal papilla or caruncle).]

Glasses should be worn when they are needed. A failure to do this ususally causes much unnecessary suffering. It is far from wise to postpone as long as possible the first use of glasses. The selection and proper fitting of glasses call for the combined skill of both the physician and the optician. Obstinate headaches are often caused by defective vision, and may disappear after discontinuing improper glasses.

The habit of reading, in the cars or elsewhere, the daily paper and poorly printed books, with their blurred and indistinct type, is a severe strain on the accommodation apparatus of the eyes. It is a dangerous practice to read in bed at night, or while lying down in a darkened or shaded room. This is especially true during recovery from illness. The muscles of the eyes undergo excessive strain in accommodating themselves to the unnatural position. The battered type, wood-pulp paper, and poor presswork, now so commonly used in the cheap editions of books and periodicals, are often injurious to the eyesight.

Reading-matter should not be held nearer to the eyes than is necessary to make the print appear perfectly sharp and distinct. No print should be read continuously that cannot be seen clearly at about eighteen inches. Those who read music are especially liable to strain the eyes, because exact vision is required to follow the notes. Persons who wear glasses for reading should be careful to use them while reading music, and good light is necessary to avoid any undue strain.

After reading steadily for some time, the eyes should be rested by closing them a short period or by looking at some distant object, even if only for a few moments. The book, the sewing, and work generally, should be held as far from the eyes as is compatible with good vision. The natural tendency is to reverse this rule. We should never read, write, sew, stitch, or otherwise use the eyes when they smart or tingle, or when the sight is dim or blurred. The eyes are then tired and need a rest. Much injury may be done by reading in twilight, or by artificial light in the early morning, and by reading and working in badly lighted and ill-ventilated rooms.

Good artificial light is much to be preferred to insufficient sunlight. The artificial light should be sufficiently bright and steady; a fickering light is always bad. Riding against a strong wind, especially on a bicycle, may prove hurtful, at least for eyes that are inclined to any kind of inflammation. The light reflected from snow is a common source of injury to the eyes. It is a wise caution in passing from a dark room to avoid looking immediately at the sun, an incandescent light, the glistening snow, or other bright objects.

The eyes should never be rubbed, or the fingers thrust into them,[46] and much less when they are irritated by any foreign substance. The sooner the offending substance is removed the better.

[Illustration: Fig. 137.--Lacrymal Canals, Lacrymal Sac, and Nasal ducts, opened by their Anterior Portion.]

340. Effect of Alcohol upon the Eye. The earlier and slighter forms of injury done to the eye by the use of intoxicants are quite familiar: the watery condition of the eye and of the lids, and the red and bleared aspect of the organ. Both are the result of chronic inflammation, which crowds the blood into the vessels of the cornea, making them bloodshot and visible. The nerves controlling the circulation of the eye are partially paralyzed, and thus the relaxed vessels become distended.

But more serious results ensue. Long use of intoxicants produces diseases of the retina, involving in many cases marked diminution of acuteness as well as quickness of vision, and at times distorted images upon the surface of the retina. In other instances, the congestion of the optic nerve is so serious as to involve a progressive wasting of that organ, producing at first a hazy dimness of vision which gradually becomes worse and worse, till total blindness may ensue.

It is beyond question that a wide comparison of cases by careful observers proves that a large fraction of those who indulge in strong drink suffer from some form of disease of the eye.

341. Effect of Tobacco upon Vision. Tobacco, in its distribution of evil effects, does not neglect the senses and especially the eye. A variety of vicious results is produced. The pungent smoke inflames the lids. The narcotic dilates the pupil, causing dimness and confusion of vision. A diseased condition occurs with severe pain in the eye followed by impaired vision.

Oculists speak impressively of the ill effects of tobacco, and especially of cigarettes, upon the eyes of the young. They mention a well-known disease, tobacco blindness, usually beginning with color-blindness, and progressing occasionally with increasing dimness of vision to entire loss of sight.[47]

342. The Sense of Hearing. The structure of the human ear is much more complicated than is generally supposed. It is an apparatus constructed to respond to the waves of sound. As a whole, it may be considered a peculiar form of nerve-ending.

The external ear forms only a part of a most elaborate apparatus whereby sound waves may be transmitted inwards to the real organ of hearing. The really sensitive part of the ear, in which the auditory nerve ends, is buried for protection deep out of sight in the bones of the head; so deep that sounds cannot directly affect it. Some arrangement, therefore, is required for conducting the sounds inwards to this true organ.

[Illustration: Fig. 138.--The Pinna, or Auricle.]

In studying the structure of the ear, and how it is fitted to respond to sonorous vibrations, we may divide it into three parts: the sound-conducting part, known as the external ear, the middle ear, and the deeply placed nerve portion, the inner ear.

343. The External Ear. The external ear consists of an expanded portion known as the pinna or _auricle_, and of a passage, the auditory canal or _meatus_, leading inwards from it. The surface of the auricle is convoluted to collect and transmit the vibrations of air by which sound is produced the auditory canal conducts these vibrations to the tympanic membrane. Many animals move the auricle in the direction of the sound. Thus the horse pricks up its ears when it hears a noise, the better to judge of the direction of sounds.[48]

The external auditory meatus, the passage to the middle ear, is curved and is about an inch and a quarter long. Near its outer portion are a number of fine hairs slanting outwards to prevent the entrance of insects. Embedded in the deeper parts of the canal are glands which secrete the _cerumen_, or ear-wax, which keeps the canal moist, and helps to protect it against foreign bodies and insects. As the result of a cold, this wax may collect in sufficient quantities to block the passage, and to diminish to a considerable extent the power of hearing.

344. The Middle Ear. At the inner end of the outer ear passage is the tympanum, known as "the drum of the ear." It is a thin, oval membrane, stretched at an angle across the deep end of the passage, which it completely closes. The tympanum is thus a partition between the passage of the outer ear and the cavity of the middle ear. On its inner side is a small air chamber in the petrous portion of the temporal bone, called the cavity of the tympanum. Its bony walls are lined with mucous membrane similar to that lining the nose, mouth, and throat. On the inner wall of the tympanum are two openings, the round window, or _foramen rotundum_, and the oval window, or _foramen ovale_.

The tympanic cavity communicates with the back part of the throat, by the Eustachian tube. This tube is about one and a half inches long and lined with mucous membrane similar to that of the tympanic chamber and the throat. This passage is usually closed, but is opened in the act of swallowing. In health there is no communication between the chamber of the middle ear and the outside, except by the Eustachian tube. Thus a throat cold, with redness and swelling of the mucous membrane, is usually accompanied with some degree of deafness, because the swelling may block the lumen of the tube, and thus prevent the free passage of air to and fro.

[Illustration: Fig. 139.--General View of the Organ of Hearing.

A, pinna;
B, cavity of the concha, showing the orifices of a great number of sebaceous glands;
C, external auditory meatus;
D, membrana tympani;
F, incus;
H, malleus;
K, handle of malleus applied to the internal surface of the membrana tympani;
L, tensor tympani muscle;
between M and K is the tympanic cavity;
N, Eustachian tube;
O, P, semicircular canals;
R, internal auditory canal;
S, large nerve given off from the facial ganglion;
T, facial and auditory nerves.

]

A most curious feature of the ear is the chain of tiny movable bones which stretch across the cavity of the middle ear. They connect the tympanic membrane with the labyrinth, and serve to convey the vibrations communicated to the membrane across the cavity of the tympanum to the internal ear. These bones are three in number, and from their shape are called the malleus, or _hammer_, incus, or _anvil_; and stapes, or _stirrup_.

The hammer is attached by its long handle to the inner surface of the drum of the ear. The round head is connected with the anvil by a movable joint, while the long projection of the anvil is similarly connected with the stirrup bone. The plate of the stirrup is fixed by a membrane into the oval window of the inner wall of the tympanic chamber.

These little bones are connected with each other and the tympanum by ligaments and moved by three tiny muscles. Two are attached to the hammer, and tighten and relax the drum; the other is attached to the stirrup, and prevents it from being pushed too deeply into the oval window.

[Illustration: Fig. 140.--Ear-Bones. (Anterior View.)

1, malleus, or hammer;
2, incus, or anvil;
3, stapes, or stirrup.
]

345. The Internal Ear. This forms one of the most delicate and complex pieces of mechanism in the whole body. It is that portion of the organ which receives the impression of sound, and carries it directly to the seat of consciousness in the brain. We are then able to say that we hear.

The internal ear, or bony labyrinth, consists of three distinct parts, or variously shaped chambers, hollowed out in the temporal bone,--the vestibule, the semicircular canals, and the cochlea, or snail's shell.

[Illustration: Fig. 141.--A Cast of the External Auditory Canal. (Posterior view)]

The vestibule is the common cavity with which all the other portions of the labyrinth connect. It is an oval-shaped chamber, about 1/3 of an inch in diameter, occupying the middle part of the internal ear. It is on the inner side of the oval window, which was closed, as we have seen, by the stirrup bone. From one side of this vestibule, or central hall, the three semicircular canals pass off, and from the other side, the cochlea.

The three semicircular canals, so called from their shape, are simply bony tubes about 1/20 of an inch in width, making a curve of about 1/4 of an inch in diameter. They pass out from the vestibule, and after bending around somewhat like a hoop, they return again to the vestibule. Each bony canal contains within it a membranous canal, at the end of which it is dilated to form an _ampulla_.

Experiment 157. _To vibrate the tympanic membrane and the little ear-bones._ Shut the mouth, and pinch the nose tightly. Try to force air through the nose. The air dilates the Eustachian tube, and is forced into the ear-drum. The distinct crackle, or clicking sound, is due to the movement of the ear-bones and the tympanic membrane.

The cochlea, or snail's shell, is another chamber hollowed out in the solid bone. It is coiled on itself somewhat like a snail's shell. There is a central pillar, around which winds a long spiral canal. One passage from the cochlea opens directly into the vestibule; the other leads to the chamber of the middle ear, and is separated from it by the little round window already described.

The cochlea contains thousands of the most minute cords, known as the fibers or _organ of Corti_.[49] Under the microscope they present the appearance of the keyboard of a piano. These fibers appear to vibrate in sympathy with the countless shades of sounds which daily penetrate the ear. From the hair-like processes on these tightly stretched fibers, auditory impulses appear to be transmitted to the brain.

The tubes and chambers of the inner ear enclose and protect a delicate membranous sac of exactly the same shape as themselves. Between the bony walls of the passages and the membranous bag inside is a thin, clear fluid, the _perilymph_. The membranous bag itself contains a similar fluid, the _endolymph_. In this fluid are found some minute crystals of lime like tiny particles of sand, called _otoliths_, or ear-stones. Every movement of the fluid itself throws these grains from side to side.

[Illustration: Fig. 142.--Bony internal Ear of Right Side. (Magnified; the upper figure of the natural size.)

A, oval window (foramen ovale);
B, C, D, semicircular canals;
* represents the bulging part (ampulla) of each canal;
E, F, G cochlea, H, round window (foramen rotundum).
]

The auditory nerve, or nerve of hearing, passes to the inner ear, through a passage in the solid bone of the skull. Its minute filaments spread at last over the inner walls of the membranous labyrinth in two branches,--one going to the vestibule and the ampullae at the ends of the semicircular canals, the other leading to the cochlea.

346. Mechanism of Hearing. Waves of sound reach the ear, and are directed by the concha to the external passage, at the end of which they reach the tympanic membrane. When the sound-waves beat upon this thin membrane, it is thrown into vibration, reproducing in its movements the character of the air-vibrations that have fallen upon it.

Now the vibrations of the tympanic membrane are passed along the chain of bones attached to its inner surface and reach the stirrup bone. The stirrup now performs a to-and-fro movement at the oval window, passing the auditory impulse inwards to the internal ear.

Every time the stirrup bone is pushed in and drawn out of the oval window, the watery fluid (the perilymph) in the vestibule and inner ear is set in motion more or less violently, according to the intensity of the sound. The membranous labyrinth occupies the central portion of the vestibule and the passages leading from it. When, therefore, the perilymph is shaken it communicates the impulse to the fluid (endolymph) contained in the inner membranous bag. The endolymph and the tiny grains of ear-sand now perform their part in this marvelous and complex mechanism. They are driven against the sides of the membranous bag, and so strike the ends of the nerves of hearing, which transmit the auditory impulses to the seat of sensation in the brain.

It is in the seat of sensation in the brain called the _sensorium_ that the various auditory impulses received from different parts of the inner ear are fused into one, and interpreted as sounds. It is the extent of the vibrations that determines the loudness of the sound; the number of them that determines the pitch.

Experiment 158. Hold a ticking watch between the teeth, or touch the upper incisors with a vibrating tuning-fork; close both ears, and observe that the ticking or vibration is heard louder. Unstop one ear, and observe that the ticking or vibration is heard loudest in the stopped ear.

Experiment 159. Hold a vibrating tuning-fork on the incisor teeth until you cannot hear it sounding. Close one or both ears, and you will hear it.

Experiment 160. Listen to a ticking watch or a tuning-fork kept vibrating electrically. Close the mouth and nostrils, and take either a deep inspiration or deep expiration, so as to alter the tension of the air in the tympanum; in both cases the sound is diminished.

Experiment 161. With a blindfolded person test his sense of the direction of sound, _e.g._, by clicking two coins together. It is very imperfect. Let a person press both auricles against the side of the head, and hold both hands vertically in front of each meatus. On a person making a sound in front, the observed person will refer it to a position behind him.

347. Practical Hints on the Care of the Ear. This very delicate and complicated organ is often neglected when skilled treatment is urgently needed, and it is often ignorantly and carelessly tampered with when it should be let alone.

Never insert into the ear canal the corners of towels, ear spoons, the ends of toothpicks, hairpins, or any other pointed instruments. It is a needless and dangerous practice, usually causing, in time, some form of inflammation. The abrasion of the skin in the canal thus produced affords a favorable soil for the growth of vegetable parasites.

[Illustration: Fig. 143.--Diagram of the Middle and Internal Ear.]

This, in turn, may lead to a chronic inflammation of the canal and of the tympanic membrane. Again, there is always risk that the elbow may be jogged and the instrument pushed through the drum-head. There is, of course, a natural impulse to relieve the itching of the ear. This should be done with the tips of the fingers or not at all.

The popular notion that something should be put into the ear to cure toothache is erroneous. This treatment does not cure a toothache, and may lead to an injury to the delicate parts of the ear. A piece of absorbent cotton, carefully inserted into the ear, may be worn out of doors, when the cold air causes pain, but should be removed on coming into the house.

Frequent bathing in the cold water of ponds and rivers is liable to injure both the ears and the general health. In salt-water bathing, the force of the waves striking against the ears often leads to earache, long-continued inflammation, or defective hearing; to diminish this risk, insert into the ears a small plug of absorbent cotton.

The ears are often carelessly exposed to cold water and inclement weather. Very cold water should never be used to bathe the ears and nostrils. Bathe moderately and gently in lukewarm water, using a wash-rag in preference to a sponge; dry gently and thoroughly. Children's ears are often rudely washed, especially in the auditory canal. This is not at all necessary to cleanliness, and may result in a local inflammation.

Never shout suddenly in a person's ear. The ear is not prepared for the shock, and deafness has occasionally resulted. A sudden explosion, the noise of a cannon, may burst the drum-head, especially if the Eustachian tube be closed at the time. During heavy cannonading, soldiers are taught to keep the mouth open to allow an equal tension of air.

[Illustration: Fig. 144.--Section of Cochlea.

From A straight downwards is the direction of the central column, to which E points. B points to the projecting ridge, almost dividing the canal of the tube into an upper compartment (D), and a lower (C).]

Insects may gain entrance to the ears and occasion annoyance, pain, and fright, perhaps leading to vomiting, even to convulsions, with nervous children. A lighted lamp held at the entrance of the ear will often induce the offending insect to crawl out towards the light. A few drops of warm water, sweet oil, or molasses, dropped into the ear, will help remove the intruder.

When a discharge occurs from the ears, it is not best to plug them with cotton wads. It only keeps in what should be got rid of. Do not go to sleep with the head on a window sill or in any position, with the ears exposed to draughts of cold or damp air.

No effort should be made to remove the ear wax unless it accumulates unduly. The skin of the canal grows outward, and the extra wax and dust will be naturally carried out, if let alone. Never employ any of the many articles or "drops," advertised to cure deafness. Neuralgic pain in the canal, usually classed as earache, may be due to decayed or improperly filled teeth.

Quinine, so generally used in its many preparations for malaria, causes a peculiar ringing or buzzing in the ears. This is a warning that it should be taken in smaller doses, or perhaps stopped for a time. In some cases quinine may produce temporary deafness.

The practice of snuffing up cold water into the nostrils is occasionally followed by an acute inflammation of the middle ear, some of the water finding its way through the Eustachian tube into this part of the organ of hearing. The nasal douche, so often advised as a home remedy for nasal catarrh, should be used only with great caution, and always in accordance with detailed directions from a physician.

348. Effect of Tobacco upon the Hearing. The sense of hearing is often injured by the use of tobacco. The irritating smoke filling all the inner cavity of the mouth and throat, readily finds its way up the Eustachian tube, dries the membrane, and irritates or inflames the delicate mechanism of the inner ear. Thus may be produced a variety of

serious aural disturbances, such as unnatural noises, whistling, and roaring, followed oftentimes by a partial loss of hearing.

Hearing may be impaired by the use of alcoholic beverages. Alcohol inflames the mucous membrane of the throat, then by its nearness the lining of the Eustachian tube, and finally may injure the delicate apparatus of the internal ear.

Additional Experiments.

Experiment 162. Use a small pair of wooden compasses, or an ordinary pair of dividers with their points guarded by a small piece of cork. Apply the points of the compasses lightly and simultaneously to different parts of the body, and ascertain at what distance apart the points are felt as two. The following is the order of sensibility: tip of tongue, tip of the middle finger, palm, forehead, and back of hand.

Experiment 163. Test as in preceding experiment the skin of the arm, beginning at the shoulder and passing downwards. Observe that the sensibility is greater as one tests towards the fingers, and also in the transverse than in the long axis of the limb. In all cases compare the results obtained on both sides of the body.

Experiment 164. By means of a spray-producer, spray the back of the hand with ether, and observe how the sensibility is abolished.

Experiment 165. Touch your forehead with your forefinger; the finger appears to feel the contact, but on rubbing the forefinger rapidly over the forehead, it is the latter which is interpreted as "feeling" the finger.

Experiment 166. Generally speaking, the sensation of touch is referred to the cutaneous surfaces. In certain cases, however, it is referred even beyond this. Holding firmly in one hand a cane or a pencil, touch an object therewith; the sensation is referred to the extremity of the cane or pencil.

If, however, the cane or pencil be held loosely in one's hand, one experiences two sensations: one corresponding to the object touched, and the other due to the contact of the rod with the skin. The process of mastication affords a good example of the reference of sensations to and beyond the periphery of the body.

Experiment 167. Prepare a strong solution of sulphate of quinine with the aid of a little sulphuric acid to dissolve it (_bitter_), a five-per-cent solution of sugar (_sweet_), a ten-per-cent solution of common salt (_saline_), and a one-per-cent solution of acetic acid (_acid_). Wipe the tongue dry, and lay on its tip a crystal of sugar. It is not tasted until it is dissolved.

Experiment 168. Apply a crystal of sugar to the tip, and another to the back of the tongue. The sweet taste is more pronounced at the tip.

Experiment 169. Repeat the process with sulphate of quinine in solution. It is scarcely tasted on the tip, but is tasted immediately on the back part of the tongue. Test where salines and acids are tasted most acutely.

Experiment 170. _To illustrate the muscular sense_. Take two equal iron or lead weights; heat one and leave the other cold. The cold weight will feel the heavier.

Experiment 171. Place a thin disk of _cold_ lead, the size of a silver dollar, on the forehead of a person whose eyes are closed; remove the disk, and on the same spot place two warm disks of equal size. The person will judge the latter to be about the same weight, or lighter, than the single cold disk.

Experiment 172. Compare two similar wooden disks, and let the diameter of one be slightly greater than that of the other. Heat the smaller one to over 120 degrees F., and it will be judged heavier than the larger cold one.

Experiment 173. _To illustrate the influence of excitation of one sense organ on the other sense organs_. Small colored patches the shape and color of which are not distinctly visible may become so when a tuning-fork is kept vibrating near the ears. In other individuals the visual impressions are diminished by the same process.

On listening to the ticking of a watch, the ticking sounds feebler or louder on looking at a source of light through glasses of different colors.

If the finger be placed in cold or warm water the temperature appears to rise when a red glass is held in front of the eyes.

Experiment 174. _Formation of an inverted image on the retina_. Take a freshly removed ox-eye; dissect the sclerotic from that part of its posterior segment near the optic nerve. Roll up a piece of blackened paper in the form of a tube, black surface innermost, and place the eye in it with the cornea directed forward. Look at an object--_e.g._, a candle-flame--and observe the inverted image of the flame shining through the retina and choroid, and notice how the image moves when the candle is moved.

Experiment 175. Focus a candle-flame or other object on the ground-glass plate of an ordinary photographic camera, and observe the small inverted image.

Experiment 176. _To illustrate spherical aberration_. Make a pin-hole in a blackened piece of cardboard; look at a light placed at a greater distance than the normal distance of accommodation. One will see a radiate figure with four to eight radii. The figures obtained from opposite eyes will probably differ in shape.

Experiment 177. Hold a thin wooden rod or pencil about a foot from the eyes and look at a distant object. Note that the object appears double. Close the right eye; the left image disappears, and _vice versa_.

Experiment 178. _To show the movements of the iris_. It is an extremely beautiful experiment, and one that can easily be made. Look through a pin-hole in a card at a uniform white surface as the white shade of an ordinary reading-lamp. With the right eye look through the pin-hole, the left eye being closed. Note the size of the (slightly dull) circular visual field. Open the left eye, the field becomes brighter and smaller (contraction of pupil); close the left eye, after an appreciable time, the field (now slightly dull) is seen gradually to expand. One can thus see and observe the rate of movements of his own iris.

[Illustration: Fig. 145.]

Experiment 179. _To show the blind spot_. The left eye being shut, let the right eye be fixed upon the cross as in Fig. 145. When the book is held at arm's length, both cross and round spot will be visible; but if the book be brought to about 8 inches from the eye, the gaze being kept steadily upon the cross, the round spot will at first disappear, but as the book, is brought still nearer both cross and round spot will again be seen.

Experiment 180. _To illustrate the duration of retinal impressions_. On a circular white disk, about halfway between the center and circumference, fix a small, black, oblong disk, and rapidly rotate it by means of a rotating wheel. There appears a ring of gray on the black, showing that the impression on the retina lasts a certain time.

[Illustration: Fig. 146.--Optic Disks.

The disk A, having black and white sectors, when rotated rapidly gives an even gray tint as in B.]

Experiment 181. Mark off a round piece of cardboard into black and white sectors as in A (Fig. 146). Attach it so as to rotate it rapidly, as on a sewing machine. An even gray tint will be produced as in B.

Experiment 182._To illustrate imperfect visual judgments_. Make three round black dots, A, B, C, of the same size, in the same line, and let A and C be equidistant from B. Between A and B make several more dots of the same size. A and B will then appear to be farther apart than B and C.

```
  [Illustration:
    * * * * * *        *
    A       B        C
  ]
```

For the same reason, of two squares absolutely identical in size, one marked with alternately clear and dark cross-bands, and the other with alternately clear and dark upright markings, the former will appear broader and the latter higher than the other.

Experiment 183. Make on a white card two squares of equal size. Across the one draw _horizontal_ lines at equal distances, and in the other make similar _vertical_ lines. Hold them at some distance. The one with horizontal lines appears higher than it really is, while the one with vertical lines appears broader, i.e., both appear oblong.

Experiment 184. Look at the row of letters (S) and figures (8). To

```
  [Illustration:
    S S S S S S S S      8 8 8 8 8 8 8 8
  ]
```

some the upper halves of the letters and figures may appear to be of the same size as the lower halves, to others the lower halves may appear larger. Hold the figure upside down, and observe that there is a considerable difference between the two, the lower halves being considerably larger.

Experiment 185. _To illustrate imperfect visual judgment_. The length of a line appears to vary according to the angle and direction of certain other lines in relation to it (Fig. 147). The length of the two vertical lines is the same, yet B appears much longer than A.

[Illustration: Fig. 147.--To show False Estimate of Size.

```
         \   /
          \ /
    /|\    |
   / | \   |
     |     |
   A |   B |
     |     |
   \ | /   |
    \|/    |
          / \
         /   \
```
]

Experiment 186. In indirect vision the appreciation of direction is still more imperfect. While leaning on a large table, fix a point on the table, and then try to arrange three small pieces of colored paper in a straight line. Invariably, the papers, being at a distance from the fixation-point, and being seen by indirect vision, are arranged, not in a straight line, but in the arc of a circle with a long radius.

Chapter XII.

The Throat and the Voice.

349. The Throat. The throat is a double highway, as it were, through which the air we breathe traverses the larynx on its way to the lungs, and through which the food we swallow reaches the oesophagus on its passage to the stomach. It is, therefore, a very important region of the body, being concerned in the great acts of respiration and digestion.

The throat is enclosed and protected by various muscles and bony structures, along which run the great blood-vessels that supply the head, and the great nerve trunks that pass from the brain to the parts below.

We have already described the food passages (Chapter VI.) and the air passages (Chapter VIII.).

To get a correct idea of the throat we should look into the wide-open mouth of some friend. Depressing the tongue we can readily see the back wall of the pharynx, which is common to the two main avenues leading to the lungs and the stomach. Above, we notice the air passages, which lead to the posterior cavities of the nose. We have already described the hard palate, the soft palate, the uvula, and the tonsils (Fig. 46).

On looking directly beyond these organs, we see the beginning of the downward passage,--the pharynx. If now the tongue be forcibly drawn forward, a curved ridge may be seen behind it. This is the epiglottis, which, as we have already learned shuts down, like the lid of a box, over the top of the larynx (secs. 137 and 203).

The throat is lined with mucous membrane covered with ciliated epithelium, which secretes a lubricating fluid which keeps the parts moist and pliable. An excess of this secretion forms a thick, tenacious mass of mucus, which irritates the passages and gives rise to efforts of hawking and coughing to get rid of it.

350. The Larynx. The larynx, the essential organ of voice, forms the box-like top of the windpipe. It is built of variously shaped cartilages, connected by ligaments. It is clothed on the outside with muscles; on the inside it is lined with mucous membrane, continuous with that of the other air passages.

[Illustration: Fig. 148.--View of the Cartilages in front project and form the lages and Ligaments of the "Adam's apple," plainly seen and Larynx. (Anterior view.)

A, hyoid bone;
B, thyro-hyoid membrane;
C, thyroid cartilage;
D, erico-thyroid membrane;
E, cricoid cartilage, lateral ligaments seen on each side;
F, upper ring of the trachea.
("Adam's apple" is in the V-shaped groove on a line with B and C.)
]

The larynx has for a framework two cartilages, the thyroid and the cricoid, one above the other. The larger of these, called the thyroid, from a supposed resemblance to a shield, consists of two extended wings which join in front, but are separated by a wide interval behind. The united edges in front project and form the "Adam's apple" plainly seen and easily felt on most people, especially on very lean men.

Above and from the sides rise two horns connected by bands to the hyoid bone from which the larynx is suspended. This bone is attached by muscles and ligaments to the skull. It lies at the base of the tongue, and can be readily felt by the finger behind the chin at the angle of the jaw and the neck (sec. 41 and Fig. 46). From the under side of the thyroid two horns project downwards to become jointed to the cricoid. The thyroid thus rests upon, and is movable on, the cricoid cartilage.

The cricoid cartilage, so called from its fancied resemblance to a signet-ring, is smaller but thicker and stronger than the thyroid, and forms the lower and back part of the cavity of the larynx. This cartilage is quite sensitive to pressure from the fingers, and is the cause of the sharp pain felt when we try to swallow a large and hard piece of food not properly chewed.

[Illustration: Fig. 149.--Diagram of a Sectional of Nasal and Throat Passages.

C, nasal cavities;

T, tongue;
L, lower jaw;
M, mouth;
U, uvula;
E, epiglottis;
G, larynx;
O, oesophagus.
]

On the upper edge of the cricoid cartilage are perched a pair of very singular cartilages, pyramidal in shape, called the arytenoid, which are of great importance in the production of the voice. These cartilages are capped with little horn-like projections, and give attachment at their anterior angles to the true vocal cords, and at their posterior angles to the muscles which open and close the glottis, or upper opening of the windpipe. When in their natural position the arytenoid cartilages resemble somewhat the mouth of a pitcher, hence their name.

351. The Vocal Cords. The mucous membrane which lines the various cartilages of the larynx is thrown into several folds. Thus, one fold, the free edge of which is formed of a band of elastic fibers, passes horizontally outwards from each side towards the middle line, at the level of the base of the arytenoid cartilages. These folds are called the true vocal cords, by the movements of which the voice is produced.

Above them are other folds of mucous membrane called the false vocal cords, which take no part in the production of the voice. The arrangement of the true vocal cords, projecting as they do towards the middle line, reduces to a mere chink the space between the part of the larynx above them and the part below them. This constriction of the larynx is called the glottis.

[Illustration: Fig. 150.--View of the Cartilages and Ligaments of Larynx. (Posterior view.)

A, epiglottis;
B, thyroid cartilage;
C, arytenoid cartilage;
D, ligament connecting lower cornu of the thyroid with the back of the cricoid cartilage;
E, cricoid cartilage;
F, upper ring of the trachea.
]

352. The Mechanism of the Voice. The mechanism of the voice may be more easily understood by a study of Fig. 150. We have here the larynx, viewed from behind, with all the soft parts in connection with it. On looking down, the folds forming the true vocal cords are seen enclosing a V-shaped aperture (the glottis), the narrow part being in front.

The form of this aperture may be changed by the delicately coordinate activities of the muscles of the larynx. For instance, the vocal cords may be brought so closely together that the space becomes a mere slit. Air forced through the slit will throw the edges of the folds into vibration and a sound will be produced.

The Variations in the form of the opening will determine the variations in the sound. Now, if the various muscles of the larynx be relaxed, the opening of the glottis is wider. Thus the air enters and leaves the larynx during breathing, without throwing the cords into vibration enough to produce any sound.

We may say that the production of the voice is effected by an arrangement like that of some musical instruments, the sounds produced by the vibrations of the vocal cords being modified by the tubes above and below. All musical sounds are due to movements or vibrations occurring with a certain regularity, and they differ in loudness, pitch, and quality. Loudness of the sound depends upon the extent of the vibrations, pitch on the rapidity of the vibrations, and quality on the admixture of tones produced by vibrations of varying rates of rapidity, related to one another.

[Illustration: Fig. 151.--Longitudinal Section of the Larynx. (Showing the vocal cords.)

A, epiglottis;
B, section of hyoid bone;
C, superior vocal cord;
D, ventricle of the larynx;
E, inferior vocal cord;
F, section of the thyroid cartilage;
H, section of anterior portion of the cricoid cartilage;
K, trachea;
L, section of the posterior portion of the cricoid cartilage;
M, arytenoid cartilage;
N, section of the arytenoid muscle.
]

353. Factors in the Production of the Voice. Muscles which pass from the cricoid cartilage to the outer angle of the arytenoids act to bring the vocal cords close together, and parallel to one another, so that the space between them is narrowed to a slit. A strong expiration now drives the air from the lungs through the slit, between the cords, and throws them into vibration. The vibration is small in amount, but very rapid. Other muscles are connected with the arytenoid cartilages which serve to seperate the vocal cords and to widely open the glottis. The force of the outgoing current of air determines the extent of the movement of the cords, and thus the loudness of the sound will increase with greater force of expiration.

We have just learned that the pitch of sound depends on the rapidity of the vibrations. This depends on the length of cords and their tightness for the shorter and tighter a string is, the higher is the note which its vibration produces. The vocal cords of women are about one-third shorter than those of men, hence the higher pitch of the notes they produce. In children the vocal cords are shorter than in adults.[50] The cords of tenor singers are also shorter than those of basses and baritones. The muscles within the larynx, of course, play a very important part in altering the tension of the vocal cords. Those qualities of the voice which we speak of as sweet, harsh, and sympathetic depend to a great extent upon the peculiar structure of the vocal cords of the individual.

Besides the physical condition of the vocal cords, as their degree of smoothness, elasticity, thickness, and so on, other factors determine the quality of an individual's voice. Thus, the general shape and structure of the trachea, the larynx, the throat, and mouth all influence the quality of voice. In fact, the air passages, both below and above the vibrating cords, act as resonators, or resounding chambers, and intensify and modify the sounds produced by the cords. It is this fact that prompts skillful teachers of music and elocution to urge upon their pupils the necessity of the mouth being properly opened during speech, and especially during singing.

Experiment 187. _To show the anatomy of the throat_. Study the general construction of the throat by the help of a hand mirror. Repeat the same on the throat of some friend.

Experiment 188. _To show the construction of the vocal organs_. Get a butcher to furnish two windpipes from a sheep or a calf. They differ somewhat from the vocal organs of the human body, but will enable us to recognize the different parts which have been described, and thus to get a good idea of the gross anatomy.

One specimen should be cut open lengthwise in the middle line in front, and the other cut in the same way from behind.

354. Speech. Speech is to be distinguished from voice. It may exist without voice, as in a whisper. Speech consists of articulated sounds, produced by the action of various parts of the mouth, throat, and nose. Voice is common to most animals, but speech is the peculiar privilege of man.

[Illustration: Fig. 152.--Diagramatic Horizontal Section of Larynx to show the Direction of Pull of the Posterior Crico-Arytenoid Muscles, which abduct the Vocal Cords. (Dotted lines show position in abduction.)]

The organ of speech is perhaps the most delicate and perfect _motor_ apparatus in the whole body. It has been calculated that upwards of 900 movements per minute can be made by the movable organs of speech during reading, speaking, and singing. It is said that no less than a hundred different muscles are called into action in talking. Each part of this delicate apparatus is so admirably adjusted to every other that all parts of this most complex machinery act in perfect harmony.

There are certain articulate sounds called vowel or vocal, from the fact that they are produced by the vocal cords, and are but slightly modified as they pass out of the mouth. The true vowels, _a, e, i, o, u_, can all be sounded alone, and may be prolonged in expiration. These are the sounds chiefly used in singing. The differences in their characters are produced by changes in the position of the tongue, mouth, and lips.

Consonants are sounds produced by interruptions of the outgoing current of air, but in some cases have no sound in themselves, and serve merely to modify vowel sounds. Thus, when the interruption to the outgoing current takes place by movements of the lips, we have the _labial_ consonants, _p_, _b_, _f_, and _v_. When the tongue, in relation with the teeth or hard palate, obstructs the air, the _dental_ consonants, _d_, _t_, _l_, and _s_ are produced. _Gutturals_, such as _k_, _g_, _ch_, _gh_, and _r_, are due to the movements of the root of the tongue in connection with the soft palate or pharynx.

To secure an easy and proper production of articulate sounds, the mouth, teeth, lips, tongue, and palate should be in perfect order. The modifications in articulation occasioned by a defect in the palate, or in the uvula, by the loss of teeth, from disease, and from congenital defects, are sufficiently familiar. We have seen that speech consists essentially in a modification of the vocal sounds by the accessory organs, or by parts above the larynx, the latter being the essential vocal instrument.

Many animals have the power of making articulated sounds; a few have risen, like man, to the dignity of sentences, but these are only by imitation of the human voice. Both vowels and consonants can be distinguished in the notes of birds, the vocal powers of which are generally higher than those of mammals. The latter, as a rule, produce only vowels, though some are also able to form consonants.

Persons idiotic from birth are incapable of producing any other vocal sounds than inarticulate cries, although supplied with all the internal means of articulation. Persons deaf and dumb are in the same situation, though from a different cause; the one being incapable of imitating, and the other being deprived of hearing the sounds to be imitated.

[Illustration: Fig. 153.--Direction of Pull of the Lateral Crico-Arytenoids, which adduct the Vocal Cords. (Dotted lines show position in adduction.)]

In _whispering_, the larynx takes scarcely any part in the production of the sounds; the vocal cords remain apart and comparatively slack, and the expiratory blast rushes through without setting them in vibration.

In _stammering_, spasmodic contraction of the diaphragm interrupts the effort of expiration. The stammerer has full control of the mechanism of articulation, but not of the expiratory blast. His larynx and his lips are at his command, but not his diaphragm. To conquer this defect he must train his muscles of respiration to calm and steady action during speech. The _stutterer_, on the other hand, has full control of the muscles of expiration. His diaphragm is well drilled, but his lips and tongue are insubordinate.

355. The Care of the Throat and Voice. The throat, exposed as it is to unwholesome and overheated air, irritating dust of the street, factories, and workshops, is often inflamed, resulting in that common ailment, _sore throat_. The parts are red, swollen, and quite painful on swallowing. Speech is often indistinct, but there is no hoarseness or cough unless the uvula is lengthened and tickles the back part of the tongue. Slight sore throat rarely requires any special treatment, aside from simple nursing.

The most frequent cause of throat trouble is the action of cold upon the heated body, especially during active perspiration. For this reason a cold bath should not be taken while a person is perspiring freely. The muscles of the throat are frequently overstrained by loud talking, screaming, shouting, or by reading aloud too much. People who strain or misuse the voice often suffer from what is called "clergyman's sore throat." Attacks of sore throat due to improper methods of breathing and of using the voice should be treated by judicious elocutionary exercises and a system of vocal gymnastics, under the direction of proper teachers.

Persons subject to throat disease should take special care to wear suitable underclothing, adapted to the changes of the seasons. Frequent baths are excellent tonics to the skin, and serve indirectly to protect one liable to throat ailments from changes in the weather. It is not prudent to muffle the neck in scarfs, furs, and wraps, unless perhaps during an unusual exposure to cold. Such a dress for the neck only makes the parts tender, and increases the liability to a sore throat.

Every teacher of elocution or of vocal music, entrusted with the training of a voice of some value to its possessor, should have a good, practical knowledge of the mechanism of the voice. Good voices are often injured by injudicious management on the part of some incompetent instructor. It is always prudent to cease speaking or singing in public the moment there is any hoarseness or sore throat.

The voice should not be exercised just after a full meal, for a full stomach interferes with the free play of the diaphragm. A sip of water taken at convenient intervals, and held in the mouth for a moment or two, will relieve the dryness of the throat during the use of the voice.

356. Effect of Alcohol upon the Throat and Voice. Alcoholic beverages seriously injure the throat, and consequently the voice, by causing a chronic inflammation of the membrane lining the larynx and the vocal cords. The color is changed from the healthful pink to red, and the natural smooth surface becomes roughened and swollen, and secretes a tough phlegm.

The vocal cords usually suffer from this condition. They are thickened, roughened, and enfeebled, the delicate vibration of the cords is impaired, the clearness and purity of the vocal tones are gone, and instead the voice has become rough and husky. So well known is this result that vocalists, whose fortune is the purity and compass of their tones, are scrupulously careful not to impair these fine qualities by convivial indulgences.

357. Effect of Tobacco upon the Throat and Voice. The effect of tobacco is often specially serious upon the throat, producing a disease well known to physicians as "the smoker's sore throat." Still further, it produces inflammation of the larynx, and thus entails disorders of the vocal cords, involving rough voice and harsh tones. For this reason vocalists rarely allow themselves to come under the narcotic influence of tobacco smoke. It is stated that habitual smokers rarely have a normal condition of the throat.

Additional Experiments.

Experiment 189. _To illustrate the importance of the resonating cavity of the nose in articulation_. Pinch the nostrils, and try to pronounce slowly the words "Lincoln," "something," or any other words which require the sound of _m_, _ln_, or _ng_.

[Illustration: Fig. 154.]

Experiment 190. _To illustrate the passage of air through the glottis._ Take two strips of India rubber, and stretch them over the open end of a boy's "bean-blower," or any kind of a tube. Tie them tightly with thread, so that a chink will be left between them, as shown in Fig. 154. Force the air through such a tube by blowing hard, and if the strips are not too far apart a sound will be produced. The sound will vary in character, just as the bands are made tight or loose.

Experiment 191. "A very good illustration of the action of the vocal bands in the production of the voice may be given by means of a piece of bamboo or any hollow wooden tube, and a strip of rubber, about an inch or an inch and a half wide, cut from the pure sheet rubber used by dentists.

"One end of the tube is to be cut sloping in two directions, and the strip of sheet rubber is then to be wrapped round the tube, so as to leave a narrow slit terminating at the upper corners of the tube.

"By blowing into the other end of the tube the edges of the rubber bands will be set in vibration, and by touching the vibrating membrane at different points so as to check its movements it may be shown that the pitch of the note emitted depends upon the length and breadth of the vibrating portion of the vocal bands."[51]--Dr. H. P. Bowditch.

[NOTE. The limitations of a text-book on physiology for schools do not permit so full a description of the voice as the subject deserves. For additional details, the student is referred to Cohen's _The Throat and the Voice_, a volume in the "American Health Primer Series." Price 40 cents.]

Chapter XIII.

Accidents and Emergencies.

358. Prompt Aid to the Injured. A large proportion of the accidents, emergencies, and sudden sicknesses that happen do not call for medical or surgical attention. For those that do require the services of a physician or surgeon, much can be often done before the arrival of professional help. Many a life has been saved and much suffering and anxiety prevented by the prompt and efficient help of some person with a cool head, a steady hand, and a practical knowledge of what to do first. Many of us can recall with mingled admiration and gratitude the prompt services rendered our families by some neighbor or friend in the presence of an emergency or sudden illness.

In fact, what we have studied in the preceding chapters becomes tenfold more interesting, instructive, and of value to us, if we are able to supplement such study with its practical application to the treatment of the more common and less serious accidents and emergencies.

While no book can teach one to have presence of mind, a cool head, or to restrain a more or less excitable temperament in the midst of sudden danger, yet assuredly with proper knowledge for a foundation, a certain self-confidence may be acquired which will do much to prevent hasty action, and to maintain a useful amount of self-control.

Space allows us to describe briefly in this chapter only a few of the simplest helps in the more common accidents and emergencies which are met with in everyday life.[52]

359. Hints as to what to Do First. Retain so far as possible your presence of mind, or, in other words, keep cool. This is an all-important direction. Act promptly and quietly, but not with haste. Whatever you do,

do in earnest; and never act in a half-hearted manner in the presence of danger. Of course, a knowledge of what to-do and how to do it will contribute much towards that self-control and confidence that command success. Be sure and send for a doctor at once if the emergency calls for skilled service. All that is expected of you under such circumstances is to tide over matters until the doctor comes.

[Illustration: Fig. 155.--Showing how Digital Compression should be applied to the Brachial Artery.]

Do not presume upon any smattering of knowledge you have, to assume any risk that might lead to serious results. Make the sufferer comfortable by giving him an abundance of fresh air and placing him in a restful position. Do all that is possible to keep back the crowd of curious lookers-on, whom a morbid curiosity has gathered about the injured person. Loosen all tight articles of clothing, as belts, collars, corsets, and elastics. Avoid the use of alcoholic liquors. They are rarely of any real service, and in many instances, as in bleeding, may do much harm.

360. Incised and Lacerated Wounds. An incised or cut wound is one made by a sharp instrument, as when the finger is cut with a knife. Such a wound bleeds freely because the clean-cut edges do not favor the clotting of blood. In slight cuts the bleeding readily ceases, and the wound heals by primary union, or by "first intention," as surgeons call it.

Lacerated and contused wounds are made by a tearing or bruising instrument, for example, catching the finger on a nail. Such wounds bleed but little, and the edges and surfaces are rough and ragged.

If the incised wound is deep or extensive, a physician is necessary to bring the cut edges together by stitches in order to get primary union. Oftentimes, in severe cuts, and generally in lacerations, there is a loss of tissue, so that the wound heals by "second intention"; that is, the wound heals from the bottom by a deposit of new cells called _granulations_, which gradually fill it up. The skin begins to grow from the edges to the center, covering the new tissue and leaving a cicatrix or scar with which every one is familiar.

361. Contusion and Bruises. An injury to the soft tissues, caused by a blow from some blunt instrument, or a fall, is a contusion, or bruise. It is more or less painful, followed by discoloration due to the escape of blood under the skin, which often may not be torn through. A black eye, a knee injured by a fall from a bicycle, and a finger hurt by a baseball, are familiar examples of this sort of injury. Such injuries ordinarily require very simple treatment.

The blood which has escaped from the capillaries is slowly absorbed, changing color in the process, from blue black to green, and fading into a light yellow. Wring out old towels or pieces of flannel in hot water, and apply to the parts, changing as they become cool. For cold applications, cloths wet with equal parts of water and alcohol, vinegar, and witch-hazel may be used. Even if the injury is apparently slight it is always safe to rest the parts for a few days.

When wounds are made with ragged edges, such as those made by broken glass and splinters, more skill is called for. Remove every bit of foreign substance. Wash the parts clean with one of the many antiseptic solutions, bring the torn edges together, and hold them in place with strips of plaster. Do not cover such an injury all over with plaster, but leave room for the escape of the wound discharges. For an outside dressing, use compresses made of clean cheese-cloth or strips of any clean linen cloth. The antiseptic _corrosive-sublimate gauze_ on sale at any drug store should be used if it can be had.

Wounds made by toy pistols, percussion-caps, and rusty nails and tools, if neglected, often lead to serious results from blood-poisoning. A hot flaxseed poultice may be needed for several days. Keep such wounds clean by washing or syringing them twice a day with hot _antiseptics_, which are poisons to _bacteria_ and kill them or prevent their growth. Bacteria are widely distributed, and hence the utmost care should be taken to have everything which is to come in contact with a wounded surface free from the germs of inflammation. In brief, such injuries must be kept _scrupulously neat_ and _surgically clean_.

[Illustration: Fig. 156.--Dotted Line showing the Course of the Brachial Artery.]

The injured parts should be kept at rest. Movement and disturbance hinder the healing process.

362. Bites of Mad Dogs. Remove the clothing at once, if only from the bitten part, and apply a temporary ligature _above_ the wound. This interrupts the activity of the circulation of the part, and to that extent delays the absorption of the poisonous saliva by the blood-vessels of the wound. A dog bite is really a lacerated and contused wound, and lying in the little roughnesses, and between the shreds, is the poisonous saliva. If by any means these projections and depressions affording the lodgment can be removed, the poison cannot do much harm. If done with a knife, the wound would be converted, practically, into an incised wound, and would require treatment for such.

If a surgeon is at hand he would probably cut out the injured portion, or cauterize it thoroughly. Professional aid is not always at our command, and in such a case it would be well to take a poker, or other suitable piece of iron, heat it _red_ hot in the fire, wipe off and destroy the entire surface of the wound. As fast as destroyed, the tissue becomes white. An iron, even at a white heat, gives less pain and at once destroys the vitality of the part with which it comes in contact.

If the wound is at once well wiped out, and a stick of solid nitrate of silver (lunar caustic) rapidly applied to the entire surface of the wound, little danger is to be apprehended. Poultices and warm fomentations should be applied to the injury to hasten the sloughing away of the part whose vitality has been intentionally destroyed.

Any dog, after having bitten a person, is apt, under a mistaken belief, to be at once killed. This should not be done. There is no more danger from a dog-bite, unless the dog is suffering from the disease called _rabies_ or is "mad," than from any other lacerated wound. The suspected animal should be at once placed in confinement and watched, under proper safeguards, for the appearance of any symptoms that indicate rabies.

Should no pronounced symptoms indicate this disease in the dog, a great deal of unnecessary mental distress and worry can be saved both on the part of the person bitten and his friends.

363. Injuries to the Blood-vessels. It is very important to know the difference between the bleeding from an artery and that from a vein.

If an artery bleeds, the blood leaps in spurts, and is of a bright scarlet color.

If a vein bleeds, the blood flows in a steady stream, and is of a dark purple color.

If the capillaries are injured the blood merely oozes.

Bleeding from an artery is a dangerous matter in proportion to the size of the vessel, and life itself may be speedily lost. Hemorrhage from a vein or from the capillaries is rarely troublesome, and is ordinarily easily checked, aided, if need be, by hot water, deep pressure, the application of some form of iron styptic, or even powdered alum. When an artery is bleeding, always remember to make deep pressure between the wound and the heart. In all such cases send at once for the doctor.

[Illustration: Fig. 157.--Showing how Digital Compression should be applied to the Femoral Artery.]

Do not be afraid to act at once. A resolute grip in the right place with firm fingers will do well enough, until a twisted handkerchief, stout cord, shoestring, suspender, or an improvised tourniquet[53] is ready to take its place. If the flow of blood does not stop, change the pressure until the right spot is found.

Sometimes it will do to seize a handful of dry earth and crowd it down into the bleeding wound, with a firm pressure. Strips of an old handkerchief, underclothing, or cotton wadding may also be used as a compress, provided pressure is not neglected.

In the after-treatment it is of great importance that the wound and the dressing should be kept free from bacteria by keeping everything surgically clean.

364. Where and how to Apply Pressure. The principal places in which to apply pressure when arteries are injured and bleeding should always be kept in mind.

Experiment 192. _How to tie a square knot_. If the student would render efficient help in accidents and emergencies, to say nothing of service on scores of other occasions, he must learn how to tie a square or "reef" knot. This knot is secure and does not slip as does the "granny" knot. The square knot is the one used by surgeons in ligating vessels and securing bandages. Unless one knew the difference, the insecure "granny" knot might be substituted.

[Illustration: Fig. 158.--Showing how a Square Knot may be tied with a Cord and a Handkerchief.]

A square knot is tied by holding an end of a bandage or cord in each hand, and then passing the end in the _right_ hand over the one in the left and tying; the end now in the _left_ hand is passed over the one in the right and again tied.

If in the finger, grasp it with the thumb and forefinger, and pinch it firmly on each side; if in the hand, press on the bleeding spot, or press with the thumb just above and in front of the wrist.

For injuries below the elbow, grasp the upper part of the arm with the hands, and squeeze hard. The main artery runs in the middle line of the bend of the elbow. Tie the knotted cord here, and bend the forearm so as to press hard against the knot.

For the upper arm, press with the fingers against the bone on the inner side, and just on the edge of the swell of the biceps muscle. Now we are ready for the knotted cord. Take a stout stick of wood, about a foot long, and twist the cord hard with it, bringing the knot firmly over the artery.

For the foot or leg, pressure as before, in the hollow behind the knee, just above the calf of the leg. Bend the thigh towards the abdomen and bring the leg up against the thigh, with the knot in the bend of the knee.

365. Bleeding from the Stomach and Lungs. Blood that comes from the lungs is bright red, frothy, or "soapy." There is rarely much; it usually follows coughing, feels warm, and has a salty taste. This is a grave symptom. Perfect rest on the back in bed and quiet must be insisted upon. Bits of ice should be eaten freely. Loosen the clothing, keep the shoulders well raised, and the body in a reclining position and absolutely at rest. Do not give alcoholic drinks.

Blood from the stomach is not frothy, has a sour taste, and is usually dark colored, looking somewhat like coffee grounds. It is more in quantity than from the lungs, and is apt to be mixed with food. Employ the same treatment, except that the person should be kept flat on the back.

366. Bleeding from the Nose. This is the most frequent and the least dangerous of the various forms of bleeding. Let the patient sit upright; leaning forward with the head low only increases the hemorrhage. Raise the arm on the bleeding side; do not blow the nose. Wring two towels out of cold water; wrap one around the neck and the other properly folded over the forehead and upper part of the nose.

Add a teaspoonful of powdered _alum_ to a cup of water, and snuff it up from the hand. If necessary, soak in alum water a piece of absorbent cotton, which has been wound around the pointed end of a pencil or penholder; plug the nostril by pushing it up with a twisting motion until firmly lodged.

367. Burns or Scalds. Burns or scalds are dangerous in proportion to their extent and depth. A child may have one of his fingers burned off with less danger to life than an extensive scald of his back and legs. A deep or extensive burn or scald should always have prompt medical attendance.

In burns by acids, bathe the parts with an alkaline fluid, as diluted ammonia, or strong soda in solution, and afterwards dress the burn.

In burns caused by lime, caustic potash, and other alkalies, soak the parts with vinegar diluted with water; lemon juice, or any other diluted acid.

Remove the clothing with the greatest care. Do not pull, but carefully cut and coax the clothes away from the burned places. Save the skin unbroken if possible, taking care not to break the blisters. The secret of treatment is to prevent friction, and to keep out the air. If the burn is slight, put on strips of soft linen soaked in a strong solution of baking-soda and water, one heaping table spoonful to a cupful of water. This is especially good for scalds.

[Illustration: Fig. 159.--Dotted Line showing the Course of the Femoral Artery.]

Carron oil is one of the best applications. It is simply half linseed-oil and half lime-water shaken together. A few tablespoonfuls of carbolic acid solution to one pint may be added to this mixture to help deaden the pain. Soak strips of old linen or absorbent cotton in this time-honored remedy, and gently apply.

If carbolized or even plain _vaseline_ is at hand, spread it freely on strips of old linen, and cover well the burnt parts, keeping out the air with other strips carefully laid on. Simple cold water is better than flour, starch, toilet powder, cotton batting, and other things which are apt to stick, and make an after-examination very painful.

[Illustration: Fig. 160.--Showing how Hemorrhage from the Femoral Artery may be arrested by the Use of an Improvised Apparatus (technically called a _Tourniquet_).]

368. Frost Bites. The ears, toes, nose, and fingers are occasionally frozen, or frost-bitten. No warm air, warm water, or fire should be allowed near the frozen parts until the natural temperature is nearly restored. Rub the frozen part vigorously with snow or snow-water in a cold room. Continue this until a burning, tingling pain is felt, when all active treatment should cease.

Pain shows that warmth and circulation are beginning to return. The after effects of a frost bite are precisely like those of a burn, and require similar treatment. Poultices made from scraped raw potatoes afford much comfort for an after treatment.

369. Catching the Clothing on Fire. When the clothing catches fire, throw the person down on the ground or floor, as the flames will tend less to rise toward the mouth and nostrils. Then without a moment's delay, roll the person in a carpet or hearth-rug, so as to stifle the flames, leaving only the head out for breathing.

If no carpet or rug can be had, then take off your coat, shawl, or cloak and use it instead. Keep the flame as much as possible from the face, so as to prevent the entrance of the hot air into the lungs. This can be done by beginning at the neck and shoulders with the wrapping.

370. Foreign Bodies in the Throat. Bits of food or other small objects sometimes get lodged in the throat, and are easily extracted by the forefinger, by sharp slaps on the back, or expelled by vomiting. If it

is a sliver from a toothpick, match, or fishbone, it is no easy matter to remove it; for it generally sticks into the lining of the passage. If the object has actually passed into the windpipe, and is followed by sudden fits of spasmodic coughing, with a dusky hue to the face and fingers, surgical help must be called without delay.

If a foreign body, like coins, pencils, keys, fruit-stones, etc., is swallowed, it is not wise to give a physic. Give plenty of hard-boiled eggs, cheese, and crackers, so that the intruding substance maybe enfolded in a mass of solid food and allowed to pass off in the natural way.

371. Foreign Bodies in the Nose. Children are apt to push beans, peas, fruit-stones, buttons, and other small objects, into the nose. Sometimes we can get the child to help by blowing the nose hard. At other times, a sharp blow between the shoulders will cause the substance to fall out. If it is a pea or bean, which is apt to swell with the warmth and moisture, call in medical help at once.

372. Foreign Bodies in the Ear. It is a much more difficult matter to get foreign bodies out of the ear than from the nose. Syringe in a little warm water, which will often wash out the substance. If live insects get into the ear, drop in a little sweet oil, melted vaseline, salt and water, or even warm molasses.

If the tip of the ear is pulled up gently, the liquid will flow in more readily. If a light is held close to the outside ear, the insect may be coaxed to crawl out towards the outer opening of the ear, being attracted by the bright flame.

373. Foreign Bodies in the Eye. Cinders, particles of dust, and other small substances, often get into the eye, and cause much pain. It will only make bad matters worse to rub the eye. Often the copious flow of tears will wash the substance away. It is sometimes seen, and removed simply by the twisted corner of a handkerchief carefully used. If it is not removed, or even found, in this way, the upper lid must be turned back.

[Illustration: Fig. 161.--Showing how the Upper Eyelid may be everted with a Pencil or Penholder.]

This is done usually as follows: Seize the lashes between the thumb and forefinger, and draw the edge of the lid away from the eyeball. Now, telling the patient to look down, press a slender lead-pencil or penholder against the lid, parallel to and above the edge, and then pull the edge up, and turn it over the pencil by means of the lashes.

The eye is now readily examined, and usually the foreign body is easily seen and removed. Do not increase the trouble by rubbing the eye after you fail, but get at once skilled help. After the substance has been removed, bathe the eye for a time with hot water.

If lime gets into the eye, it may do a great amount of mischief, and generally requires medical advice, or permanent injury will result. Until such advice can be had, bathe the injured parts freely with a weak solution of vinegar and hot water.

374. Broken Bones. Loss of power, pain, and swelling are symptoms of

a broken bone that may be easily recognized. Broken limbs should always be handled with great care and tenderness. If the accident happens in the woods, the limb should be bound with handkerchiefs, suspenders, or strips of clothing, to a piece of board, pasteboard, or bark, padded with moss or grass, which will do well enough for a temporary splint. Always put a broken arm into a sling after the splints are on.

[Illustration: Fig. 162.--Showing how an Umbrella may be used as a Temporary Splint in Fracture of the Leg.]

Never move the injured person until the limb is made safe from further injuries by putting on temporary splints. If you do not need to move the person, keep the limb in a natural, easy position, until the doctor comes.

Remember that this treatment for broken bones is only to enable the patient to be moved without further injury. A surgeon is needed at once to set the broken bone.

[Illustration: Fig. 163.--Showing how a Pillow may be used as a Temporary Splint in Fracture of the Leg.]

375. Fainting. A fainting person should be laid flat at once. Give plenty of fresh air, and dash cold water, if necessary, on the head and neck. Loosen all tight clothing. Smelling-salts may be held to the nose, to excite the nerves of sensation.

376. Epileptic and Hysterical Fits, Convulsions of Children. Sufferers from "fits" are more or less common. In _epilepsy_, the sufferer falls with a peculiar cry; a loss of consciousness, a moment of rigidity, and violent convulsions follow. There is foaming at the mouth, the eyes are rolled up, and the tongue or lips are often bitten. When the fit is over the patient remains in a dazed, stupid state for some time. It is a mistake to struggle with such patients, or to hold them down and keep them quiet. It does more harm than good.

See that the person does not injure himself; crowd a pad made from a folded handkerchief or towel between the teeth, to prevent biting of the lips or tongue. Do not try to make the sufferer swallow any drink. Unfasten the clothes, especially about the neck and chest. Persons who are subject to such fits should rarely go out alone, and never into crowded or excited gatherings of any kind.

Hysterical fits almost always occur in young women. Such patients never bite their tongue nor hurt themselves. Placing a towel wrung out in cold water across the face, or dashing a little cold water on the face or neck, will usually cut short the fit, speaking firmly to the patient at the same time. Never sympathize too much with such patients; it will only make them a great deal worse.

377. Asphyxia. Asphyxia is from the Greek, and means an "absence of pulse." This states a fact, but not the cause. The word is now commonly used to mean _suspended animation_. When for any reason the proper supply of oxygen is cut off, the tissues rapidly load up with carbon dioxid. The blood turns dark, and does not circulate. The healthy red or pink look of the lips and finger-nails becomes a dusky purple. The person is suffering from a lack of oxygen; that is, from asphyxia, or suffocation.
It is evident there can be several varieties of asphyxia, as in apparent drowning, strangulation and hanging, inhalation of gases, etc.

The first and essential thing to do is to give fresh air. Remove the person to the open air and place him on his back. Remove tight clothing about the throat and waist, dash on cold water, give a few drops of ammonia in hot water or hot ginger tea. Friction applied to the limbs should be kept up. If necessary, use artificial respiration by the Sylvester method (sec. 380).

The chief dangers from poisoning by noxious gases come from the fumes of burning coal in the furnace, stove, or range; from "blowing out" gas, turning it down, and having it blown out by a draught; from the foul air often found in old wells; from the fumes of charcoal and the foul air of mines.

378. Apparent Drowning. Remove all tight clothing from the neck, chest, and waist. Sweep the forefinger, covered with a handkerchief or towel, round the mouth, to free it from froth and mucus. Turn the body on the face, raising it a little, with the hands under the hips, to allow any water to run out from the air passages. Take only a moment for this.

Lay the person flat upon the back, with a folded coat, or pad of any kind, to keep the shoulders raised a little. Remove all the wet, clinging clothing that is convenient. If in a room or sheltered place, strip the body, and wrap it in blankets, overcoats, etc. If at hand, use bottles of hot water, hot flats, or bags of hot sand round the limbs and feet. Watch the tongue: it generally tends to slip back, and to shut off the air from the glottis. Wrap a coarse towel round the tip of the tongue, and keep it well pulled forward.

The main thing to do is to keep up artificial respiration until the natural breathing comes, or all hope is lost. This is the simplest way to do it: The person lies on the back; let some one kneel behind the head. Grasp both arms near the elbows, and sweep them upward above the head until they nearly touch. Make a firm pull for a moment. This tends to fill the lungs with air by drawing the ribs up, and making the chest cavity larger. Now return the arms to the sides of the body until they press hard against the ribs. This tends to force out the air. This makes artificially a complete act of respiration. Repeat this act about fifteen times every minute.

[Illustration: Fig. 164.--The Sylvester Method. (First movement--inspiration.)]

All this may be kept up for several hours. The first sign of recovery is often seen in the slight pinkish tinge of the lips or finger-nails. That the pulse cannot be felt at the wrist is of little value in itself as a sign of death. Life may be present when only the most experienced ear can detect the faintest heart-beat.

When a person can breathe, even a little, he can swallow. Hold smelling-salts or hartshorn to the nose. Put one teaspoonful of the aromatic spirits of ammonia, or even of ammonia water, into a half-glass of hot water, and give a few teaspoonfuls of this mixture every few minutes. Meanwhile do not fail to keep up artificial warmth in the most vigorous manner.

379. Methods of Artificial Respiration. There are several well-established methods of artificial respiration. The two known as the Sylvester and the Marshall Hall methods are generally accepted

as efficient and practical.

[Illustration: Fig. 165.--The Sylvester Method. (Second movement--expiration.)]

380. The Sylvester Method. The water and mucus are supposed to have been removed from the interior of the body by the means above described (sec. 378).

The patient is to be placed on his back, with a roll made of a coat or a shawl under the shoulders; the tongue should then be drawn forward and retained by a handkerchief which is placed across the extended organ and carried under the chin, then crossed and tied at the back of the neck. An elastic band or small rubber tube or a suspender may be used for the same purpose.

The attendant should kneel at the head and grasp the elbows of the patient and draw them upward until the hands are carried above the head and kept in this position until one, two, three, can be slowly counted. This movement elevates the ribs, expands the chest, and creates a vacuum in the lungs into which the air rushes, or in other words, the movement produces _inspiration_. The elbows are then slowly carried downward, placed by the side, and pressed inward against the chest, thereby diminishing the size of the latter and producing _expiration_.

These movements should be repeated about fifteen times each minute for at least two hours, provided no signs of animation show themselves.

381. The Marshall Hall Method. The patient should be placed face downwards, the head resting on the forearm with a roll or pillow placed under the chest; he should then be turned on his side, an assistant supporting the head and keeping the mouth open; after an interval of two or three seconds, the patient should again be placed face downward and allowed to remain in this position the same length of time. This operation should be repeated fifteen or sixteen times each minute, and continued (unless the patient recovers) for at least two hours.

[Illustration: Fig. 166.--The Marshall Hall Method. (First position.)]

If, after using one of the above methods, evidence of recovery appears, such as an occasional gasp or muscular movement, the efforts to produce artificial respiration must not be discontinued, but kept up until respiration is fully established. All wet clothing should then be removed, the patient rubbed dry, and if possible placed in bed, where warmth and warm drinks can be properly administered. A small amount of nourishment, in the form of hot milk or beef tea, should be given, and the patient kept quiet for two or three days.

[Illustration: Fig. 167.--The Marshall Hall Method. (Second position.)]

382. Sunstroke or Heatstroke. This serious accident, so far-reaching oftentimes in its result, is due to an unnatural elevation of the bodily temperature by exposure to the direct rays of the sun, or from the extreme heat of close and confined rooms, as in the cook-rooms and laundries of hotel basements, from overheated workshops, etc.

There is sudden loss of consciousness, with deep, labored breathing, an intense burning heat of the skin, and a marked absence of sweat. The main thing is to lower the temperature. Strip off the clothing; apply chopped ice, wrapped in flannel to the head. Rub ice over the chest, and place pieces under the armpits and at the sides. If there is no ice, use sheets or cloths wet with cold water. The body may be stripped, and sprinkled with ice-water from a common watering-pot.

If the skin is cold, moist, or clammy, the trouble is due to heat exhaustion. Give plenty of fresh air, but apply no cold to the body. Apply heat, and give hot drinks, like hot ginger tea. Sunstroke or heatstroke is a dangerous affliction. It is often followed by serious and permanent results. Persons who have once suffered in this way should carefully avoid any risk in the future.

Chapter XIV.

In Sickness and in Health.

383. Arrangement of the Sick-room. This room, if possible, should be on the quiet and sunny side of the house. Pure, fresh air, sunshine, and freedom from noise and odor are almost indispensable. A fireplace as a means of ventilation is invaluable. The bed should be so placed that the air may get to it on all sides and the nurse move easily around it. Screens should be placed, if necessary, so as to exclude superfluous light and draughts.

The sick-room should be kept free from all odors which affect the sick unpleasantly, as perfumery, highly scented soaps, and certain flowers. Remove all useless ornaments and articles likely to collect dust, as unnecessary pieces of furniture and heavy draperies. A clean floor, with a few rugs to deaden the footsteps, is much better than a woolen carpet. Rocking-chairs should be banished from the sick-room, as they are almost sure to disturb the sick.

A daily supply of fresh flowers tends to brighten the room. Keep the medicines close at hand, but all poisonous drugs should be kept carefully by themselves and ordinarily under lock and key. A small table should be placed at the bedside, and on it the bell, food tray, flowers and other small things which promote the comfort of the patient.

The nurse should not sleep with the patient. Sofas and couches are not commonly comfortable enough to secure needed rest. A cot bed is at once convenient and inexpensive, and can be readily folded and put out of sight in the daytime. It can also be used by the patient occasionally, especially during convalescence.

384. Ventilation of the Sick-room. Proper ventilation is most essential to the sick-room, but little provision is ordinarily made for so important a matter. It is seldom that one of the windows cannot be let down an inch or more at the top, a screen being arranged to avoid any draught on the patient. Remove all odors by ventilation and not by spraying perfumery, or burning pastilles, which merely conceal offensive odors without purifying the air. During cold weather and in certain diseases, the patient may be covered entirely with blankets and the windows opened wide for a few minutes.

Avoid ventilation by means of doors, for the stale air of the house, kitchen smells, and noises made by the occupants of the house, are apt to reach the sick-room. The entire air of the room should be changed at least two or three times a day, in addition to the introduction of a constant supply of fresh air in small quantities.

385. Hints for the Sick-room. Always strive to look cheerful and pleasant before the patient. Whatever may happen, do not appear to be annoyed, discouraged, or despondent. Do your best to keep up the courage of sick persons under all circumstances. In all things keep in constant mind the comfort and ease of the patient.

Do not worry the sick with unnecessary questions, idle talk, or silly gossip. It is cruel to whisper in the sick-room, for patients are always annoyed by it. They are usually suspicious that something is wrong and generally imagine that their condition has changed for the worse.

Symptoms of the disease should never be discussed before the patient, especially if he is thought to be asleep. He may be only dozing, and any such talk would then be gross cruelty. Loud talking must, of course, be avoided. The directions of the physician must be rigidly carried out in regard to visitors in the sick-room. This is always a matter of foremost importance, for an hour or even a night of needed sleep and rest may be lost from the untimely call of some thoughtless visitor. A competent nurse, who has good sense and tact, should be able to relieve the family of any embarrassment under such circumstances.

Do not ever allow a kerosene light with the flame turned down to remain in the sick-room. Use the lamp with the flame carefully shaded, or in an adjoining room, or better still, use a sperm candle for a night light.

Keep, so far as possible, the various bottles of medicine, spoons, glasses, and so on in an adjoining room, rather than to make a formidable array of them on a bureau or table near the sick-bed. A few simple things, as an orange, a tiny bouquet, one or two playthings, or even a pretty book, may well take their place.

The ideal bed is single, made of iron or brass, and provided with woven wire springs and a hair mattress. Feather-beds are always objectionable in the sick-room for many and obvious reasons. The proper making of a sick-bed, with the forethought and skill demanded in certain diseases, is of great importance and an art learned only after long experience. The same principle obtains in all that concerns the lifting and the moving of the sick.

Sick people take great comfort in the use of fresh linen and fresh pillows. Two sets should be used, letting one be aired while the other is in use. In making changes the fresh linen should be thoroughly aired and warmed and everything in readiness before the patient is disturbed.

386. Rules for Sick-room. Do not deceive sick people. Tell what is proper or safe to be told, promptly and plainly. If a physician is employed, carry out his orders to the very letter, as long as he visits you. Make on a slip of paper a note of his directions. Make a brief record of exactly what to do, the precise time of giving medicines, etc. This should always be done in serious cases, and by night watchers. Then there is no guesswork. You have the record before you for easy reference. All

such things are valuable helps to the doctor.

Whatever must be said in the sick-room, say it openly and aloud. How often a sudden turn in bed, or a quick glance of inquiry, shows that whispering is doing harm! If the patient is in his right mind, answer his questions plainly and squarely. It may not be best to tell all the truth, but nothing is gained in trying to avoid a straightforward reply.

Noises that are liable to disturb the patient, in other parts of the house than the sick-room, should be avoided. Sounds of a startling character, especially those not easily explained, as the rattling or slamming of distant blinds and doors, are always irritating to the sick.

Always attract the attention of a patient before addressing him, otherwise he may be startled and a nervous spell be induced. The same hint applies equally to leaning or sitting upon the sick-bed, or running against furniture in moving about the sick-room.

387. Rest of Mind and Body. The great importance of rest for the sick is not so generally recognized as its value warrants. If it is worry and not work that breaks down the mental and physical health of the well, how much more important is it that the minds and bodies of the sick should be kept at rest, free from worry and excitement! Hence the skilled nurse does her best to aid in restoring the sick to a condition of health by securing for her patient complete rest both of mind and body. To this end, she skillfully removes all minor causes of alarm, irritation, or worry. There are numberless ways in which this may be done of which space does not allow even mention. Details apparently trifling, as noiseless shoes, quietness, wearing garments that do not rustle, use of small pillows of different sizes, and countless other small things that make up the refinement of modern nursing, play an important part in building up the impaired tissues of the sick.

388. Care of Infectious and Contagious Diseases. There are certain diseases which are known to be infectious and can be communicated from one person to another, either by direct contact, through the medium of the atmosphere, or otherwise.

Of the more prevalent infectious and contagious diseases are _scarlet fever, diphtheria, erysipelas, measles_, and _typhoid fever_.

Considerations of health demand that a person suffering from any one of these diseases should be thoroughly isolated from all other members of the family. All that has been stated in regard to general nursing in previous sections of this chapter, applies, of course, to nursing infectious and contagious diseases. In addition to these certain special directions must be always kept in mind.

Upon the nurse, or the person having the immediate charge of the patient, rests the responsibility of preventing the spread of infectious diseases. The importance must be fully understood of carrying out in every detail the measures calculated to check the spread or compass the destruction of the germs of disease.

389. Hints on Nursing Infectious and Contagious Diseases. Strip the room of superfluous rugs, carpets, furniture, etc. Isolate two rooms, if

possible, and have these, if convenient, at the top of the house. Tack sheets, wet in some proper disinfectant, to the outer frame of the sick-room door. Boil these sheets every third day. In case of diseases to which young folks are very susceptible, send the children away, if possible, to other houses where there are no children.

Most scrupulous care should be taken in regard to cleanliness and neatness in every detail. Old pieces of linen, cheese-cloth, paper napkins, should be used wherever convenient or necessary and then at once burnt. All soiled clothing that cannot well be burnt should be put to soak at once in disinfectants, and afterward boiled apart from the family wash. Dishes and all utensils should be kept scrupulously clean by frequent boiling. For the bed and person old and worn articles of clothing that can be destroyed should be worn so far as possible.

During convalescence, or when ready to leave isolation, the patient should be thoroughly bathed in water properly disinfected, the hair and nails especially being carefully treated.

Many details of the after treatment depend upon the special disease, as the rubbing of the body with carbolized vaseline after scarlet fever, the care of the eyes after measles, and other particulars of which space does not admit mention here.

Poisons and Their Antidotes.

390. Poisons. A poison is a substance which, if taken into the system in sufficient amounts, will cause serious trouble or death. For convenience poisons may be divided into two classes, irritants and narcotics.

The effects of irritant poisons are evident immediately after being taken. They burn and corrode the skin or membrane or other parts with which they come in contact. There are burning pains in the mouth, throat, stomach, and abdomen, with nausea and vomiting. A certain amount of faintness and shock is also present.

With narcotic poisoning, the symptoms come on more slowly. After a time there is drowsiness, which gradually increases until there is a profound sleep or stupor, from which the patient can be aroused only with great difficulty. There are some substances which possess both the irritant and narcotic properties and in which the symptoms are of a mixed character.

391. Treatment of Poisoning. An antidote is a substance which will either combine with a poison to render it harmless, or which will have a directly opposite effect upon the body, thus neutralizing the effect of the poison. Hence in treatment of poisoning the first thing to do, if you know the special poison, is to give its antidote at once.

If the poison is unknown, and there is any delay in obtaining the antidote, the first thing to do is to remove the poison from the stomach. Therefore cause vomiting as quickly as possible. This may be done by an emetic given as follows: Stir a tablespoonful of mustard or of common salt in a glass of warm water and make the patient swallow the whole. It will usually be vomited in a few moments. If mustard or salt is not at hand, compel the patient to drink lukewarm water very freely until vomiting occurs.

Vomiting may be hastened by thrusting the forefinger down the throat. Two teaspoonfuls of the syrup of ipecac, or a heaping teaspoonful of powdered ipecac taken in a cup of warm water, make an efficient emetic, especially if followed with large amounts of warm water.

It is to be remembered that in some poisons, as certain acids and alkalies, no emetic should be given. Again, for certain poisons (except in case of arsenic) causing local irritation, but which also affect the system at large, no emetic should be given.

392. Reference Table of Common Poisons; Prominent Symptoms; Antidotes and Treatment. The common poisons with their leading symptoms, treatment, and antidotes, may be conveniently arranged for easy reference in the form of a table.

It is to be remembered, of course, that a complete mastery of the table of poisons, as set forth on the two following pages, is really a physician's business. At the same time, no one of fair education should neglect to learn a few of the essential things to do in accidental or intentional poisoning.

A Table of the More Common Poisons,

With their prominent symptoms, antidotes, and treatment.

Poison	Prominent Symptoms	Antidotes and Treatment
Strong Acids:		
Muriatic, Nitric, Sulphuric (vitriol), Oxalic.	Burning sensation in mouth, throat, and stomach; blisters about mouth; vomiting; great weakness	_No emetic_ Saleratus; chalk; soap; plaster from the wall; lime; magnesia; baking soda (3 or 4 teaspoonfuls in a glass of water).
Alkalies:		
Caustic potash and soda, Ammonia, Lye, Pearlash, Saltpeter.	Burning sensation in the parts; severe pain in stomach; vomiting; difficulty in swallowing; cold skin; weak pulse.	_No emetic_ Olive oil freely; lemon juice, vinegar; melted butter and vaseline; thick cream.
Arsenic:		
Paris green, Rough on rats, White arsenic, Fowler's solution, Scheele's green.	Intense pains in stomach and bowels; thirst; vomiting, perhaps with blood; cold and clammy skin.	Vomit patient repeatedly, give hydrated oxide of iron with magnesia, usually kept by druggists for emergencies; follow with strong solution of common salt and water.

Other Metallic Poisons:

Blue vitriol, Copperas, Green vitriol, Sugar of lead, Corrosive sublimate, Bedbug poison.	Symptoms in general, same as in arsenical poisoning. With lead and mercury there may be a metallic taste in the mouth.	Emetic with lead; none with copper and iron; white of eggs in abundance with copper; with iron and lead give epsom salts freely; afterwards, oils, flour, and water. _No emetic with mercury;_ raw eggs; milk, or flour, and water.

Phosphorus from

Matches, rat poisons,etc.	Pain in the stomach; vomiting; purging; general collapse.	_Cause vomiting_. Strong soapsuds; magnesia in water. Never give oils.

Opium:

Morphine, Laudanum, Paregoric, Dover's powder, Soothing syrups, Cholera and diarrhoea mixtures.	Sleepiness; dullness; stupor; "pin-hole" pupils; slow breathing; profuse sweat.	_Cause vomiting_. Keep patient awake by any means, especially by vigorous walking; give strong coffee freely; dash cold water on face and chest.

Carbolic Acid:

Creasote.	Severe pain in abdomen; odor of carbolic acid, mucous membrane in around mouth white and benumbed; cold and clammy skin.	_No emetic._ Milk or flour and water; white of eggs.

Aconite:

Wolfsbane Monkshood	Numbness everywhere, great weakness; cold sweat.	_Vomit patient freely._ Stimulating drinks.

Belladonna

Deadly Nightshade Atropia	Eyes bright, with pupil enlarged; dry mouth and throat.	_Vomit patient freely._

Various Vegetable Poisons

Wild parsley, Indian tobacco, Toadstools, Tobacco plant, Hemlock, Berries of the mountain ash, Bitter sweet etc.	Stupor, nausea, great weakness and other symptoms according to the poison.	_Cause brisk vomiting_. Stimulating drinks.

393. Practical Points about Poisons. Poisons should never be kept in the same place with medicines or other preparations used in the household. They should always be put in some secure place under lock and key. Never

use internally or externally any part of the contents of any package or bottle unless its exact nature is known. If there is the least doubt about the substance, do not assume the least risk, but destroy it at once. Many times the unknown contents of some bottle or package has been carelessly taken and found to be poison.

Careless and stupid people often take, by mistake, with serious, and often fatal, results, poisonous doses of carbolic acid, bed-bug poison, horse-liniment, oxalic acid, and other poisons. A safe rule is to keep all bottles and boxes containing poisonous substances securely bottled or packed, and carefully labeled with the word POISON plainly written in large letters across the label. Fasten the cork of a bottle containing poison to the bottle itself with copper or iron wire twisted into a knot at the top. This is an effective means of preventing any mistakes, especially in the night.

This subject of poisons assumes nowadays great importance, as it is a common custom to keep about stables, workshops, bathrooms, and living rooms generally a more or less formidable array of germicides, disinfectants, horse-liniments, insect-poisons, and other preparations of a similar character. For the most part they contain poisonous ingredients.

Bacteria.

394. Nature Of Bacteria. The word bacteria is the name applied to very low forms of plant life of microscopic size. Thus, if hay be soaked in water for some time, and a few drops of the liquid are examined under a high power of the microscope, the water is found to be swarming with various forms of living vegetable organisms, or bacteria. These microscopic plants belong to the great fungus division, and consist of many varieties, which may be roughly divided into groups, according as they are spherical, rod-like, spiral, or otherwise in shape.

Each plant consists of a mass of protoplasm surrounded by an ill-defined cell wall. The bacteria vary cably in size. Some of the rod-shaped varieties are from 1/12,000 to 1/8,000 of an inch in length, and average about 1/50,000 of an inch in diameter. It has been calculated that a space of one cubic millimeter would contain 250,000,000 of these minute organisms, and that they would not weigh more than a milligram.

[Illustration: Fig. 168.--Examples of Micro-Organisms called Bacteria. (Drawn from photographs.)

  A, spheroidal bacteria (called _cocci_) in pairs;
  B, same kind of bacteria in chains;
  C, bacteria found in pus (grouped in masses like a bunch of grapes).
    [Bacteria in A, B, and C magnified about 1000 diameters].
  D, bacteria found in pus (tendency to grow in the form of chains).
    [Magnified about 500 diameters.]
]

Bacteria are propagated in a very simple manner. The parent cell divides into two; these two into two others, and so on. The rapidity with which these organisms multiply under favorable conditions, makes them, in some cases, most dangerous enemies. It has been calculated that if all of the organisms survived, one bacterium would lead to the production of several billions of others in twenty-four hours.

395. The Struggle of Bacteria for Existence. Like all kinds of living things, many species of bacteria are destroyed if exposed to boiling water or steam, but seem able to endure prolonged cold, far below the freezing-point. Thus ice from ponds and rivers may contain numerous germs which resume their activity when the ice is melted. Typhoid fever germs have been known to take an active and vigorous growth after they have been kept for weeks exposed in ice to a temperature below zero.

The bacteria of consumption (bacillus tuberculosis) may retain their vitality for months, and then the dried expectoration of the invalids may become a source of danger to those who inhale air laden with such impurities (sec. 220 and Fig. 94).

Like other living organisms, bacteria need warmth, moisture, and some chemical compound which answers for food, in order to maintain the phenomena of life. Some species grow only in contact with air, others need no more oxygen than they can obtain in the fluid or semi-fluid which they inhabit.

396. Importance of Bacteria in Nature. We might well ask why the myriads of bacteria do not devastate the earth with their marvelous rapidity of propagation. So indeed they might, were it not for the winds, rains, melting snow and ice which scatter them far and wide, and destroy them.

Again, as in countless other species of living organisms, bacteria are subject to the relentless law which allows only the fittest to survive. The bacteria of higher and more complex types devour those of a lower type. Myriads perish in the digestive tract of man and other animals. The excreta of some species of bacteria act as poison to destroy other species.

It is true from the strictest scientific point of view that all living things literally return to the dust whence they came. While living they borrow a few elementary substances and arrange them in new combinations, by aid of the energy given them by the sun, and after a time die and leave behind all they had borrowed both of energy and matter.

Countless myriads of bacteria are silently at work changing dead animal and vegetable matter into useful substances. In brief, bacteria prepare food for all the rest of the world. Were they all destroyed, life upon the earth would be impossible, for the elements necessary to maintain it would be embalmed in the bodies of the dead.

397. Action of Bacteria. In certain well-known processes bacteria have the power of bringing about decomposition of various kinds. Thus a highly organized fungus, like the yeast plant, growing in the presence of sugar, has the power of breaking down this complex body into simpler ones, _viz._, alcohol and carbon dioxid.

In the same way, various forms of bacteria have the power of breaking down complex bodies in their immediate neighborhood, the products depending upon the substance, the kind of bacteria, and the conditions under which they act. Thus the _bacteria lactis_ act upon the milk sugar present in milk, and convert it into lactic acid, thus bringing about the souring of milk.

[Illustration: Fig. 169.--Examples of Pathogenic Bacteria. (Drawn from photographs.)

A, spiral form of bacteria found in cholera (Magnified about 1000 diameters)
B, rod-shaped bacteria (called _bacilli_) from a culture obtained in _anthrax_ or malignant fustule of the face. Diseased hides carry this micro-organism, and thus may occasion disease among those who handle hides and wool. (Magnified about 1000 diameters)
]

Now, while most species of bacteria are harmless, some are the cause of sickness and death when they gain admittance to the body under certain conditions. These disease-producing bacteria (known as _pathogenic_), when established in the blood and tissues of the body, bring about important chemical changes, depending upon the species of bacteria, and also produce a particular form of disease. The production of certain diseases by the agency of bacteria has now been proved beyond all doubt. In yellow fever, erysipelas, diphtheria, typhoid fever, consumption and other diseases, the connection has been definitely established.

The evil results these germs of disease produce vary greatly in kind and severity. Thus the bacteria of Asiatic cholera and diphtheria may destroy life in a few hours, while those of consumption may take years to produce a fatal result. Again, the bacteria may attack some particular organ, or group of organs, and produce mostly local symptoms. Thus in a boil there is painful swelling due to the local effect of the bacteria, with slight general disturbance.

398. The Battle against Bacteria. When we reflect upon the terrible ravages made by infectious diseases, and all their attendant evils for these many years, we can the better appreciate the work done of late years by tireless scientists in their efforts to modify the activity of disease-producing bacteria. It is now possible to cultivate certain pathogenic bacteria, and by modifying the conditions under which they are grown, to destroy their violence.

In brief, science has taught us, within certain limitations, how to change the virulent germs of a few diseases into harmless microbes.

399. Alcoholic Fermentation and Bacteria. Men of the lowest, as well as of the highest, type of civilization have always known that when the sugary juice of any fruit is left to itself for a time, at a moderately warm temperature, a change takes place under certain conditions, and the result is a liquid which, when drank, produces a pronounced effect upon the body. In brief, man has long known how to make for himself alcoholic beverages, by means of which he may become intoxicated with their poisonous ingredients.

Whether it is a degraded South Sea Islander making a crude intoxicant from a sugary plant, a Japanese preparing his favorite alcoholic beverage from the fermentation of rice by means of a fungus plant grown for the purpose, a farmer of this country making cider from fermenting apple juice, or a French expert manufacturing costly champagne by a complicated process, the outcome and the intent are one and the same. The essential thing is to produce an alcoholic beverage which will have a marked physiological effect. This effect is poisonous, and is due solely to the alcoholic ingredient, without which man would have little or no use for the otherwise harmless liquid.

While the practical process of making some form of alcoholic beverage has been understood for these many centuries, the real reason of this remarkable change in a wholesome fruit juice was not known until revealed by recent progress in chemistry, and by the use of the microscope. We know now that the change is due to fermentation, brought about from the influence, and by the action, of bacteria (sec. 125).

In other words, fermentation is the result of the growth of low form of vegetable life known as an organised ferment. The ferment, whether it be the commonly used brewer's yeast, or any other species of alcoholic ferment, has the power to decompose or break down a large part of the sugar present in the liquid into alcohol, which remains as a poison, and _carbon dioxid_, which escapes more or less completely.

Thus man, ever prone to do evil, was once obliged, in his ignorance, to make his alcoholic drinks in the crudest manner; but now he has forced into his service the latest discoveries in science, more especially in bacteriology, that he may manufacture more scientifically and more economically alcoholic beverages of all sorts and kinds, and distribute them broadcast all over God's earth for the physical and moral ruin of the people.

Disinfectants.

400. Disinfectants, Antiseptics, and Deodorants. The word disinfectant is synonymous with the term _bactericide_ or _germicide_. A disinfectant is a substance which destroys infectious material. An antiseptic is an agent which may hinder the growth, but does not destroy the vitality, of bacteria. A deodorant is not necessarily a disinfectant, or even an antiseptic, but refers to a substance that destroys or masks offensive odors.

401. Air and Water as Disinfectants. Nature has provided for our protection two most efficient means of disinfection,--pure air (sec. 218) and pure water (sec. 119). The air of crowded rooms contains large quantities of bacteria, whereas in pure air there are comparatively few, especially after rain, which carries them to the earth. Living micro-organisms have never been detected in breezes coming from the sea, but in those blowing out from the shore large numbers may be found.

In water tainted with organic matter putrefactive bacteria will flourish, whereas pure water is fatal to their existence. Surface water, because it comes from that part of the soil where bacteria are most active, and where there is most organic matter, generally contains great quantities of these organisms. In the deeper strata of the soil there is practically no decomposition of organic matter going on, hence, water taken from deep sources is comparatively free from bacteria. For this reason, deep well water is greatly to be preferred for drinking purposes to that from surface wells.

402. Disinfectants. It is evident that air and water are not always

sufficient to secure disinfection, and this must be accomplished by other means. The destruction of infected material by fire is, of course, a sure but costly means of disinfection. Dry heat, steam, and boiling water are valuable disinfectants and do not injure most fabrics. These agents are generally used in combination with various chemical disinfectants.

Certain chemical agents that are capable of destroying micro-organisms and their spores have come, of late years, into general use. A form of mercury, called _corrosive sublimate_, is a most efficacious and powerful germicide, but is exceedingly poisonous and can be bought only under restrictions.[54] _Carbolic acid, chloride of lime, permanganate of potash_, and various other preparations made from zinc, iron, and petroleum, are the chemical disinfectants most commonly and successfully used at the present time. There are also numerous varieties of commercial disinfectants now in popular use, such as Platt's chlorides, bromo-chloral, sanitas, etc., which have proved efficient germicides.

Instructions for the Management of Contagious Diseases.

The following instructions for the management of contagious diseases were prepared for the National Board of Health by an able corps of scientists and experienced physicians.

403. Instructions for Disinfection. Disinfection is the destruction of the poisons of infectious and contagious diseases. Deodorizers, or substances which destroy smells, are not necessarily disinfectants, and disinfectants do not necessarily have an odor. Disinfection cannot compensate for want of cleanliness nor of ventilation.

404. Disinfectants to be Employed. 1. Roll sulphur (brimstone); for fumigation.

2. Sulphate of iron (copperas) dissolved in water in the proportion of one and a half pounds to the gallon; for soil, sewers, etc.

> [NOTE. A most useful little manual to consult in connection with this chapter is the _Hand-Book of Sanitary Information_, written by Roger S. Tracy, Sanitary Inspector of the New York City Health Department. Price, 50 cents.]

3. Sulphate of zinc and common salt, dissolved together in water in the proportion of four ounces sulphate and two ounces salt to the gallon; for clothing, bed-linen, etc.

405. How to Use Disinfectants. 1. _In the sick-room._ The most available agents are fresh air and cleanliness. The clothing, towels, bed-linen, etc., should, on removal from the patient, and before they are taken from the room, be placed in a pail or tub of the zinc solution, boiling-hot, if possible.

All discharges should either be received in vessels containing copperas solution, or, when this is impracticable, should be immediately covered with copperas solution. All vessels used about the patient should be cleansed with the same solution.

Unnecessary furniture, especially that which is stuffed, carpets, and hangings, should, when possible, be removed from the room at the outset; otherwise they should remain for subsequent fumigation and treatment.

2. _Fumigation_. Fumigation with sulphur is the only practicable method for disinfecting the house. For this purpose, the rooms to be disinfected must be vacated. Heavy clothing, blankets, bedding, and other articles which cannot be treated with zinc solution, should be opened and exposed during fumigation, as directed below. Close the rooms as tightly as possible, place the sulphur in iron pans supported upon bricks placed in washtubs containing a little water, set it on fire by hot coals or with the aid of a spoonful of alcohol, and allow the room to remain closed for twenty-four hours. For a room about ten feet square, at least two pounds of sulphur should be used; for larger rooms, proportionally increased quantities.[55]

3. _Premises_. Cellars, yards, stables, gutters, privies, cesspools, water-closets, drains, sewers, etc., should be frequently and liberally treated with copperas solution. The copperas solution is easily prepared by hanging a basket containing about sixty pounds of copperas in a barrel of water.[56]

4. _Body and bed clothing, etc_. It is best to burn all articles which have been in contact with persons sick with contagious or infectious diseases. Articles too valuable to be destroyed should be treated as follows:

_(a)_ Cotton, linen, flannels, blankets, etc., should be treated with the boiling-hot zinc solution; introduce piece by piece, secure thorough wetting, and boil for at least half an hour.

_(b)_ Heavy woolen clothing, silks, furs, stuffed bed-covers, beds, and other articles which cannot be treated with the zinc solution, should be hung in the room during fumigation, their surfaces thoroughly exposed and pockets turned inside out. Afterward they should be hung in the open air, beaten, and shaken. Pillows, beds, stuffed mattresses, upholstered furniture, etc., should be cut open, the contents spread out and thoroughly fumigated. Carpets are best fumigated on the floor, but should afterward be removed to the open air and thoroughly beaten.

Books for Collateral Study. Among the many works which may be consulted with profit, the following are recommended as among those most useful: Parkes _Elements of Health_; Canfield's _Hygiene of the Sick-Room;_ Coplin & Bevan's _Practical Hygiene;_ Lincoln's _School Hygiene_; Edward Smith's _Health_; McSherrys _Health; American Health Primers_ (12 little volumes, edited by Dr. Keen of Philadelphia); Reynold's _Primer of Health_; Corfield's _Health_; Appleton's _Health Primers;_ Clara S. Weeks' _Nursing_; Church's _Food_; Yeo's _Food in Health and Disease;_ Hampton's _Nursing, its Principles and Practice_; Price's _Nurses and Nursing;_ Cullinworth's _Manual of Nursing_; Wise's _Text-Book of Nursing_ (2 vols.); and Humphrey's _Manual of Nursing_.

Chapter XV.

Experimental Work in Physiology.

406. The Limitations of Experimental Work in Physiology in Schools. Unlike other branches of science taught in the schools from the experimental point of view, the study of physiology has its limitations. The scope and range of such experiments is necessarily extremely limited compared with what may be done with the costly and elaborate apparatus of the medical laboratory. Again, the foundation of physiology rests upon systematic and painstaking dissection of the dead human body and the lower animals, which mode of study very properly is not permitted in ordinary school work. Experiments upon the living human body and the lower animals, now so generally depended upon in our medical and more advanced scientific schools, for obvious reasons can be performed only in a crude and quite superficial manner in secondary schools.

Hence in the study of physiology in schools many things must be taken for granted. The observation and experience of medical men, and the experiments of the physiologist in his laboratory must be depended upon for data which cannot be well obtained at first hand by young students.

407. Value of Experiments in Physiology in Secondary Schools. While circumstances and regard for certain proprieties of social life forbid the use of a range of experiments, in anatomy and physiology, such as are permitted in other branches of science in secondary schools, it by no means follows that we are shut out altogether from this most important and interesting part of the study. However simple and crude the apparatus, the skillful and enthusiastic teacher has at his command a wide series of materials which can be profitably utilized for experimental instruction. As every experienced teacher knows, pupils gain a far better knowledge, and keep up a livelier interest in any branch of science, if they see with their own eyes and do with their own hands that which serves to illuminate and illustrate the subject-matter.

[NOTE. For additional suggestions and practical helps on the subject of experimental work in physiology the reader is referred to Blaisdell's _How to Teach Physiology_, a handbook for teachers. A copy of this pamphlet will be sent postpaid to any address by the publishers of this book on receipt of ten cents.]

The experimental method of instruction rivets the attention and arouses and keeps alive the interest of the young student; in fact, it is the only true method of cultivating a scientific habit of study[57]. The subject-matter as set forth on the printed pages of this book should be mastered, of course, but at the same time the topics discussed should be illuminated and made more interesting and practical by a well-arranged series of experiments, a goodly show of specimens, and a certain amount of microscopical work.

408. The Question of Apparatus. The author well understands from personal experience the many practical difficulties in the way of providing a suitable amount of apparatus for classroom use. If there are ample funds for this purpose, there need be no excuse or delay in providing all that is necessary from dealers in apparatus in the larger towns, from the drug store, markets, and elsewhere. In schools where both the funds and the time for such purposes are limited, the zeal and ingenuity of teachers and students are often put to a severe test. Fortunately a very little money and a great deal of ingenuity and patience

will do apparent wonders towards providing a working supply of apparatus.

It will be noticed that many of the experiments in the preceding chapters of this book can be performed with very simple, and often a crude and home-made sort of apparatus. This plan has been rigidly followed by the author, first, because he fully realizes the limitations and restrictions of the subject; and secondly, because he wishes to emphasize the fact that expensive and complicated apparatus is by no means necessary to illustrate the great principles of anatomy and physiology.

409. Use of the Microscope. To do thorough and satisfactory work in physiology in our higher schools a compound microscope is almost indispensable. Inasmuch as many of our best secondary schools are equipped with one or more microscopes for use in other studies, notably botany, it is much less difficult than it was a few years ago to obtain this important help for the classes in physiology.

[Illustration: Fig. 170.--A Compound Microscope]

For elementary class work a moderate-priced, but well-made and strong, instrument should be provided. If the school does not own a microscope, the loan of an instrument should be obtained for at least a few weeks from some person in the neighborhood.

The appearance of the various structures and tissues of the human body as revealed by the microscope possesses a curious fascination for every observer, especially for young people. No one ever forgets the first look at a drop of blood, or the circulation of blood in a frog's foot as shown by the microscope.

[NOTE. For detailed suggestions in regard to the manipulation and use of the microscope the student is referred to any of the standard works on the subject. The catalogues of scientific-instrument makers of our larger cities generally furnish a list of the requisite materials or handbooks which describe the use of the various microscopes of standard make.

The author is indebted to Bergen's _Elements of Botany_ for the following information concerning the different firms which deal in microscopes. "Several of the German makers furnish excellent instruments for use in such a course as that here outlined. The author is most familar with the Leitz microscopes, which are furnished by Wm. Krafft, 411 West 59th St., New York city, or by the Franklin Educational Co., 15 and 17 Harcourt St., Boston. The Leitz Stand, No. IV., can be furnished duty free (for schools only), with objectives 1, 3, and 5, eye-pieces I. and III., for $24.50. If several instruments are being provided, it would be well to have part of them equipped with objectives 3 and 7, and eye-pieces I. and III.

"The American manufacturers, Bausch & Lomb Optical Company, Rochester, N.Y., and No. 130 Fulton St., New York city, have this year produced a microscope of the Continental type which is especially designed to meet the requirements of the secondary schools for an instrument with rack and pinion coarse adjustment and serviceable fine adjustment, at a low price. They furnish this new stand, 'AAB,' to schools and teachers at 'duty-free' rates, the prices being for the stand with two eye-pieces (any desired power), 2/3-inch and 1/4-inch objectives, $25.60, or with 2-inch, 2/3-inch, and 1/4-inch objectives, and two eye-pieces, $29.20. Stand 'A,' the same stand as the 'AAB,' without joint and with sliding tube coarse adjustment (as in the Leitz Stand IV.), and with three eye-pieces and 2/3-inch and 1/4-inch objectives, is furnished for $20.40. Stand 'A,' with two eye-pieces, 2/3-inch and 1/6-inch objectives, $20.40."]

410. The Use of the Skeleton and Manikin. The study of the bones by the help of a skeleton is almost a necessity. To this intent, schools of a higher grade should be provided both with a skeleton and a manikin. If the former is not owned by the school, oftentimes a loan of one can be secured of some medical man in the vicinity. Separate bones will also prove useful. In fact, there is no other way to study properly the structure and use of the bones and joints than by the bones themselves. A good manikin is also equally serviceable, although not so commonly provided for schools on account of its cost.

411. The Question of Vivisection and Dissection. There should be no question at all concerning vivisection. _In no shape or form should it be allowed in any grade of our schools._ Nor is there any need of much dissection in the grammar-school grades. A few simple dissections to be performed with fresh beef-joints, tendons of turkey legs, and so on, will never engender cruel or brutal feelings toward living things. In the lower grades a discreet teacher will rarely advise his pupils to dissect a dead cat, dog, frog, or any other animal. Instead of actual dissection, the pupils should examine specimens or certain parts previously dissected by the teacher,--as the muscles and tendons of a sheep, the heart of an ox, the eye of a codfish, and so on. Even under these restrictions the teacher should not use the knife or scissors before the class to open up any part of the specimen. In brief, avoid everything that can possibly arouse any cruel or brutal feeling on the part of young students.

In the higher schools, in normal and other training schools, different conditions prevail. Never allow vivisection in any form whatever, either in school or at home. Under the most exact restrictions students in these schools may be taught to make a few simple dissections.

Most teachers will find, however, even in schools of a higher grade, that the whole subject is fraught with many difficulties. It will not require much oftentimes to provoke in a community a deal of unjust criticism. A teacher's good sense and discretion are often put to a severe test.

Additional Experiments.

To the somewhat extended list of experiments as described in the preceding chapters a few more are herewith presented which may be used as opportunity allows to supplement those already given.

Experiment 193. _To examine white fibrous tissue._ Snip off a very minute portion from the muscle of a rabbit, or any small animal recently dead. Tease the specimen with needles, mount in salt solution and examine under a high power. Note the course and characters of the fibers.

Experiment 194. _To examine elastic tissue._ Tease out a small piece of ligament from a rabbit's leg in salt solution; mount in the same, and examine as before. Note the curled elastic fibers.

Experiment 195. _To examine areolar tissue._ Gently tease apart some muscular fibers, noting that they are attached to each other by connective tissue. Remove a little of this tissue to a slide and examine as before. Examine the matrix with curled elastic fiber mixed with straight white fibers.

Experiment 196. _To examine adipose tissue._ Take a bit of fat from the mesentery of a rabbit. Tease the specimen in salt solution and mount in the same. Note the fat cells lying in a vascular meshwork.

Experiment 197. _To examine connective tissues._ Take a very small portion from one of the tendons of a rabbit, or any animal recently dead; place upon a glass slide with a drop of salt solution; tease it apart with needles, cover with thin glass and examine with microscope. The fine wavy filaments will be seen. Allow a drop of dilute acetic acid to run under the cover glass; the filaments will swell and become transparent.

Experiment 198. Tease out a small piece of ligament from the rabbit's leg in salt solution; mount in the same, and examine under a high power. Note the curled elastic fibers.

Experiment 199. _A crude experiment to represent the way in which a person's neck is broken._ Bring the ends of the left thumb and the left second finger together in the form of a ring. Place a piece of a wooden toothpick across it from the middle of the finger to the middle of the thumb. Put the right forefinger of the other hand up through the front part to represent the odontoid process of the axis, and place some absorbent cotton through the other part to represent the spinal cord. Push backwards with the forefinger with just enough force to break the toothpick and drive its fragments on to the cotton.

Experiment 200. _To illustrate how the pulse-wave is transmitted along an artery._ Use the same apparatus as in Experiment 106, p. 201. Take several thin, narrow strips of pine wood. Make little flags by fastening a small piece of tissue paper on one end of a wooden toothpick. Wedge the other end of the toothpick into one end of the strips of pine wood. Use these strips like levers by placing them across the long rubber tube at different points. Let each lever compress the tube a little by weighting one end of it with a blackboard eraser or book of convenient size.

As the pulse-wave passes along under the levers they will be successively raised, causing a slight movement of the tissue-paper flags.

Experiment 201. _The dissection of a sheep's heart._ Get a sheep's heart with the lungs attached, as the position of the heart will be better understood. Let the lungs be laid upon a dish so that the heart is uppermost, with its apex turned toward the observer.

The line of fat which extends from the upper and left side of the heart downwards and across towards the right side, indicates the division between the right and left ventricles.

Examine the large vessels, and, by reference to the text and illustrations, make quite certain which are the _aorta_, the _pulmonary artery_, the _superior_ and _inferior venae cavae_, and the _pulmonary veins_.

Tie variously colored yarns to the vessels, so that they may be distinguished when separated from the surrounding parts.

Having separated the heart from the lungs, cut out a portion of the wall of the _right ventricle_ towards its lower part, so as to lay the cavity open. Gradually enlarge the opening until the _chordae tendineae_ and the flaps of the _tricuspid valve_ are seen. Continue to lay open the ventricle towards the pulmonary artery until the _semilunar valves_ come into view.

The pulmonary artery may now be opened from above so as to display the upper surfaces of the semilunar valves. Remove part of the wall of the right auricle, and examine the right auriculo-ventricular opening.

The heart may now be turned over, and the _left ventricle_ laid open in a similar manner. Notice that the mitral valve has only two flaps. The form of the valves is better seen if they are placed under water, and allowed to float out. Observe that the walls of the _left_ ventricle are much thicker than those of the _right_.

Open the left auricle, and notice the entrance of the _pulmonary veins_, and the passage into the ventricle.

The ventricular cavity should now be opened up as far as the aorta, and the semilunar valves examined. Cut open the aorta, and notice the form of the _semilunar valves_.

Experiment 202. _To show the circulation in a frog's foot_ (see Fig. 78, p. 192). In order to see the blood circulating in the membrane of a frog's foot it is necessary to firmly hold the frog. For this purpose obtain a piece of soft wood, about six inches long and three wide, and half an inch thick. At about two inches from one end of this, cut a hole three-quarters of an inch in diameter and cover it with a piece of glass, which should be let into the wood, so as to be level with the surface. Then tie up the frog in a wet cloth, leaving one of the hind legs outside. Next, fasten a piece of cotton to each of the two longest toes, but not too tightly, or the circulation will be stopped and you may hurt the frog.

Tie the frog upon the board in such a way that the foot will just come over the glass in the aperture. Pull carefully the pieces of cotton tied to the toes, so as to spread out the membrane between them over the glass. Fasten the threads by drawing them into notches cut in the sides of the board. The board should now be fixed by elastic bands, or by any other convenient means, upon the stage of the microscope, so as to bring the membrane of the foot under the object glass.

The flow of blood thus shown is indeed a wonderful sight, and never to be forgotten. The membrane should be occasionally moistened with water.

Care should be taken not to occasion any pain to the frog.

Experiment 203. _To illustrate the mechanics of respiration_[58] (see Experiment 122, p. 234). "In a large lamp-chimney, the top of which is closed by a tightly fitting perforated cork (A), is arranged a pair of rubber bags (C) which are attached to a Y connecting tube (B), to be had of any dealer in chemical apparatus or which can be made by a teacher having a bunsen burner and a little practice in the manipulation of glass (Fig. 171). From the center of the cork is attached a rubber band by means of a staple driven through the cork, the other end of which (D) is attached to the center of a disk of rubber (E) such as dentists use. This disk is held to the edge of the chimney by a wide elastic band (F). There is a string (G) also attached to the center of the rubber disk by means of which the diaphragm may be lowered.

[Illustration: Fig. 171.]

Such is a description of the essentials of the model. The difficulties encountered in its construction are few and easily overcome. In the first place, the cork must be air-tight, and it is best made so by pouring a little melted paraffin over it, care being taken not to close the tube. The rubber bags were taken from toy balloon-whistles.

In the construction of the diaphragm, it is to be remembered that it also must be air-tight, and in order to resemble the human diaphragm, it must have a conical appearance when at rest. In order to avoid making any holes in the rubber, the two attachments (one of the rubber band, and the other of the string) were made in this wise: the rubber was stretched over a button having an eye, then under the button was placed a smaller ring from an old umbrella; to this ring was attached the rubber band, and to the eye of the button was fastened the operating string. When not in use the diaphragm should be taken off to relieve the strain on the rubber band."

Experiment 204. _To illustrate the action of the intercostal muscles_ (see sec. 210). The action of the intercostal muscles is not at first easy to understand; but it will be readily comprehended by reference to a model such as that represented in Fig. 172. This maybe easily made by the student himself with four laths of wood, fastened together at the corners, A, B, C, D, with pins or small screws, so as to be movable. At the points E, F, G, H, pins are placed, to which elastic bands may be attached (A). B D represents the vertebral column; A C, the sternum; and A B and C D, the ribs. The elastic band F G represents the _external_ intercostal muscles, and E H, the _internal_ intercostals.

[Illustration: Fig. 172.]

If now the elastic band E H be removed, the remaining band, F G, will tend to bring the two points to which it is attached, nearer together, and the result will be that the bars A B and C D will be drawn upwards (B), that is, in the same direction as the ribs in the act of _inspiration_. When the elastic band E H is allowed to exert its force, the opposite effect will be produced (C); in this case representing the position of the ribs in an act of _expiration_.

Experiment 205. Pin a round piece of bright red paper (large as a dinner-plate) to a white wall, with a single pin. Fasten a long piece of thread to it, so it can be pulled down in a moment. Gaze steadily at the red paper. Have it removed while looking at it intently, and a greenish spot takes its place.

Experiment 206. Lay on different parts of the skin a small, square piece of paper with a small central hole in it. Let the person close his eyes, while another person gently touches the uncovered piece of skin with cotton wool, or brings near it a hot body. In each case ask the observed person to distinguish between them. He will always succeed on the volar side of the hand, but occasionally fail on the dorsal surface of the hand, the extensor surface of the arm, and very frequently on the skin of the back.

Experiment 207. _Wheatstone's fluttering hearts_. Make a drawing of a red heart on a bright blue ground. In a dark room lighted by a candle hold the picture below the level of the eyes and give it a gentle to-and-fro motion. On continuing to look at the heart it will appear to move or flutter over the blue background.

Experiment 208. At a distance of six inches from the eyes hold a veil or thin gauze in front of some printed matter placed at a distance of about two feet. Close one eye, and with the other we soon see either the letters distinctly or the fine threads of the veil, but we cannot see both equally distinct at the same time. The eye, therefore, can form a distinct image of a near or distant object, but not of both at the same time; hence the necessity for accommodation.

Experiment 209. Place a person in front of a bright light opposite a window, and let him look at the light; or place one's self opposite a well-illuminated mirror. Close one eye with the hand and observe the diameter of the other pupil. Then suddenly remove the hand from the closed eye: light falls upon it; at the same time the pupil of the other eye contracts.

Experiment 210. _To illustrate the blind spot. Marriott's experiment_. On a white card make a cross and a large dot, either black or colored. Hold the card vertically about ten inches from the right eye, the left being closed. Look steadily at the cross with the right eye, when both the cross and the circle will be seen. Gradually approach the card toward the eye, keeping the axis of vision fixed on the cross. At a certain distance the circle will disappear, i.e., when its image falls on the entrance of the optic nerve. On bringing the card nearer, the circle reappears, the cross, of course, being visible all the time (see Experiment 180, p. 355).

Experiment 211. _To map out the field of vision_. A crude method is to place the person with his back to a window, ask him to close one eye, stand in front of him about two feet distant, hold up the forefingers of both hands in front of and in the plane of your own face. Ask the person to look steadily at your nose, and as he does so observe to what extent the fingers can be separated horizontally, vertically, and in oblique directions before they disappear from his field of vision.

Experiment 212. _To illustrate imperfect judgment of distance_. Close one eye and hold the left forefinger vertically in front of the other eye, at arm's length, and try to strike it with the right forefinger.

On the first trial one will probably fall short of the mark, and fail to touch it. Close one eye, and rapidly try to dip a pen into an inkstand, or put a finger into the mouth of a bottle placed at a convenient distance. In both cases one will not succeed at first.

In these cases one loses the impressions produced by the convergence of the optic axes, which are important factors in judging of distance.

Experiment 213. Hold a pencil vertically about twelve inches from the nose, fix it with both eyes, close the left eye, and then hold the right index finger vertically, so as to cover the lower part of the pencil. With a sudden move, try to strike the pencil with the finger. In every case one misses the pencil and sweeps to the right of it.

Experiment 214. _To illustrate imperfect judgment of direction_. As the retina is spherical, a line beyond a certain length when looked at always shows an appreciable curvature.

Hold a straight edge just below the level of the eyes. Its upper margin shows a slight concavity.

Surface Anatomy and Landmarks.

In all of our leading medical colleges the students are carefully and thoroughly drilled on a study of certain persons selected as models. The object is to master by observation and manipulation the details of what is known as surface anatomy and landmarks. Now while detailed work of this kind is not necessary in secondary schools, yet a limited amount of study along these lines is deeply interesting and profitable. The habit of looking at the living body with anatomical eyes and with eyes at our fingers' ends, during the course in physiology, cannot be too highly estimated.

In elementary work it is only fair to state that many points of surface anatomy and many of the landmarks cannot always be defined or located with precision. A great deal in this direction can, however, be done in higher schools with ingenuity, patience, and a due regard for the feelings of all concerned. Students should be taught to examine their own bodies for this purpose. Two friends may thus work together, each serving as a "model" to the other.

To the following syllabus may be added such other similar exercises as ingenuity may suggest or time permit.

Syllabus.

I. Bony Landmarks.

1. The _occipital protuberance_ can be distinctly felt at the back of the head. This is always the thickest part (often three-quarters of an inch or more) of the skull-cap, and is more prominent in some than in others. The thinnest part is over the temples, where it may be almost as thin as parchment.

2. The working of the _condyle of the lower jaw_ vertically and from side to side can be distinctly felt and seen in front of the ear. When the mouth is opened wide, the condyle advances out of the glenoid cavity, and returns to its socket when the mouth is shut. In front of the ear, lies the zygoma, one of the most marked and important landmarks to the touch, and in lean persons to the eye.

3. The sliding movement of the _scapula_ on the chest can be properly understood only on the living subject. It can move not only upwards and downwards, as in shrugging the shoulders, backwards and forwards, as in throwing back the shoulders, but it has a rotary movement round a movable center. This rotation is seen while the arm is being raised from the horizontal to the vertical position, and is effected by the cooperation of the trapezius with the serratus magnus muscles.

4. The _patella_, or knee-pan, the _two condyles of the tibia_, the _tubercle on the tibia_ for the attachment of the ligament of the patella, and the _head of the fibula_ are the chief bony landmarks of the knee. The head of the fibula lies at the outer and back part of the tibia. In extension of the knee, the patella is nearly all above the condyles. The inner border of the patella is thicker and more prominent than the outer, which slopes down toward its condyle.

5. The short, front edge of the _tibia_, called the "shin," and the broad, flat, subcutaneous surface of the bone can be felt all the way down. The inner edge can be felt, but not so plainly.

6. The head of the _fibula_ is a good landmark on the outer side of the leg, about one inch below the top of the tibia. Note that it is placed well back, and that it forms no part of the knee joint, and takes no share in supporting the weight. The shaft of the fibula arches backwards and is buried deep among the muscles, except at the lower fourth, which can be distinctly felt.

7. The _malleoli_ form the great landmarks of the ankle. The outer malleolus descends lower than the inner. The inner malleolus advances more to the front and does not descend so low as the outer.

8. The line of the _clavicle_, or collar bone, and the projection of the joint at either end of it can always be felt. Its direction is not perfectly horizontal, but slightly inclined downwards. We can distinctly feel the _spine_ of the scapula and its highest point, the _acromion_.

9. Projecting beyond the acromion (the arm hanging by the side), we can feel, through the fibers of the _deltoid_, the upper part of the humerus. It distinctly moves under the hand when the arm is rotated. It is not the head of the bone which is felt, but its prominences (the tuberosities). The greater, externally; the lesser in front.

10. The _tuberosities of the humerus_ form the convexity of the shoulder. When the arm is raised, the convexity disappears,--there is a slight depression in its place. The head of the bone can be felt by pressing the fingers high up in the axilla.

11. The _humerus_ ends at the elbow in two bony prominences (internal and external condyles). The internal is more prominent. We can always feel the _olecranon_. Between this bony projection of the ulna and the internal condyle is a deep depression along which runs the ulna nerve (commonly called the "funny" or "crazy" bone).

12. Turn the hand over with the palm upwards, and the edge of the _ulna_ can be felt from the olecranon to the prominent knob (styloid process) at the wrist. Turn the forearm over with the palm down, and the head of the ulna can be plainly felt and seen projecting at the back of the wrist.

13. The upper half of the _radius_ cannot be felt because it is so covered by muscles; the lower half is more accessible to the touch.

14. The three rows of projections called the "knuckles" are formed by the proximal bones of the several joints. Thus the first row is formed by the ends of the metacarpals, the second by the ends of the first phalanges, and the third by the ends of the second phalanges. That is, in all cases the line of the joints is a little in advance of the knuckles and nearer the ends of the fingers.

II. Muscular Landmarks.

1. The position of the _sterno-mastoid_ muscle as an important and interesting landmark of the neck has already been described (p. 70).

2. If the left arm be raised to a vertical position and dropped to a horizontal, somewhat vigorously, the tapering ends of the _pectoralis major_ and the tendons of the _biceps_ and _deltoid_ may be felt by pressing the parts in the axilla between the fingers and thumb of the right hand.

3. The appearance of the _biceps_ as a landmark of the arm has already been described (p. 70). The action of its antagonist, the _triceps_, may be studied in the same manner.

4. The _sartorius_ is one of the fleshy landmarks of the thigh, as the biceps is of the arm, and the sterno-cleido-mastoid of the neck. Its direction and borders may be easily traced by raising the leg,--a movement which puts the muscle in action.

5. If the model be directed to stand on tiptoe, both of the large muscles of the calf, the _gastrocnemius_ and _soleus_, can be distinguished.

6. Direct the model, while sitting upright, to cross one leg over the other, using his utmost strength. The great muscles of the inner thigh are fully contracted. Note the force required to pull the legs to the ordinary position.

7. With the model lying in a horizontal position with both legs firmly held together, note the force required to pull the feet apart while the great muscles of the thigh are fully contracted.

8. In forcible and resisted flexion of the wrist two tendons come up in relief. On the outer side of one we feel the pulse at the wrist, the radial artery here lying close to the radius.

9. On the outer side of the wrist we can distinctly see and feel when in action, the three extensor tendons of the thumbs. Between two of them is a deep depression at the base of the thumb, which the French call the "anatomical tobacco box."

10. The relative position of the several extensor tendons on the back of the wrist and fingers as they play in their grooves over the back of the radius and ulna can be distinctly traced when the several muscles are

put in action.

11. There are several strong tendons to be seen and felt about the ankle. Behind is the _tendo Achillis_. It forms a high relief with a shallow depression on each side of it. Behind both the inner and outer ankle several tendons can be felt. Over the front of the ankle, when the muscles are in action, we can see and feel several tendons. They start up like cords when the action is resisted. They are kept in their proper relative position by strong pulleys formed by the annular ligament. Most of these tendons can be best seen by stand a model on one foot, _i.e._ in unstable equilibrium.

III. Landmarks of the Heart.

To have a general idea of the form and position of the _heart_, map its outline with colored pencils or crayon on the chest wall itself, or on some piece of clean, white cloth, tightly pinned over the clothing. A pattern of the heart may be cut out of pasteboard, painted red, or papered with red paper, and pinned in position outside the clothing. The apex of the heart is at a point about two inches below the left nipple and one inch to its sternal side. This point will be between the fifth and sixth ribs, and can generally be determined by feeling the apex beat.

IV. Landmarks of a Few Arteries.

The pulsation of the _temporal_ artery can be felt in front of the ear, between the zygoma and the ear. The _facial_ artery can be distinctly felt as it passes over the upper jaw at the front edge of the masseter muscle. The pulse of a sleeping child can often be counted at the anterior fontanelle by the eye alone.

About one inch above the clavicle, near the outer border of the sterno-mastoid, we can feel the pulsation of the great _subclavian_ artery. At the back of the knee the _popliteal_ artery can be felt beating. The _dorsal_ artery of the foot can be felt beating on a line from the middle of the ankle to the interval between the first and second metatarsal bones.

When the arm is raised to a right angle with the body, the _axillary_ artery can be plainly felt beating in the axilla. Extend the arm with palm upwards and the _brachial_ artery can be felt close to the inner side of the biceps. The position of the _radial_ artery is described in Experiment 102.

Glossary.

Abdomen (Lat. _abdo_, _abdere_, to conceal). The largest cavity of the body, containing the liver, stomach, intestines, and other organs.

Abductor (Lat. _abduco_, to draw from). A muscle which draws a limb from the middle line of the body, or a finger or toe from the middle line of the foot or hand.

Absorbents (Lat. _absorbere_, to suck up). The vessels which take part in the process of absorption. Absorption. The process of sucking up nutritive or waste matters by the blood-vessels or lymphatics.

Accommodation of the Eye. The alteration in the shape of the crystalline lens, which accommodates, or adjusts, the eye for near or remote vision.

Acetabulum (Lat. _acetabulum_, a small vinegar-cup). The cup-shaped cavity of the innominate bone for receiving the head of the femur.

Acid (Lat. _acidus_, from _acere_, to be sour). A substance usually sour, sharp, or biting to the taste.

Acromion (Gr. akron the tip, and omos, the shoulder). The part of the scapula forming the tip of the shoulder.

Adam's Apple. An angular projection of cartilage in the front of the neck. It may be particularly prominent in men.

Adductor (Lat. _adduco_, to draw to). A muscle which draws towards the middle line of the body, or of the hand or foot.

Adenoid (Gr. aden, a gland). Tissue resembling gland tissue.

Afferent (Lat. _ad_, to, and _fero_, to convey). Vessels or nerves carrying the contents or impulses from the periphery to the center.

Albumen, or Albumin (Lat. _albus_, white). An animal substance resembling the white of an egg.

Albuminuria. A combination of the words "albumin" and "urine." Presence of _albumen_ in the _urine_.

Aliment (Lat. _alo_, to nourish). That which affords nourishment; food.

Alimentary (Lat. _alimentum_, food). Pertaining to _aliment_, or food.

Alimentary Canal (Lat. _alimentum_). The tube in which the food is digested or prepared for reception into the blood.

Alkali (Arabic _al kali_, the soda plant). A name given to certain substances, such as soda, potash, and the like, which have the power of combining with acids.

Alveolar (Lat. _alveolus_, a little hollow). Pertaining to the alveoli, the _cavities_ for the reception of the teeth.

Amoeba (Gr. ameibo, to change). A single-celled, protoplasmic organism, which is constantly changing its form by protrusions and withdrawals of its substance.

Amoeboid. Like an _amoeba_.

Ampulla (Lat. _ampulla_, a wine-flask). The dilated part of the semicircular canals of the internal ear.

Anabolism (Gr. anaballo, to throw or build up). The process by means of which simpler elements are _built up_ into more complex.

Anaesthetics (Gr. an, without, and aisthesia, feeling). Those medicinal agents which prevent the feeling of pain, such as chloroform, ether, laughing-gas, etc.

Anastomosis (Gr. ana, by, and stoma, a mouth). The intercommunication of vessels.

Anatomy (Gr. anatemno, to cut up). The science which describes the structure of living things. The word literally means dissection.

Antiseptic (Lat. _anti_, against, and _sepsis_, poison). Opposing or counter-acting putrefaction.

Antrum (Lat. _antrum_, a cave). The cavity in the upper jaw.

Aorta (Gr. aorte, from aeipo, to raise up). The great artery that _rises up_ from the left ventricle of the heart.

Aponeurosis (Gr. apo, from, and neuron, a nerve). A fibrous membranous expansion of a tendon; the nerves and tendons were formerly thought to be identical structures, both appearing as white cords.

Apoplexy (Gr. apoplechia, a sudden stroke). The escape of blood from a ruptured blood-vessel into the substance of the brain.

Apparatus. A number of organs of various sizes and structures working together for some special object.

Appendages (Lat. _ad_ and _pendeo_, to hang from). Something connected with a part.

Aqueous Humor (Lat. _aqua_, water). The watery fluid occupying the space between the cornea and crystalline lens of the eye.

Arachnoid Membrane (Gr. arachne, a spider, and eidos, like). The thin covering of the brain and spinal cord, between the dura mater and the pia mater.

Arbor Vitae. Literally, "the tree of life"; a name given to the peculiar appearance presented by a section of the cerebellum.

Areolar (Lat. _areola_, a small space, dim. of _area_). A term applied to a connective tissue containing _small spaces_.

Artery (Gr. aer, air, and tereo, to contain). A vessel by which blood is carried away from the heart. It was supposed by the ancients to contain only air, hence the name.

Articulation (Lat. _articulo_, to form a joint). The more or less movable union of bones, etc.; a joint.

Arytenoid Cartilages (Gr. arytaina, a ladle). Two small cartilages of the larynx, resembling the mouth of a pitcher.

Asphyxia (Gr. a, without, and sphixis, the pulse). Literally, "without pulse." Condition caused by non-oxygenation of the blood.

Assimilation (Lat. _ad_, to, and _similis_, like). The conversion of food into living tissue.

Asthma (Gr. asthma, a gasping). Spasmodic affection of the bronchial tubes in which free respiration is interfered with, owing to their diminished caliber.

Astigmatism (Gr. a, without, and stigma, a point). Irregular refraction of the eye, producing a blurred image.

Atrophy (Gr. a, without, and trophe, nourishment). Wasting of a part from lack of nutrition.

Auditory Nerve (Lat. _audio_, to hear). The special nerve of hearing.

Auricle (Lat. _auricula_, a little ear). A cavity of the heart.

Azygos (Gr. a, without, and zugos, a yoke). Without fellow; not paired.

Bacteria (bakterion, a staff). A microscopic, vegetable organism; certain species are active agents in fermentation, while others appear to be the cause of infectious diseases.

Bactericide (_Bacterium_ and Lat. _caedere_, to kill). Same as _germicide_.

Bile. The gall, or peculiar secretion of the liver; a viscid, yellowish fluid, and very bitter to the taste.

Biology (Gr. bios, life, and logos, discourse). The science which treats of living bodies.

Bladder (Saxon _bleddra_, a bladder, a goblet). A bag, or sac, serving as a receptacle of some secreted fluid, as the _gall bladder_, etc. The receptacle of the urine in man and other animals.

Bright's Disease. A group of diseases of the kidney, first described by Dr. Bright, an English physician.

Bronchi (Gr. brogchos, windpipe). The first two divisions, or branches, of the trachea; one enters each lung.

Bronchial Tubes. The smaller branches of the trachea within the substance of the lungs terminating in the air cells.

Bronchitis. Inflammation of the larger bronchial tubes; a "cold" affecting the air passages.

Bunion. An enlargement and inflammation of the first joint of the great toe.

Bursa. A pouch; a membranous sac interposed between parts which are subject to movement, one on the other, to allow them to glide smoothly.

Callus (Lat. _calleo_, to be thick-skinned). Any excessive hardness of the skin caused by friction or pressure.

Canal (Lat. _canalis_, a canal). A tube or passage.

Capillary (Lat. _capillus_, hair). The smallest blood-vessels, so called because they are so minute.

Capsule (Lat. _capsula_, a little chest). A membranous bag enclosing a part.

Carbon Dioxid, often called _carbonic acid_. The gas which is present in the air breathed out from the lungs; a waste product of the animal kingdom and a food of the vegetable kingdom.

Cardiac (Gr. kardia, the heart). The cardiac orifice of the stomach is the upper one, and is near the heart; hence its name.

Carnivorous (Lat. _caro_, flesh, and _voro_, to devour). Subsisting upon flesh.

Carron Oil. A mixture of equal parts of linseed oil and lime-water, so called because first used at the Carron Iron Works in Scotland.

Cartilage. A tough but flexible material forming a part of the joints, air passages, nostrils, ear; gristle, etc.

Caruncle (Lat. _caro_, flesh). The small, red, conical-shaped body at the inner angle of the eye, consisting of a cluster of follicles.

Casein (Lat. _caseus_, cheese). The albuminoid substance of milk; it forms the basis of cheese.

Catarrh. An inflammation of a mucous membrane, usually attended with an increased secretion of mucus. The word is often limited to _nasal_ catarrh.

Cauda Equina (Lat., horse's tail). The collection of large nerves descending from the lower end of the spinal cord.

Cell (Lat. _cella_, a storeroom). The name of the tiny miscroscopic elements, which, with slender threads or fibers, make up most of the body; they were once believed to be little hollow chambers; hence the name.

Cement. The substance which forms the outer part of the fang of a tooth.

Cerebellum (dim. for _cerebrum_, the brain). The little brain, situated beneath the posterior third of the cerebrum.

Cerebrum. The brain proper, occupying the upper portion of the skull.

Ceruminous (Lat. _cerumen_, ear wax). A term applied to the glands secreting cerumen, or _ear wax_.

Chloral. A powerful drug and narcotic poison used to produce sleep.

Chloroform. A narcotic poison generally used by inhalation; of extensive use in surgical operations. It produces anaesthesia.

Chondrin (Gr. chondros, cartilage). A kind of gelatine obtained by boiling _cartilage_.

Chordae Tendineae. Tendinous cords.

Choroid (Gr. chorion, skin, and eidos, form). The middle coat of the eyeball.

Chyle (Gr. chulos, juice). The milk-like fluid formed by the digestion of fatty articles of food in the intestines.

Chyme (Gr. chumos, juice). The pulpy liquid formed by digestion in the stomach.

Cilia (pl. of _cilium_, an eyelash). Minute hair-like processes found upon the cells of the air passages and other parts.

Ciliary Muscle. A small muscle of the eye which assists in accommodation.

Circumvallate (Lat. _circum_, around, and _vallum_, a rampart). Surrounded by a rampart, as are certain papillae of the tongue.

Coagulation (Lat. _coagulo_, to curdle). Applied to the process by which the blood clots or solidifies.

Cochlea (Lat. _cochlea_, a snail shell). The spiral cavity of the internal ear.

Columnae Carneae. Fleshy projections in the ventricles of the heart.

Commissure (Lat. _con_, together, and _mitto_, _missum_, to put). A joining or uniting together.

Compress. A pad or bandage applied directly to an injury to compress it.

Concha (Gr. kogche, a mussel shell). The shell-shaped portion of the external ear.

Congestion (Lat. _con_, together, and _gero_, to bring). Abnormal gathering of blood in any part of the body.

Conjunctiva (Lat. _con_, together, and _jungo_, to join). A thin layer of mucous membrane which lines the eyelids and covers the front of the eyeball, thus joining the latter to the lids.

Connective Tissue. The network which connects the minute parts of most of the structures of the body.

Constipation (Lat. _con_, together, and _stipo_, to crowd close). Costiveness.

Consumption (Lat. _consumo_, to consume). A disease of the lungs, attended with fever and cough, and causing a decay of the bodily powers. The medical name is _phthisis_.

Contagion (Lat. _con_, with, and _tango_ or _tago_, to touch). The communication of disease by contact, or by the inhalation of the effluvia of a sick person.

Contractility (Lat. _con_, together, and _traho_, to draw). The property of a muscle which enables it to contract, or draw its extremities closer together.

Convolutions (Lat. _con_, together, and _volvo_, to roll). The tortuous foldings of the external surface of the brain.

Convulsion (Lat. _convello_, to pull together). A more or less violent agitation of the limbs or body.

Cooerdination. The manner in which several different organs of the body are brought into such relations with one another that their functions are performed in harmony.

Coracoid (Gr. koraxi, a crow, eidos, form). Shaped like a crow's beak.
Cornea (Lat. _cornu_, a horn). The transparent horn-like substance which covers a part of the front of the eyeball.

Coronary (Lat. _corona_, a crown). A term applied to vessels and nerves which encircle parts, as the _coronary_ arteries of the heart.

Coronoid (Gr. koro#x3CE;ne, a crow). Like a crow's beak; thus the _coronoid_ process of the ulna.

Cricoid (Gr. krikos, a ring, and eidos, form). A cartilage of the larynx resembling a seal ring in shape.

Crystalline Lens (Lat. _crystallum_, a crystal). One of the humors of the eye; a double-convex body situated in the front part of the eyeball.

Cumulative. A term applied to the violent action from drugs which supervenes after the taking of several doses with little or no effect.

Cuticle (Lat. dim. of _cutis_, the skin). Scarf skin; the epidermis.

Cutis (Gr. sky#1FE6;tos, a skin or hide). The true skin, also called the _dermis_.

Decussation (Lat. _decusso_, _decussatum_, to cross). The _crossing_ or running of one portion athwart another.

Degeneration (Lat. _degenerare_, to grow worse, to deteriorate). A change in the structure of any organ which makes it less fit to perform its duty.

Deglutition (Lat. _deglutire_, to swallow). The process of swallowing.

Deltoid. Having a triangular shape; resembling the Greek letter D (_delta_).

Dentine (Lat. _dens_, _dentis_, a tooth). The hard substance which forms the greater part of a tooth; ivory.

Deodorizer. An agent which corrects any foul or unwholesome odor.

Dextrin. A soluble substance obtained from starch.

Diabetes Mellitus (Gr. dia, through, baino, to go, and me#x3AD;li, honey). Excessive flow of sugar-containing urine.

Diaphragm (Gr. diaphrasso, to divide by a partition). A large, thin muscle which separates the cavity of the chest from the abdomen.

Diastole (Gr. diastello, to dilate). The _dilatation_ of the heart.

Dietetics. That part of medicine which relates to diet, or food.

Diffusion of Gases. The power of gases to become intimately mingled.

Diploee (Gr. diploo, to double, to fold). The osseous tissue between the tables of the skull.

Dipsomania (Gr. dipsa, thirst, and mania, madness). An insatiable desire for intoxicants. Disinfectants. Agents used to destroy the germs or particles of living matter that are believed to be the causes of infection.

Dislocation (Lat. _dislocare_, to put out of place). An injury to a joint in which the bones are displaced or forced out of their sockets.

Dissection (Lat. _dis_, apart, and _seco_, to cut). The cutting up of an animal in order to learn its structure.

Distal (Lat. _dis_, apart, and _sto_, to stand). Away from the center.

Duct (Lat. _duco_, to lead). A narrow tube.

Duodenum (Lat. _duodeni_, twelve). The first division of the small intestines, about twelve fingers' breadth long.

Dyspepsia (Gr. -dys, ill, and peptein, to digest). A condition of the alimentary canal in which it digests imperfectly. Indigestion.

Dyspnoea (Gr. dys, difficult, and pneo, to breathe). Difficult breathing.

Efferent (Lat. _effero_, to carry out). _Bearing_ or _carrying outwards_, as from the center to the periphery.

Effluvia (Lat. _effluo_, to flow out). Exhalations or vapors coming from the body, and from decaying animal or vegetable substances.

Element. One of the simplest parts of which anything consists.

Elimination (Lat. _e_, out of, and _limen, liminis_, a threshold). The act of _expelling_ waste matters. Signifies, literally, "to throw out of doors."

Emetic (Gr. emeo, to vomit). A medicine which causes vomiting.

Emulsion (Lat. _emulgere_, to milk). Oil in a finely divided state, suspended in water.

Enamel (Fr. _email_). Dense material covering the crown of a tooth.

Endolymph (Gr. endon, within, and Lat. _lympha_, water). The fluid in the membranous labyrinth of the ear.

Endosmosis (Gr. endon, within, and o#x1F60;theo, to push). The current from without _inwards_ when diffusion of fluids takes place through a membrane.

Epidemic (Gr. epi, upon, and demos, the people). An extensively prevalent disease.

Epiglottis (Gr. epi, upon, and glottis, the entrance to the windpipe). A leaf-shaped piece of cartilage which covers the top of the larynx during the act of swallowing.

Epilepsy (Gr. epilepsis, a seizure). A nervous disease accompanied by fits in which consciousness is lost; the falling sickness.

Ether (Gr. aither, the pure, upper air). A narcotic poison. Used as an anaesthetic in surgical operations.

Eustachian (from an Italian anatomist named Eustachi). The tube which leads from the throat to the middle ear, or tympanum. Excretion (Lat. _excerno_, to separate). The separation from the blood of the waste matters of the body; also the materials excreted.

Exosmosis (Gr. exio, without, and atheo, to push). The current from within _outwards_ when diffusion of fluids takes place through a membrane.

Expiration (Lat. _expiro_, to breathe out). The act of forcing air out of the lungs.

Extension (Lat. _ex_, out, and _tendo_, to stretch). The act of restoring a limb, etc., to its natural position after it has been flexed or bent; the opposite of _flexion_.

Fauces. The part of the mouth which opens into the pharynx.

Fenestra (Lat.). Literally, "a window." Fenestra ovalis and fenestra rotunda, the oval and the round window; two apertures in the bone between the tympanic cavity and the labyrinth of the ear.

Ferment. That which causes fermentation, as yeast.

Fermentation (Lat. _fermentum_, boiling). The process of undergoing an effervescent change, as by the action of yeast; in a wider sense, the change of organized substances into new compounds by the action of a ferment. It differs in kind according to the nature of the ferment.

Fiber (Lat. _fibra_, a filament). One of the tiny threads of which many parts of the body are composed.

Fibrilla. A little fiber; one of the longitudinal threads into which a striped muscular fiber can be divided.

Fibrin (Lat. _fibra_, a fiber). An albuminoid substance contained in the flesh of animals, and also produced by the coagulation of blood.

Flexion (Lat. _flecto_, to bend). The act of bending a limb, etc.

Follicle (Lat. dim. of _follis_, a money bag). A little pouch or depression.

Fomentation (Lat. _foveo_, to keep warm). The application of any warm, medicinal substance to the body, by which the vessels are relaxed.

Foramen. A hole, or aperture.

Frontal Sinus. A blind or closed cavity in the bones of the skull just over the eyebrows.

Fumigation (Lat. _fumigo_, to perfume a place). The use of certain fumes to counteract contagious effluvia.

Function (Lat. _functio_, a doing). The special duty of any organ.

Ganglion (Gr. ganglin, a knot). A knot-like swelling in a nerve; a smaller nerve center.

Gastric (Gr. gaster, stomach). Pertaining to the stomach.

Gelatine (Lat. _gelo_, to congeal). An animal substance which dissolves in hot water and forms a jelly on cooling. Germ (Lat. _germen_, a sprout, bud). Disease germ; a name applied to certain tiny bacterial organisms which have been demonstrated to be the cause of disease.

Germicide (_Germ_, and Lat. _caedere_, to kill). Any agent which has a destructive action upon living germs, especially _bacteria_.

Gland (Lat. _glans_, an acorn). An organ consisting of follicles and ducts, with numerous blood-vessels interwoven.

Glottis (Gr. glotta, the tongue). The narrow opening between the vocal cords.

Glucose. A kind of sugar found in fruits, also known as grape sugar.

Gluten. The glutinous albuminoid ingredient of cereals.

Glycogen. Literally, "producing glucose." Animal starch found in liver, which may be changed into glucose.

Gram. Unit of metric system, 15.43 grains troy.

Groin. The lower part of the abdomen, just above each thigh.

Gustatory (Lat. _gusto_, _gustatum_, to taste). Belonging to the sense of _taste_.

Gymnastics (Gr. gumnaxio, to exercise). The practice of athletic exercises.

Haemoglobin (Gr. haima, blood, and Lat. _globus_, a globe or globule). A complex substance which forms the principal coloring constituent of the red corpuscles of the blood.

Hemispheres (Gr. hemi, half, and sphaira, a sphere). Half a sphere, the lateral halves of the cerebrum, or brain proper.

Hemorrhage (Gr. haima, blood, and hregnumi, to burst). Bleeding, or the loss of blood.

Hepatic (Gr. he#x1F27;par, the liver). Pertaining to the liver.

Herbivorous (Lat. _herba_, an herb, and _voro_, to devour). Applied to animals that subsist upon vegetable food.

Heredity. The predisposition or tendency derived from one's ancestors to definite physiological actions.

Hiccough. A convulsive motion of some of the muscles used in breathing, accompanied by a shutting of the glottis.

Hilum, sometimes written Hilus. A small fissure, notch, or depression. A term applied to the concave part of the kidney.

Homogeneous (Gr. ho#1F41;mos, the same, and genos, kind). Of the _same kind_ or quality throughout; uniform in nature,--the reverse of heterogeneous.

Humor. The transparent contents of the eyeball.

Hyaline (Gr. hyalos, glass). Glass-like, resembling glass in transparency.

Hydrogen. An elementary gaseous substance, which, in combination with oxygen, produces water.

Hydrophobia (Gr. hydor, water, and phobeomai, to fear). A disease caused by the bite of a rabid dog or other animal.

Hygiene (Gr. hygieia health). The art of preserving health and preventing disease.

Hyoid (Gr. letter u, and eidos, form, resemblance). The bone at the root of the tongue, shaped like the Greek letter u.

Hypermetropia (Gr. hyper over, beyond, metron, measure, and ops, the eye). Far-sightedness.

Hypertrophy (Gr. hyper, over, and trophe, nourishment). Excessive growth; thickening or enlargement of any part or organ.

Incisor (Lat. _incido_, to cut). Applied to the four front teeth of both jaws, which have sharp, cutting edges.

Incus. An anvil; the name of one of the bones of the middle ear.

Indian Hemp. The common name of _Cannabis Indica_, an intoxicating drug known as _hasheesh_ and by other names in Eastern countries.

Inferior Vena Cava. The chief vein of the lower part of the body.

Inflammation (Lat. prefix _in_ and _flammo_, to flame). A redness or swelling of any part of the body with heat and pain.

Insalivation (Lat. _in_ and _saliva_, the fluid of the mouth). The mingling of the saliva with the food during the act of chewing.

Inspiration (Lat. _inspiro, spiratum_, to breathe in). The act of drawing in the breath.

Intestine (Lat. _intus_, within). The part of the alimentary canal which is continuous with the lower end of the stomach; also called the bowels.

Iris (Lat. _iris_, the rainbow). The thin, muscular ring which lies between the cornea and crystalline lens, giving the eye its special color.

Jaundice (Fr. _jaunisse_, yellow). A disorder in which the skin and eyes assume a yellowish tint.

Katabolism (Gr. kataballo, to throw down). The process by means of which the more complex elements are rendered more simple and less complex. The opposite of _anabolism_.

Labyrinth. The internal ear, so named from its many windings.

Lacrymal Apparatus (Lat. _lacryma_, a tear). The organs for forming and carrying away the tears.

Lacteals (Lat. _lac, lactis_, milk). The absorbent vessels of the small intestines.

Laryngoscope (Gr. larugxi, larynx, and skopeo, to behold). An instrument consisting of a mirror held in the throat, and a reflector to throw light on it, by which the interior of the larynx is brought into view.

Larynx. The cartilaginous tube situated at the top of the windpipe.

Lens. Literally, a lentil; a piece of transparent glass or other substance so shaped as either to converge or disperse the rays of light.

Ligament (Lat. _ligo_, to bind). A strong, fibrous material binding bones or other solid parts together.

Ligature (Lat. _ligo_, to bind). A thread of some material used in tying a cut or injured artery.

Lobe. A round, projecting part of an organ, as of the liver, lungs, or brain.

Lymph (Lat. _lympha_, pure water). The watery fluid conveyed by the lymphatic vessels.

Lymphatic Vessels. A system of absorbent vessels.

Malleus. Literally, the mallet; one of the small bones of the middle ear.

Marrow. The soft, fatty substance contained in the cavities of bones.

Mastication (Lat. _mastico_, to chew). The act of cutting and grinding the food to pieces by means of the teeth.

Meatus (Lat. _meo_, _meatum_, to pass). A _passage_ or canal.

Medulla Oblongata. The "oblong marrow"; that portion of the brain which lies upon the basilar process of the occipital bone.

Meibomian. A term applied to the small glands between the conjunctiva and tarsal cartilages, discovered by _Meibomius_.

Membrana Tympani. Literally, the membrane of the drum; a delicate partition separating the outer from the middle ear; it is sometimes popularly called "the drum of the ear."

Membrane. A thin layer of tissue serving to cover some part of the body.

Mesentery (Gr. mesos, middle, and enteron, the intestine). A duplicature of the peritoneum covering the small _intestine_, which occupies the _middle_ or center of the abdominal cavity.

Metabolism (Gr. metabole, change). The _changes_ taking place in cells, whereby they become more complex and contain more force, or less complex and contain less force. The former is constructive metabolism, or _anabolism_; the latter, destructive metabolism, or _katabolism_.

Microbe (Gr. mikros, little, and bios, life). A microscopic organism, particularly applied to bacteria.

Microscope (Gr. mikro#3CC;s, small, and skopeo, to look at). An optical instrument which assists in the examination of minute objects.

Molar (Lat. _mola_, a mill). The name applied to the three back teeth at each side of the jaw; the grinders, or mill-like teeth.

Molecule (dim. of Lat. _moles_, a mass). The smallest quantity into which the mass of any substance can physically be divided. A molecule may be chemically separated into two or more atoms.

Morphology (Gr. morphe, form, and logos, discourse). The study of the laws of form or structure in living beings.

Motor (Lat. _moveo_, _motum_, to move). The name of the nerves which conduct to the muscles the stimulus which causes them to contract.

Mucous Membrane. The thin layer of tissue which covers those internal cavities or passages which communicate with the external air.

Mucus. The glairy fluid secreted by mucous membranes.

Myopia (Gr. myo, to shut, and o#x1F64;ps, the eye). A defect of vision dependent upon an eyeball that is too long, rendering distant objects indistinct; _near sight_.

Myosin (Gr. mos, muscle). Chief proteid substance of muscle.

Narcotic (Gr. narkao, to benumb). A medicine which, in poisonous doses, produces stupor, convulsions, and sometimes death.

Nerve Cell. A minute round and ashen-gray cell found in the brain and other nervous centers.

Nerve Fiber. An exceedingly slender thread of nervous tissue.

Nicotine. The poisonous and stupefying oil extracted from tobacco.

Nostril (Anglo-Saxon _nosu_, nose, and _thyrl_, a hole). One of the two outer openings of the nose.

Nucleolus (dim. of _nucleus_). A little nucleus.

Nucleus (Lat. _nux_, a nut). A central part of any body, or that about which matter is collected. In anatomy, a cell within a cell.

Nutrition (Lat. _nutrio_, to nourish). The processes by which the nourishment of the body is accomplished.

Odontoid (Gr. o#x1F40;doys, a tooth, eids, shape). The name of the bony peg of the second vertebra, around which the first turns.

OEsophagus. Literally, that which carries food. The tube leading from the throat to the stomach; the gullet.

Olecranon (Gr. olene, the elbow, and kranion, the top of the head). A curved eminence at the upper and back part of the ulna.

Olfactory (Lat. _olfacio_, to smell). Pertaining to the sense of smell.

Optic (Gr. o#1F40;pteyo, to see). Pertaining to the sense of sight.

Orbit (Lat. _orbis_, a circle). The bony socket or cavity in which the eyeball is situated.

Organ (Lat. _organum_, an instrument or implement). A portion of the body having some special function or duty.

Osmosis (Gr. osmos, impulsion). Diffusion of liquids through membranes.

Ossa Innominata, pl. of Os Innominatum (Lat.). "Unnamed bones." The irregular bones of the pelvis, unnamed on account of their non-resemblance to any known object.

Otoconia (Gr. oys, an ear, and konia, dust). Minute crystals of lime in the vestibule of the ear; also known as _otoliths_.

Palate (Lat. _palatum_, the palate). The roof of the mouth, consisting of the hard and soft palate.

Palpitation (Lat. _palpitatio_, a frequent or throbbing motion). A violent and irregular beating of the heart.

Papilla. The small elevations found on the skin and mucous membranes.

Paralysis (Gr. paralyo, to loosen; also, to disable). Loss of function, especially of motion or feeling. Palsy.

Parasite. A plant or animal that grows or lives on another.

Pelvis. Literally, a basin. The bony cavity at the lower part of the trunk.

Pepsin (Gr. pepto, to digest). The active principle of the gastric juice.

Pericardium (Gr. peri, about, and kardia, heart). The sac enclosing the heart.

Periosteum (Gr. peri, around, osteon, a bone). A delicate fibrous membrane which invests the bones.

Peristaltic Movements (Gr. peri, round, and stello, to send). The slow, wave-like movements of the stomach and intestines.

Peritoneum (Gr. periteino, to stretch around). The investing membrane of the stomach, intestines, and other abdominal organs.

Perspiration (Lat. _perspiro_, to breathe through). The sweat.

Petrous (Gr. petra, a rock). The name of the hard portion of the temporal bone, in which are situated the drum of the ear and labyrinth.

Phalanges (Gr. phalagxi, a body of soldiers closely arranged in ranks and files). The bones of the fingers and toes.

Pharynx (Gr. pharmgxi, the throat). The cavity between the back of the mouth and the gullet.

Physiology (Gr. physis, nature, and logos, a discourse). The science of the functions of living, organized beings.

Pia Mater (Lat.). Literally, the tender mother; the innermost of the three coverings of the brain. It is thin and delicate; hence the name.

Pinna (Lat. a feather or wing). External cartilaginous flap of the ear.

Plasma (Gr. plasso, to mould). Anything formed or moulded. The liquid part of the blood.

Pleura (Gr. pleura, the side, also a rib). A membrane covering the lung, and lining the chest.

Pleurisy. An inflammation affecting the pleura. Pneumogastric (Gr. pneymon, the lungs, and gaster, the stomach). The chief nerve of respiration; also called the _vagus_, or wandering nerve.

Pneumonia. An inflammation affecting the air cells of the lungs.

Poison (Fr. _poison_). Any substance, which, when applied externally, or taken into the stomach or the blood, works such a change in the animal economy as to produce disease or death.

Pons Varolii. Bridge of Varolius. The white fibers which form a _bridge_ connecting the different parts of the brain, first described by _Varolius_.

Popliteal (Lat. _poples_, _poplitis_, the ham, the back part of the knee). The space _behind the knee joint_ is called the _popliteal_ space.

Portal Vein (Lat. _porta_, a gate). The venous trunk formed by the veins coming from the intestines. It carries the blood to the liver.

Presbyopia (Gr. presbus, old, and ops, the eye). A defect of the accommodation of the eye, caused by the hardening of the crystalline lens; the "far sight" of adults and aged persons.

Process (Lat. _procedo_, _processus_, to proceed, to go forth). Any projection from a surface; also, a method of performance; a procedure.

Pronation (Lat. _pronus_, inclined forwards). The turning of the hand with the palm downwards.

Pronator. The group of muscles which turn the hand palm downwards.

Proteids (Gr. protos, first, and eidos, form). A general term for the albuminoid constitutents of the body.

Protoplasm (Gr. pro#x1FF6;tos, first, and plasso, to form). A _first-formed_ organized substance; primitive organic cell matter.

Pterygoid (Gr. pteron, a wing, and eidos, form, resemblance). Wing-like.

Ptomaine (Gr. ptoma, a dead body). One of a class of animal bases or alkaloids formed in the putrefaction of various kinds of albuminous matter.

Ptyalin (Gr. sialon, saliva). A ferment principle in _saliva_, having power to convert starch into sugar.

Pulse (Lat. _pello, pulsum_, to beat). The throbbing of an artery against the finger, occasioned by the contraction of the heart. Commonly felt at the _wrist_.

Pupil (Lat. _pupilla_). The central, round opening in the iris, through which light passes into the interior of the eye.

Pylorus (Gr. pulouros, a gatekeeper). The lower opening of the stomach, at the beginning of the small intestine.

Reflex (Lat. _reflexus_, turned back). The name given to involuntary movements produced by an excitation traveling along a sensory nerve to a center, where it is turned back or reflected along motor nerves.

Renal (Lat. _ren_, _renis_, the kidney). Pertaining to the _kidneys_.

Respiration (Lat. _respiro_, to breathe frequently). The function of breathing, comprising two acts,--_inspiration_, or breathing in, and _expiration_, or breathing out.

Retina (Lat. _rete_, a net). The innermost of the three tunics, or coats, of the eyeball, being an expansion of the optic nerve.

Rima Glottidis (Lat. _rima_, a chink or cleft). The _opening_ of the glottis.

Saccharine (Lat. _saccharum_, sugar). The group of food substances which embraces the different varieties of sugar, starch, and gum.

Saliva. The moisture, or fluids, of the mouth, secreted by the salivary glands; the spittle.

Sarcolemma (Gr. sarxi, flesh, and lemma, a husk). The membrane which surrounds the contractile substance of a striped muscular fiber.

Sclerotic (Gr. skleros, hard). The tough, fibrous, outer coat of the eyeball.

Scurvy. Scorbutus,--a disease of the general system, having prominent skin symptoms.

Sebaceous (Lat. _sebum_, fat). Resembling fat; the name of the oily secretion by which the skin is kept flexible and soft.

Secretion (Lat. _secerno_, _secretum_, to separate). The process of separating from the blood some essential, important fluid; which fluid is also called a _secretion_.

Semicircular Canals. Three canals in the internal ear.

Sensation. The perception of an external impression by the nervous system.

Serum. The clear, watery fluid which separates from the clot of the blood.

Spasm (Gr. spasmos, convulsion). A sudden, violent, and involuntary contraction of one or more muscles.

Special Sense. A sense by which we receive particular sensations, such as those of sight, hearing, taste, and smell.

Sputum, pi. Sputa (Lat. _spuo_, _sputum_, to _spit_). The matter which is coughed up from the air passages.

Stapes. Literally, a stirrup; one of the small bones of the middle ear.

Stimulant (Lat. _stimulo_, to prick or goad on). An agent which causes an increase of vital activity in the body or in any of its parts.

Striated (Lat. _strio_, to furnish with channels). Marked with fine lines.

Styptics (Gr. stuptikos astringent). Substances used to produce a contraction or shrinking of living tissues.

Subclavian Vein (Lat. _sub_, under, and _clavis_, a key). The great vein bringing back the blood from the arm and side of the head; so called because it is situated underneath the _clavicle_, or collar bone.

Superior Vena Cava (Lat., upper hollow vein). The great vein of the upper part of the body.

Suture (Lat. _sutura_, a seam). The union of certain bones of the skull by the interlocking of jagged edges.

Sympathetic System of Nerves. A double chain of nervous ganglia, situated chiefly in front of, and on each side of, the spinal column.

Symptom (Gr. syn, with, and pipto, to fall). A sign or token of disease.

Synovial (Gr. syn, with, and oon, an egg). The liquid which lubricates the joints; joint-oil. It resembles the white of a raw egg.

System. A number of different organs, of similar structures, distributed throughout the body and performing similar functions.

Systemic. Belonging to the system, or body, as a whole.

Systole (Gr. sustello, to contract). The contraction of the heart, by which the blood is expelled from that organ.

Tactile (Lat. _tactus_, touch). Relating to the sense of touch.

Tartar. A hard crust which forms on the teeth, and is composed of salivary mucus, animal matter, and a compound of lime.

Temporal (Lat. _tempus_, time, and _tempora_, the temples). Pertaining to the temples; so called because the hair begins to turn white with age in that portion of the scalp.

Tendon (Lat. _tendo_, to stretch). The white, fibrous cord, or band, by which a muscle is attached to a bone; a sinew.

Tetanus (Gr. teino, to stretch). A disease marked by persistent contractions of all or some of the voluntary muscles; those of the jaw are sometimes solely affected; the disorder is then termed lockjaw.

Thorax (Gr. thoraxi, a breast-plate). The upper cavity of the trunk of the body, containing the lungs, heart, etc.; the chest.

Thyroid (Gr. thureos, a shield, and ei#x313;dos, form). The largest of the cartilages of the larynx: its projection in front is called "Adam's Apple."

Tissue. Any substance or texture in the body formed of various elements, such as cells, fibers, blood-vessels, etc., interwoven with each other.

Tobacco (Indian _tabaco_, the tube, or pipe, in which the Indians smoked the plant). A plant used for smoking and chewing, and in snuff.

Trachea (Gr. trachys, rough). The windpipe.

Tragus (Gr. tragos, a goat). The eminence in front of the opening of the ear; sometimes hairy, like a goat's beard.

Transfusion (Lat. _transfundo_, to pour from one vessel to another). The operation of injecting blood taken from one person into the veins of another.

Trichina Spiralis. (A twisted hair). A minute species of parasite, or worm, which infests the flesh of the hog: may be introduced into the human system by eating pork not thoroughly cooked.

Trochanter (Gr. trochao, to turn, to revolve). Name given to two projections on the upper extremities of the femur, which give attachment to the _rotator_ muscles of the thigh.

Trypsin. The ferment principle in pancreatic juice, which converts proteid material into peptones.

Tubercle (Lat. _tuber_, a bunch). A pimple, swelling, or tumor. A morbid product occurring in certain lung diseases.

Tuberosity (Lat. _tuber, tuberis_, a swelling). A protuberance.

Turbinated (Lat. _turbinatus_, from _turbo, turbinis_, a top). Formed like a _top_; a name given to the bones in the outer wall of the nasal fossae.

Tympanum (Gr. _tympanon_, a drum). The cavity of the middle ear, resembling a drum in being closed by two membranes.

Umbilicus (Lat., the navel.) A round cicatrix or scar in the median line of the abdomen.

Urea (Lat. _urina_, urine). Chief solid constitutent of _urine_. Nitrogenous product of tissue decomposition.

Ureter (Gr. _oureo_, to pass urine). The tube through which the _urine_ is conveyed from the kidneys to the bladder.

Uvula (Lat. _uva_, a grape). The small, pendulous body attached to the back part of the palate.

Vaccine Virus (Lat. _vacca_, a cow, and _virus_, poison). The material derived from heifers for the purpose of vaccination,--the great preventive of smallpox.

Valvulae Conniventes. A name given to transverse folds of the mucous membrane in the small intestine.

Varicose (Lat. _varix_, a dilated vein). A distended or enlarged vein.

Vascular (Lat. _vasculum_, a little vessel). Pertaining to or possessing blood or lymph vessels.

Vaso-motor (Lat. _vas_, a vessel, and _moveo, motum_, to move). Causing _motion_ to the _vessels_. Vaso-motor nerves cause contraction and relaxation of the blood-vessels.

Venae Cavae, pl. of Vena Cava. "Hollow veins." A name given to the two great veins of the body which meet at the right auricle of the heart

Venous (Lat. _vena_, a vein). Pertaining to, or contained within, a vein.

Ventilation. The introduction of fresh air into a room or building in such a manner as to keep the air within it in a pure condition.

Ventral (Lat. _venter, ventris_, the belly). Belonging to the abdominal or belly cavity.

Ventricles of the Heart. The two largest cavities of the heart.

Vermiform (Lat. _vermis_, a worm, and _forma_, form). Worm-shaped.

Vertebral Column (Lat. _vertebra_, a joint). The backbone; also called the spinal column and spine.

Vestibule. A portion of the internal ear, communicating with the semicircular canals and the cochlea, so called from its fancied resemblance to the vestibule, or porch, of a house.

Villi (Lat. _villus_, shaggy hair). Minute, thread-like projections upon the internal surface of the small intestine, giving it a velvety appearance.

Virus (Lat., poison). Foul matter of an ulcer; poison.

Vital Knot. A part of the medulla oblongata, the destruction of which causes instant death.

Vitreous (Lat. _vitrum_, glass). Having the appearance of glass; applied to the humor occupying the largest part of the cavity of the eyeball.

Vivisection (Lat. _vivus_, alive, and _seco_, to cut). The practice of operating upon living animals, for the purpose of studying some physiological process.

Vocal Cords. Two elastic bands or ridges situated in the larynx; the essential parts of the organ of voice.

Zygoma (Gr. zugos, a yoke). The arch formed by the malar bone and the zygomatic process of the temporal bone.

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Footnotes:

[1] The Value of Physiological Knowledge. "If any one doubts the importance of an acquaintance with the fundamental principles of physiology as a means to complete living, let him look around and see how many men and women he can find in middle life, or later, who are thoroughly well. Occasionally only do we meet with an example of vigorous health continued to old age; hourly do we meet with examples of acute disorder, chronic ailment, general debility, premature decrepitude. Scarcely is there one to whom you put the question, who has not, in the course of his life, brought upon himself illness from which a little knowledge would have saved him. Here is a case of heart disease consequent on a rheumatic fever that followed a reckless exposure. There is a case of eyes spoiled for life by overstudy.

"Not to dwell on the natural pain, the gloom, and the waste of time and money thus entailed, only consider how greatly ill health hinders the discharge of all duties,--makes business often impossible, and always more difficult; produces irritability fatal to the right management of children, puts the functions of citizenship out of the question, and makes amusement a bore. Is it not clear that the physical sins--partly our ancestors' and partly our own--which produce this ill health deduct more from complete living than anything else, and to a great extent make life a failure and a burden, instead of a benefaction and a pleasure?"--Herbert Spencer.

[2] The word protoplasm must not be misunderstood to mean a substance of a definite chemical nature, or of an invariable morphological structure; it is applied to any part of a cell which shows the properties of life, and is therefore only a convenient abbreviation for the phrase "mass of living matter."

[3] "Did we possess some optic aid which should overcome the grossness of

our vision, so that we might watch the dance of atoms in the double process of making and unmaking in the living body, we should see the commonplace, lifeless things which are brought by the blood, and which we call food, caught up into and made part of the molecular whorls of the living muscle, linked together for a while in the intricate figures of the dance of life, giving and taking energy as they dance, and then we should see how, loosing hands, they slipped back into the blood as dead, inert, used-up matter."--Michael Foster, Professor of Physiology in the University of Cambridge, England.

[4] "Our material frame is composed of innumerable atoms, and each separate and individual atom has its birth, life, and death, and then its removal from the 'place of the living.' Thus there is going on a continuous process of decay and death among the individual atoms which make up each tissue. Each tissue preserves its vitality for a limited space only, is then separated from the tissue of which it has formed a part, and is resolved into its inorganic elements, to be in due course eliminated from the body by the organs of excretion."--Maclaren's _Physical Education_.

[5] The periosteum is often of great practical importance to the surgeon. Instances are on record where bones have been removed, leaving the periosteum, within which the entire bone has grown again. The importance of this remarkable tissue is still farther illustrated by experiments upon the transplantation of this membrane in the different tissues of living animals, which has been followed by the formation of bone in these situations. Some years ago a famous surgeon in New York removed the whole lower jawbone from a young woman, leaving the periosteum and even retaining in position the teeth by a special apparatus. The entire jawbone grew again, and the teeth resumed their original places as it grew.

[6] The mechanism of this remarkable effect is clearly shown by an experiment which the late Dr. Oliver Wendell Holmes used to take delight in performing in his anatomical lectures at the Harvard Medical College. He had a strong iron bar made into a ring of some eight inches in diameter, with a space left between the ends just large enough to be filled by an English walnut. The ring was then dropped to the floor so as to strike on the convexity just opposite to the walnut, which invariably was broken to pieces.

[7] For the treatment of accidents and emergencies which may occur with reference to the bones, see Chapter XIII.

[8] "Besides the danger connected with the use of alcoholic drinks which is common to them with other narcotic poisons, alcohol retards the growth of young cells and prevents their proper development. Now, the bodies of all animals are made up largely of cells, ... and the cells being the living part of the animal, it is especially important that they should not be injured or badly nourished while they are growing. So that alcohol in all its forms is particularly injurious to young persons, as it retards their growth, and stunts both body and mind. This is the theory of Dr. Lionel S. Beale, a celebrated microscopist and thinker, and is quite generally accepted."--Dr. Roger S. Tracy, of the New York Board of Health.

[9] "In its action on the system nicotine is one of the most powerful poisons known. A drop of it in a concentrated form was found sufficient to kill a dog, and small birds perished at the approach of a tube containing it."--Wood's _Materia Medica_.

"Tobacco appears to chiefly affect the heart and brain, and I have therefore placed it among cerebral and cardiac poisons."--Taylor's _Treatise on Poisons_.

[10] "Certain events occur in the brain; these give rise to other events, to changes which travel along certain bundles of fibers called nerves, and so reach certain muscles. Arrived at the muscles, these changes in the nerves, which physiologists call nervous impulses, induce changes in the muscles, by virtue of which these shorten contract, bring their ends together, and so, working upon bony levers, bend the arm or hand, or lift the weight."--Professor Michael Foster.

[11] The synovial membranes are almost identical in structure with serous membranes (page 176), but the secretion is thicker and more like the white of egg.

[12] "Smoking among students or men training for contests is a mistake. It not only affects the wind, but relaxes the nerves in a way to make them less vigorous for the coming contest. It shows its results at once, and when the athlete is trying to do his best to win he will do well to avoid it." Joseph Hamblen Sears, Harvard Coach, and Ex-Captain of the Harvard Football Team, Article in _In Sickness and in Health_.

[13] "There is no profession, there is no calling or occupation in which men can be engaged, there is no position in life, no state in which a man can be placed, in which a fairly developed frame will not be valuable to him; there are many of these, even the most purely and highly intellectual, in which it is essential to success--essential simply as a means, material, but none the less imperative, to enable the mind to do its work. Year by year, almost day by day, we see men (and women) falter and fail in the midst of their labors; ... and all for want of a little bodily stamina--a little bodily power and bodily capacity for the endurance of fatigue, or protracted unrest, or anxiety, or grief."--Maclaren's _Physical Education_.

[14] "One half the struggle of physical training has been won when a boy can be induced to take a genuine interest in his bodily condition,--to want to remedy its defects, and to pride himself on the purity of his skin, the firmness of his muscles, and the uprightness of his figure. Whether the young man chooses afterwards to use the gymnasium, to run, to row, to play ball, or to saw wood, for the purpose of improving his physical condition, matters little, provided he accomplishes that object."--Dr. D. A. Sargent, Director of the Hemenway Gymnasium at Harvard University.

[15] "It is _health_ rather than _strength_ that is the great requirement of modern men at modern occupations; it is not the power to travel great distances, carry great burdens, lift great weights, or overcome great material obstructions; it is simply that condition of body, and that amount of vital capacity, which shall enable each man in his place to pursue his calling, and work on in his working life, with the greatest amount of comfort to himself and usefulness to his fellowmen."--Maclaren's _Physical Education_.

[16] To this classification may be added what are called albuminoids, a group of bodies resembling proteids, but having in some respects a different nutritive value. Gelatine, such as is found in soups or table gelatine is a familiar example of the albuminoids. They are not found to any important extent in our raw foods, and do not therefore usually appear

in the analyses of the composition of foods. The albuminoids closely resemble the proteids, but cannot be used like them to build up protoplasm.

[17] The amount of water in various tissues of the body is given by the following table in parts of 1000:

Solids.		Liquids.	
Enamel,	2	Blood,	791
Dentine,	100	Bile,	864
Bone,	486	Blood plasma,	901
Fat,	299	Chyle,	928
Cartilage,	550	Lymph,	958
Liver,	693	Serum,	959
Skin,	720	Gastric juice,	973
Brain,	750	Tears,	982
Muscle,	757	Saliva,	995
Spleen,	758	Sweat,	995
Kidney,	827		
Vitreous humor,	987		

[18] The work of some kinds of moulds may be apparent to the eye, as in the growths that form on old leather and stale bread and cheese. That of others goes on unseen, as when acids are formed in stewed fruits. Concerning the work of the different kinds of moulds. Troussart says: "_Mucor mucedo_ devours our preserves; _Ascophora mucedo_ turns our bread mouldy; _Molinia_ is nourished at the expense of our fruits; _Mucor herbarium_ destroys the herbarium of the botanist; and _Choetonium chartatum_ develops itself on paper, on the insides of books and on their bindings, when they come in contact with a damp wall."--Troussart's _Microbes, Ferments, and Moulds_.

[19] "The physiological wear of the organism is constantly being repaired by the blood; but in order to keep the great nutritive fluid from becoming impoverished, the matters which it is constantly losing must be supplied from some source out of the body, and this necessitates the ingestion of articles which are known as food."--Flint's _Text-book of Human Physiology_.

[20] Glands. Glands are organs of various shapes and sizes, whose special work it is to separate materials from the blood for further use in the body, the products being known as secretion and excretion.
The means by which secretion and excretion are effected are, however, identical. The essential parts of a gland consist of a basement membrane, on one side of which are found actively growing cells, on the other is the blood current, flowing in exceedingly thin-walled vessels known as the capillaries. The cells are able to select from the blood whatever material they require and which they elaborate into the particular secretion. In Fig. 47 is illustrated, diagrammatically, the structure of a few typical secreting glands. The continuous line represents the basement membrane. The dotted line represents the position of the cells on one side of the basement membrane. The irregular lines show the position of the blood-vessels.

[21] Tablets and other material for Fehling and additional tests for sugar can be purchased at a drug store. The practical details of these and other tests which assume some knowledge of chemistry, should be learned from some manual on the subject.

[22] The Peritoneum. The intestines do not lie in a loose mass in the abdominal cavity. Lining the walls of this cavity, just as in a general way, a paper lines the walls of a room, is a delicate serous membrane, called the peritoneum. It envelops, in a greater or less degree, all the viscera in the cavity and forms folds by which they are connected with each other, or are attached to the posterior wall. Its arrangement is therefore very complicated. When the peritoneum comes in contact with the large intestine, it passes over it just as the paper of a room would pass over a gas pipe which ran along the surface of the wall, and in passing over it binds it down to the wall of the cavity. The small intestines are suspended from the back wall of the cavity by a double fold of the peritoneum, called the mesentery. The bowels are also protected from external cold by several folds of this membrane loaded with fat. This is known as the _great omentum_.

The peritoneum, when in health, secretes only enough fluid to keep its surface lubricated so that the bowels may move freely and smoothly on each other and on the other viscera. In disease this fluid may increase in amount, and the abdominal cavity may become greatly distended. This is known as _ascites_ or dropsy.

[23] The human bile when fresh is generally of a bright golden red, sometimes of a greenish yellow color. It becomes quite green when kept, and is alkaline in reaction. When it has been omited it is distinctly yellow, because of its action on the gastric juice. The bile contains a great deal of coloring matter, and its chief ingiedients are two salts of soda, sodium taurocholate and glycocholate.

[24] Nansen emphasizes this point in his recently published work, _Farthest North_.

[25] We should make it a point not to omit a meal unless forced to do so. Children, and even adults, often have the habit of going to school or to work in a hurry, without eating any breakfast. There is almost sure to be a fainting, or "all-gone" feeling at the stomach before another mealtime. This habit is injurious, and sure to produce pernicious results.

[26] The teeth of children should be often examined by the dentist, especially from the beginning of the second dentition, at about the sixth year, until growth is completed. In infancy the mother should make it a part of her daily care of the child to secure perfect cleanliness of the teeth. The child thus trained will not, when old enough to rinse the mouth properly or to use the brush, feel comfortable after a meal until the teeth have been cleansed. The habit thus formed is almost sure to be continued through life.

[27] "If the amount of alcohol be increased, or the repetition become frequent, some part of it undergoes acid fermentation in the stomach, and acid eructations or vomitings occur. With these phenomena are associated catarrh of the stomach and liver with its characteristic symptoms,--loss of appetite, feeble digestion, sallowness, mental depression, and headache."--James C. Wilson, Professor in the Jefferson Medical College, Philadelphia.

"Man has recourse to alcohol, not for the minute quantity of energy which may be supplied by itself, but for its powerful influence on the distribution of the energy furnished by other things. That influence is a very complex one."--Professor Michael Foster.

[28] "When constantly irritated by the direct action of alcoholic drinks, the stomach gradually undergoes lasting structural changes. Its vessels remain dilated and congested, its connective tissue becomes excessive, its power of secreting gastric juice diminishes, and its mucous secretions abnormally abundant."--H. Newell Martin, late Professor of Physiology in Johns Hopkins University.

"Chemical experiments have demonstrated that the action of alcohol on the digestive fluids is to destroy its active principle, the pepsin, thus confirming the observations of physiologists that its use gives ride to the most serious disorders of the stomach and the most malignant aberrations of the entire economy."--Professor E. C. Youmans, author of standard scientific works.

"The structural changes induced by habitual use of alcohol and the action of this agent on the pepsin, seriously impair the digestive power. Hence it is, that those who are habitual consumers of alcoholic fluids suffer from disorders o digestion."--Robert Bartholow, recently Professor of Materia Medica in the University of Pennsylvania.

"Alcohol in any appreciable quantity diminishes the solvent power of the gastric fluid so as to interfere with the process of digestion instead of aiding it."--Professor W. B. Carpenter, the eminent English physiologist.

[29] "Cirrhosis of the liver is notoriously frequent among drunkards, and is in fact almost, though not absolutely, confined to them."--Robert T. Edes, formerly Professor of Materia Medica in Harvard Medical College.

"Alcohol acts on the liver by producing enlargement of that organ, and a fat deposit, or 'hob-nailed' liver mentioned by the English writers."--Professor W. B. Carpenter.

[30] Preparation of Artificial Gastric Juice. _(a)_ Take part of the cardiac end of the pig's stomach, which has been previously opened and washed rapidly in cold water, and spread it, mucous surface upwards, on the convex surface of an inverted capsule. Scrape the mucous surface firmly with the back of a knife blade, and rub up the scrapings in a mortar with fine sand. Add water, and rub up the whole vigorously for some time, and filter. The filtrate is an artificial gastric juice.

_(b)_ From the cardiac end of a pig's stomach detach the mucous membrane in shreds, dry them between folds of blotting-paper, place them in a bottle, and cover them with strong glycerine for several days. The glycerine dissolves the pepsin, and on filtering, a glycerine extract with high digestive properties is obtained.

These artificial juices, when added to hydrochloric acid of the proper strength, have high digestive powers.

Instead of _(a)_ or _(b)_ use the artificial pepsin prepared for the market by the wholesale manufacturers of such goods.

[31] The cause of the clotting of blood is not yet fully understood. Although the process has been thoroughly investigated we have not yet a satisfactory explanation why the circulating blood does not clot in healthy blood-vessels. The ablest physiologists of our day do not, as formerly, regard the process as a so-called vital, but a purely chemical one.

[32] Serous Membranes.--The serous membranes form shut sacs, of which one portion is applied to the walls of the cavity which it lines; the other is reflected over the surface of the organ or organs contained in the cavity. The sac is completely closed, so that no communication exists between the serous cavity and the parts in its neighborhood. The various serous membranes are the _pleura_ which envelops the lungs; the _pericardium_ which surrounds the heart; the _peritoneum_ which invests the viscera of the abdomen, and the _arachnoid_ in the spinal canal and cranial cavity. In health the serous membranes secrete only sufficient fluid to lubricate and keep soft and smooth the opposing surfaces.

[33] A correct idea may be formed of the arrangement of the pericardium around the heart by recalling how a boy puts on and wears his toboggan cap. The pericardium encloses the heart exactly as this cap covers the boy's head.

[34] "Alcohol taken in small and single doses, acts almost exclusively on the brain and the blood-vessels of the brain, whereas taken in large and repeated doses its chief effects are always nervous effects. The first effects of alcohol on the function of inhibition are to paralyze the controlling nerves, so that the blood-centers are dilated, and more blood is let into the brain. In consequence of this flushing of the brain, its nerve centers are asked to do more work."--Dr. T. S. Clouston, Medical Superintendent of the Royal Asylum, Edinburgh.

"Alcoholic drinks prevent the natural changes going on in the blood, and obstruct the nutritive and reparative functions."--Professor E. L. Youmans, well-known scientist and author of _Class Book of Chemistry_.

[35] The word "cell" is not used in this connection in its technical signification of a histological unit of the body (sec. 12), but merely in its primary sense of a small cavity

[36] "The student must guard himself against the idea that arterial blood contains no carbonic acid, and venous blood no oxygen. In passing through the lungs venous blood loses only a part of its carbonic acid; and arterial blood, in passing through the tissues, loses only a part of its oxygen. In blood, however venous, there is in health always some oxygen; and in even the brightest arterial blood there is actually more carbonic acid than oxygen."--T. H. Huxley.

[37] "Consumption is a disease which can be taken from others, and is not simply caused by colds. A cold may make it easier to take the disease. It is usually caused by germs which enter the body with the air breathed. The matter which consumptives cough or spit up contains these germs in great numbers--frequently millions are discharged in a single day. This matter spit upon the floor, wall, or elsewhere is apt to dry, become pulverized, and float in the air as dust. The dust contains the germs, and thus they enter the body with the air breathed. The breath of a consumptive does not contain the germs and will not produce the disease. A well person catches the disease from a consumptive only by in some way taking in the matter coughed up by the consumptive."--Extract from a circular issued by the Board of Health of New York City.

[38] "The lungs from the congested state of their vessels produced by alcohol are more subject to the influence of cold, the result being frequent attacks of bronchitis. It has been recognized of late years that there is a peculiar form of consumption of the lungs which is very rapidly fatal and found only in alcohol drinkers."--Professor H. Newell Martin.

[39] "The relation to Bright's Disease is not so clearly made out as is assumed by some writers, though I must confess to myself sharing the popular belief that alcohol is one among its most important factors."--Robert T. Edes, M.D.

[40] Thus the fibers which pass out from the sacral plexus in the loins, and extend by means of the great sciatic nerve and its branches to the ends of the toes, may be more than a yard long.

[41] Remarkable instances are cited to illustrate the imperative demand for sleep. Gunner boys have been known to fall asleep during the height of a naval battle, owing to the fatigue occasioned by the arduous labor in carrying ammunition for the gunner. A case is reported of a captain of a British frigate who fell asleep and remained so for two hours beside one of the largest guns of his vessel, the gun being served vigorously all the time. Whole companies of men have been known to sleep while on the march during an arduous campaign. Cavalrymen and frontiersmen have slept soundly in the saddle during the exhausting campaigns against the Indians.

[42] According to the Annual Report of New York State Reformatory, for 1896, drunkenness among the inmates can be clearly traced to no less than 38 per cent of the fathers and mothers only.

Drunkenness among the parents of 38 per cent of the prisoners in a reformatory of this kind is a high and a serious percentage. It shows that the demoralizing influence of drink is apt to destroy the future of the child as well as the character of the parent.

"There is a marked tendency in nature to transmit all diseased conditions. Thus the children of consumptive parents are apt to be consumptive. But, of all agents, alcohol is the most potent in establishing a heredity that exhibits itself in the destruction of mind and body. There is not only a propensity transmitted, but an actual disease of the nervous system."--Dr. Willard Parker.

[43] "It is very certain that many infants annually perish from this single cause."--Reese's _Manual of Toxicology_.

[44] If an eye removed from its socket be stripped posteriorly of the sclerotic coat, an inverted image or the field of view will be seen on the retina; but if the lens or other part of the refractive media be removed, the image will become blurred or disappear altogether.

[45] This change in the convexity of the lens is only a slight one, as the difference in the focal point between rays from an object twenty feet distant and one four inches distant is only one-tenth of an inch. While this muscular action is taking place, the pupil contracts and the eyeballs converge by the action of the internal rectus muscles. These three acts are due to the third nerve (the motor oculi). This is necessary in order that each part should he imprinted on the same portion of the retina, otherwise there would be double vision.

[46] The Germans have a quaint proverb that one should never rub his eyes except with his elbows

[47] "The deleterious effect of tobacco upon eyesight is an acknowledged fact. The Belgian government instituted an investigation into the cause of the prevalence of color-blindness. The unanimous verdict of the experts

making the examination was that the use of tobacco was one of the principal causes of this defect of vision.

"The dimness of sight caused by alcohol or tobacco has long been clinically recognized, although not until recently accurately understood. The main facts can now be stated with much assurance, since the publication of an article by Uhthoff which leaves little more to be said. He examined one thousand patients who were detained in hospital because of alcoholic excess, and out of these found a total of eye diseases of about thirty per cent.

"Commonly both eyes are affected, and the progress of the disease is slow, both in culmination and in recovery.... Treatment demands entire abstinence."--Henry D. Noyes, Professor of Otology in the Bellevue Hospital Medical College, New York.

[48] "The student who will take a little trouble in noticing the ears of the persons whom he meets from day to day will be greatly interested and surprised to see how much the auricle varies. It may be a thick and clumsy ear or a beautifully delicate one; long and narrow or short and broad, may have a neatly formed and distinct lobule, or one that is heavy, ungainly, and united to the cheek so as hardly to form a separate part of the auricle, may hug the head closely or flare outward so as to form almost two wings to the head. In art, and especially in medallion portraits, in which the ear is a marked (because central) feature, the auricle is of great importance"--William W. Keen, M.D., editor of Gray's _Anatomy_

[49] The organ of Corti is a very complicated structure which it is needless to describe in this connection. It consists essentially of modified ephithelial cells floated upon the auditory epithelium, or basilar membrane, of the cochlea. There is a series of fibers, each made of two parts sloped against each other like the rafters of a roof. It is estimated that there are no less than 3000 of these arches in the human ear, placed side by side in a continuous series along the whole length of the basilar membrane. Resting on these arches are numbers of conical epithelial cells, from the free surface of which bundles of stiff hairs (cilia) project. The fact that these hair-cells are connected with the fibers of the cochlear division of the auditory nerve suggests that they must play an important part in auditory sensation.

[50] The voices of boys "break," or "change," because of the sudden growth or enlargement of the larynx, and consequent increase in length of the vocal cords, at from fourteen to sixteen years of age. No such enlargement takes place in the larynxes of girls: therefore their voices undergo no such sudden change.

[51] This experiment and several others in this book, are taken from Professor Bowditch's little book called _Hints for Teachers of Physiology_, a work which should be mastered by every teacher of physiology in higher schools.

[52] The teacher or student who is disposed to study the subject more thoroughly and in more detail than is possible in a class text-book, will find all that is needed in the following excellent books, which are readily obtained by purchase, or may be found in the public libraries of larger towns: Dulles' _Accidents and Emergencies;_ Pilcher's _First Aid in Illness and Injury_; Doty's _Prompt Aid to the Injured;_ and Johnston's "Surgical Injuries and Surgical Diseases," a special article in Roosevelt's _In Sickness and in Health_.

[53] "A tourniquet is a bandage, handkerchief, or strap of webbing, into the middle of which a stone, a potato, a small block of wood, or any hard, smooth body is tied. The band is tied loosely about the limb, the hard body is held over the artery to be constricted, and a stick is inserted beneath the band on the opposite side of the limb and used to twist the band in such a way that the limb is tightly constricted thereby, and the hard body thus made to compress the artery (Fig. 160).

"The entire circumference of the limb may be constricted by any sort of elastic band or rubber tube, or any other strong elastic material passed around the limb several times on a stretch, drawn tight and tied in a knot. In this way, bleeding may be stopped at once from the largest arteries. The longer and softer the tube the better. It requires no skill and but little knowledge of anatomy to apply it efficiently." Alexander B. Johnson, Surgeon to Roosevelt Hospital, New York City.

[54] Corrosive sublimate is probably the most powerful disinfectant known. A solution of one part in 2000 will destroy microscopic organisms. Two teaspoonfuls of this substance will make a solution strong enough to kill all disease germs.

[55] The burning of sulphur produces sulphurous acid, which is an irrespirable gas. The person who lights the sulphur must, therefore, immediately leave the room, and after the lapse of the proper time, must hold his breath as he enters the room to open the windows and let out the gas. After fumigation, plastered walls should be white-washed, the woodwork well scrubbed with carbolic soap, and painted portions repainted.

[56] Put copperas in a pail of water, in such quantity that some may constantly remain undissolved at the bottom. This makes a saturated solution. To every privy or water-closet, allow one pint of the solution for every four persons when cholera is about. To keep privies from being offensive, pour one pint into each seat, night and morning.

[57] "While physiology is one of the biological sciences, it should be clearly recognized that it is not, like botany or zoology, a science of observation and description; but rather, like physics or chemistry, a science of experiment. While the amount of experimental instruction (not involving vivisection or experiment otherwise unsuitable) that may with propriety be given in the high school is neither small nor unimportant, the limitations to such experimental teaching, both as to kind and as to amount, are plainly indicated.

"The obvious limitations to experimental work in physiology in the high school, already referred to, make it necessary for the student to acquire much of the desired knowledge from the text-book only. Nevertheless, much may be done by a thoughtful and ingenious teacher to make such knowledge real, by the aid of suitable practical exercises and demonstrations."--_Report of the Committee of Ten on Secondary School Studies_.

[58] This ingenious and excellent experiment is taken from the _New York School Journal_ for May, 1897, for which paper it was prepared by Charles D. Nason, of Philadelphia.

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