

HANDBOOK

OF THE

HOSPITAL CORPS

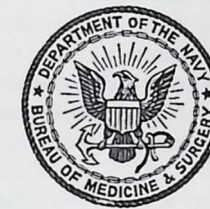
UNITED STATES NAVY

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HANDBOOK
OF THE
HOSPITAL CORPS
UNITED STATES NAVY
1939



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FOREWORD

In this 1939 edition of the Handbook of the Hospital Corps, U. S. Navy, the subject matter has been revised, enlarged, and brought up-to-date, as nearly as possible, with the sciences which are briefly discussed in the various chapters and sections.

The handbook is intended to serve as a general guide and reference book for the hospital corpsmen of the Navy, especially those performing duty independent of medical officers, and as a textbook for their instruction in the Hospital Corps Schools and elsewhere. It contains information and instructions concerning the duties of the Hospital Corps of the Navy, but hospital corpsmen, particularly those in the upper ratings, are urged to make frequent reference to the U. S. Navy Regulations, the Manual of the Medical Department, U. S. Navy, the manuals of other Navy Department bureaus, circular letters, etc., for additional information and instructions.

The principal subjects have been arranged in the order in which they occur in examinations for advancement in rating. As these subjects necessarily are presented in epitomized form, readers of the handbook should realize that the information contained in it must be supplemented by reference to the standard textbooks and professional journals usually available in the medical libraries of hospitals, ships, and stations.

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CHAPTER I

HISTORY OF THE HOSPITAL CORPS OF THE UNITED STATES NAVY

Prior to 1898 the duties attendant upon the care of the sick and injured of the Naval Establishment were performed by certain individuals whose appointment or enlistment was provided for from time to time, under various designations and titles, by order of the Navy Department.

In the earliest days of the Navy, afloat, the care of the sick and injured devolved upon the surgeon and the surgeon's mate, with the assistance of such members of the crew as were detailed to help in emergencies.

An act of Congress, approved March 2, 1799, provided: "A convenient place shall be set apart for the sick and hurt men, to which they are to be removed * * * and some of the crew shall be appointed to attend them, and keep the place clean." The place assigned on board ships for the care of the sick, in accordance with the above act, was usually referred to as the "cockpit" and in later years it was designated as the "sickbay."

The "loblolly boy" was the title designating the man or boy first specifically detailed to assist in the care of the sick and injured. The name probably originated in the British Navy, as it appears in some of the early writings on that service. The first official use of the title in the United States Navy appears in the Naval Regulations published in 1814 where it is stated: "The loblolly boy is to serve the surgeon and surgeon's mate."

The following is quoted from United States Naval Regulations, 1818: "The surgeon shall be allowed a faithful attendant to issue, under his direction, all supplies and provisions and hospital stores, and to attend the preparation of nourishment for the sick.

"The surgeon's mates shall be particularly careful in directing the loblolly boy to keep the cockpit clean, and every article therein belonging to the Medical Department.

"The surgeon shall prescribe for casual cases on the gun deck every morning at 9 o'clock, due notice having been previously given by his loblolly boy by the ringing of a bell."

The loblolly boy was succeeded by a male "nurse" in accordance with a general order of the Navy Department of June 16, 1861, which stated: "There shall be allowed to each vessel commissioned for sea service, with a complement of less than two hundred, one nurse, and with two hundred and over two nurses * * * to be appointed by the surgeon and approved by the commander of the ship, and to be borne upon the ship's books for special service upon the sick."

About the year 1873 the title of "bayman" came into use, and this title was recognized officially in the United States Naval Regulations published in 1876, and it remained in effect until the organization of the Hospital Corps of the Navy in 1898.

Baymen were enlisted as landsmen for general service, and rated bayman by the commanding officer on the recommendation of the surgeon, or senior medical officer. The number was regulated by the complement of the vessel.

The record of the advent of surgeon's stewards in the Navy is more or less obscure, but this seems to have been shortly after the Bureau of Medicine and Surgery was established in 1842. The following is an extract from a letter found in the old files of the bureau under date of May 5, 1843.

"A circular is now under consideration to allow a surgeon's steward to all hospitals and vessels, without necessity to sign articles, but to be appointed."

The Medical Journal of the U. S. S. *Rapidan*, 1844, bears a notation that an applicant for surgeon's steward was found disqualified for appointment on account of physical disability.

Originally surgeon's stewards were enlisted as landsmen or seamen, and were appointed by the commanding officer on the recommendation of the surgeon of the vessel. They were classed as petty officers and could be disgraced for incompetency or misbehavior.

By general order of the Navy Department, November 11, 1861, their status was changed to "appointed petty officer"; appointments were made for the "duration of the cruise" and they were subject to discharge for misbehavior, "the fact of misbehavior to be established by a summary court."

The title of surgeon's steward was changed to apothecary by circular order of the Navy Department, dated December 8, 1866. This order reads: "The designation of persons serving as surgeon's steward is changed to that of apothecary, and they will be appointed for duty in the Medical Department of the Navy, ashore and afloat, in the same manner as surgeon's stewards have heretofore been appointed. Apothecaries of the first class will rank with boatswains, * * *, Apothecaries of the second class will rank with boatswain's mates in charge, * * *, Apothecaries of the third class will rank with boatswain's mates."

United States Naval Regulations, 1893, article 1683, prescribed that: "Apothecaries for shore stations shall, with the approval of the Secretary of the Navy, be appointed by the Chief of the Bureau of Medicine and Surgery."

United States Naval Regulations, 1896, article 797, prescribed that: "A candidate for examination and first enlistment as apothecary must be a graduate of some recognized college of pharmacy."

The title of "apothecary" was changed to "hospital steward" by act of Congress of June 17, 1898.

The Hospital Corps of the United States Navy came into existence as an organized unit of the Medical Department under the provisions of an act of Congress, approved June 17, 1898.

This act established the grade of pharmacist, and the ratings of hospital steward, hospital apprentice, first class, and hospital apprentice; provided for appointments to the grade of pharmacist, and the enlisted ratings; fixed the pay and allowances; and specified the duties to be performed.

An act of Congress, approved August 22, 1912, provided that pharmacists after 6 years from date of warrant and after satisfactorily passing the prescribed examination should be commissioned chief pharmacists, and when so commissioned, have the rank, pay, and allowances of a chief boatswain.

The present organization of the Hospital Corps is in accordance with an act of Congress, approved August 29, 1916, and it is considered of sufficient importance, as a matter of general information to all hospital corpsmen, to quote the text of this act relating to the Hospital Corps in full.

"Hereafter the authorized strength of the Hospital Corps of the Navy shall equal three and one-half percentum of the authorized enlisted strength of the Navy and Marine Corps, and shall be in addition thereto, and as soon as the necessary transfers or appointments may be effected the Hospital Corps of the United

States Navy shall consist of the following grades and ratings: Chief pharmacists, pharmacists, and enlisted men classified as chief pharmacist's mates; pharmacist's mates, first class; pharmacist's mates, second class; pharmacist's mates, third class; hospital apprentices, first class; and hospital apprentices, second class; such classifications in enlisted ratings to correspond respectively to the enlisted ratings, seaman branch, of chief petty officers; petty officers, first class; petty officers, second class; petty officers, third class; seaman, first class; and seaman, second class: *Provided*, That enlisted men of other ratings in the Navy and in the Marine Corps shall be eligible for transfer to the Hospital Corps, and men of that corps to other ratings in the Navy and the Marine Corps.

"The President may hereafter, from time to time, appoint as many pharmacists as may be deemed necessary, from the rating of chief pharmacist's mate, subject to such moral, physical, and professional examinations and requirements as to length of service as the Secretary of the Navy may prescribe: *Provided*, That the pharmacists now in the Hospital Corps of the United States Navy or hereafter appointed therein in accordance with the provisions of this act shall have the same rank, pay, and allowances as are now or may hereafter be allowed other warrant officers.

"Pharmacists shall, after 6 years from the date of warrant, be commissioned chief pharmacists after passing satisfactorily such examinations as the Secretary of the Navy may prescribe, and shall, when so commissioned, have the same rank, pay, and allowances as now or may hereafter be allowed other commissioned warrant officers: *Provided*, That the pharmacists at present in the service who have served or may hereafter serve 6 or more years in that grade shall be eligible for promotion to the grade of chief pharmacist upon satisfactorily passing the examinations provided for in this act.

"The Secretary of the Navy is hereby empowered to limit and fix the numbers in the various ratings.

"Section three of an act entitled 'An act to organize a Hospital Corps of the Navy of the United States; to define its duties and regulate its pay,' approved June seventeenth, eighteen hundred and ninety-eight, be, and the same is hereby, repealed, and the pay, allowances, and emoluments of the enlisted men of the Hospital Corps shall be the same as are now, or may hereafter be, allowed for respective corresponding ratings, except the rating of turret captain of the first class in the seaman branch of the Navy: *Provided*, That the pay of the rating of the chief pharmacist's mate shall be the same as that now allowed for the existing rating of hospital steward.

"Hospital and ambulance service with such commands and at such places as may be prescribed by the Secretary of the Navy, shall be performed by members of said corps, and the corps shall be a constituent part of the Medical Department of the Navy; and the enlisted men thereof shall be a part of the enlisted force provided by law for the Navy.

"Officers and enlisted men of the Medical Department of the Navy, serving with a body of marines detached for service with the Army in accordance with the provisions of section sixteen hundred and twenty-one of the Revised Statutes, shall, while so serving, be subject to the rules and articles of war prescribed for the government of the Army in the same manner as the officers and men of the Marine Corps while so serving."

CHAPTER II

ANATOMY AND PHYSIOLOGY

General introduction.

If the hospital corpsman is to intelligently perform his duties in caring for the sick and injured he must not only have a good, general knowledge of the structure of the human body but he must also know considerable about the complicated mechanism that constitutes human life. In this chapter human anatomy and some simple physiology will be presented in as brief a way as is consistent with providing the elementary information which the hospital corpsman needs in his work and a ready source to which he can turn for study and review. Between the structure and function of the various parts of the body there exists an intimate relationship that cannot possibly be covered in an abridged chapter such as this must necessarily be. For the hospital corpsman in whom there is aroused a real interest in the anatomy and physiology of the human body fuller text-books must be consulted and studied. In this chapter anatomy will be discussed more completely than physiology, the discussion of which will principally concern the essentials of function.

All objects existing in Nature are commonly classified into three grand divisions or groups called the animal, vegetable, and mineral kingdoms. Objects in the mineral kingdom are without life, are known as *inorganic*, and are made up of *inorganic matter*. Objects belonging to the animal and the vegetable kingdoms are known as *organic*, are made up of *organic matter*, and possess life, that quality or character which distinguishes an animal or a plant from inorganic or from dead organic bodies. By organic matter is implied the organization or arrangement of materials in the way that can be accomplished only through the processes of life.

Any living thing, whether animal or vegetable, is spoken of as an *organism*. Animal organisms are distinguished from vegetable organisms by fundamental differences in their processes of life. Stated in a very general way, vegetable life builds up substances in the organism from water vapors and carbon dioxide in the air and from solutions of mineral salts in the soil, while animal life absorbs complex substances such as proteins and carbohydrates and brings about their oxidation in the organism with absorbed oxygen. Animal organisms possess the attributes of sensation and voluntary motion, while vegetable organisms, though exhibiting irritability in response to stimuli, are generally without voluntary motion or true sense perception; animal organisms receive and digest solid food in an internal cavity previous to its absorption and use, while vegetable organisms make their own food from simple raw materials and utilize it directly within the tissues of the organism; at least part of the food required by animal organisms must be protein matter derived from the bodies of other animal organisms or from vegetable organisms; the life processes of an animal organism must be such that oxygen is absorbed and carbon dioxide produced during its life.

The building up of substances in the vegetable organism, or plant, from simple raw materials, is a process dependent on the presence of a green-colored pigment called *chlorophyll* in the plant and on the radiant energy of the sun.

In a chemical sense this process, which is known as *photosynthesis*, is one of *reduction*. At the same time *synthesis*, or reconstruction, takes place, and two of the products of the process are proteins and carbohydrates, both of which are required in the life processes of animal organisms.

The oxidation of substances in the animal organisms, or animal, is, chemically, a *decomposition* process, and two of the products are carbon dioxide and water vapor, both of which are required in the life processes of plants. For this process the presence of absorbed oxygen in the animal is necessary.

The animal uses portions of plants, either dead or alive, to obtain proteins and carbohydrates. These it decomposes and returns to the air and soil as animal waste products in the form of carbon dioxide and water. The plant, through its green coloring matter and the light rays of the sun, recovers the carbon dioxide and water, synthesizes them into proteins and carbohydrates, and at the same time returns oxygen to the air. It is therefore quite evident that the life processes of plants and animals are closely related and necessary to each other.

The life processes of animals and plants are largely chemical in nature and are proceeding continually in living cells. They are concerned in the building up and destruction of protoplasm, the essential substance of living cells, incidental to the manifestation of vital phenomena, and when considered collectively are spoken of as *metabolism*.

The living organisms called animals are classified according to their natural relationships, the organization of their bodies, and their characteristics or attributes. In this classification the division of *vertebrates* (those with a backbone) stands first, and the highest class of vertebrate animals is that known as the *mammalia* (those which nourish their young with milk).

One of the members of the class of mammalia is man, considered to be the highest type of animal existing or known to have existed. Of all animals man is the only one possessing the power of articulate speech and it is largely because of this power that man has the capacity of abstract reasoning, the extraordinary mental development that is the most characteristic difference between man and other animals. Man is commonly spoken of as a human, or a human being, and it is the structure and life processes of the human being that will be dealt with in this chapter.

The human body is composed of a combination of several systems of organs contained within a supporting framework and the whole surrounded with an external covering. The systems of organs fulfill special functions and are divided into their component tissues which are collections of the fundamental life unit, the animal cell. The study of the human body is divided into a number of closely related sciences which are named according to the structures or parts of the body with which they deal.

Broadly speaking, *anatomy* is the science which treats of the structure of animals or plants. General anatomy deals with the tissues and their properties regardless of the organs into which they are formed. Because the characters of these tissues are to be made out only with the aid of the microscope, general anatomy is practically synonymous with histology. Gross anatomy deals only with the structures and characters discernible with the naked eye.

Human anatomy is the study of the structure of the body of man and the relation of its parts, one to another. It is divided into *descriptive anatomy*, which deals with the character, form, size, and position of organs and parts, *surgical anatomy*, which treats of the situation and relative position of organs and parts as affecting their liability to injury and their accessibility to surgical operations, and *topographical anatomy*, which treats of the anatomy of par-

ticular regions or parts of the body with reference to medical diagnosis and to surgery. It may be divided also into *osteology*, *arthrology*, *myology*, *neurology*, *angiology*, and *splanchnology*, or the anatomy of the systems of the body.

Physiology is the study of the functions and activities of the various parts and organs of living bodies, and is sometimes described as "the physics and chemistry of living matter." It is that branch of the science of biology which deals with the processes, activities, and phenomena incidental to and characteristic of life or of living organisms. These processes and phenomena include many that are chemical, physical, and mechanical, as well as others apparently of a peculiar nature, but those which are purely mental are not usually included in the ordinary scope of physiology, being considered under *psychology*, the science of mind.

Embryology is the study of the origin and development of the body and its organs.

Histology is the study of the minute structure of the normal tissues of the body. It is sometimes called microscopic anatomy and is a synonym for general anatomy.

Pathology is the study of the changes in structure and function of the various parts and organs of the living body that occur in disease.

Biology is the general study of all forms of life. In its broadest sense it includes *botany*, the science of vegetable life, *zoölogy*, the science of animal life, *cytology*, the science of cell-formation and cell-life, *anatomy*, *physiology*, and allied sciences. It involves the study of the origin, development, structure, functions, and distribution of plants and animals, and the more generally occurring phenomena accompanying their life, growth, and reproduction. As man is but a complex animal organism it becomes apparent that in studying human anatomy and physiology one is but studying branches of general biology, and a real understanding of human anatomy and physiology must be prefaced by some knowledge of elementary biological principles. Certain of those principles have been very briefly discussed in the paragraphs pertaining to living organisms and their life processes, and the fundamental unit of life, the *cell*, will next be considered.

The cell is the structural unit of which animals and plants are built up. Usually microscopic in size, it consists of a small mass of *protoplasm* called the *cell body*, or *cytoplasm*, in which is a smaller body of modified protoplasm called the *nucleus*, and is enclosed in a more or less resistant outer covering, the *cell wall*. The cell wall in animal cells, when present, is usually of soft, nitrogenous material, while in plant cells it is composed almost wholly of cellulose. The hard parts of animal tissues are materials secreted by the cells and are not a part of the cells.

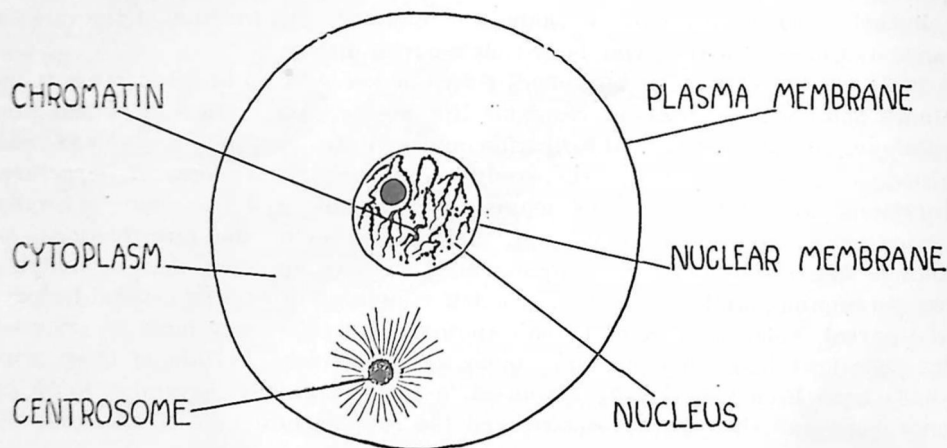
Protoplasm is the viscid, jelly-like material which constitutes the essential substance of living cells and upon which all the vital functions of nutrition, secretion, growth, reproduction, irritability, and motility depend. It is regarded as the only form of matter in which, or by which, the phenomena of life are manifested, and is hence often called the physical basis of life.

The simplest forms of both animal and vegetable life are made up of only one cell. Yeast and bacteria are unicellular vegetable organisms; the *amœba* is a unicellular animal organism. In an organism composed of only one cell that cell must necessarily have the full variety of characteristics that will enable it to carry out all the processes of life of the organism. Such a cell is called a *simple cell*, an *unspecialized* or *undifferentiated* cell. An organism so constituted reproduces by a simple and equal division of its cell into two cells, each of which grows and is capable of again dividing.

Cells vary in the shape, size and structure of the protoplasm, in the shape, size and location, and sometimes in the number, of the nucleus within the cell, and in staining qualities.

In more complex forms of life the single organism is made up of many cells with varying characteristics. Certain groups of cells are *specialized* to perform special functions, one group specialized in performing one function, other groups differentiated to perform other special functions, with consequent variations in structure and composition. In a given organism masses or groups of specialized cells similar in structure and function are called *tissues*. A delimited mass of highly specialized tissue is termed an *organ*.

The human body is made up of animal cells, all of which, with the exception of the red blood cells, consist of the cytoplasm, nucleus, and usually the cell wall. The nucleus is highly specialized in structure and function, is enclosed in a delicate membrane, and inside of it is a network of material called *chromatin*. In the cytoplasm and near the nucleus is a minute structure called the *centrosome* which is concerned with the changes which take place when the cell reproduces (fig. 1).



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FIGURE 1.—Simple animal cell. (U. S. Naval Medical School.)

The cell wall, or *plasma membrane*, when present as a distinct layer, is a very thin, condensed film surrounding the cytoplasm, from which it differs in some way. Frequently it can be recognized only because certain substances can and others cannot penetrate it.

Animal cells all are able to *grow* and mature, they can be stimulated into activity, which property is known as *irritability* or *excitability*, and they can *reproduce*.

It is known that protoplasm consists chiefly of proteins, salts, and water, and for the *growth* of cells these substances must be supplied in a form that can be absorbed and used. A fluid called *tissue fluid*, which is derived mainly from the blood and contains the food substances required, bathes the cells and is their source of nutrition. If for any reason they are deprived of tissue fluid cells cease to grow and die. After reaching maturity cells may remain indefinitely in that state or may reproduce.

Cell *irritability* may be caused by mechanical, chemical, and nervous forms of stimulation, the action of heat and light, etc. Singly, the cause is called a *stimulus*, collectively, they are called *stimuli*. The result of cell stimulation may be noted as a movement or alteration of the shape of the cell, as in

muscular movements, by the liberation of substances secreted by the cell, as in the flow of digestive juices, and in other ways. The stimuli exciting the cell into activity usually are the impulses carried by nerves to the cell, or the action of chemical substances which reach the cell from the blood through the tissue fluid.

The reproduction of cells in the human body occurs during the period when the organ or tissue of which the cell is a part is growing and lasts until the maximum growth of the whole body has been reached. After that cells may reproduce to replace those destroyed by injury or disease or that have become worn out. Cell reproduction takes place by the parent cell dividing equally into two daughter cells. Each daughter cell contains half the substances in the parent cell and exhibits all the properties of the parent cell. It is thought that new cells inherit the characteristics of the parent cell through the chromatin in the nucleus.

When a cell reproduces by division the process begins by the chromatin in the nucleus elongating into structures called *chromosomes* and the centrosome near the nucleus developing two star-shaped structures called *asters*, each of which has a central mass that becomes the centrosome in the new cell, and radiating fibers called *aster rays*. The fibers between the two central masses of the asters begin to form a structure shaped like and called a *spindle*, the membrane enclosing the nucleus bursts and the chromosomes become attached to the fibers of the spindle. By the time development of the spindle is completed the chromosomes have been drawn into the equator of the spindle and begun to split into equal halves. The halves then separate and the spindle begins to divide at its equator, the chromosomes group themselves at the spindle poles, the aster rays disappear, and the cell body begins to divide. When division of the cell body is finished two new cells have been formed and the process of reproduction is complete (fig. 2).

Cell reproduction by this form of division in which there are extensive preliminary changes in the nucleus is known as *mitosis* or *mitotic division*. Bacteria reproduce by a simpler form of division called *amitosis* or *amitotic division*, which is also called *fission*.

In man the parent cell is known as the *ovum*, or egg. After leaving the ovary of the mother the ovum unites with the male germ cell or *spermatozoon*, and the union is called the *fertilization* of the ovum. Immediately after this union cell reproduction begins. The fertilized ovum divides into 2 daughter cells, which then divide to make 4, the 4 to make 8, the 8 to make 16, etc. As this division or segmentation goes on, there occurs a gradual differentiation in the cells produced, so that there are cells of several different types, each capable of reproducing others of its kind. Through this process of *fertilization*, *segmentation*, *differentiation*, and *growth* there is finally brought about the complex animal organism known as man.

In a preceding paragraph it was stated that when the life processes of animals and plants are considered collectively they are spoken of as *metabolism*. In these life processes the cells are involved. During periods of cell activity certain parts of the cellular substance become broken down, or destroyed or decomposed. This is sometimes spoken of as destructive metabolism but is usually called *katabolism*. To replace the loss or repair the breakdown of cellular substance the cell takes up nutrient material in a process called *assimilation* and uses it to build up new protoplasm by the process known as *anabolism*.

Tissues, as stated before, are masses or groups of specialized cells similar in structure and function. Tissues have their own characteristic *intercellular*

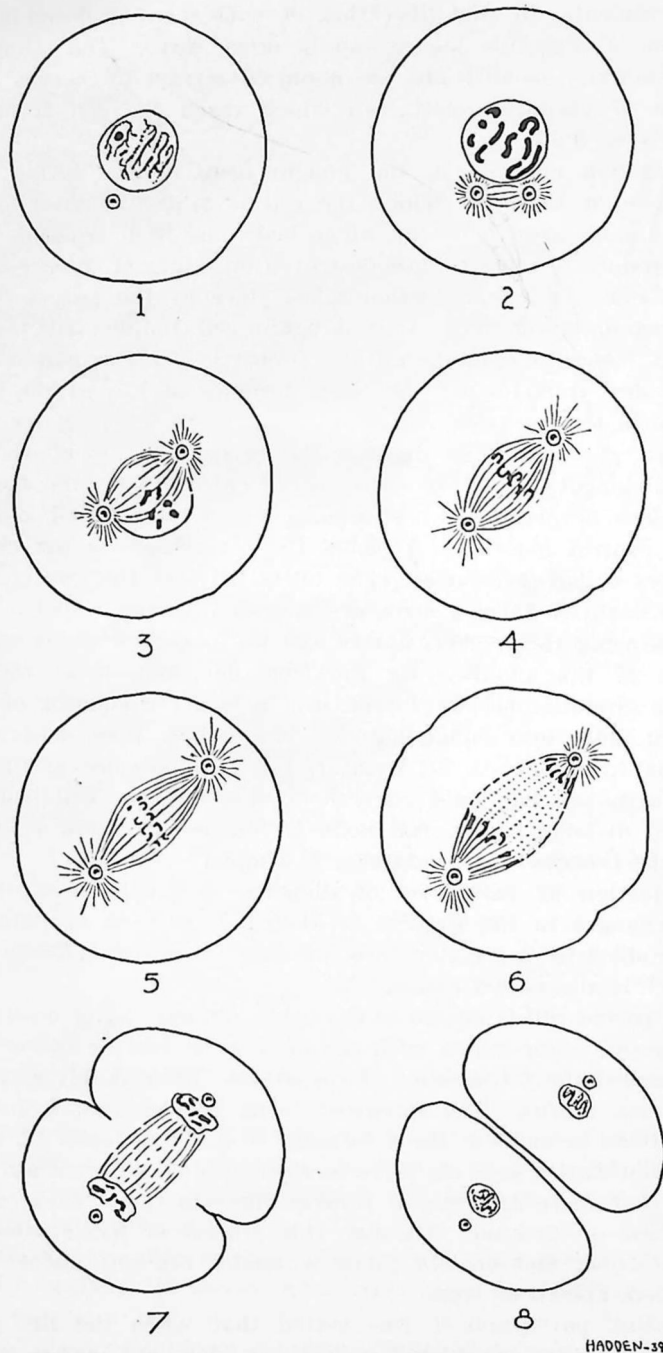


FIGURE 2.—Cell reproduction by mitotic division. 1, Normal cell before commencement of process of reproduction showing network of chromatin in nucleus, and adjacent centrosome; 2, Chromatin elongated into chromosomes and centrosome developing asters and aster rays; 3, Nuclear membrane broken, spindle developing, and chromosomes attached to spindle fibers; 4, Spindle fully developed, with chromosomes in equator; 5, Chromosomes splitting into halves; 6, Chromosomes separated and spindle beginning to divide at equator; 7, Chromosomes grouped at spindle poles, aster rays disappearing and cell body beginning to divide; 8, Cell body divided and reproduction process complete with two daughter cells formed. (U. S. Naval Medical School.)

substance which joins the cells in it together. Although a tissue may be modified by situation it can always be identified when studied microscopically. The tissues in the adult human body are usually classified into five main groups: 1. *Epithelial tissue*; 2. *Connective tissue*; 3. *Muscular tissue*; 4. *Blood and lymph*; and 5. *Nervous tissue*. Each tissue is characterized by certain peculiarities of structure and function.

The free surface of the skin, the linings of the digestive, respiratory, and urinary tracts, the linings of blood and lymph vessels and serous cavities, and certain important secreting glands as the liver, kidneys, etc., are made up of epithelial tissue, or *epithelium* (fig. 3). Having such different services to per-

form the cells in epithelial tissue are generally divided according to arrangement and shape into five principal classes as *cuboidal*, *columnar*, *flat*, *squamous*, and *ciliated*, and according to function into *glandular* or *secreting*, and *protective*. The epithelium forming the various linings spoken of is commonly known as *endothelium*. When the cells are arranged in single layers epithelial tissue is called *simple* and when they are arranged in distinct layers one above another it is called *stratified*. Unlike other tissues the cells in epithelial tissue are joined together by thickened lymph instead of intercellular substance.

The epithelial cells known as ciliated have hair-like appendages on their free edges whose function is to propel fluid or particles. These ciliated cells also are generally columnar. Other epithelial cells can produce the viscid substance called mucus and the tissues where these cells are located are known as mucous membranes.

Connective tissue is the supporting tissue of the body and has a general distribution (fig. 4). In this tissue the cells are scanty and the intercellular substance is considerable. The principal forms of connective tissue are: 1. *Adipose*, or fat, in which fat-cells are lodged in meshes of areolar tissue and fat replaces most of the cytoplasm; 2. *Areolar*, found beneath the skin and between muscle fibers and also called loose fibrous, in which the cells are enmeshed in a loose network of delicate, elastic fibers interlacing in every direction; 3. *Cartilaginous*, often called gristle, in which the cells lie in cavities of an intercellular substance called the matrix which may be finely granular and translucent, be mixed with white fibrous tissue, or contain a network of yellow elastic fibers; 4. *Elastic*, found in the trachea and bronchi,

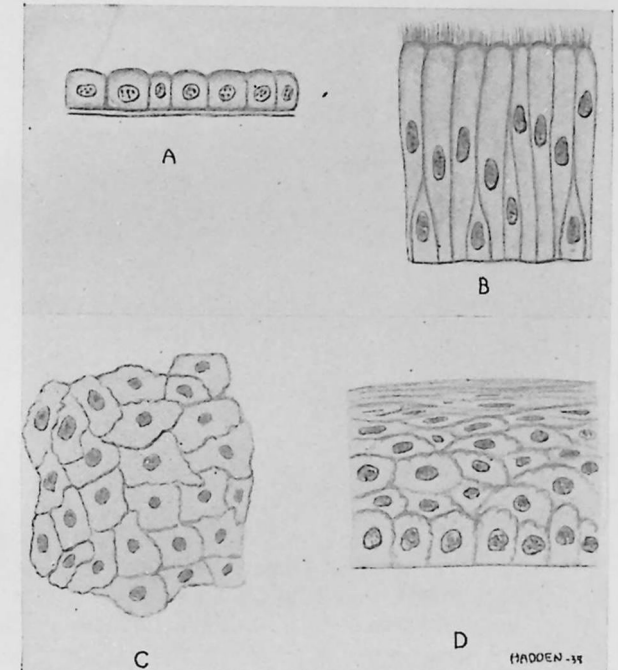


FIGURE 3.—Epithelial tissue. a, Cuboidal; b, ciliated columnar; c, flat; d, stratified squamous. (U. S. Naval Medical School.)

the inner coats of blood vessels, and elsewhere in the body, in which the intercellular substance consists of yellow, elastic fibers branching and uniting with one another; 5. *Fibrous*, found in tendons and ligaments and also called dense fibrous, in which the intercellular substance consists of bundles of closely

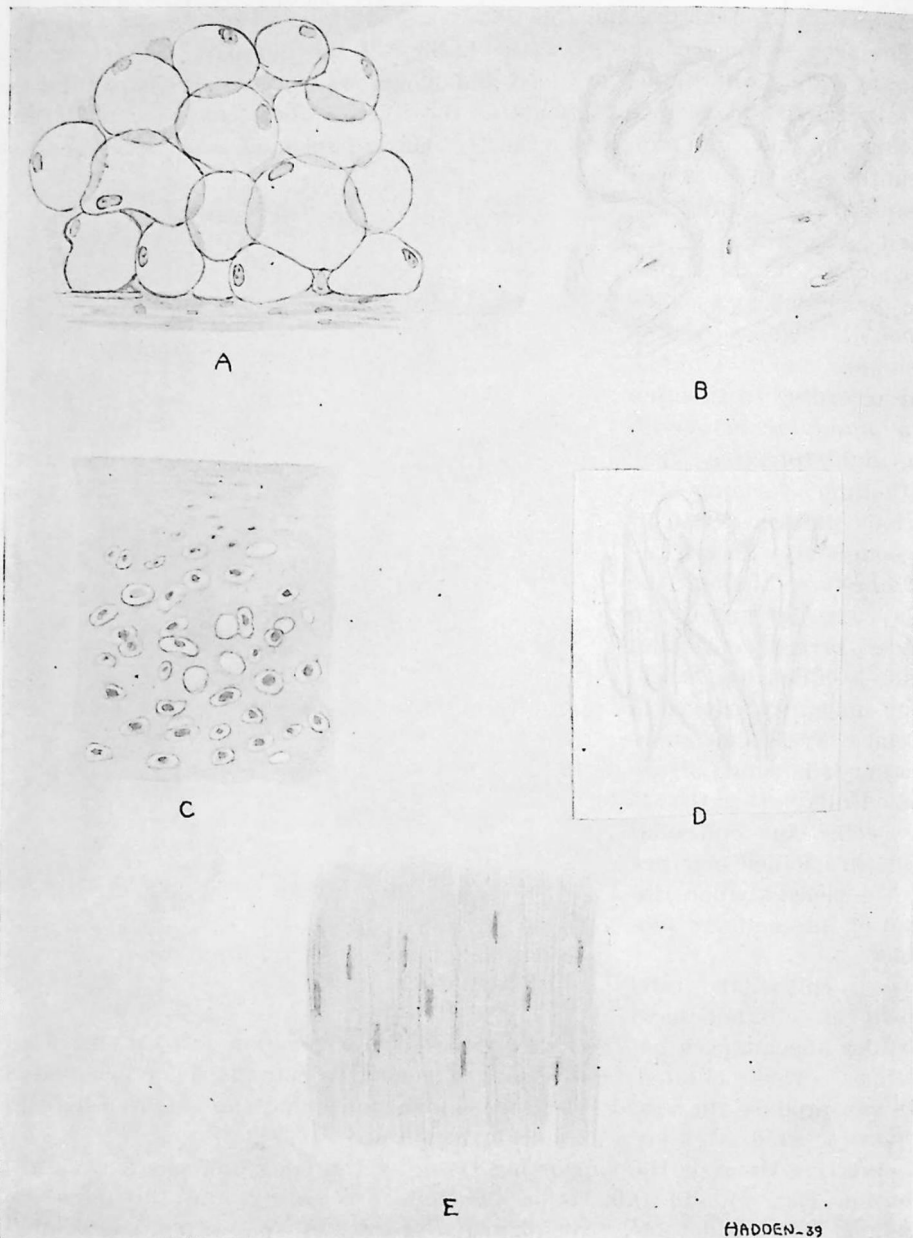


FIGURE 4.—Connective tissue. *a*, Adipose; *b*, areolar; *c*, cartilaginous; *d*, elastic; *e*, fibrous. (U. S. Naval Medical School.)

packed parallel white fibers bound firmly together and with some areolar tissue between the bundles; 6. *Lymphoid*, found in the tonsils, spleen, and lymphatic glands and also called reticular, in which the intercellular substance is largely fluid and consists of a loose network of white fibers containing lymphoid cells; and 7. *Ossous*, in which the intercellular substance is in

layers and may be regarded as white fibrous tissue in which calcium and other mineral salts have been deposited and made it very hard.

Muscular tissue is the tissue of which muscles are formed (fig. 5). It is composed of cells which have been modified and elongated to form thread-like *muscle fibers* held together by delicate connective tissue. Muscle fibers have a reddish color, are lightly covered by elastic, connective-tissue sheaths, are bound together in bundles or fasciculi by delicate connective-tissue envelopes, and those bundles grouped together into larger bundles or sheets to form various *muscles*. Muscular tissue has the following properties: *Irritability*, or response to stimulations usually received from nerves; *contractility*, the power to become shorter and thicker; *tonicity*, a mild, sustained contraction giving the skeletal muscles firmness and maintaining a slight steady pull on their attachments; and *extensibility*, ability to be stretched. Muscular tissue is of three distinct types and the characteristics of each are imparted to the muscles they form. The muscles of the skeleton are known as *striated*, *striped*, or *voluntary*, and

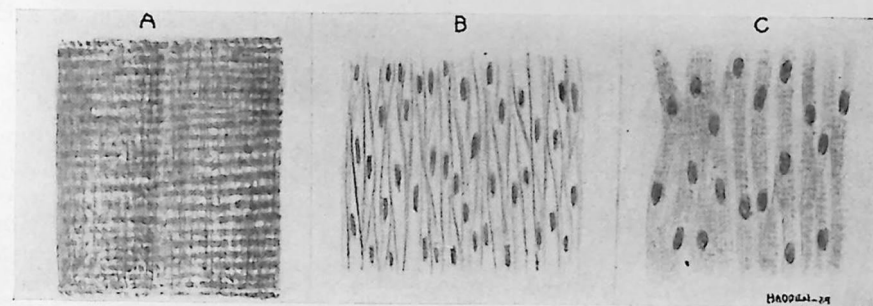


FIGURE 5.—Muscular tissue. *a*, Striated; *b*, nonstriated; *c*, cardiac. (U. S. Naval Medical School.)

the individual cells of this type are elongated, multinuclear, contain transverse striations peculiar to them, and can be controlled by the will; the muscles of hollow internal organs, blood vessels, etc., are known as *nonstriated*, *unstriated*, or *involuntary*, and the individual cells are plain, flattened, without striations, and cannot be controlled by the will; the muscle of the heart is known as *cardiac*, *striated* or *striped* but *involuntary*, and has short, mononucleated cells which branch and unite with adjacent cells, and have striations which are different from those in the skeletal muscles.

Blood and lymph may be considered as tissues consisting of free cells in a fluid intercellular substance which does not join the cells together.

Nervous tissue, composed of nerve cells, nerve fibers, and an intercellular supporting tissue, is the most highly specialized tissue in the body and will be discussed more fully in the section dealing with the nervous system.

Having discussed the masses or groups of cells called tissues the delimited, or bounded, masses of tissues termed organs will next be briefly considered.

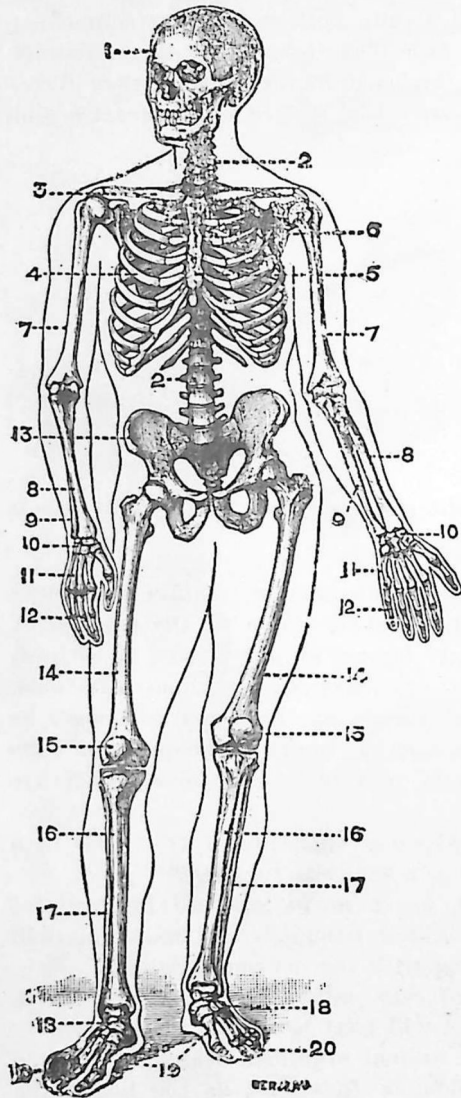
An **organ** is that part or structure in an animal organism which is adapted for the performance of some specific function, or functions, as the heart, the kidneys, etc. In most multicellular organisms, as in man, the essential and active part of an organ is made up of the particular form of specialized tissue on which the function of the organ depends, while other tissues serve for the support, nutrition, control, etc., of the organ.

Groups of organs which act together and collectively have a common function in contributing toward one of the more important and complex vital functions are known as **systems**, as the digestive system, the nervous system, etc.

In order to understand anatomical descriptions the meaning of the following words should be known: *Anterior*, in front; *posterior*, to the back; *superior*, higher; *inferior*, lower; *internal*, within, inside; *external*, outside; *lateral*, at the side; *medial*, *median*, in the middle; *ventral*, the abdominal side; *dorsal*, on the back; *proximal*, nearest to a point; *distal*, farthest from a point.

THE BONES AND JOINTS

Osteology is the study of the structure of bones. It also includes the study of the cartilages and ligaments which bind bones together.



- 1. Cranium.
- 2. Vertebral column.
- 3. Clavicle.
- 6. Scapula.
- 4. Ribs.
- 5. Sternum.
- 7. Humerus.
- 8. Radius.
- 9. Ulna.
- 10. Carpus.
- 11. Metacarpus.
- 12. Phalanges.
- 14. Femur.
- 15. Patella.
- 16. Tibia.
- 17. Fibula.
- 18. Tarsus.
- 13. Pelvis.
- 19. Metatarsus.
- 20. Phalanges.

FIGURE 6.—The skeleton. (Manual of Instruction, Royal Naval Sick Berth Staff.)

remains, and this substance, which is perfectly flexible, can be bent and twisted without difficulty.

Bones consist of a hard, outer shell called the *compact tissue*, and an inner, spongy, and porous part called *cancellous tissue*. In long bones a cavity called the *medullary canal* extends the whole length of the shaft. This cavity and

Arthrology or *syndesmology* is the study of the joints or articulations. It takes into consideration the parts forming the joints and the mechanism of each joint.

The skeleton is the bony framework of the body (fig. 6). Its function is to support and give shape to the body, to protect certain vital organs, to afford attachments for tendons, muscles, and ligaments, and to act as joined levers by which movements may be accomplished.

Bone, or osseous tissue, has been stated to be one of the connective tissues in which there are deposits of calcium and other mineral salts. These salts normally constitute about 67 per cent of the weight of bone but their amount increases as the body ages with the result that bones become harder and more brittle. By dissolving out the mineral salts or inorganic matter in bone by means of dilute mineral acid an organic substance called *ossein*

the spaces in the cancellous tissue are filled with a substance called *marrow* which is of two types, yellow and red. Yellow marrow is composed chiefly of fat; red marrow contains little fat but is abundantly supplied with blood and in it are also found reddish-colored, nucleated cells called *erythroblasts* from which red blood cells are formed. The ends and facets of bones are covered with a special variety of cartilage which is called *articular cartilage* and forms the articulating surfaces and enters into the formation of joints. Those parts of bones not covered by articular cartilage are covered with a thin, vascular membrane of fibrous tissue called *periosteum* which, when it reaches the articular cartilage, continues as the *perichondrium*, a fibrous connective tissue covering the surface of the cartilage. Periosteum has the power of generating new bone and does so in the normal growth of bone or when the original bone has been destroyed. Bones are nourished from capillaries in the periosteum which dip down into small pits on the bone surface and from small arteries, one or more to each bone, which enter through small openings called *nutrient foramina* and branch out into the marrow and bone tissue, passing through the compact tissue in small passages called canals, those located in the center of concentric rings of compact tissue being known as *Haversian canals* (fig. 7).

Bones are classified by shape as: *Long*, which have two *extremities* and a *shaft* of compact tissue, thickest in the middle where the bone is the most slender and the strain the greatest, and containing the central medullary canal, as the femur, the humerus, etc.; *short*, which are small, irregularly shaped, and made of cancellous tissue throughout except for a thin layer of compact tissue covering the surface, as the bones of the wrist and the ankles; *flat*, which have broad or elongated flat plates of compact tissue enclosing a variable amount of cancellous tissue and afford extensive protection and broad surfaces for the attachment of muscles, as some of the bones of the skull, the sternum, the shoulder blades, and the pelvic bones; and *irregular*, which cannot be placed in any of the other classes because of their peculiar shape and consist largely of cancellous tissue with a thin layer of compact tissue covering the surface, as the vertebræ, the mandible, the hyoid.

Two hundred and six distinct bones make up the skeleton of the adult. In the child there are more, some of which fuse together during growth. In the table following no sesamoid bones (small bones developed in tendons at points of much pressure) except the patellæ are included.

THE BONES OF THE SKELETON

Bones of the skull.....	22
Bones of the ears (auditory ossicles).....	6
Hyoid bone	1
Bones of the vertebral column.....	26
The sternum	1
The ribs	24
Bones of the upper extremities.....	64
Bones of the lower extremities (including the patellæ).....	62
Total	206

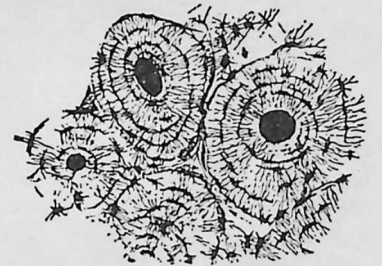


FIGURE 7.—Transverse section of compact tissue of bone, showing concentric rings and Haversian canals. Magnified about 150 diameters. (Sharpey.)

The meaning of the following words used in describing bones should be known: *Process*, a prominence; *tuberosity*, a large process; *tubercle*, a small process; *spine*, a sharp, slender process; *condyle*, a rounded, knuckle-like process; *crest*, a narrow ridge; *head*, a portion of bone supported on a constricted part or *neck*; *fossa*, a depression or pit, a cavity; *notch*, a deep indentation; *groove*, a furrow or channel; *sinus*, a cavity within a bone; *antrum*, a hollow space in a bone; *foramen*, a perforation or opening; *fissure*, a groove.

The bones.

The skull is the bony framework of the head, is elliptical in shape, and is commonly divided into two parts, the *cranium* and the *face* (fig. 8). The cranium is made up of various flat bones which are united in irregular lines called *sutures*, and form the *cranial cavity* which is more or less oval in shape and in life holds the brain. The upper wall of this cavity is called

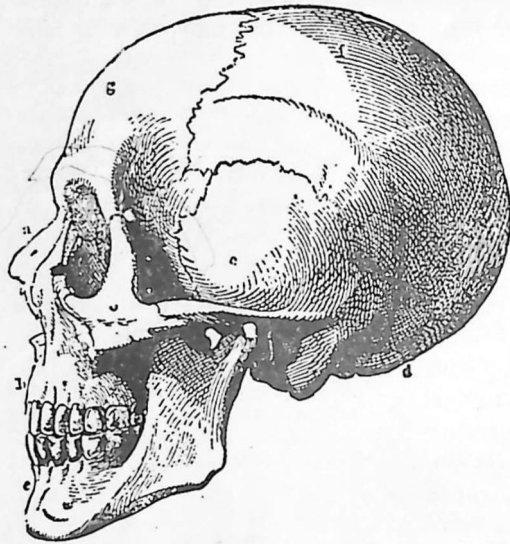


FIGURE 8.—Skull: *a*, Nasal bones; *b*, superior maxilla; *c*, mandible; *d*, occipital bone; *e*, temporal bone; *f*, parietal bone; *g*, frontal bone. (Mason.)

the *vault of the skull*; the floor is called the *base of the skull* and has three distinct *fossæ* or hollows, the *anterior cranial fossa*, the *posterior cranial fossa*, and the *middle cranial fossa*. In the base of the skull are many small *foramina* for the passage of nerves and blood vessels to and from the brain. Just posterior to its middle the base has a large round opening, the *foramen magnum*, through which the spinal cord, its coverings, certain cranial nerves, and the vertebral arteries emerge.

In front and below the cranium are the bones of the face which form two *orbital cavities*, one on each side of the root of the nose, for the eyes, the *nasal cavity* for the passages of the nose, and the *oral cavity* for the mouth.

When the skull is viewed from the side there is seen, just behind the orbital cavity of the eye, a broad depression, the *temporal fossa*, the whole area of which in life affords attachment for the temporal muscle, which closes the jaw. The temporal fossa is limited below by a bony arch, the *zygomatic arch*, or *zygoma*. Just below and posterior to the zygomatic arch is an opening leading into the bone, the *external auditory canal*, below and behind which is a bony prominence called the *mastoid process*. This contains the mastoid air cells, the seat of the inflammation in mastoid disease.

Viewing the skull from below, the foramen magnum is seen just posterior to the middle with an articular surface on either side for articulation with the *atlas*, the first cervical vertebra. Anteriorly on either side are the zygomatic arches, and directly in front, bordered on three sides by the teeth of the upper jaw, is the roof of the oral cavity, the *hard palate*. Just above the hard palate and opening backward are the *posterior nasal apertures*.

THE BONES OF THE CRANIUM

Occipital.....	1
Frontal.....	1
Parietal.....	2
Temporal.....	2
Sphenoid.....	1
Ethmoid.....	1
Bones of the ear.....	3×2=6
Total.....	14

The occipital bone forms the posterior part of the vault and the posterior fossa of the base. It contains the foramen magnum.

The frontal bone is the bone of the forehead and forms the whole anterior part of the vault. At its lower anterior border it extends abruptly backward on either side to form the roof of the orbital cavity and at the same time the very front part of the floor of the cranial cavity. Just internal to the upper orbital margin on either side it contains large air cells, the *frontal sinuses*, which have openings leading into the nasal cavity.

The parietal bones articulate with each other in the mid-line, with the occipital behind and the frontal in front, thus completing the upper part of the vault.

The temporal bones are located one on each side of the base. Each has a *squamous* (flat, scale-like) portion extending upward to form a part of the side of the vault and at the same time a part of the floor of the temporal fossa. A process extends forward to form the zygomatic arch, and posteriorly, extending downward, is the heavy mastoid process. Extending inward and forming a large part of the floor of the middle fossa of the base is the *petrous* (stony hard) portion of the bone. This portion contains the organ of hearing and the external auditory canal leading into the ear.

Each middle ear contains three small bones named from their shape, *malleus* (hammer), *incus* (anvil), and *stapes* (stirrup).

The sphenoid lies in the base of the skull, between the frontal bone in front, the occipital bone behind, and the temporal bone at either side and behind.

The ethmoid lies anterior to the sphenoid. One part of the bone forms a small portion of the floor of the anterior fossa, lying in the mid-line between the orbital parts of the frontal bone. From this part three processes extend downward—a perpendicular plate in the mid-line to form the upper part of the nasal septum, and a process on each side to form the upper lateral wall of the nasal cavity.

THE BONES OF THE FACE

Maxillæ.....	2
Palate bones.....	2
Vomer.....	1
Inferior turbinated bones.....	2
Nasal bones.....	2
Lacrimal bones.....	2
Malar or zygomatic bones.....	2
Mandible.....	1
Hyoid.....	1
Total.....	15

The two maxillæ unite to form the upper jaw. In the body of each is a large air cell, the *maxillary sinus* or antrum of Highmore. The lower border of the bone is the *alveolar process* and in this the upper teeth are embedded. Running horizontally inward from just above the alveolar process is a thin plate of bone that unites with its fellow of the opposite side to form all but the very posterior part of the hard palate. Above the hard palate the medial aspect of the bone forms the lateral wall of the nasal cavity.

Each palate bone is L-shaped, the horizontal part forming the posterior portion of the hard palate and the vertical part forming the lower posterior portion of the lateral wall of the nasal cavity.

The vomer is a thin flat bone that forms the lower posterior part of the nasal septum.

The inferior turbinated bones are two small shell-like bones, lying along each lower lateral wall of the nasal cavity, forming a sort of curved shelf.

The nasal bones are two small flat pieces of bone, one on each side of the root of the nose, that join in the mid-line to form the bridge of the nose.

The lacrimal bones are two small bones that form a part of the wall of the orbital cavity at its inner and lower angle, one on each side.

The malar bones are the cheek bones and underlie the most prominent part of the cheek.

The mandible is the horseshoe shaped bone of the lower jaw. The horizontal part of the bone is called the *body*, and the upper part of the body, which supports the teeth, is called the *alveolar process*. The vertical part of the bone on each side is called the *ramus*. The juncture of the ramus and the body is called the *angle of the jaw*. Each ramus is topped by two processes—the *condyloid process* behind, for articulation with the temporal bone, and the *coronoid process* in front, for the insertion of the temporal muscle.

The hyoid bone is a small U-shaped bone lying anteriorly in the neck and serving for the attachment of various muscles of the throat and tongue.

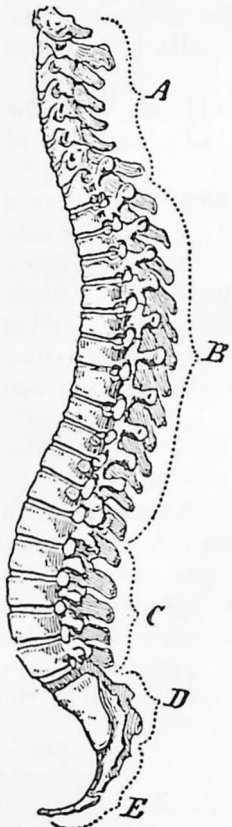


FIGURE 9.—Spinal column: a, Cervical; b, dorsal; c, lumbar; d, sacrum; e, coccyx. (Mason.)

THE BONES OF THE NECK AND TRUNK

Vertebræ (true)-----	24
Sacrum-----	1
Coccyx-----	1
Sternum-----	1
Ribs-----	24
-----	—
Total-----	51

The spinal column consists of 24 movable or true vertebræ, the sacrum and the coccyx (fig. 9). Each of the latter two bones are made up of vertebral segments (false or fixed vertebræ) that are fused in adult life.

The true vertebræ are irregular bones placed one on top of another with cartilage between, and named according to their location. There are 7 *cervical*, 12 *thoracic* or *dorsal* and 5 *lumbar* vertebræ.

The form of the individual vertebræ, at different levels, varies somewhat, but a typical vertebræ may be described as consisting of a *body*, cylindrical in form; a *vertebral arch*, enclosing the *vertebral foramen*; and three processes that act as levers for the attachment of muscles. These three processes spring from the vertebral arch—one on each side, the *transverse process*, and one posteriorly, the *spinous process* (fig. 10). The spinous process may be felt underneath the skin in the mid-line of the back. There are four articular processes that also spring from the arch.

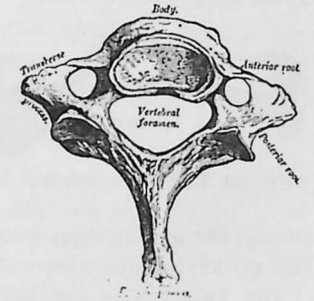


FIGURE 10.—Seventh cervical vertebra. (Gray.)

The sacrum is roughly triangular in shape and is formed by the fusion of five false vertebræ. It articulates on each side with a hip bone to form, with the coccyx, the posterior wall of the pelvis.

The coccyx is the lower extremity of the spinal column and consists of four, sometimes five, vertebral segments fused together. It corresponds to the tail of lower animals.

The thorax is a conical elongated bony cage formed by the sternum and costal cartilages in front, the 12 ribs on each side, and the bodies of the 12 thoracic vertebræ behind. It contains and protects the principal organs of circulation and respiration (fig. 11).

The sternum occupies the middle of the upper part of the chest wall in front. It is divided into an upper part, the *manubrium*, a small lower part, the *xiphoid process*, and between these a *body*. It articulates above with the clavicles and on each side with the cartilages of the first seven ribs.

The ribs, of which there are 12 pairs, form a series of curved bony bands that support the chest wall. Behind, they articulate with the thoracic vertebræ. In front, each rib is provided with a costal cartilage. The first seven ribs articulate with the sternum by means of their cartilages and are called *true ribs*. The lower 5 ribs are not supported and are called *false ribs*. The eighth, ninth, and tenth are united by their cartilages to the cartilages of the seventh, while the last 2 are free at their anterior ends and are called *floating ribs*.

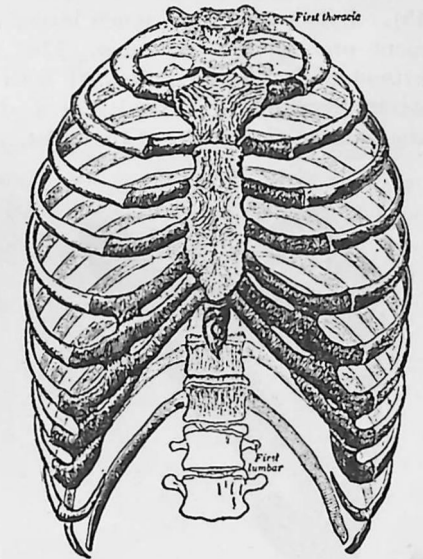


FIGURE 11.—The thorax. Ventral view. (Gray.)

THE BONES OF AN UPPER EXTREMITY

Clavicle-----	1
Scapula-----	1
Humerus-----	1
Ulna-----	1
Radius-----	1
Carpal bones-----	8
Metacarpal bones-----	5
Phalanges-----	14
-----	—
Total-----	32×2=64

The clavicle (collar bone) consists of a rounded curved shaft with enlarged ends. Medially it articulates with the sternum and laterally with the acromion process of the scapula (fig. 12).

The scapula (shoulder blade) is a flat bone of roughly triangular shape. From its posterior surface there springs a shelf-like process, the *spine*. At the outer end of the spine is the *acromion process*, with an articular facet for the clavicle. At the extreme lateral root of the spine is a constriction of the upper lateral angle of the bone. This constriction is the *neck*, and beyond it is the *head*. The head supports the *glenoid cavity*, for articulation with the head of the humerus, and above this is a beak-like projection, the *coracoid process* (fig. 13).

The humerus is the bone of the arm (fig. 14). It articulates proximally with the glenoid cavity of the scapula and distally with the ulna and the radius. It is made up of a *head*, an *anatomical neck*, a *surgical neck*, a *shaft*, and a *distal extremity*. The distal extremity has on each side a prominence, the *medial* and the *lateral epicondyles*. Below these are two articular facets, one for the ulna and one for the radius.

The ulna is placed on the medial side (little-finger side) of the forearm (fig. 15). It is a long bone, much larger at its proximal end, where it has a prominent process, the *olecranon*. This forms the point of the elbow. The ulna articulates with the radius at both ends and with the humerus proximally. At its very distal extremity is a *styloid process*, which can be felt beneath the skin on the inside of the wrist.



FIGURE 12.—The clavicle. (Mason.)



FIGURE 13.—Posterior aspect of right scapula. (Potter.)



FIGURE 14.—Humerus. (Potter.)



FIGURE 15.—Radius and ulna. (Mason.)

The radius is placed on the lateral side (thumb side) of the forearm (fig. 15). It is a long bone, much larger below than above. It articulates above with the humerus and the ulna and below with the carpal bones and the ulna. On its lower end it has a *styloid process* that can be felt beneath the skin on the outside of the wrist.

The carpal bones are small six-sided bones arranged in the wrist or *carpus* in two rows. The distal row, or row nearest the finger tips, contains, beginning from the radial side of the wrist, the *greater multangular*, *lesser multangular*, *capitate*, and *hamate* bones. The proximal row, or row nearest the elbow, contains, beginning from the radial side of the wrist, the *navicular*, *lunate*, *triangular*, and *pisiform* bones.

The metacarpal bones are located in the palm. The proximal end of each is called the *base* and it articulates with the carpus. The shaft extends through the palm, and the *head*, or distal end, articulates with the *proximal phalanx* of the corresponding digit. The metacarpals are numbered from 1 to 5, beginning at the thumb side.

There are three *phalanges* in each finger and two in the thumb. The phalanx at the end of the digit is called the *distal phalanx*, the one next to the hand the *proximal phalanx*, and the one between, the *middle phalanx*.

THE BONES OF A LOWER EXTREMITY

Innominate bone.....	1
Femur.....	1
Patella.....	1
Tibia.....	1
Fibula.....	1
Metatarsal bones.....	5
Tarsal bones.....	7
Phalanges.....	14
Total.....	31×2=62

The innominate bone (hip bone) is made up of three parts, the *ilium*, the *ischium*, and the *pubis*. In adult life these three parts are fused together. The pubis lies below and in front, joining with the pubic part of the opposite bone to form the *symphysis pubis*. The ischium lies below and to the back, while above and posteriorly is the large flat portion of the bone, the *ilium*. At its central part the bone is heavy and on its outer aspect there is a deep cavity, the *acetabulum*, for articulation with the head of the femur.



FIGURE 17.—Femur. (Mason.)

Just below the acetabulum is a large opening, the *obturator foramen*. Posteriorly the iliac portion of each bone articulates with the sacrum, and, with coccyx, forms the *pelvis* (fig. 16).

The femur is the bone of the thigh and the longest bone of the body (fig. 17). It is composed of a *proximal end*, a *distal end*, and a *shaft*. The proximal end is made up of a *head*, a *neck*, and two processes called the *greater* and *lesser trochanters*. The head fits into the acetabulum to form the hip joint. The distal end is made up of two *condyles* which articulate with the tibia.

The patella, a sesamoid bone, overlies the front of the knee joint and is in the tendon of the quadriceps muscle.

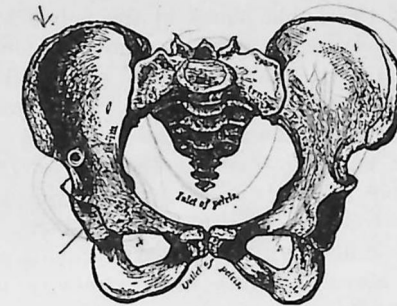


FIGURE 16.—Pelvis (adult.) (Gray.)

The tibia, or shin bone, is the larger of the two bones of the leg and it lies to the inner side (fig. 18). The proximal end of the bone has the *medial* and *lateral condyles* for articulation with the femur. The lateral side of the outer condyle articulates with the fibula. The distal extremity is smaller than the proximal. Medially it presents a prominence, the *internal malleolus*, distally an articular surface for the talus, and laterally a smaller articular surface for the fibula.



FIGURE 18.—Tibia and fibula. (Mason.)

The fibula is the slender bone lying on the outer side of the leg (fig. 18). It has two enlarged ends. The upper end articulates with the tibia alone. The lower end articulates with the tibia and also with the talus. The outer prominent portion of the lower end of the bone is called the *lateral malleolus*. It can be felt beneath the skin.

There are seven tarsal bones in each ankle, the *talus*, which articulates with the tibia and fibula to form the ankle joint, the *calcaneus*, the heel bone, the *navicular*, a boat-shaped bone; the *first*, *second*, and *third cuneiform*, and the *cuboid* bones.

The *metatarsal* bones are similar to the metacarpal but are slightly longer and heavier.

The *phalanges* of the toes are similar to those of the fingers but are shorter.

The joints.

Joints, or articulations, are the connections by which the various bones of the skeleton come together. There are two types of joints, the *immovable*, whose object is to preserve the rigidity of the bones joined together, and the *movable*, whose object is to permit movement of the bones joined together, and which may be either freely or partly movable. The best example of the immovable joint is in the skull where the bones are "dovetailed" together; the hip and shoulder joints are examples of freely movable joints; and the articulations of the pubic bones in the pelvis and the lower ends of the tibia and fibula are examples of partly movable joints.

The substances which enter into the formation of joints vary with the character of the joint. In every joint there are two or more skeletal elements (bone or cartilage) and a uniting substance or medium, the amount and kind of which depends on the type of the joint. The uniting substance in immovable joints is a very thin layer of fibrous tissue which corresponds to and is continuous with the periosteum, or is of cartilage, while in movable joints it is fibrous and fibrocartilaginous material, and cartilage.

Movable joints have a cavity separating the bones entering into them. Cartilage covers the articulating surfaces of the bones in movable joints and in some joints there are also discs of cartilage in the joint cavities. The bones entering into the joint are held together by strong bands of fibrous tissue called *ligaments*, which pass from one bone to the other on every side of the joint and form a *capsule* which is the external boundary of the joint cavity. This fibrous capsule is lined with *synovial membrane* which secretes a substance called *synovial fluid* that is retained in the cavity and serves to lubricate the joint (fig. 19).

According to their type of movement, movable joints are known as *gliding*, as those between the articular processes of the vertebræ, *hinge*, as the elbow, knee, finger, and toe joints, *ball and socket*, in which the round head of one bone fits into a cup-like cavity in another as in the hip and shoulder joints, *rotary*, in which one bone rotates on one which is stationary, as the first and

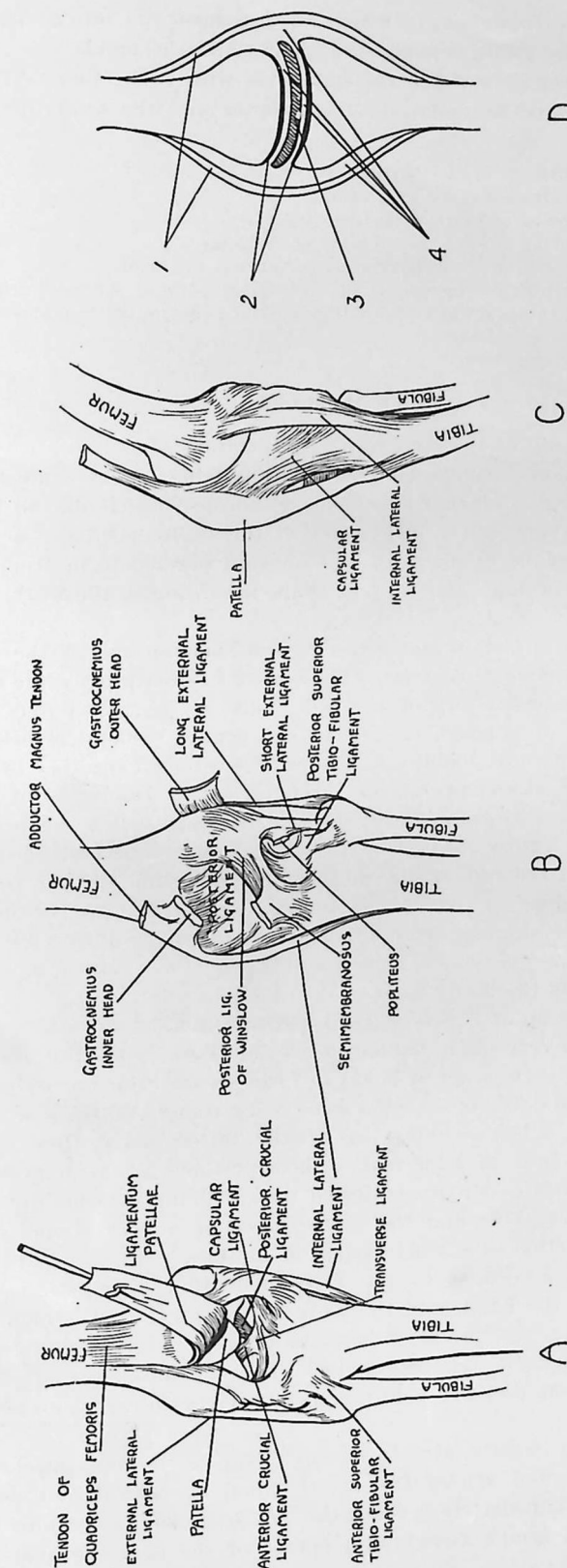


Figure 19.—Anterior, a, posterior, b, and lateral, c, views of left knee joint; d, schema of a movable joint showing: 1, capsular ligaments; 2, articular cartilages continuous with periosteum; 3, disc; and 4, spaces lined with synovial membrane and containing synovial fluid.

second vertebræ, and *condyloid*, in which an oval head fits into a shallow elliptical cavity, as in the joints between the fingers and the hand.

Joints permit movements of the skeletal parts with each other. These movements are accomplished by means of the muscles and the kinds of movement are as follows:

- FLEXION—Bending, as in raising the forearm on the arm.
- EXTENSION—Straightening or unbending.
- ABDUCTION—Moving away from the mid-line of the body.
- ADDUCTION—Moving toward the mid-line of the body.
- ROTATION—Turning on its own axis, as in turning the head.
- PRONATION—Turning downward, as in turning the palm of the hand downward.
- SUPINATION—Turning upward, as in turning the palm of the hand upward.
- EVERSION—Turning outward.
- INVERSION—Turning inward.

THE MUSCLES

Myology is the study of the structure and functions of muscles.

Muscles are structures composed chiefly of muscular tissue and all motion of any sort in the body, whether conscious or unconscious, is due to the action of muscles. They constitute a large part of the fleshy portions of the body, enter into the structures of many of the internal organs, form from 40 to 50 per cent of the body weight, and vary in shape according to the work they have to do.

All the muscles attached to the bones of the skeleton are of the voluntary type and are termed *skeletal muscles*. Those used in breathing, while ordinarily acting without conscious effort of the will, may be controlled and breathing accelerated, slowed, or stopped, as desired. A typical skeletal muscle consists of a fleshy mass of parallel bundles of muscle fibers bound together by a sheath of fibrous tissue called the *epimysium*, each bundle or fasciculus of fibers being surrounded by a delicate connective-tissue envelope called the *perimysium*, and each fiber being lightly covered by an elastic, connective-tissue sheath called the *sarcolemma*. At the ends of the muscle the epimysium and the perimysium unite with the tendons by which the muscle is attached to the bone. The attachment of a skeletal muscle which is fixed or stationary during use is known as the *origin* and the one which moves as the *insertion*. Many muscles have an insertion far from the fleshy belly.

Tendons are made up of closely packed, parallel bundles of nonelastic, dense fibrous tissue, with a very small amount of areolar tissue separating the bundles. They unite with the periosteum of bones to form secure attachments of muscles and differ in shape in different muscles, some being round and thick while others are flat and thin. When tendons are of the latter shape they are called *aponeuroses*. Their lack of bulk makes their presence about joints desirable as joint movements are easier accomplished than if bulky muscles were present.

Muscles seldom act alone and the performance of a very simple motion is usually due to the action of a whole group of muscles. Muscles and groups of muscles are named according to the type of motion they produce, as the *extensor* muscles of the hand, and the *adductor* muscles of the thigh, and for each group of muscles that produces one type of motion there is another group that produces the opposite type of motion. To keep muscles in position and place during movement they are held together by layers of areolar tissue called *fasciæ*.

The *fasciæ* vary in density, structure, and thickness, in some places forming considerable masses, and are of two types called *superficial* and *deep*. The superficial type lies immediately beneath the skin and usually contains considerable fat. Blood and lymph vessels and nerves of the skin are also found in

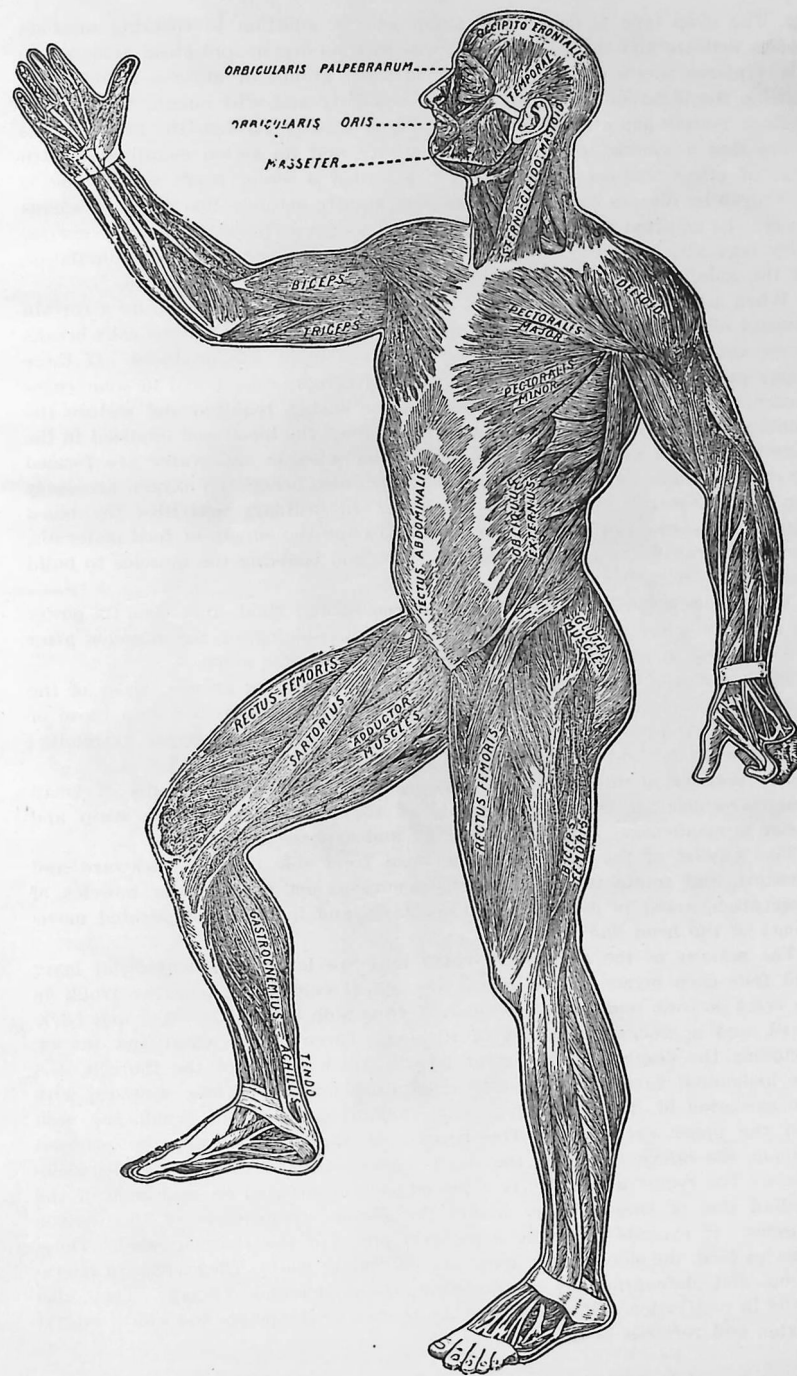


FIGURE 20.—Superficial muscles of the body. (After Brubaker.)

it. The deep type is dense and tough and in addition to covering muscles, covers delicate and specialized structures such as organs and blood vessels. In many places sheets of it lie between adjacent groups of muscles thereby permitting the different groups to act independently and still remain in place.

Each muscle has a nerve supply and it is usually through the action of its nerve that a muscle is brought into activity and its action coordinated with that of other muscles. Such a nerve is called a *motor nerve* and if one is destroyed by disease or injury the muscle usually becomes inactive and wastes away. In addition to the normal stimulation of muscles through their nerves, they may also be activated by mechanical, chemical, or electrical stimulation of the muscles themselves, and by the application of heat and cold.

When a muscle contracts it uses a certain amount of energy to do a certain amount of work. In doing this work the protoplasm in the muscle cells breaks down and chemical waste products, which are toxic, are produced. If these waste products accumulate the phenomena of fatigue result, and in some cases muscular cramps may occur. To supply the energy required and restore the muscle protoplasm, carbohydrates are taken from the blood and oxidized in the muscle. During contraction, or work, carbon dioxide and water are formed by oxidation, and removed by the blood which also brings the oxygen necessary for the restoration of muscle protoplasm. In ordinary activities the blood supply to muscles is increased, thereby increasing the supply of food materials, carrying away waste products more quickly, and enabling the muscles to build up and restore their efficiency.

When muscle substance dies it becomes solid and rigid, and loses its power to react to stimulation. The stiffening and hardening of the muscles after death is due to this phenomenon, which is called *rigor mortis*.

The muscles of the body are divided into the following groups: those of the head and face; of the neck; of the trunk, which is subdivided into those of chest, thorax, abdomen, back and perineum; those of the upper extremity; and those of the lower extremity (fig. 20).

The muscles of the head and face consist of numerous groups of small muscles which act in the movements of the eyes, the face, the scalp and assist in mastication, deglutition, talking and expression.

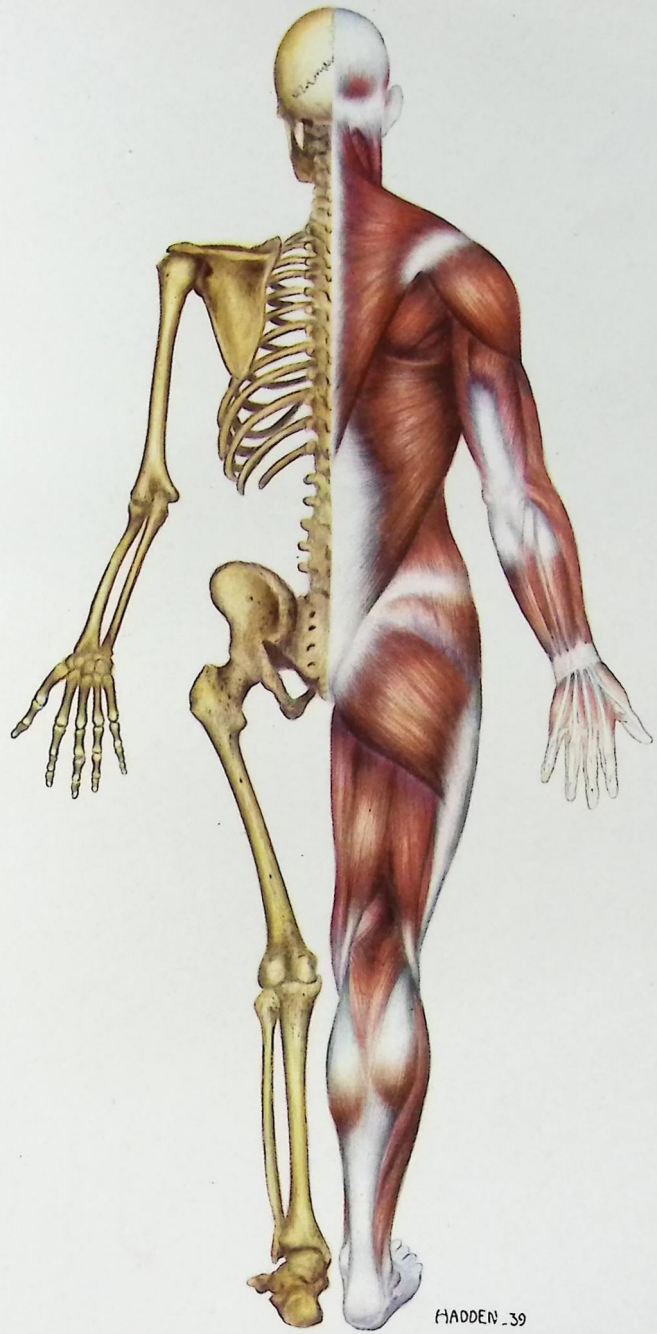
The muscles of the neck move the head from side to side, backward and forward, and rotate it. Some of these muscles act as auxiliary muscles of respiration, assist in deglutition, in speaking, and in other complicated movements of the head and neck.

The muscles of the back are divided into five layers, the superficial layer and four deep layers. They act on the spinal column to keep the trunk in an erect posture, and permit movements from side to side, forward and backward, and a moderate amount of turning. Those of the chest and thorax, including the diaphragm, the great muscle which separates the thoracic and the abdominal cavities, are chiefly respiratory muscles. These muscles, with the exception of the diaphragm, assist in movements of the trunk, the neck and the upper extremities. The muscles of the abdomen are the *external oblique*, the *internal oblique*, the *rectus abdominis*, and the *transversus abdominis*. The rectus abdominis is a paired muscle situated on each side of the median line of the abdomen within the fibrous aponeurosis of the oblique muscles. It extends from the symphysis pubis to the thoracic wall. These muscles form the sides and front of the abdominal wall. They assist in micturition and defæcation by compressing the abdominal viscera. They also assist in respiration and emesis, flex the thorax on the pelvis and aid in lateral flexion and rotation of the spine.



HADDEN-39

FIGURE 21.—ANTERIOR VIEW OF RELATION OF SKELETAL MUSCLES TO SKELETON (U. S. NAVAL MEDICAL SCHOOL)



HADDEN .39

FIGURE 22.—POSTERIOR VIEW OF RELATION OF
SKELETAL MUSCLES TO SKELETON
(U. S. NAVAL MEDICAL SCHOOL)

The inguinal ligament (Poupart's) is a thickened band of fibers of the aponeurosis of the external oblique muscle, extending from the anterior superior spine of the ilium to the spine of the pubis. Just above this ligament and parallel to it is the inguinal canal through which pass the spermatic cord in the male, and the round ligament of the uterus in the female. The inner opening in the transversus muscle is called the *internal inguinal ring*; the outer opening in the tendon of the external oblique muscle is called the *external inguinal ring*. These openings form weak places in the abdominal wall, and are the frequent sites of a protrusion of parts of the viscera which is called a *hernia* or rupture. Other weak places are the *umbilicus*, and the *femoral ring* which serves as a passage for the blood vessels to the lower extremity.

The muscles of the perineum are those surrounding the base of the reproductive organs and the rectum and form the floor of the pelvis. Their action is to assist in micturition and defæcation.

The muscles of the upper extremity are divided into those of the shoulder, which act to move that joint; those of the arm; those of the forearm; and those of the hand.

The muscles on the front of the arm flex the forearm; those on the back extend it. The same principle applies generally to the muscles which arise from the bones of the forearm and are attached to the bones of the hands or fingers. Some of these muscles however act to *pronate* the hand (turn palmar surface down) and others to *supinate* the hand (turn the palmar surface up). The muscles of the palm and the back of the hand, flex, extend, adduct, abduct and circumduct the fingers and the thumbs.

The muscles of the lower extremity are divided into those of the hip; the thigh; the leg; and the foot. The muscles on the anterior side of the hip flex the thigh on the abdomen, those on the posterior extend, those on the medial side adduct and those on the lateral side abduct. Combinations of these actions produce circumduction of the lower extremity.

The muscles of the posterior portion of the thigh flex the leg on the thigh. Those of the anterior portion extend the leg. The muscles having origin on the anterior surface and on the posterior surface of the bones of the leg, flex, extend, and circumduct the foot. The muscles of the dorsal and the ventral surfaces of the foot extend and flex the toes respectively.

It is not possible to present a complete study of the individual skeletal muscles in this chapter, but to show the way they should be studied a few that form important anatomical landmarks and typify the action of muscles in general will be individually described.

The temporal muscle.

Origin: From the whole area of the temporal fossa.

Insertion: The coronoid process of the mandible.

The muscle is fan-shaped, and its principal action is to close the jaw.

The sternocleidomastoid muscle is an important landmark in the neck and can be easily demonstrated by bending the head forward and to the opposite side.

Origin: The manubrium of the sternum and the medial third of the upper surface of the clavicle.

Insertion: The mastoid process of the temporal bone.

Action: When acting alone flexes head laterally and rotates it to the opposite side. Both acting together bend the head forward. (If muscles in the back of the neck hold the head extended they may act as extraordinary muscles of inspiration by raising the sternum and the clavicles.)

The **biceps muscle** is located on the front of the arm.

Origin: By two heads, which accounts for its name. The tendon of the short head is attached to the tip of the coracoid process. The tendon of the long head is attached just above the upper rim of the glenoid cavity and passes through the capsule of the shoulder joint.

Insertion: By a tendon which attaches to the tubercle of the radius.

Action: Draws the arm forward, flexes the elbow, and supinates the forearm. The **triceps muscle** is located on the back of the arm.

Origin: By three heads, hence its name; the long head from the scapula, the lateral head from the upper part of the humerus, and the medial head from the lower posterior surface of the humerus.

Insertion: By a tendon to the olecranon process of the ulna.

Action: To extend the elbow and to adduct the arm.

The **deltoid muscle** forms the prominence of the shoulder.

Origin: From the lateral part of the shoulder girdle.

Insertion: The outer surface of the shaft of the humerus at about its middle (the deltoid tuberosity).

Action: To raise (abduct) the arm.

The **diaphragm** is the muscular wall which separates the abdominal cavity from the thoracic cavity. It is vaulted upward. Its fibers arise from the bony cartilaginous chest wall, converge, and are inserted into the fibrous central portion. When the fibers contract they pull the central portion downward.

SPECIAL MEMBRANES AND GLANDS IN GENERAL

A **membrane** is an enveloping or lining tissue of the body. The chief membranes are classified as: *Serous*, *synovial*, *mucous* and *cutaneous*.

Serous membranes are thin, transparent, fairly strong and elastic. Their surfaces are moistened by a fluid resembling serum. They are found lining closed cavities and passages which do not communicate with the exterior. These membranes consist of two layers; the *endothelium*, a modified epithelium, and the *corium*, a thin layer of fibrous tissue and blood and lymph vessels. They are divided into the following three classes:

Serous membranes proper, which consist of a closed sac, one part of which is attached to the walls of the cavity which it lines, and the other reflected over the surface of the organs contained in that cavity. This class includes the *pleurae*, which cover the lungs and line the thoracic cavity; the *pericardium* which covers the heart; the *peritoneum* which lines the abdominal wall, and clothes its contained viscera; the *lining membrane of the vascular system*; the *internal coat of the heart, blood vessels and lymphatics*; the *capsule of Tenon*, back of the eyeball; and the *arachnoid coat of the meninges*. The serous membranes serve as a protective covering by forming a smooth slippery lining and secreting a serum which acts as a lubricating fluid.

Synovial membranes are associated with joints and muscles and secrete a viscid glairy fluid called *synovial* or *joint fluid*. These membranes are *articular*, which surround and lubricate the joints; *vaginal*, which form the sheaths of tendons about some joints; and *bursal*, which form simple sacs interposed between soft tissue and bone. The latter may be deep seated between muscle or tendon and bone, or superficial between skin and bone, for example, the patellar bursæ.

Mucous membranes line the cavities which communicate with the exterior. Their surfaces are coated over and protected by mucus. The mucous membranes of the body may be divided into the *gastro-pulmonary*, and the *genito-urinary*.

The *gastro-pulmonary mucous membrane* covers the inside of the alimentary tract and the air passages and all cavities communicating with them. This includes the accessory sinuses of the nose; the lacrimal ducts; the conjunctiva; the auditory canals, including the middle ear and the mastoid cells; the common bile duct; the gall bladder; the biliary ducts; the pancreatic duct; and the salivary ducts. The *genito-urinary mucous membrane* furnishes the inside lining of the urethra; the bladder; the ureters; the pelvis and tubules of the kidney; and all of the genital ducts including the prostatic, the seminal and the ductus deferens.

Cutaneous membrane is the external covering of the body, or skin. Its structure and functions will be discussed later.

A **gland** is an organ which secretes something essential to the system or excretes waste materials the retention of which would be injurious to the body.

Glands are of three types: Simple, compound, and ductless. *Simple glands* are generally tubular or sacular in structure and open to the surface by a single duct, their secretions being thrown directly onto a free surface. *Compound glands* are glands the structure of which is subdivided into smaller tubular or sacular structures which open by smaller ducts into a main duct. Their structure may be compared to a bunch of grapes, the branching stem of which corresponds to the ducts of the gland and the grapes to the groups of gland tissue called *lobules*. The secretions of compound glands are carried off through their ducts. *Ductless glands* are glandular structures which have no ducts and whose secretions are discharged directly into the blood or lymph.

THE BLOOD AND THE BLOOD VASCULAR SYSTEM

Blood is the fluid tissue which is contained and circulates in the *blood vascular system* of the body. This system consists of the heart, arteries, capillaries, and veins, and in it the blood is kept circulating by the force of the heart beat. In the adult the quantity of blood is estimated to be about one-thirteenth of the body weight or about 6 quarts in an average adult weighing 160 pounds. It is a reddish colored, viscid, opaque fluid slightly heavier than water, normally having a specific gravity averaging about 1.055 and a slightly alkaline reaction. In composition blood consists of a fluid portion, the *plasma* or *blood plasma*, in which are suspended the "formed elements," the *red blood cells*, the *white blood cells*, and the *blood platelets*. The blood cells are also known as *blood corpuscles* and the blood platelets as *thrombocytes*. In blood the cells are not joined together by intercellular substance as in other tissues but float freely in the plasma.

The functions of the blood are numerous and all are important and necessary to the well-being of the body. In performing its functions blood:

1. Serves as a medium for the exchange of gases, carrying oxygen to the tissue cells and removing carbon dioxide from them;
2. Serves as a medium for the interchange of nutritive and waste materials, carrying food materials absorbed from the digestive tract to the tissue cells and removing waste materials from them for elimination by the excretory organs;
3. Serves as a medium for the transmission of hormones;
4. Aids in equalizing and maintaining body temperature;
5. Aids in protecting the body against infection by contributing cellular and body-fluid factors to the defense mechanism of the body known as immunity;
6. Guards against hæmorrhage by clotting when shed; and
7. Maintains the all-important acid-base equilibrium or balance of the body.

Healthy blood (plasma and blood cells) consists of about 78 per cent water and 22 per cent solids, and contains a great variety of substances, most of which are found in the plasma.

Blood plasma is the fluid portion of the blood and when free from blood cells is a clear, straw-colored liquid having a specific gravity of about 1.026 and a slightly alkaline reaction. The term blood plasma should not be confused with the term blood serum for the two terms refer to quite different substances. Blood plasma is the liquid part of blood *before* coagulation takes place. When blood escapes from its vessels it usually coagulates, or clots, and as the clot forms it generally shrinks and squeezes out a clear, yellowish liquid known as blood serum, which may be defined as the liquid part of blood *after* coagulation takes place. By filtration the plasma passes through the walls of the capillaries into the tissues where it is known as *lymph*.

The composition of blood plasma is about 90 to 92 per cent water and about 8 to 9 per cent solids. In addition to water its constituents may be listed as follows:

1. Gases: Oxygen, carbon dioxide, and nitrogen;
2. Proteins: Fibrinogen, globulins, albumins, and cell proteins, excluding hæmoglobin;
3. Pigments: Hæmoglobin, in red blood cells, bilirubin, in serum, etc.;
4. Nonprotein nitrogenous bodies: Urea, uric acid, creatine, creatinine, amino acids, ammonium salts, and an unidentified fraction;
5. Nonnitrogenous bodies: Sugar, lactates, phenols, cholesterol and "lipoids" such as fats, soaps, and the phosphatides (phospholipoids); together with the intermediate products of fat metabolism ("acetone bodies");
6. Inorganic salts: The chlorides, carbonates, sulfates, and phosphates of sodium, potassium, calcium, magnesium, and iron;
7. Enzymes and antienzymes: Glycolase, lipase, enterase, oxidase, antiprotease, etc.; and
8. Special substances: Hormones, immune bodies, opsonins, complement, etc.

Acid-base equilibrium.

The normal metabolic processes of the body result in the continuous production of acid end-products which tend to alter the reaction of the blood when added to it, i. e., make it less alkaline. Oxidation in all tissues produces carbon dioxide which has acid properties, muscular activity produces lactic acid, and sulfuric and phosphoric acids are formed in the oxidation of proteins containing sulfur and phosphorus. In spite of such acid substances being constantly added to the blood its slightly alkaline reaction remains remarkably uniform and constant because the physiological activities of the body are so adjusted that variations in the reaction are kept within narrow limits. The maximum variation in reaction that is not dangerous to life is only eight-tenths of a point. Keeping the alkaline reaction of the blood within those limits is known as *maintaining the acid-base equilibrium* or *balance* and is accomplished by neutralization of the acid products as soon as they are formed in the tissues, by the prompt elimination of excess acid through the regulating action of the lungs and kidneys, and by the presence in the blood of substances called *buffers*.

A buffer is any substance which when present in a solution tends to prevent the reaction of the solution from changing on the addition of acid or alkali. All buffers are mixtures of a weak acid and its basic salts, or a weak base and its acid salts, and among the substances present in the blood which act as buffers carbonic acid and its bicarbonate salts and hæmoglobin and its basic salts

are of chief importance; proteins in the plasma have some buffer action, and also the phosphates.

The action of buffers in maintaining the acid-base equilibrium is a very complicated process and only a brief explanation can be given here. This action, which is spoken of as *buffering*, depends on the presence of substances in the blood and tissues which convert strong acids into weaker ones by chemical reaction. One of these substances is sodium, an alkali, which reacts chemically with weak acids such as carbonic acid and phosphoric acid, and with proteins to form the alkaline salts sodium bicarbonate, sodium phosphate, and the sodium salts of the proteins. These salts in turn react with stronger acids to form sodium salts of the stronger acids and at the same time liberate the weaker acids. In this way the effect of the stronger acids is greatly weakened and there is prevented an increase in acidity which would tend to make the reaction of the blood less alkaline.

The combination of sodium with a weak acid, mainly as sodium bicarbonate, constitutes the principal buffering mechanism of the blood, and the amount of sodium that is so combined and available for use in neutralizing stronger acids is spoken of as the *alkali reserve*.

The principal acid added to the blood as the result of the metabolic processes in the body is carbonic acid, considerable of which is formed when carbon dioxide enters the blood from the tissues. As soon as this acid is formed most of it combines with the sodium chloride present in the blood plasma and forms sodium bicarbonate, the remainder diffuses into the red blood cells where it unites with the potassium present as potassium hæmoglobinate and forms potassium bicarbonate. The chlorine liberated in the formation of sodium bicarbonate passes to the red blood cells where it combines with the hæmoglobin. The result of these reactions is an increase in the amount of bicarbonates available for the neutralization of acids.

On reaching the lungs the blood becomes oxygenated or purified and the hæmoglobin gives up the chlorine it had taken up. The liberated chlorine passes into the blood-plasma, reacts with the sodium bicarbonate to form sodium chloride and liberates carbon dioxide which is exhaled. Should there be any tendency toward an increase in the acidity of the blood such as would follow an increase in carbon dioxide the respiratory center is stimulated and respiration becomes more rapid with consequent increased elimination of carbon dioxide.

As the neutralization of acids cannot be accomplished without lowering the alkali reserve and as acids are constantly being added to the body in foods and by the acids formed within the body, to prevent lowering the alkali reserve to a point where it is dangerous it is necessary to eliminate the acids without losing a corresponding amount of alkali, or base. This is largely done through the secretory and excretory functions of the kidneys, which play an important part in maintaining the normal acid-base balance or equilibrium of the blood by excreting the excess of acids above the normal equilibrium.

The normal acid reaction of urine as compared with the slightly alkaline reaction of blood is due to the selective ability of the kidneys to excrete weak acids and acid salts and at the same time hold back a large part of the alkali base with which they are combined in the blood. The part which is held back is used to replenish the alkali reserve. Acid elimination takes place through the kidneys principally in the form of acid phosphates, and in some conditions as much as 50 per cent of the acid excreted may be free acid. Should the alkali base begin to be depleted in spite of this excretion of acid the kidneys break up urea which is accompanied by the production of ammonia.

The ammonia so formed is then used instead of alkali base to neutralize much of the acid excreted which appears in the form of ammonium salts. Even strong acids like hydrochloric and sulfuric are sometimes excreted as ammonium salts.

This neutralizing mechanism may be so overtaxed or its activities so disturbed by the ingestion of unusual amounts of acid or alkali or as a result of disease that there occurs a noticeable change in the reaction of the blood and resulting conditions known as *acidosis* or *alkalosis*. Any marked change of reaction is fatal unless quickly corrected or compensated.

Acid-base equilibrium or balance is also discussed in the section on Laboratory Procedures and Technique.

Immunity.

The body possesses a defense mechanism termed *immunity* by which it can resist and overcome infection. (See section on Hygiene and Sanitation.) By immunity is meant the ability of the body to protect itself against injury by harmful bacteria or by the poisonous products of bacteria called *toxins*. In this defense mechanism the blood and lymph play an important part. The protective function of the blood in immunity is partly due to the blood plasma and partly to the white blood cells.

Any substance which, when injected into an organism, is capable of stimulating the production of a substance antagonistic to the substance injected is known as an *antigen*, and the substance produced is known as an *antibody*. When foreign substances such as bacteria or their toxins enter the blood they act as antigens and stimulate the production in the blood plasma of specifically antagonistic antibodies. There are various types of antibodies and they are usually designated according to the manner in which they act against the invading substance. Some of the more important types are known as *bacteriolysins*, which kill the bacteria themselves, *agglutinins*, which cause the bacteria to settle together in clumps, *precipitins*, which cause precipitation of the bacteria, and *antitoxins*, which neutralize the poisons produced by bacteria.

Also produced in the blood plasma are substances called *opsonins* which so change bacteria that they can be more easily ingested by the white blood cells.

Through their power of amoeboid movement the white blood cells are able to surround bacteria and ingest and destroy them. Often the white cells are themselves destroyed and the dead ones may be removed by other cells. When killed in large numbers the white cells form a large part of the solid or semi-solid matter called *pus* that is found in an abscess.

Transmission of hormones.

The glands of internal secretion, commonly called ductless glands, produce substances termed internal secretions or *hormones* which play a most important part in body functions. Because these glands have no ducts their secretions are absorbed into the blood through the walls of the capillaries present in the substance of the glands and are then carried by the blood to the parts of the body where their action or effect is to be produced.

As a rule the ductless glands are not located near the organs with which they are functionally associated and consequently the hormones may be carried considerable distances in order to produce their effects. Some hormones which have a more or less general systemic action are continually carried to all parts of the body.

By this distribution of hormones the blood serves as a means of providing the coordinated function and harmonious working of the body so necessary to its well-being.

Blood coagulation.

One of the most striking properties of blood is its power to coagulate or clot. Undisturbed blood circulates in the blood vascular system of the healthy body without showing any tendency to clot, but on escaping from the blood vessels it normally begins to clot immediately. Clotting is the body's method of preventing excessive loss of blood in the unavoidable injuries met with in ordinary life.

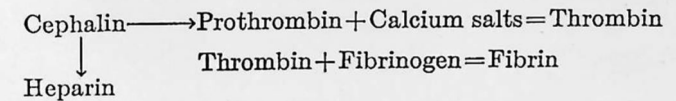
In the process of clotting both physical and chemical factors are involved. When blood escapes from blood vessels it leaves its natural environment and its normal physical state is changed by exposure to changes in temperature, by changes in its gas and acid-base balances, and by contact with objects foreign to its natural surroundings such as air and the skin. The chemical factors are those having to do with the formation of the clot.

The blood which forms a clot is at first perfectly fluid but soon becomes viscous and then "sets" into a soft jelly which quickly becomes firm enough to act as a plug. The clot becomes more compact and gradually shrinks in volume, at the same time squeezing out blood serum. The essential part of the clot is an insoluble protein substance called *fibrin* which is not present in normal blood but is produced from substances in the blood plasma, blood cells, and tissues when formation of a clot is necessary.

Among the protein constituents of the blood plasma was named *fibrinogen* which is the essential chemical factor in the formation of fibrin. Fibrinogen is a protein of the globulin type probably produced in the liver, and by itself is inert or inactive. In the generally accepted theory of clotting, when fibrinogen comes in contact with *thrombin*, a so-called fibrin ferment formed from *prothrombin* (or *thrombogen*) by the action of calcium salts, they interact and fibrin formation occurs. For prothrombin to be converted into thrombin by the action of calcium salts a third substance known as *cephalin* (or *thrombokinase*) must be present. This substance, called a thromboplastic agent, neutralizes the substance *heparin* which ordinarily prevents the activation of prothrombin, and is released from the injured tissues and from blood platelets which quickly disintegrate when exposed to air.

As fibrin is formed fine threads, fibrils, or needles of it traverse the escaping blood in various directions and encircle groups of blood cells. The meshes of this fibrin network draw closer together, the cells are packed more tightly together, blood serum is squeezed out, and a clot or *coagulum* is formed.

The process of clotting may be expressed diagrammatically as follows:



The formation of a clot closes the opening of wounded blood vessels and prevents great loss of blood. A clot also closes the opening in a wound and is the basis for the growth of new tissue in the process of healing. The clotting power differs in different individuals and normally 3 to 5 minutes is sufficient time for a clot to form, but in rare cases even trivial wounds may cause severe and dangerous bleeding. The condition in which clotting of the blood is delayed is known as *hemophilia* and a person having this condition is known as a *hemophiliac*.

The formed elements of the blood.

Red blood cells, or *erythrocytes*, are circular, biconcave discs or bodies without a nucleus that give to the blood its characteristic color (fig. 23). They are about $\frac{1}{3200}$ of an inch in diameter and in the adult male number about 5,000,000

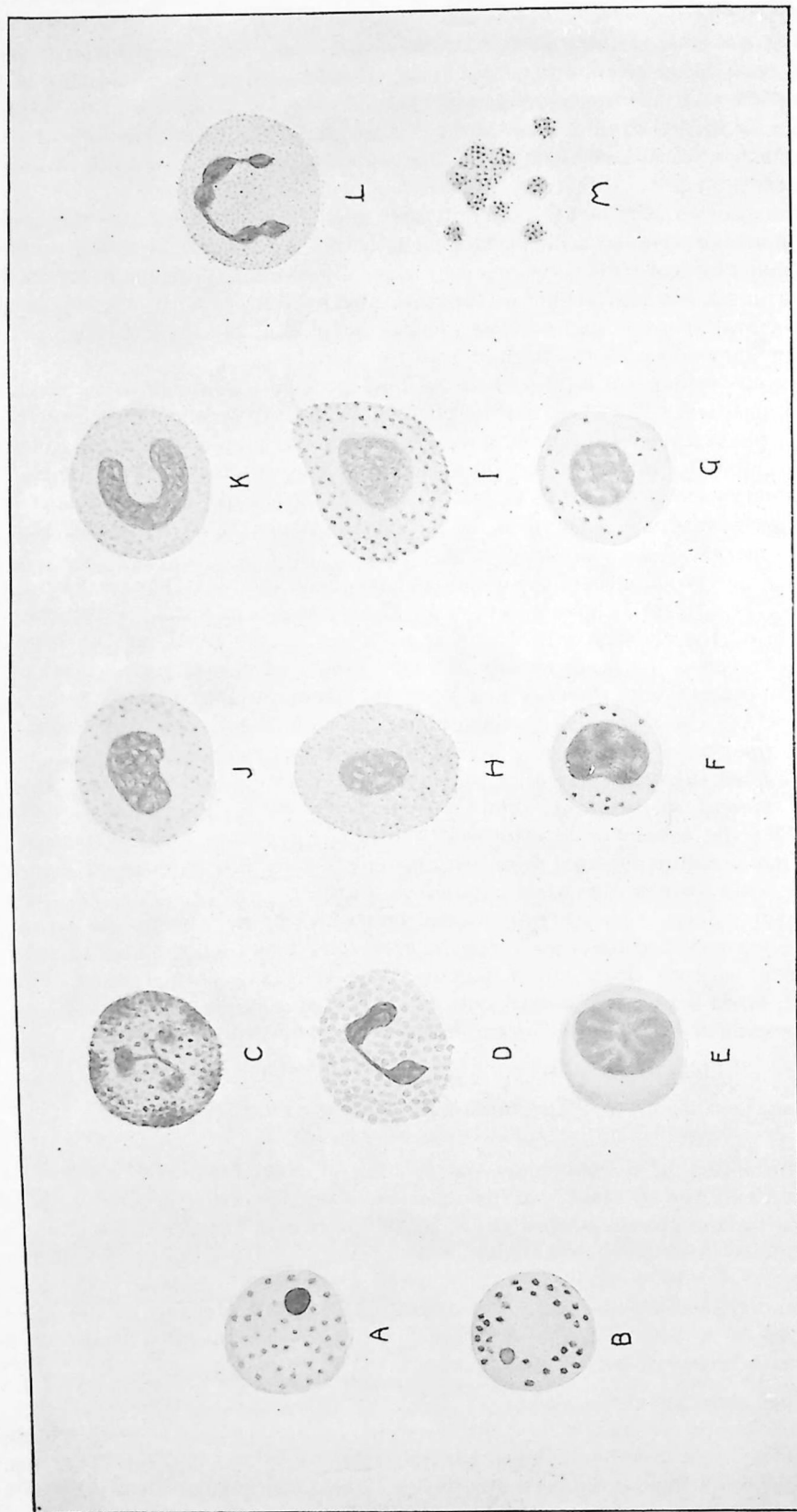


FIGURE 23.—Types of blood cells: *a* and *b*, red blood cells; *c*, polymorphonuclear basophil; *d*, polymorphonuclear eosinophile; *e* and *f*, small lymphocytes; *g*, large lymphocyte; *h*, neutrophilic myelocyte; *i*, primitive type of myelocyte; *j* and *k*, monocytes; *l*, polymorphonuclear neutrophile; *m*, clump of normal platelets. (Stitt, Clough, and Clough, modified.)

per cubic millimeter of blood. Their red color is due to the presence in them of *hæmoglobin*, a substance composed of an iron salt and a protein and which has the power of combining easily with oxygen to form *oxyhæmoglobin*, a loose chemical combination of oxygen and hæmoglobin by which oxygen is carried from the lungs to the body tissues. Hæmoglobin also possesses the power of readily combining with carbon dioxide and carries it from the tissues to the lungs. The affinity of oxygen and carbon dioxide for hæmoglobin depends upon the concentration of these gases at the point of exchange. In the lungs, oxygen being at a greater concentration than carbon dioxide, the hæmoglobin exchanges its carbon dioxide for oxygen and forms *oxyhæmoglobin*, but in the body tissues carbon dioxide is at a greater concentration than oxygen and the hæmoglobin exchanges its oxygen for carbon dioxide forming *carb-hæmoglobin*. In the adult, red blood cells are reproduced in the red marrow of bone. The cells there produced have a nucleus which they lose before entering the blood stream. A large number of red blood cells are destroyed daily, in what manner it is not definitely known. It may take place in the liver, the spleen, or in the lymph nodes, and it is probable that many are broken to pieces by the buffetings they receive in the circulation. It is known, however, that a certain amount of hæmatin, a decomposition product of hæmoglobin, is excreted in the bile, a fact which apparently substantiates the belief that some red blood cells are destroyed in the liver. Red blood cells depend upon the percentage of salt or sodium chloride present in the blood plasma for the maintenance of their form. Normally the amount of salt is equivalent to about a nine-tenths of 1 per cent solution of sodium chloride which fluid is isotonic or has the same osmotic pressure as the tissue fluids. If the percentage of salt is less the red cells will absorb water, swell, and burst, and their hæmoglobin is discharged. This is called *hæmolysis* and it may be caused by certain bacterial products called *hæmolysins*. If the percentage of salt is above the normal, water is extracted from the red cells and they shrivel or become *crenated*. These facts must be remembered in intravenous medications.

In the human being the color of the blood in the arteries is bright red, because the hæmoglobin in it is combined with oxygen, or is oxygenated; in the veins the color of the blood is dark red because the hæmoglobin has given off its oxygen and exchanged it for carbon dioxide.

White blood cells, or *leucocytes*, are nucleated blood cells and vary in size and shape (fig. 23). They are, in fact, almost colorless, are somewhat larger than red cells, and number about six to eight thousand per cubic millimeter of blood under normal conditions. This number may increase for various reasons and such an increase is called *leucocytosis*. Certain pathological conditions such as acute infections, malignant growths, poisonings, etc., usually cause an increase in the number of white cells. When the number of white cells drops below the normal standard the condition is known as *leucopenia* and is found in certain uncomplicated infections, poisonings, debilitations, etc.

The principal function of the white cells is to combat disease. This they do by contributing to the formation of antibodies and by ingesting and destroying bacteria, a process called *phagocytosis*. They also aid in the absorption of digested fat and proteins, and in the clotting of blood. Leucocytes have the striking property of amœboid movement which enables them to alter their shape, ingest and destroy bacteria, and to move themselves and pass through the walls of blood vessels into the surrounding tissues. This passing into tissues is known as *migration* and is one of the phenomena of inflammation.

White blood cells are divided into three distinct groups known as *granulocytes*, *lymphocytes*, and *monocytes*, which differ from one another in origin, structure, and function. There are three varieties of granulocytes called *neutrophiles*, *eosinophiles*, and *basophiles*, all of which are *polymorphonuclear* (having more than one irregularly shaped nucleus). Lymphocytes are known as *large* and *small*.

When stained for microscopical examination and differential counting, white blood cells show many variations of color in the nucleus and cytoplasm, and it is by these variations that the different kinds of white cells are recognized. When a differential count made in acute infections shows an increase in the percentage of immature white cells it is considered roughly proportional to the severity of the infection. Such an increase of immature white cells is due to the fact that infections promptly cause a demand for additional white cells to combat the infecting organism and as the reserve supply of mature or fully formed white cells is relatively small the demand for the increase is met by the production of new cells, many of which enter the circulation before their development is completed.

Blood platelets, or *thrombocytes*, are round or oval bodies in the blood that consist only of cytoplasm (fig. 23). They vary greatly in size and shape, have no nucleus, are smaller than red blood cells, and number from 300,000 to 800,000 per cubic millimeter of blood, according to the method used to count

them. They are an essential element in blood coagulation or clotting, mixing with fibrin to form a firm clot, and are believed to be fragments of the cytoplasm of multinuclear giant cells of the bone marrow (*megakaryocytes*) that have been pinched or broken off.

The blood-vascular system.

The organs of the blood vascular system are the heart, the arteries, the capillaries, and the veins. These form a closed system of tubes called *vessels* through which the blood circulates and reaches all parts of the body, and a muscular pump which propels the blood through the vessels.

The heart is a hollow, muscular organ located in the front and center of the thoracic cavity of the chest, between the lungs, with a large part of it lying directly back of the sternum or breast bone. It is about the size of a closed fist and closely resembles a strawberry in shape. The *base* of the heart points upward, backward, and to the right, and the pointed end, or *apex*, points downward, forward, and to the left (fig. 24).

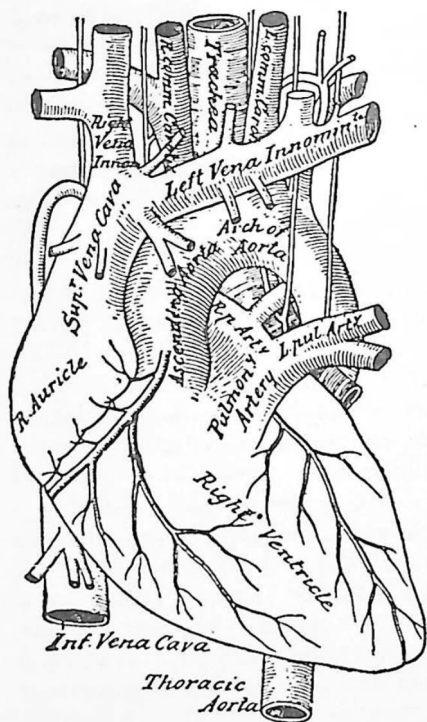


FIGURE 24.—The heart. (Mason.)

The heart is enclosed in an inverted sac of fibro-serous membrane called the *pericardium*, the inner layer of which adheres closely to the musculature of the heart. The outer surface of the pericardium turns back over the inner layer and forms a cavity which contains a small quantity of fluid known as the *pericardial fluid* that lubricates the surfaces of the pericardium and prevents

friction during the movements of the heart. The inside of the heart is lined with a delicate serous membrane called the *endocardium*.

The main portion of the heart is composed of muscular tissue called the *myocardium*. This muscular tissue is of a type found only in the heart, being striated or striped, but involuntary. Some of the muscles of the heart run transversely, others longitudinally, others obliquely, while those in the apex make a spiral turn or twist. This intricate arrangement makes possible an even and complete closing of the heart cavities during contraction.

The interior of the heart is completely separated into right and left halves by a longitudinal muscular septum, and each half is divided into an upper, receiving chamber, the *auricle*, and a lower, ejecting chamber, the *ventricle*. Consequently, there are four cavities in the heart. Each auricle communicates with its corresponding ventricle by means of an oval aperture called the *auriculo-ventricular* opening or valve. During fetal life there is an opening between the auricles of the heart known as the *foramen ovale*, which, however, closes immediately after birth. The walls of the auricles are much thinner than those of the ventricles and the wall of the left ventricle is much thicker than that of the right ventricle. This difference in development is because the ventricles perform a greater amount of work than the auricles and the left ventricle performs more work than the right.

Each of the four cavities of the heart is lined with endocardium which, by folding back upon itself, forms the *valves* of the heart. These valves allow the free passage of blood in the proper direction but effectually prevent its return. The valves differ in the number and shape of the *cusps* or *segments* of which they are made and are named according to the number and shape of the cusps, or the openings which they guard. The right *auriculo-ventricular valve* is also known as the *tricuspid valve* from the fact that it has three triangular-shaped cusps; the left *auriculo-ventricular valve* is also known as the *bicuspid* or *mitral valve* from its two triangular-shaped cusps. Both the *pulmonary valve* and the *aortic valve*, opening respectively into the pulmonary artery and the aorta, have three half-moon-shaped cusps because of which they are known as *semilunar valves*.

The heart is nourished by blood supplied to it through the right and left *coronary arteries* and its nerve supply is from the pneumogastric nerve and the sympathetic nervous system. The central nervous system can control and regulate the rhythmical, automatic contractions of the heart which are continuous during life but it has nothing to do with the cause of those contractions, whose origin is not definitely known.

The heart action consists of wave-like contractions, beginning in the auricles and passing to the ventricles, followed by dilatations. These contractions and dilatations are alternate and continuous and occur normally at the rate of about 72 per minute, although this rate varies according to age, sex, exercise, temperature, and in some pathological conditions. Contraction, or *systole*, as it is called, is a period of work; dilatation, or *diastole*, is a period of rest or relaxation.

The time from the appearance of any feature of heart action to the appearance of that feature again is known as a complete *cardiac cycle*, during which blood is received into and ejected from the heart cavities. The events occurring in the heart during a single cardiac cycle and which show how the heart acts are here summarized. Ejection of blood from the ventricles having been completed, the ventricles quickly relax from the contraction which ejected the blood and the semilunar valves in the ventricles close. The auriculo-ventricular valves have been closed since the last filling of the ventricles with

blood and the auricles are now being steadily filled with blood from the large veins entering them while the ventricles are relaxed or resting. During this period of relaxation all the valves in the ventricles are closed and the ventricles are completely shut off on both sides for a short time. By the time the relaxation of the ventricles is complete the pressure of blood in the auricles has caused the auriculo-ventricular valves to open and from then until the beginning of the brief auricular contraction blood from the large veins entering the auricles is flowing into and filling both the auricles and the ventricles. Soon the ventricles become more tense as the quantity of blood in them increases, the auriculo-ventricular valves float into position for closing, and the auricular contraction begins. At the end of the brief contraction of the auricles a sudden wave of blood is sent into the ventricles, completely filling them, the auriculo-ventricular valves close, and contraction of the ventricles begins, with the ventricles again being shut off momentarily due to all their valves being closed. The increasing pressure of the blood from the ventricular contraction causes the semilunar valves to open and blood is forced into the large arteries opening from the ventricles as long as the contraction lasts.

The action of a normal heart produces two distinct sounds which may be heard by applying the ear to the chest. One is a long, booming sound caused when the auriculo-ventricular valves close and the ventricles contract; the other is a short, sharp sound, attributed to the closing of the semilunar valves.

Arteries are hollow, elastic tubes that carry blood away from the heart. They have a certain amount of rigidity and consist of three layers, an inner lining of vascular endothelium, a middle muscular layer composed of involuntary muscle tissue and elastic fibrous tissue, and an outer fibrous-tissue coat. Arteries have a nerve supply from the sympathetic nervous system by which the size of the passage-way in the arteries may be dilated or constricted. The smaller divisions of arteries are called *arterioles*.

Capillaries are minute, half-sized vessels through which the blood passes from the arteries to the veins. They have very thin walls of endothelium only, communicate with each other, and form a dense, interlacing network in all parts of the body. In passing through the capillaries the blood gives its nutritive materials to the tissues and takes from the tissues the various waste products that are to be carried away, the exchange taking place through the very thin walls of the capillaries.

Veins are hollow collapsible tubes that carry blood to the heart. Their structure is similar to that of the arteries but their walls are much thinner, the middle layer containing less muscular tissue and elastic fibrous tissue. In many of the veins there are *semilunar valves* in pairs which act to prevent the backward flow of blood. They begin as minute *venules* formed from capillaries which have joined together.

In tracing the circulation of the blood (Fig. 25) it is necessary to begin at and return to a given point. In this case the given point will be the right auricle where venous, or impure, blood is entering from the *inferior* and *superior venæ cavæ*. This venous blood passes from the right auricle through the right auriculo-ventricular opening past the tricuspid valve, into the right ventricle. When the right ventricle contracts the tricuspid valve closes and the blood is forced past the pulmonary semilunar valve into the *pulmonary artery*. This artery divides into two branches, one going to each lung where it subdivides into smaller arteries, arterioles, and capillaries which surround the *alveoli*, or air sacs, of the lungs. During its circulation in the lungs the blood becomes aerated and is returned through small vessels to the four pulmonary veins, two from each lung, which empty into the left auricle. From

the left auricle the blood passes through the left auriculo-ventricular opening past the bicuspid or mitral valve into the left ventricle, where upon contraction of this part it is discharged past the aortic semilunar valves into the aorta. From the aorta the blood flows through its branches, the arteries, and the arterioles, to the capillaries in every part of the body. The blood is returned by the capillaries to the veins and finally reaches the right auricle through the *venæ cavæ*.

The contraction of the left ventricle, forcing the blood into the arteries, causes a wavelike expansions of the arteries which is synchronous with a heart beat. This is called the *pulse*, and may be felt at certain points where the arteries approach the body surface. The most common location is where the *radial artery* passes over the distal end of the radius, in each of the upper extremities.

Blood pressure is the force of the blood exerted against the walls of the vessels in which it is contained. Although the term includes the pressure in the arteries, veins, and capillaries, the usual application of

the term is to arterial pressure alone. The highest pressure—that is, that produced by the forceful propulsion of the blood through the arteries at each contraction of the ventricle—is known as the *systolic blood pressure*. Under normal conditions in the young adult this pressure is equivalent to about 120 millimeters of mercury, but varies as to age, sex, and condition of arteries and heart. Roughly, systolic blood pressure equals 100 plus the age of the individual. A certain amount of blood pressure is maintained in the arteries during the period of cardiac relaxation. This is caused by the elasticity and tonicity of the arteries and by the peripheral resistance. This pressure is known as the *diastolic blood pressure*. In normal young adults it is equivalent to from 70 to 90 millimeters of mercury. The difference between these pressures is called the *pulse pressure*.

The blood vessels.

The system of arteries and arterioles may be compared to a tree with the trunk giving off main branches which divide and subdivide again and again

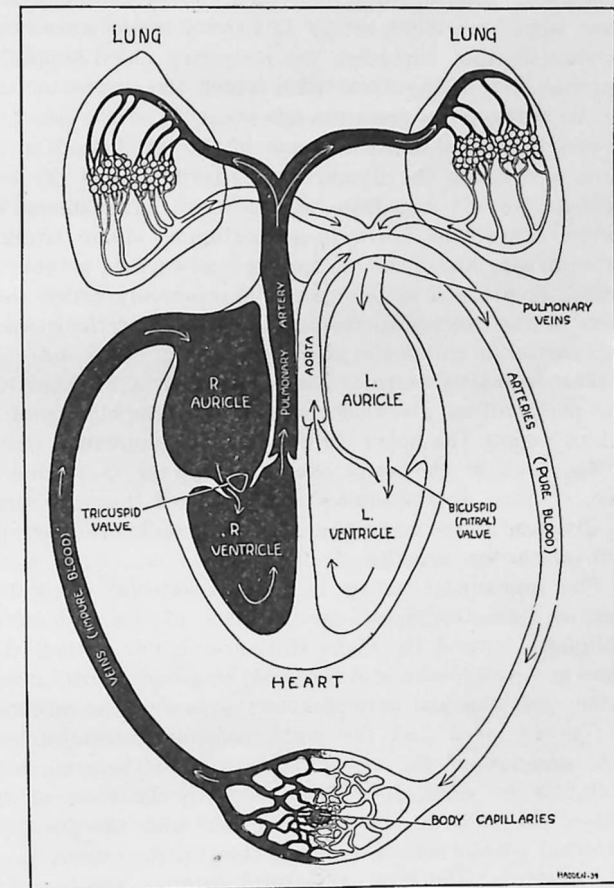


FIGURE 25.—Schema of circulation of the blood. (American Red Cross, modified.)

until they are but minute twigs. The arteries are constantly carrying a pulsating stream of blood which leaves the arterial tree at the finest subdivision and passes into the network of capillaries. In many locations in the body arteries that arise from different sources join together to form a union called *anastomosis*, a good example of which can be found in the palm of the hand. In case some important artery is injured these anastomoses provide a *collateral circulation* that furnishes the necessary blood supply. The main trunk of the arterial tree is the *aorta* with which the discussion of the arteries will begin.

The *aorta* arises from the left ventricle of the heart, ascends a short distance, arches backward above the root of the left lung, and descends along the spinal column through the diaphragm to terminate at the level of the fourth lumbar vertebra by dividing into the right and left common iliac arteries. During its entire course the *aorta* is a continuous single trunk which gradually diminishes in size and gives off branches at various points. The portion of the *aorta* which is situated in the thorax is commonly called the *thoracic aorta* and consists of the ascending, the arch, and part of the descending *aorta*; the remaining portion is called the *abdominal aorta*.

The ascending *aorta*, a short part 2 to 2¼ inches long and contained within the pericardium, gives off two branches, the right and the left *coronary* arteries which supply the heart itself with nourishment.

The arch of the *aorta* extends from the ascending *aorta*, above the root of the left lung, to the border of the fourth thoracic vertebra. During its course it gives off three branches, the *innominate*, the *left common carotid*, and the *left subclavian* arteries.

The *innominate* artery is a short arterial trunk 1½ to 2 inches in length arising from the right upper surface of the arch of the *aorta* and ascending obliquely toward the right sterno-clavicular articulation where it divides into the *right subclavian* and the *right common carotid* arteries.

The left common carotid artery arises at the middle of the upper surface of the aortic arch and the right common carotid artery is one of the terminal branches of the *innominate* artery. The common carotid arteries ascend obliquely on each side of the neck to the level of the laryngeal prominence where they divide into the *external* and the *internal carotid* arteries. The *external carotid* arteries supply the throat, tongue, face, ears, and the walls of the cranium; the *internal carotid* arteries supply the brain and the eyes.

The *subclavian* arteries, the right a terminal branch of the *innominate* artery and the left springing directly from the aortic arch, form the first part of the arterial trunks supplying the upper extremities. They give off branches to the back, the chest, the neck, and the brain, the principal one being the *vertebral* which runs upward through the transverse processes of the vertebrae to the brain. Both pass upward and outward under the clavicle and over the first rib, at the outer border of which they continue as the *axillary* arteries. These vessels give off branches to the chest, the shoulder, and the arm. The *axillary* artery on passing the armpit becomes the *brachial* artery, which gives off branches to the bone and muscles of the arm, and terminates just below the level of the elbow by dividing into the *ulnar* and the *radial* arteries. The *ulnar* artery, the larger of the two branches of the *brachial* artery, extends along the medial side of the forearm to the palm of the hand where it forms the *superficial volar arch*. The *radial* artery extends along the outer side of the forearm to the palm of the hand where it forms the *deep volar arch*. The *deep volar arch* anastomoses with the *superficial volar arch* and supplies the hand with blood.

The descending *aorta* is from 7 to 8 inches long and extends from the arch of the *aorta* to the diaphragm. It gives off the following branches:

1. The *intercostal* arteries which are paired, 9 and 10 on each side, and supply the intercostal muscles and the adjacent structures.
2. The *superior phrenic* arteries, which are small branches supplying the upper surface of the diaphragm.
3. The *bronchial* arteries, two left and one right, which are the nutrient vessels of the lungs and the bronchi.
4. The *mediastinal* arteries which are numerous small branches supplying the lymph nodes and the areolar tissue of the mediastinum.
5. The *oesophageal* arteries, four or five in number, which anastomose around the *oesophagus*.
6. The *pericardial* arteries, three or four small vessels distributed to the pericardium.

The *abdominal aorta* begins at the aortic opening of the diaphragm at the lower level of the last thoracic vertebra, and terminates at the level of the fourth lumbar vertebra by dividing into the common iliac arteries. The branches of the *abdominal aorta* are divided into two groups, those which supply the viscera, the *visceral* arteries, and those which are distributed to the walls of the abdomen, the *parietal* arteries.

The *visceral* group consists of:

1. The *celiac* artery, a short wide vessel, one-half inch in length which arises from the front of the *aorta* just below the diaphragm and divides into three branches; the *gastric*, supplying the stomach; the *hepatic*, supplying the liver, the gall bladder, and the duodenum; and the *splenic*, supplying the spleen and a part of the stomach and the pancreas.
2. The *suprarenal* arteries, right and left, which are distributed to the suprarenal glands.
3. The *superior mesenteric* artery which arises from the front of the *aorta* just below the suprarenal arteries and supplies the small intestine, except the duodenum, and half of the large intestine.
4. The *spermatic* arteries (*ovarian* in female), right and left, which are distributed to the testes (*ovaries* in the female).
5. The *inferior mesenteric* artery which arises from the front of the *aorta* about an inch above its division and is distributed over the lower half of the large intestine and the rectum.

The *parietal* group includes:

1. The *inferior phrenic* arteries, right and left, which supply the lower surface of the diaphragm.
2. The *lumbar* arteries, usually four pairs, which supply the posterior and lateral abdominal wall and muscles.
3. The *middle sacral* artery, a small vessel which is a direct continuation of the *abdominal aorta* and supplies the sacrum and coccyx.

The common iliac arteries (left and right) begin at the division of the *aorta*, extend downward and outward for 2 inches, when they divide into the *hypogastric* and the *external iliac* arteries. The *hypogastric* arteries supply branches to the pelvic walls, the pelvic viscera, the external genitals, and the buttocks. The *external iliac* artery forms the first part of a continuous arterial trunk which supplies the lower extremity and extends to the lower border of the inguinal ligament, where it passes from the abdomen through the femoral opening and becomes the *femoral* artery. The *external iliac* artery partially supplies the anterior abdominal wall and the external genitals. The

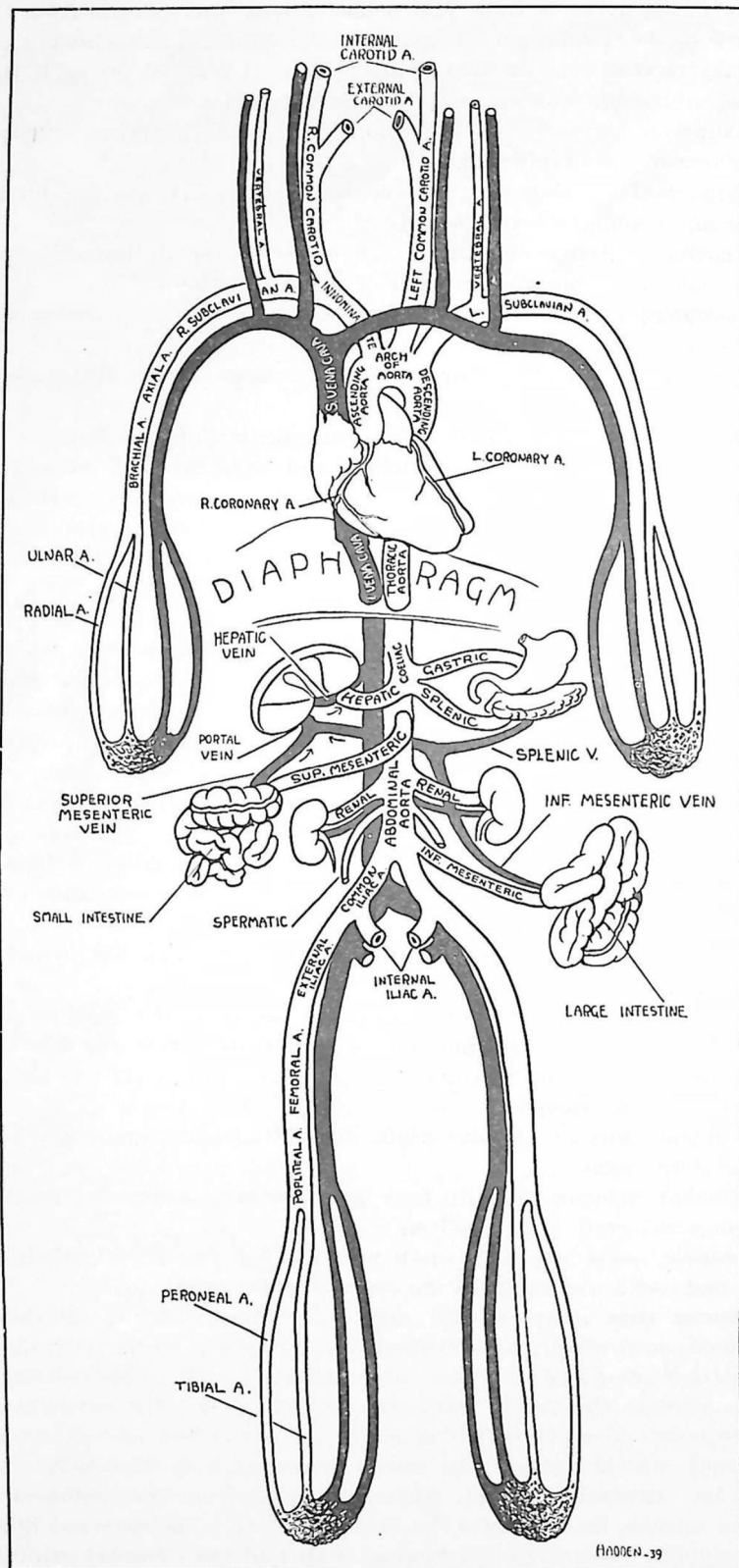


FIGURE 26.—Schema of principal arteries and veins. (U. S. Naval Medical School.)

femoral artery runs an oblique course around the femur inward and backward in the upper three fourths of the thigh to the posterior surface of the knee joint, where it becomes the *popliteal* artery. The femoral artery supplies branches to the muscles, the bone, and the skin of the thigh. The popliteal artery, after giving off branches anastomosing around the knee joint, divides into the *anterior* and the *posterior tibial* arteries. The anterior tibial artery, the smaller of the two branches, passes forward between the tibia and fibula, and then down the front of the leg to the ankle, where it becomes the *dorsalis pedis* artery which supplies the dorsal surface of the foot. The posterior tibial artery passes down the back of the leg to the ankle, where it divides into two branches which supply the sole of the foot. It gives off various branches, the largest of which, the *peroneal* artery, also passes to the plantar surface of the foot and supplies some of the muscles and skin of the foot and the ankle joint.

The veins begin as small branches called *venules* which unite to form larger vessels. Veins differ from arteries in that they have a larger capacity, thinner walls, and contain valves which assist in supporting the column of blood. This is necessary because most of the cardiac impulse is lost during the course of blood through the capillaries.

The veins are divided into the *pulmonary*, the *systemic*, and the *portal* systems.

It has been shown that the pulmonary arteries end in capillaries in the walls of the alveoli of the lungs. After oxygenation, blood is collected from these capillaries by the venules which unite to form a vein from each of the five lobes of the lungs. The right lung, however, sends but two veins to the heart as does the left lung, for the veins of the superior and the inferior lobes of the right lung unite. There are, then, four pulmonary veins carrying blood from the root of the lungs to the left auricle of the heart. These are the only veins in the body which carry arterial, or oxygenated blood.

The veins of the systemic circulation are arranged in two sets, the *deep* and the *superficial*. The deep veins as a rule accompany their corresponding arteries and usually are called by like names. The larger arteries have only one accompanying vein but the medium sized or smaller arteries usually have two accompanying veins which anastomose freely with each other. The superficial veins lie just under the skin where in many localities they may be easily seen, and end by entering the deeper tissues to join the deep veins.

The superficial veins of the head which drain the venous blood from the scalp and face and from the cancellous tissue of the skull empty into the right and left external jugular veins. The anterior jugular vein of the neck usually empties into the external jugular veins and with them drains the neck. The external jugular veins empty into the subclavian veins.

Venous blood from the brain and the interior of the skull drains into *venous channels* situated between two layers of the dura mater of the brain and having the same lining as the veins which empty into them. These channels are also known as *venous sinuses* and the most important ones are the superior sagittal sinus running from front to back across the top of the brain, the two transverse or lateral sinuses, one on each side of the brain, and the two cavernous sinuses, one on each side of the sphenoid bone. The cavernous sinuses communicate with the veins of the face through the veins of the orbits and are therefore especially receptive to the backward spread of infective organisms from the nose and cheeks with resultant clotting of blood in the sinuses and almost certain death. The sagittal and cavernous sinuses empty into the transverse sinuses and they empty into the internal jugular veins, one on each side of the

neck, which, with their tributaries, also drain the deep portions of the neck, the tongue, the pharynx, and the thyroid gland.

The superficial veins of the upper extremity start from the *dorsal venous arch* and the *volar venous plexus* of the hand and consist of the *cephalic*, *basilic*, *median*, and tributary veins. The *cephalic* vein passes up the outer side of the forearm and arm in front of the elbow and empties into the upper part of the axillary vein just below the clavicle. Below the elbow it gives off the *median cubital* or *median basilic* vein which passes across and joins the basilic vein. The *basilic* vein passes up the inner side and back of the forearm, receives the median cubital vein below the elbow, and in the axilla joins the brachial veins to form the axillary vein. The *median* vein passes up the forearm to the level of the elbow where it joins the basilic vein.

The deep veins of the upper extremity begin from smaller veins in the hand as the radial veins and the ulnar veins and as they pass upward receive tributary veins. In front of the elbow they unite to form the brachial veins which continue upward through the arm and in the axilla unite with the basilic vein to form the axillary vein. The axillary vein passes on across the axilla and at the outer border of the first rib becomes the subclavian vein which continues on to the sternal end of the clavicle and there unites with the internal jugular vein to form the innominate vein. At this point the right subclavian vein receives the lymphatic duct and the left receives the thoracic duct. Before uniting with the internal jugular vein the subclavian vein receives the external jugular vein and sometimes the anterior jugular vein.

The innominate veins, one on each side, receive numerous tributary veins draining various parts of the thorax and pass obliquely downward toward the sternum and unite to form the *superior vena cava* which receives the *azygos* vein draining most of the intercostal spaces and several small tributary veins. The *superior vena cava*, which returns to the heart all venous blood from the body above the diaphragm, descends on the right side of the center of the thorax, with a slight convexity to the right, and ends in the upper part of the right auricle of the heart.

The blood which has supplied the heart itself with nourishment is returned as venous blood by a *venous channel* called the *coronary sinus* which lies in a groove on the back of the heart and enters the right auricle near the junction of the inferior vena cava with the right auricle. Tributary veins, most of which empty into the coronary sinus, collect the venous blood from the heart.

The superficial veins of the lower extremity are the *internal, great, or long saphenous* vein which starts on top of the inner side of the foot and runs up the inner side of the leg and thigh to terminate just below the groin in the femoral vein, and the *external, small, or short saphenous* vein which starts in a similar manner on the outer side of the foot and terminates just behind the knee in the popliteal vein. Both saphenous veins are joined by numerous tributary veins. The principal deep veins of the lower extremity are the *anterior* and *posterior tibial* veins, the *peroneal* veins, the *popliteal* vein, the *femoral* vein, and the *deep femoral* vein. The *anterior* and *posterior tibial* veins start from smaller veins in the foot, run upward and unite behind the knee to form the popliteal, the posterior tibial veins in the passage upward being joined by the peroneal veins which accompany the peroneal artery. The *popliteal* vein extends upward through the lower third of the thigh where it becomes the femoral vein, being joined shortly after its origin by the small saphenous vein. The *femoral* vein extends upward through the upper two-thirds of the thigh and then becomes the external iliac vein, being joined just before its termina-

tion by the great saphenous vein. The *deep femoral* vein communicates with the popliteal vein below and the inferior gluteal vein above.

Only the principal veins of the abdomen and pelvis will be named, beginning with the *external iliac* vein which runs along the brim of the pelvis to the sacroiliac joint where it unites with the *hypogastric* or *internal iliac* vein, which drains the pelvis, to form the common iliac vein. The *common iliac* veins, one from each side of the body, pass obliquely upward and unite on the right side of the fifth lumbar vertebra to form the *inferior vena cava*, into which the lumbar veins, the renal veins with the left suprarenal and left spermatic or ovarian veins, the right suprarenal and right spermatic or ovarian veins, and the hepatic veins empty. The *inferior vena cava*, which returns to the heart all venous blood from the body below the diaphragm, ascends along the spinal column on the right of the aorta, passes through the diaphragm into the thoracic cavity and ends in the lower part of the right auricle of the heart.

The *portal system* of veins consists of the veins which drain blood from the stomach, the intestines (with the exception of the lower part of the rectum), the spleen, the pancreas, and the gall-bladder. Among the veins collecting blood from these viscera are the splenic and the superior mesenteric veins which unite behind the neck of the pancreas to form the *portal* vein, the principal one in the system as all the others ultimately empty into it. The veins communicating with the portal vein all have numerous tributary veins. The *portal* vein runs upward and slightly to the right to the transverse fissure of the liver where it divides into two branches which enter the right and left lobes of the liver respectively. After entering the liver the branches of the portal vein continue to branch until they end in small capillaries in blood spaces in the liver substance where the *hepatic* veins begin and, after leaving the liver, continue on to enter the inferior vena cava, as mentioned before. The purpose of the portal circulation is to subject the blood containing the end products of digestion to the special action of the liver prior to entering the general circulation.

THE LYMPH AND THE LYMPH-VASCULAR SYSTEM

Lymph is a colorless fluid, rich in white blood cells, of essentially the same composition as blood plasma, and largely the product of the filtration of blood plasma through the walls of the blood capillaries. It is found in the lymph vessels and in all of the tissue spaces of the body and serves as a medium for carrying nourishment and oxygen to the tissues and waste products from them. The tissues and organs of the body are bathed in lymph which then acts as a lubricant in aiding movement. After a meal, the lymph coming from the small intestine has a milky appearance because of the presence of fat in it and it is then called *chyle*.

The lymph-vascular system.

Lymph vessels and lymph glands constitute the lymph-vascular system which forms a network throughout the body and connects with serous and tissue spaces. There are also certain lymph trunks in the system the most important of which is known as the *thoracic duct*. The flow of lymph in the system is always from the tissues toward the terminal lymph vessels and is maintained in this direction mainly by the difference in pressure at the two ends of the system. The pressure is lowest at the terminal end and the terminal lymph vessels are the *thoracic duct* and the *right lymphatic duct* which empty into the left and right subclavian veins, respectively.

The lymph vessels.

In many respects the lymph vessels resemble veins and have been found in every part of the body which possesses blood vessels except the brain, spinal cord, eyeball, and internal ear. Like the veins many of the lymph vessels contain valves which prevent the backward flow of the lymph, but, unlike the veins, they communicate directly or indirectly with the great serous cavities of the body and their continuity is interrupted by interposed lymph glands. Lymph vessels find their beginning in the tissues and organs of the body where they are known as *lymphatic capillaries* and which unite to form larger vessels. As the lymph vessels attain a larger size their walls become stronger due to the presence of elastic tissue and the larger vessels are composed of three layers as are blood vessels. Lymph vessels are known as *superficial lymph vessels* and *deep lymph vessels*, according to their position in the body. The superficial vessels collect lymph from the skin and subcutaneous tissue; the deep from all other parts of the body.

The *thoracic duct* is about the size of a goose quill and is from 15 to 18 inches long. It extends from the level of the second lumbar vertebra to the root of the neck where it empties into the left subclavian vein at its junction with the left internal jugular vein. This lymph vessel lies just in front of the spinal column and receives the lymph from all lymphatic vessels of the body except those from the right side of the head, the right upper extremity, the right chest and its contents, the right side of the diaphragm, and the upper surface of the liver, all of which finally empty into the *right lymphatic duct*.

The *right lymphatic duct*, which is not always present in the body as a distinct lymph trunk, is about $\frac{1}{2}$ to $\frac{3}{4}$ inch long, lies at the right side of the root of the neck, and empties into the right subclavian vein at its junction with the right internal jugular vein.

The lymph glands.

These are small bean-shaped bodies that occur in groups of from 2 to 15 along the courses of the lymph vessels except for a few in the subcutaneous tissue that are single. These groups of lymph glands are known as *lymph nodes*. The glands vary considerably in size, are composed of lymphoid tissue, and act partly as filters for the removal of minute infective organisms and particles from the lymph stream. They also are the source of origin of most of the white blood cells known as lymphocytes.

THE RESPIRATORY SYSTEM AND RESPIRATION

Respiration, or breathing, in some form is a characteristic of all living organisms and without it life cannot continue. It may be defined as the process of gaseous exchange between a living organism and the medium in which it lives. The medium in which the animals and plants of Earth live is air, the mixture of gases which surrounds the earth. One of the gases in air is oxygen which both animals and plants require for their vital processes, those functions of the body on which life is directly dependent. These vital processes, for which the term *metabolism* is used, are the chemical changes proceeding continually in living cells by which the energy to maintain the processes and activities necessary for life is provided. In the production of this energy, destruction or waste occurs and one of the waste products is the gas called carbon dioxide which is exchanged for oxygen in the process of respiration. In the single-celled animals and plants the exchange takes place directly between the organism and its surrounding medium but in the more complex animals some form of respiratory apparatus is necessary. Man and the air-breathing

vertebrates are provided with lungs or gills where the waste product carbon dioxide is exchanged for oxygen present in the surrounding medium of air.

The respiratory apparatus.

In man the respiratory apparatus consists essentially of the *lungs* and the air passages leading into them (fig. 27), the *nasal chambers*, the *mouth*, the *pharynx*, the *trachea*, and the *bronchi*. The *thorax*, the *ribs*, and the *diaphragm* and other respiratory muscles taking part in respiratory movements may be considered as accessory respiratory apparatus.

The *nasal chambers* are the normal entrance for air to the respiratory tract. They are irregular, wedge-shaped cavities having a vestibule, a respiratory region and an olfactory region and are covered with a highly vascular mucous membrane which in the respiratory region serves to warm and moisten the inspired air. In the respiratory region there are many fine hairs called *cilia* which act as filters and remove dust particles from the air being inhaled. The *nasal septum* separates the two chambers, both of which open posteriorly into the pharynx.

The *mouth*, strictly speaking, is a part of the alimentary canal or digestive tube, but because the back of it connects with the pharynx and respiration can therefore be carried on through it when it is open, the mouth is sometimes considered as a part of the respiratory apparatus.

The *pharynx*, like the mouth, is really a part of the alimentary canal, of which it is the expanded upper part. In the respiratory system it serves merely as a passageway for the air as it connects above with the nasal chambers and below with the larynx.

The *larynx*, or *organ of voice*, lies in the upper and front part of the neck between the trachea and the hyoid bone and tongue. Above it opens into the pharynx, below it becomes continuous with the trachea. It is a triangular, box-like structure made up of several cartilages connected together at certain points by ligaments and membranes, and the upper part of the largest of these cartilages, the *thyroid cartilage*, forms a marked prominence in the midline of the neck which is the so-called "Adam's apple." In the upper part of the larynx there is a space commonly called the *glottis*. Along the sides of this space, extending from front to back and projecting into it are two pairs of elevated folds of mucous membrane. The folds in the upper pair are called the *false vocal cords*; those of the lower, more definite pair are the *true vocal cords*, the chief agents in the production of voice. Extending upward and

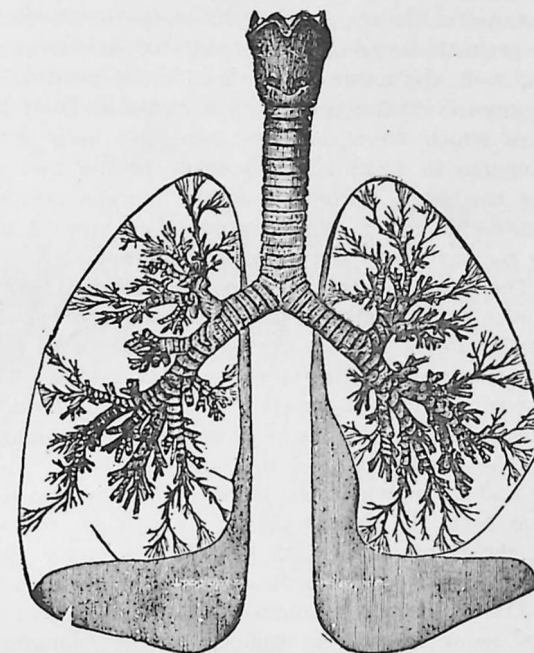


FIGURE 27.—The larynx, trachea, right and left bronchi, and the lungs. The latter have been cut open to show the method of division and subdivision of the bronchi. (Mason.)

backward over the upper opening of the larynx is a thin leaf-like flap of fibrous-cartilage called the *epiglottis* which in the act of swallowing directs the material being swallowed into the opening of the œsophagus.

The trachea, or *windpipe*, is a wide fibro-muscular tube which extends downward from the larynx about 4 to 4½ inches and there divides into the right and left bronchi. It lies in front of the œsophagus and its walls consist of fibro-elastic membrane and muscular tissue with a lining of mucous membrane. Because of the elasticity of its walls the trachea has considerable mobility but to prevent dragging on the roots of the lungs during movements of the head and neck the lower end is fixed in its position. Embedded in the fibro-elastic membrane of the trachea is a series of from 15 to 20 C-shaped cartilaginous bars which strengthen the tube and keep it always open. These bars are complete in front but incomplete behind and consequently the back wall of the trachea is flattened. In the mucous membrane lining of the trachea are many cilia which help to produce an upward movement of the mucus present on the surface of the mucous membrane.

The bronchi begin as the two terminal branches of the trachea and are known individually as the right and the left *bronchus*. They are structures similar to the trachea but have cartilaginous plaques instead of bars and each bronchus enters into the corresponding lung. There they branch and rebranch like a tree, and the smallest branches, the *bronchioles*, end in tiny membranous sacs called air vesicles or *alveoli*, which are multitudinous in number and make up the greater part of the lung substance. The alveoli have very thin walls in and about which the blood capillaries are distributed in such numbers that they form the densest plexus, or network, of capillaries to be found anywhere in the body. The right bronchus is larger, shorter, and more vertical than the left and foreign bodies in the trachea are likely to be directed toward it.

The lungs, two in number, occupy practically all of the cavity of the thorax, one being located in each of the two chambers called pleural cavities into which the thoracic cavity is divided by the *mediastinal septum*. They are light, soft spongy organs made up of the alveoli, bronchial tubes, blood vessels, lymphatics, and nerves, held together by connective tissue. The right lung has three lobes and is larger, broader, and shorter than the left which has only two lobes. The surfaces of the lungs next to the ribs are convex so as to fit the curvature of the thorax, and the other surfaces present concave hollows to fit the various organs which are in contact with the lungs. One of these hollows is the pericardial concavity which is adapted to the shape of the heart. Above the back of this hollow there is a wedge-shaped depression on each lung known as the *hilum*, within which the bronchus, blood vessels, nerves, and lymph vessels enter and leave. These structures are bound together by a sheath of pleura to form a pedicle or stem by which the lung is attached to the mediastinal wall of the pleural cavity. This pedicle or stem is called the *root* of the lung. There are two types of circulation in the lungs, the pulmonary, which brings the blood from the right heart to the lungs for the exchange of gases called oxygenation or aëration and returns it to the left heart, and that from the bronchial branches of the aorta which supply the lung tissue itself. The nerve supply of the lungs is from the vagus nerve and the sympathetic nervous system.

The pleura is a serous membrane which envelopes the lungs and lines the walls of the thoracic cavity. It is without a break in its continuity and thereby forms a closed sac within which are all the organs located in the thorax. The inner surface of the pleura has a smooth, glossy appearance and is moistened with a small amount of serous fluid. The portion of the pleura which covers

the lungs is known as *pulmonary* or *visceral pleura* and is very firmly bound down to the surface of the lung. It is very thin and completely covers the entire surface of the lung. At the root of the lung the pulmonary pleura turns back on itself to line the walls of the thoracic cavity and it is then known as the *parietal pleura* or, according to the different parts of the thoracic cavity it lines, as the *costal pleura*, the *diaphragmatic pleura*, the *mediastinal pleura*, and the *cervical pleura*. Each lung is enveloped in its own pleural sac and these sacs do not communicate with each other. The serous fluid on the pleura permits respiratory movements of the lungs with little if any friction as it acts as a lubricant. The inner surface of the pleura sometimes becomes roughened by inflammation and this condition is known as pleurisy. Should the thoracic wall be perforated, thus allowing air to enter a pleural cavity, the lung of that side will collapse.

The process of respiration.

As has been explained at the beginning of this section, respiration is a necessity in the life of air-breathing vertebrates and it may be said that the purpose of respiration is to supply the body with oxygen and to remove carbon dioxide. This interchange of gases, which takes place in the lungs, is known as the oxygenation or aëration of the blood, and the actual exchange occurs in the alveoli of the lungs. Oxygen and carbon dioxide readily pass through the thin membranous walls of the alveoli and of the capillaries because both have the property of being able to pass through permeable and semi-permeable membranes in accordance with the natural laws of diffusion of gases.

The gaseous exchange or absorption of oxygen and elimination of carbon dioxide that takes place in the lungs between the blood in the capillaries in the walls of the alveoli and the air in the alveoli may be called *external respiration*; the similar exchange that occurs in the systemic capillaries between the blood and the tissues of the body may be called *internal* or *tissue respiration*. The latter is the respiration truly vital to life.

In the section concerning blood it was stated that the blood carries oxygen from the lungs to the body tissues and carbon dioxide from the tissues to the lungs. The oxygen required by the tissues for their activities is carried to them principally in *chemical combination* with the hæmoglobin in the red blood cells, only a very small amount being carried in *physical solution* as oxygen is not a very soluble gas. In the compound formed by the chemical combination of hæmoglobin and oxygen, called oxyhæmoglobin, the hæmoglobin is almost completely saturated with oxygen.

The carbon dioxide produced in the tissues during their metabolic activity is removed from them in *chemical combination* with hæmoglobin and with constituents in the plasma, and in *physical solution* in the plasma. Carbon dioxide is a very soluble gas and upon reaching the plasma some of it dissolves to form *carbonic acid* which reacts with sodium chloride in the plasma and produces *sodium bicarbonate*, and a small amount is retained in the plasma in simple physical solution. The remaining carbon dioxide enters into *chemical combination* with hæmoglobin to form carb-hæmoglobin.

Oxygenated blood reaches the tissues through the blood capillaries at which point the oxygen content, and consequently its pressure, is higher than in the tissues. This difference in oxygen pressure causes the oxyhæmoglobin, which under those conditions has the property of dissociation, to give off free oxygen which diffuses through the thin walls of the capillaries and the lymph into the tissue cells.

The blood, having given up its oxygen to the tissues, again contains uncombined or *reduced hæmoglobin*, and therefore is ready to take up carbon dioxide.

Being under higher pressure in the tissues than in the blood, the carbon dioxide diffuses from the tissue cells through the lymph and the capillary walls into the blood where it is taken up as previously explained.

Deoxygenated or impure blood is carried to the lungs where the oxygen pressure in the alveoli is higher and the carbon-dioxide pressure lower than in the blood. In the lungs the carbon dioxide which was changed into sodium bicarbonate changes back to carbon dioxide. On reaching the capillaries in the alveoli the lower pressure of the carbon dioxide there causes that in the blood to diffuse through the thin walls of the capillaries and of the alveoli until an equilibrium in pressure between the carbon dioxide in the blood and in the alveoli is reached. At the same time the higher pressure of oxygen in the alveoli causes it to diffuse through the walls of the alveoli and the capillaries and enter the blood where it combines with the reduced hæmoglobin and oxyhæmoglobin is again present in the blood. In the lungs the blood does not ordinarily give up all its carbon dioxide as some is required for its action in the maintenance of respiration.

The chemical change attendant upon the formation of sodium bicarbonate from carbon dioxide plays an important part in maintaining the slightly alkaline reaction of the blood.

The ordinarily automatic, rhythmical movements of respiration are controlled by the *respiratory center* in the medulla oblongata which originates the impulses causing them. These impulses pass down the spinal cord to the nerves which supply the respiratory muscles. Probably the most important of these nerves is the *phrenic* which supplies the diaphragm, others being the *vagus*, supplying the larynx, and the *intercostals*, supplying the muscles of the thorax and abdomen.

The respiratory center may be affected by various conditions and it follows that the respiration is also affected. An increase in the amount of carbon dioxide (which has acid properties) in the blood increases the acidity of the blood and is immediately followed by increased respiratory movements. A decrease in the amount of carbon dioxide in the blood can cause all respirations to cease, which condition will remain until the normal amount of carbon dioxide is again present in the blood which stimulates the respiratory center and breathing is resumed. External sensations may affect the respiratory center; for example, the splashing of cold water on the face and chest often will stimulate resumption of breathing; a sudden plunge into cold water will cause a deep, gasping respiration. Emotional disturbances affecting the higher centers of the brain may alter respiration; for example, in excitement the respirations may increase while in shock they are usually shallow and sighing; laughing, crying, speaking, or singing, may to some extent modify respiratory movements. If for any reason the respiratory center loses its blood supply failure of respiration will ultimately occur.

As has been stated in the section concerning muscles, the respiratory muscles ordinarily act automatically without conscious effort of the will. Activity of those muscles produces alternate inspirations and expirations of air in and out of the lungs which, with a period of rest between movements, constitutes what is called the *cycle of respiration*. This cycle is divided into three phases: 1. *Inspiration*, or the flow of air into the lungs; 2. *Expiration*, or the flow of air out of the lungs; and 3. A period of *rest*.

The cycle is completed about 14 to 18 times per minute in the normal adult while at rest. In the act of inspiration the diaphragm contracts and the ribs are elevated by the accessory muscles of respiration, thus enlarging the thoracic cavity and creating a negative pressure in the cavity. This permits the lungs to expand and causes the outside air to rush in and equalize the pressure. In

expiration the diaphragm relaxes, and the elasticity of the lungs, together with the weight and the elasticity of the chest walls, causes the chest to return to its original size, expelling a certain amount of air from the lungs.

The lungs, when filled to their utmost capacity, hold about 4,500 cc of air. Practically 500 cc of air is breathed out at a normal quiet expiration. This air which is changed at each respiration is called the *tidal air*. The amount of air breathed out or in may be increased by forceful expiration and inspiration. The amount of air left in the lungs after the most forceful expiration is about 1,000 cc and is known as the *residual air*. Under normal conditions the reserve supply of air in the lungs is about 2,600 cc.

Certain sounds are produced by the entry and exit of air from the alveoli of the lungs and the bronchi. These sounds may be variously modified in lung diseases.

Certain abnormal types of breathing may be noted. *Dyspnoea* is labored or difficult breathing. *Apnoea* is a condition in which there is a temporary cessation of breathing. *Asphyxia* is the condition produced by oxygen starvation and is caused by prolonged interference with the aëration of the blood.

THE DIGESTIVE SYSTEM AND DIGESTION

In order to understand the processes concerned with digestion, it is necessary to know the meaning of the various terms used in describing this process.

Digestion is the process or act by which various food substances are converted into simpler substances which can be absorbed and assimilated.

Mastication is the division of food into small particles. This is accomplished by means of the teeth.

Insalivation is the mixing of food with the saliva. This takes place within the mouth.

Deglutition or swallowing is the act of transferring food from the mouth to the stomach.

Enzymes are complex organic substances capable of effecting, by catalytic action, the transformation of some other compound or compounds.

Absorption, as applied to digestion, means the taking up of digested food products, either in solution or suspension, by the blood and the lymph from the alimentary tract.

Peristalsis is a wave-like contraction which passes along the intestinal tract. This movement moves or propels the contents of the intestine.

Defæcation is the term applied to the act of expelling fæces from the rectum.

The digestive system consists of the *alimentary canal* and the *accessory organs* (fig. 28). The alimentary canal is a continuous tube extending from the mouth to the anus, 28 to 30 feet long and varying in size. It is composed of the *mouth*, the *pharynx*, the *oesophagus*, the *stomach*, and the *small* and *large intestine*. The accessory organs of digestion are the *teeth*, the *tongue*, the *salivary glands*, the *liver*, the *gall bladder*, and the *pancreas*.

The mouth or *buccal cavity* is nearly oval in shape, and is formed in front by the lips; above, by the *hard palate* in front and the *soft palate* behind; at the sides, by the *cheeks*; and below or at the floor, by the *tongue*. This cavity opens posteriorly into the *pharynx* from which it is partially separated by the

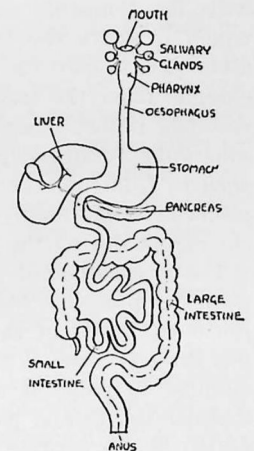


FIGURE 28.—Diagram of the alimentary tube and its appendages. (Testut.)

uvula, a small flap of mucous membrane hanging from the soft palate, and the *anterior pillars of the fauces*, two curved folds of mucous membrane running from the uvula to the sides of the base of the tongue. In the small depression between the anterior and the posterior pillars of the fauces, on either side, is a small mass of lymphoid tissue called the *tonsil*. The semicircular borders of the upper and lower jaw bones, the *alveolar processes*, contain sockets for the reception of the *teeth*, of which there are two sets, the *deciduous*, or "milk" teeth, which erupt between the ages of 6 months and 3 years and are 20 in number, and the *permanent teeth*, which replace the first set between the ages of 6 and 21 years. In the adult there are 32 teeth, 16 in each jaw, 4 incisors, 2 cuspids (canines), 4 bicuspid, and 6 molars. The structure of the teeth is described in the section on Emergency Dental Treatment (p. 165).

The tongue is a muscular organ occupying the floor of the mouth. It is covered with mucous membrane, contains the special organs of taste, is an important organ of speech, and assists in the mixing and swallowing of food.

The salivary glands, consisting of three pairs, are compound glands which discharge their secretion, *saliva*, into the mouth. The *parotid glands* situated in front of and below the ears, discharge their secretion by way of *Stenson's ducts* which enter the mouth opposite the second upper molar teeth. The *submaxillary glands*, lying under the lower jaw, and the *sublingual glands*, lying under the tongue, discharge their secretion by way of ducts opening into the floor of the mouth and known as *Wharton's ducts*.

The pharynx is the expanded upper part of the alimentary canal and lies behind and communicates directly with the mouth, the nasal chambers, and the larynx. By means of the *Eustachian* or *auditory tubes* it also communicates with the tympanic cavities, or the middle ears. That part of the pharynx which is above the level of the soft palate is used only for respiration, the other part is used for the passage of food. It is a fibro-muscular structure and extends from the base of the skull, above, to the level of the sixth cervical vertebra below, where it joins and is continuous with the œsophagus. It is somewhat funnel-shaped with the wide part at the top. The upper part is open in front but the lower part gradually becomes tube-like, the anterior and posterior walls finally join, and the opening reduces in size until it is only a slit except during the passage of food.

The œsophagus, or *gullet*, is a muscular tube about 10 inches long extending from the pharynx, above, to the stomach, below. It is situated practically in the median line of the body and inclines slightly to the left. Its upper part lies directly behind the trachea and in front of the vertebral column, the remainder in front of the vertebral column. It passes downward through the thoracic cavity and pierces the diaphragm about one-half inch above its termination at the cardiac orifice of the stomach. Its walls are composed of three layers, an inner lining of mucous membrane, a middle layer of connective tissue, and an outer coat of both voluntary and involuntary muscle tissue. In addition it is surrounded by a covering of connective tissue which permits its free movement and by which it is loosely connected to the various structures adjacent to it.

The remaining parts of the digestive system are located in the abdomen which will be briefly described before continuing with the digestive system.

The *abdomen* is that portion of the trunk lying below the diaphragm and consists of a wall made up in part of bones, muscles, tendons, etc., and of the largest cavity in the body in which are contained the stomach, liver, gall bladder, intestine, pancreas, spleen, kidneys, bladder, some of the generative organs, blood vessels, nerves, etc. This cavity is termed the *abdominal cavity* but for

descriptive purposes is considered in two parts, an upper, larger part called the *abdomen proper*, and a lower, smaller part called the *pelvis*. The abdominal cavity in the adult male is shaped much like a barrel, with the upper end bounded by the diaphragm and somewhat wider than the lower. For convenience in describing or locating the organs contained in the abdominal cavity the abdomen is considered as divided into nine regions by imaginary lines drawn on its ventral surface and each region is named appropriately (fig. 29). A continuous, smooth membrane known as the *peritoneum* covers the wall of the abdominal cavity and the surfaces of the organs in it.

The *peritoneum* is a thin, glistening, serous membrane composed of a layer of fibrous tissue covered over on the cavity side with a layer of flattened endothelium which secretes a small quantity of serous fluid known as *peritoneal fluid* that lubricates the inner surface of the peritoneum and permits movement of the structures in the cavity with the least degree of friction. In the male the peritoneum is a completely closed sac but in the female it is indirectly open to the surface. The portion of the peritoneum lining the walls of the abdominal cavity is known as the *parietal peritoneum*; that which clothes the organs, or viscera, therein is known as the *visceral peritoneum*. Parts of the duodenum, the colon, the bladder, and the kidneys are not covered with peritoneum; the remaining principal abdominal organs are completely clothed with it. Numerous folds of the peritoneum extend between the various organs and serve to connect them with the posterior wall of the abdomen and with one another, such as

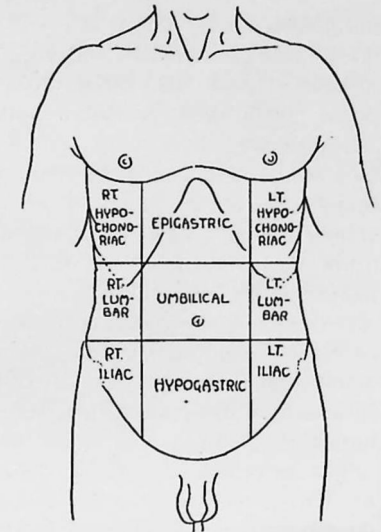


FIGURE 29.—Surface markings of thorax and abdomen. (Gray, modified.)

the various ligaments of the liver, and the *mesentery* which holds the intestine in place and contains the vessels which supply it. The *omentum*, an apron-like structure composed of four layers of peritoneum with enclosed fat, is pendant from the transverse colon and is freely movable. It is of service in walling off inflammations or infections within the abdominal cavity.

The *stomach* is a hollow, muscular organ situated in the abdomen between the œsophagus, above, and the small intestine, below (fig. 30). In shape it is much like a gourd, its wide, upper end, which is called the *fundus*, lying in the hollow of the diaphragm and directed upward, backward, and to the left, and its narrow, tapering end passing downward, forward, and to the right. The fully distended stomach of an adult is about 10 to 11 inches long, its greatest diameter is about 4 to 4½ inches, and its

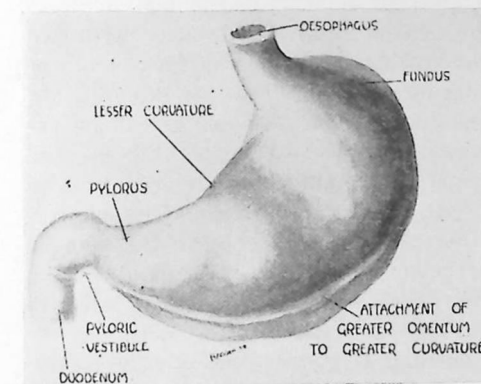


FIGURE 30.—The stomach. (Cunningham modified.)

average capacity is about 2 to 2½ pints. The size and shape of the stomach depend considerably upon its contents. The stomach has two openings, one at the upper, œsophageal end called the *cardiac orifice*, and one at the lower, intestinal end called the *pylorus* or *pyloric orifice*. The portion of the stomach about the cardiac orifice is called the *cardiac part*, that about the pyloric orifice the *pyloric part*. The portion of the stomach which extends from the fundus to the pyloric part, called the *body of the stomach*, forms a rounded chamber, is capable of great distension, and contracts to a narrow, tube-like structure when the stomach is empty. Surrounding the pylorus is a circular ring of muscle called the *sphincter pylori* which closes and opens the stomach outlet. The upper surface of the stomach is concave and is known as the *lesser curvature*; the lower surface is convex and is known as the *greater curvature*. The walls of the stomach consist of four layers of tissue, a thick, inner lining of mucous membrane, a layer of strong connective tissue closely attached to the lining and loosely to the muscular layer, a layer of muscular tissue in which the fibers are arranged circularly, obliquely, and longitudinally in sets, and an outer coat of serous membrane which is formed of the peritoneum. When the stomach is empty the three outer coats contract and the inner coat is thrown into many folds which disappear when the stomach is distended. In the inner lining are numerous glands which secrete the gastric juice.

The intestine is a musculo-membranous tube about 28 feet long beginning at the pyloric orifice of the stomach and ending at the *anal orifice* which opens on the surface. It consists of the *small* and the *large intestine* which together occupy a large portion of the abdominal and pelvic cavities. The *small intestine* is about 23 feet long and is divided into three parts, the first, the *duodenum*, immediately succeeds the stomach and is about 1 foot long; the second, the *jejunum*, is about 9 feet long; and the third, the *ileum*, is about 13 feet long. The duodenum lies in a horseshoe-shaped curve and is closely fixed to the posterior abdominal wall; the jejunum and the ileum lie in a series of irregular loops which are quite freely movable. The small intestine is made up of four layers of tissue, an inner lining of mucous membrane, a layer of loose but strong connective tissue attached to the lining and the muscular layer, a layer of muscle tissue consisting of an inner stratum of involuntary muscle fibers arranged circularly and an outer stratum of involuntary muscle fibers arranged longitudinally, and an outer coat of serous membrane which is formed of the peritoneum. The mucous membrane lining of the small intestine lies in folds, some of which disappear when the intestine is distended while others are permanent, and when examined it presents a soft, velvety appearance because of the presence on it of an enormous number of minute, fingerlike projections called *villi* (fig. 31). The villi contain small blood capillaries and lymph vessels, called *lacteals*, and play an important part in the process of digestion by collecting digested food products. In the mucous lining are also many simple glands which secrete a digestive fluid, the *intestinal juice*. The small intestine opens into the large intestine through the *ileocæcal orifice* at the junction of the cæcum with the ascending colon. This opening is guarded by a valve called the *ileocæcal valve* which prevents the regurgitation of contents of the large into the small intestine. The valve consists of two crescent-shaped segments or folds that project into the cæcum and are continuations of the walls of the ileum. The muscle fibers in these segments keep the opening which lies between them closed except during the passage of digested food from the small into the large intestine.

The large intestine begins on the right side about 2½ inches below the ileocæcal junction and extends to the anus. It is about 5 feet long, is larger in diameter than the small intestine, and is divided into the following parts:

the *cæcum*; the *ascending colon*, which curves at the lower border of the liver to form the *hepatic flexure*; the *transverse colon* which crosses the abdomen from right to left to the splenic region where it curves downward, forming the *splenic flexure*; the *descending colon*, which descends to the brim of the pelvis over which it curves to form the *sigmoid flexure*; and the *rectum*, the terminal dilated portion of the intestine that communicates with the outside through the *anal orifice*. The walls of the large intestine are arranged in the same manner as those of the small intestine, and are of the same structure, except that the longitudinal muscle fibers of the large intestine are arranged in three

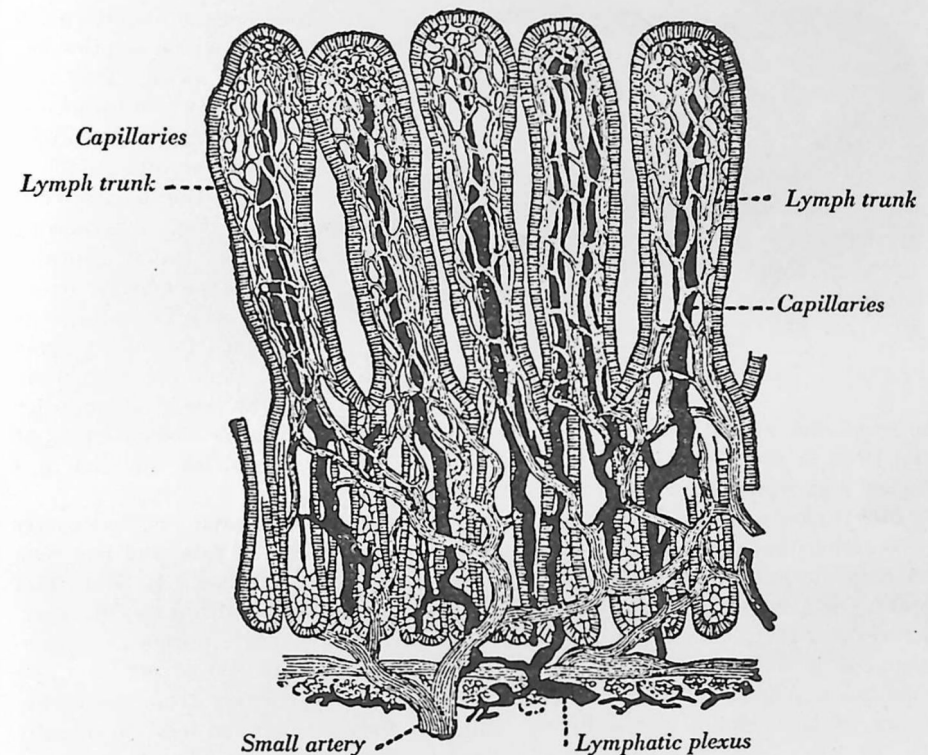


FIGURE 31.—Villi of small intestine. (Cadiat.)

bands which extend the entire length of the colon and are a little shorter than the colon, thus causing the walls to pucker. The mucous lining of the large intestine is smooth and contains no villi, but secretes a mucus which lubricates the tube. At the blind end of the cæcum is a small worm-like projection called the *vermiform appendix* which is the seat of the pathological condition known as appendicitis.

This concludes the description of the structures and organs comprising the alimentary canal and the accessory organs of digestion which have not been discussed will now be considered.

The liver is the largest gland in the body and weighs from 50 to 60 ounces in the normal adult (fig. 32). This organ measures 8 to 9 inches from side to side, 4 to 5 inches perpendicularly, and 6 to 7 inches from front to back, is located in the very upper part of the abdomen, directly beneath the diaphragm, more of it lying to the right side than to the left, and is held in position by ligaments which are formed by the peritoneum. Its general shape is that of

a wedge, much thicker at the right than at the left, and with the thin edge turned forward. The upper surface of the liver is convex, conforming to the dome shape of the diaphragm. The lower surface is irregular and contains many fissures and fossæ.

The liver is divided into five lobes by five fissures, the largest of which is the *transverse fissure*, through which the vessels, ducts, and nerves enter and leave the organ. The liver has a double blood supply, one being from the hepatic artery of the systemic circulation, and the other from the portal

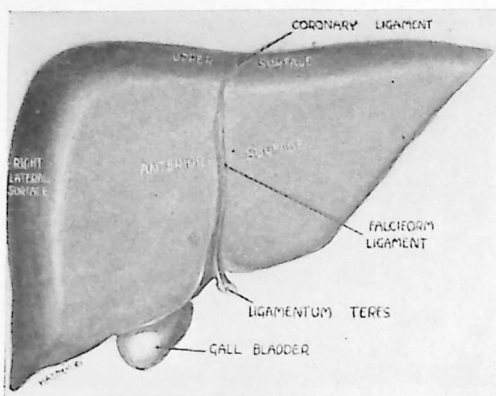


FIGURE 32.—The liver. (Cunningham modified)

vein carrying absorbed food material from the intestine. The drainage for both sets of capillaries is the hepatic vein which empties into the inferior vena cava. The liver is made up of many minute lobules of liver cells arranged concentrically about a central vein, which is a small venule of the hepatic vein. The lobules are held together by connective tissue which contains the capillaries of the hepatic artery and the portal vein, as well as the bile ducts, and the blood from these vessels comes in close association with the liver cells in order

to reach the central venule. In the *gall-bladder fissure* on the lower surface of the liver is the *gall-bladder*, a small, muscular, pear-shaped sac about 3 to 4 inches long which serves as a reservoir for the *bile*.
Bile is partly an excretion which carries off certain waste products, and partly a secretion that plays an important part in the absorption of fats, and has been thought to limit putrefaction in the intestine to some extent. It is a thin, watery or a viscid, golden-yellow or dark olive colored liquid with a specific gravity varying from 1.050 to 1.10, a feebly alkaline reaction, and a complex composition. It is secreted normally in amounts of from 500 to 800 cc per day and contains a pigment, *bilirubin*, which is derived almost entirely from the breakdown of hæmoglobin in the liver. Although formed more or less continually in the liver cells, bile enters the intestine only during periods of digestion, being prevented from entering at other times because the opening of the common bile duct is closed, and it therefore backs up into the gall-bladder. Bile is collected from the liver cells by the *biliary ducts* which unite and gradually form larger and larger ducts that finally end in two main ducts which leave the liver and immediately join together to form the *hepatic duct*. The hepatic duct is soon joined by the *cystic duct* from the gall-bladder to form the *common bile duct* which enters into the duodenum with the pancreatic duct.

The functions of the liver are important and numerous and are as follows:

1. *Bile secreting*.—It manufactures and secretes bile.

2. *Glycogenic*.—It manufactures glycogen from monosaccharides brought to the liver from the digestive tract by the portal vein. Glycogen is stored in the liver and is reconverted into dextrose by the action of a special enzyme at such times as body activities require it. Because it has the same chemical formula as the general one given to starch ($C_6H_{10}O_5$)_n, glycogen is sometimes called "animal starch."

3. *Storing of fat*.—A certain amount of fat may be stored within the liver cells.

4. *Urea producing*.—Takes up nitrogenous waste products from the blood and converts them into urea, which is discharged back into the blood stream for elimination by the kidneys.

5. *Removes* by means of the bile certain other waste products, such as broken-down red corpuscles, disintegrated liver cells, and bile pigments.

6. The *liver* is considered as the source of fibrinogen and prothrombin. This organ is the site of origin of blood cells in the embryo.

The *pancreas* is a compound gland, long and irregularly prismatic in shape, and situated in the abdomen behind the stomach at about the level of the second lumbar vertebra (fig. 33). It has a head, which lies in the concavity

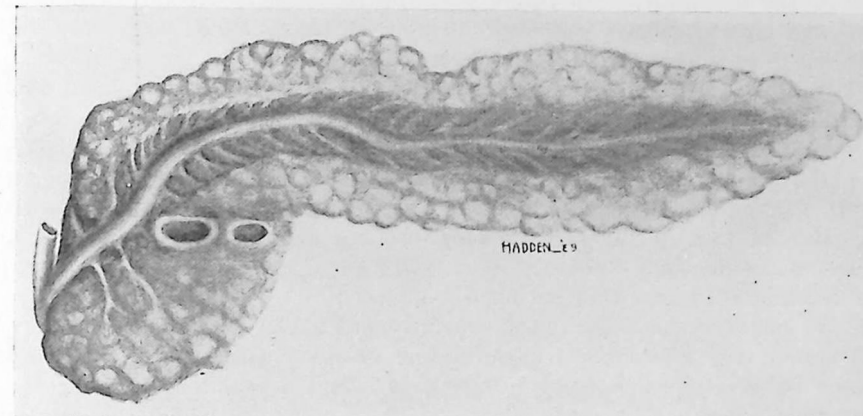


FIGURE 33.—Pancreas. (Mason, modified.)

of the duodenum, a neck, a body, and a tail, which touches the spleen. It is about 5 to 8 inches long, the three surfaces of the body are each about 1¼ inches wide, and it secretes the *pancreatic juice*, a digestive fluid which is one of the chief agents in intestinal digestion, and is carried to the duodenum by the *pancreatic duct*. Beginning in the tail of the gland this duct runs from left to right through the body and neck into the head where it leaves and enters into the duodenum with the common bile duct. During its course through the gland the pancreatic duct receives tributary ducts from all portions of the gland and increases in size until, near the duodenum, it is about as large as a goose quill. In the connective tissue between the lobules of the gland are small areas of modified glandular tissue having no ducts which are known as the *Islands of Langerhans* and secrete a substance which is discharged directly into the blood stream. The function of this secretion will be described in the section on ductless glands.

The process of digestion.

Before describing the process of digestion the substances used as foods must be briefly considered. Foods are those substances necessary to maintain the normal composition of the body by building up tissue or, by oxidation, supplying heat and energy. Foods include: 1. *Water*; 2. *Inorganic salts*, principally of sodium, calcium, potassium, magnesium, and iron; 3. *Vitamins*, organic chemical compounds essential to normal life and growth; 4. *Proteins*, nitrogen-containing substances, chiefly lean meats and leguminous vegetables; 5. *Carbohydrates*, starches and sugars; and 6. *Fats*, animal and vegetable oils and fats.

Water, inorganic salts, and vitamins are substances essential to life but have no energy-producing properties. Water and organic salts are necessary to maintain the normal composition of the tissues and complete withdrawal of either would cause the death of the organism. Vitamins are essential, in some as yet unknown way, to normal metabolism. The body's energy is derived from the proteins, carbohydrates, and fats, complex organic substances whose chemical structure is known in whole or in part. After being eaten these substances must undergo various chemical changes, generally spoken of as metabolism, before they can be utilized by the body. These chemical changes take place during the process known as digestion, break up the complex molecules of the substances into forms that the tissue cells are adjusted to act upon, and are attended by the production of heat. Foods are more fully discussed in the chapter on Diets and Messing for the Sick.

The process of digestion begins in the mouth and ends in the small intestine and is both mechanical and chemical. The mechanical features of the process include the chewing and grinding of the food, the passage of the food along the alimentary canal by muscular action, and the mixing of the food and its dilution and solution in aqueous secretions. The chemical changes that take place in food during digestion are brought about by the action of substances in the digestive fluids called *enzymes*, or *digestive ferments*, the latter term being used because they act upon foods used by the body.

In the definition for these substances given at the beginning of this section it is stated they effect the transformation of other compounds by *catalytic action*. By catalytic action, or catalysis, is meant a reaction or change produced in a substance by contact with another substance called the *catalytic agent* or *catalyst* which itself appears to remain unchanged as a result of the reaction it has produced. As the enzymes which bring about the changes in foods necessary for them to be used by the body are produced in living body cells they could well be termed organic catalysts.

The chemical composition of enzymes is complex, uncertain, or unknown, and although they all apparently contain nitrogen, and most of them sulfur, about all that can be said positively in regard to their chemical structure is that they are organic substances derived from living cells and are colloids or so closely associated with colloids that they have not been isolated in a noncolloidal state.

The action of enzymes is specific to a high degree, a given enzyme attacking only a certain compound or group of compounds. Consequently the enzymes that act upon carbohydrates cannot affect proteins or fats, those acting on proteins cannot affect fats, etc. Even closely related substances such as maltose and lactose seem to require their own specific enzyme.

The enzymes concerned in human digestion and nutrition are classified according to the nature of the substances upon which they act, the principal classes being shown in the following table:

CLASSES OF ENZYMES

Name	Action	Example
Proteolytic.....	Protein splitting.....	Pepsin of gastric juice; trypsin of pancreatic juice; erepsin of pancreatic and intestinal juices.
Amylolytic.....	Starch splitting.....	Ptyalin of saliva; amylase of pancreatic juice.
Lipolytic.....	Fat splitting.....	Lipase of pancreatic juice, of liver, connective tissue, etc.
Glycolytic.....	Sugar splitting.....	Maltase of saliva and of intestinal juice; invertase of intestinal juice; lactase of intestinal juice.
Coagulating.....	Convert soluble to insoluble proteins.	Rennin of gastric juice.

In the table which follows the enzymes that take part in the process of digestion are arranged in groups under the class title of the substances on which they act.

Name	Chiefly found in	Action
Acting on carbohydrates:		
Ptyalin.....	Saliva.....	Converts starch to sugar (maltose).
Amylase.....	Pancreatic juice.....	Do.
Invertase.....	Intestinal juice.....	Converts cane-sugar to dextrose and levulose.
Maltase.....	Saliva, intestinal juice, pancreatic juice.	Converts maltose (malt sugar) to dextrose.
Lactase.....	Intestinal juice.....	Converts lactose (milk sugar) to dextrose and galactose.
Acting on fats:		
Lipase (steapsin).....	Pancreatic juice.....	Splits fats into fatty acids and glycerin. (Some of fatty acid and alkali forms soap which emulsifies fat.)
Acting on proteins:		
Pepsin.....	Gastric juice.....	Converts proteins to peptones and proteoses.
Trypsin.....	Pancreatic juice.....	Splits proteins, peptones, and proteoses into amino-acid compounds.
Erepsin.....	Pancreatic juice, intestinal juice.	Splits amino-acid compounds into their constituent amino-acids.
Rennin.....	Gastric juice.....	Precipitates casein from caseinogen and makes the curd of milk.

In the process of digestion, food is first taken into the mouth where *mastication* takes place. This is accomplished by the teeth and the lower jaw and after this mechanical dividing or grinding the food presents a larger surface for the action of the *saliva*. During mastication the saliva pours into the mouth from the salivary glands and is mixed with the food through the movements of the tongue and the muscles of the cheeks. This moistens and softens the food, and starch is converted into sugar through the action of the salivary enzymes, *ptyalin* and *maltase*. As found in the mouth, saliva is a colorless or opalescent, turbid, and viscid liquid with a specific gravity of about 1.003 and a neutral or slightly acid reaction. The enzyme ptyalin converts starch to maltose (malt sugar), and maltase breaks up the maltose into dextrose. The presence of food in the mouth and the sight and smell of appetizing foods act as nerve stimuli to increase the amount of saliva necessary for mouth digestion.

The food taken into the mouth has there been reduced to a consistency suitable for swallowing and has been formed into what is known as a *bolus*. By deglutition, or swallowing, the bolus passes from the mouth to the pharynx and thence into the œsophagus through which it is carried into the stomach. The act of swallowing is largely voluntary but the final stage and the passage of the bolus through the pharynx and œsophagus is the result of involuntary muscular action. The musculature of the œsophagus causes a contraction of the tube to occur immediately after the passage of the bolus which follows the bolus from above downward like a wave, finally forcing it through the cardiac opening of the stomach. This wave-like contraction is called *peristalsis*.

In the stomach the food which has been swallowed is thoroughly mixed with the gastric juice by muscular movements of the stomach walls. These movements, somewhat peristaltic in character, not only mix the food and the gastric juice but eject the liquefied portions of the food into the duodenum. As digestion proceeds in the stomach the food becomes a thin, liquid mass known as *chyme*, which periodically passes through the pylorus into the duodenum.

In the mucous membrane of the stomach are myriads of simple glands called *gastric glands* which secrete the gastric juice, a thin, colorless or nearly color-

less liquid with a specific gravity of about 1.002 to 1.003, a strongly acid reaction because of the presence in it of *hydrochloric acid*, and a characteristic odor. Two enzymes, *pepsin* and *rennin*, and perhaps a third, *lipase*, are found in the gastric juice. The flow of gastric juice occurs partly in response to nerve impulses sent to the stomach as a result principally of the sensory impressions of taste and smell received in the brain, and partly by the presence of chemical substances in the stomach itself. Hard work should not be performed or strenuous exercise taken immediately after eating as this retards digestion in the stomach chiefly by checking the flow of gastric juice, with gastric distress and possibly vomiting as a result. Nor should a hearty meal be eaten when physically exhausted because the nervous, circulatory and digestive systems cannot properly perform their parts in the process of digestion. The food on mixing with the gastric juice becomes acid in reaction. The hydrochloric acid in the gastric juice stops the action of ptyalin, aids in coagulating proteins, activates the enzyme pepsin which is secreted in an inactive form, *pepsinogen*, and seems to favor relaxation of the pyloric sphincter, which remains closed after each ejection of chyme until the acidity of the ejected chyme in the duodenum has been neutralized. The enzyme pepsin prepares the proteins of the food for complete digestion by breaking them down into simpler chemical compounds known as *peptones* and *proteoses*. *Rennin*, which is present in many persons only during early life, precipitates *casein* from the *caseinogen* in milk and causes the milk to clot, or curdle, and form a curd. *Lipase*, which when present is in small amounts, has very little activity in the stomach, its action probably being the splitting up of the finely emulsified fat found in milk.

The chyme on passing into the duodenum from the stomach consists of water, inorganic salts, partially digested foods, and the indigestible portion of meats, cereals, and fruits. The acid character of the chyme causes the secretion and discharge of the intestinal fluids secreted by glands in the mucous membrane of the duodenum and of the small intestine, the pancreatic juice, and the bile. The intestinal fluids, which are alkaline in reaction, exert a neutralizing and precipitating influence on the various constituents of the chyme and as soon as this occurs gastric digestion ends and intestinal digestion starts.

Beginning in the duodenum, intestinal digestion is largely completed by the time the food reaches the ileo-cæcal valve and produces the important changes in the food necessary for its absorption. In intestinal digestion the partially digested food received from the stomach is subjected to the action of the *pancreatic juice*, the *intestinal juice*, and the *bile*. These secretions mix with the food from the duodenum on and they act at the same time.

The pancreatic juice in man is a thin, limpid liquid with a specific gravity of about 1.0075 and an alkaline reaction. It is undoubtedly the most important digestive fluid in the body and contains four enzymes, *trypsin* and *erepsin*, proteolytic enzymes, *amylase* (also known as amylopsin), a starch-splitting enzyme, and *lipase* (also known as steapsin), a fat-splitting enzyme. Trypsin, like pepsin, is secreted in an inactive form *trypsinogen*, which is activated by *enterokinase*, a constituent of the intestinal juice. The erepsin in the pancreatic juice is similar to that in the intestinal juice. Lipase is aided and facilitated in its action by the presence of bile. The action of the pancreatic enzymes is shown in the table on page 59.

Human bile plays an important part in the digestion and absorption of fats as it accelerates the action of lipase and perhaps of amylase, and helps in the neutralizing of the hydrochloric acid of the gastric juice. It is also considered to aid in lubricating the intestine to facilitate the passage of indigestible and waste matter.

Peristaltic movement forces the contents of the small intestine along until finally they enter the large intestine through the ileo-cæcal valve, at which time digestion is virtually complete. When the contents of the small intestine enter the large intestine they contain some unabsorbed food material, and, as they also contain digestive enzymes received in the small intestine, it is probable that digestion and absorption continue for a time in the large intestine. The indigestible waste material, combined with certain waste substances from the bile and intestinal secretions, passes slowly along the large intestine by peristaltic movement and rapidly loses its water content by absorption until, by the time it reaches the descending colon it has acquired the consistency of *fæces*. When the *fæces* reach the terminal portion of the large intestine they are ready to be expelled from the body by the act of defæcation.

By digestion the carbohydrates, proteins, and fats contained in the various foods that have been eaten have been changed into substances of simpler chemical composition. Starches and compound sugars have been changed into simple sugars, proteins have been broken down into their constituent amino-acids, and fats have been finely emulsified and split into fatty acids and glycerin, all of which are forms suitable for absorption.

In physiology absorption is a term to describe the passage of digested foods from the alimentary canal into the blood or lymph. The absorption of food takes place principally from the small intestine. There is some food absorption and a large absorption of water from the large intestine, and little or no absorption from the stomach. Absorption from the small intestine takes place by two paths: 1. By the *capillaries of the villi* to the blood stream; and 2. By the *lymphatics* to the thoracic duct and the superior vena cava. The products of fat digestion are taken up chiefly by the lymph capillaries, or lacteals, in the villi and carried by the lymph stream into the thoracic duct and finally into the blood stream at the junction of the left internal jugular and the left subclavian veins. A small amount of fat is absorbed by the blood capillaries, part of which is appropriated by the liver for its own use and storage. The products of protein and carbohydrate digestion are taken up by the blood in the capillaries of the villi and carried through the portal circulation to the liver. In the liver the excess of dextrose (simple sugar) is withdrawn and changed to *glycogen* by the action of the liver cells, the amount of sugar in the blood remaining constant. Some of the amino-acids are also converted to glycogen by the action of the liver cells with the formation of urea, which is carried in the blood to be excreted by the kidneys. The glycogen is stored in the liver to be liberated again as dextrose when needed by the body.

THE SPLEEN AND OTHER DUCTLESS GLANDS

The term ductless glands is applied to those organs whose function is to produce special secretions containing *hormones*, which are discharged into the blood or the lymph. These organs are also called *endocrine glands* or *glands of internal secretion* and, as previously stated, are of glandular structure and have no ducts. A hormone is a chemical substance produced in a more or less distant organ which, carried by the blood or lymph to a functionally associated organ, excites the latter to activity. The glands generally spoken of as ductless glands are the *thyroid*, the *parathyroid*, the *thymus*, the *suprarenals*, the *pituitary body*, or *hypophysis*, and the *pineal body*, or *epiphysis*. The spleen, though it has no ducts, has not been found to have an internal secretion, and therefore, while anatomically a ductless gland, physiologically it is not a gland of internal secretion. Some other glands in the body that have

ducts, as the pancreas and the gonads (testes in the male, ovaries in the female), also form internal secretions that are discharged directly into the blood and therefore act as ductless glands in addition to their more obvious functions. There are a few other ductless glands which will not be described in this section.

The spleen is situated in the upper left part of the abdomen directly beneath the diaphragm in front of the upper part of the left kidney and behind and to the left of the stomach. Its border is roughly oval or circular in outline, its size varies greatly, and its average weight is from 5 to 8 ounces. It is a soft, highly-elastic, contractile organ, purplish in color, and composed of a fibrous capsule containing a soft substance called *pulp* in which nodules of lymph tissue are embedded. There are no capillaries in the spleen, the blood escaping from the arterioles into the pulp and being collected from the pulp by the small venules. The spleen is known to be active in the destruction of defective blood cells, both red and white, as well as being the source of some of the lymphocytes of the blood stream. It undoubtedly has other functions not now definitely known. In some diseases, as chronic malaria, it becomes greatly enlarged.

The thyroid gland is a highly vascular body situated anteriorly in the neck at the junction of the trachea with the larynx, and its tissue consists of spherical vesicles lined with epithelium and containing a fluid called *colloidal material*. It is composed of two conical *lobes* connected across the median line by a narrow strand of gland tissue called the *isthmus*, one lobe lying on each side of the larynx and extending upward. The gland secretes a substance called *thyroxin* which contains a large percentage of iodine and has a marked influence on body growth and on nervous stability. Complete removal of this gland, leaving the parathyroids uninjured, does not cause death but does cause marked changes in metabolism and is usually followed by a state of chronic malnutrition or *cachexia*. *Cretinism* is the result of a congenital defect or atrophy of the thyroid gland, which causes the arrest of skeletal and mental development. On atrophy of this gland in the adult, a similar phenomenon called *myxedema* results, the body becomes puffed and pasty, and the mentality blunted. In *hyper-thyroidism*, or *goiter*, there is an extreme nervousness, increased metabolism, quickened heart action, and in some cases protrusion of the eyeballs (*exophthalmos*).

The parathyroids, usually four in number, are small grain-like bodies located on or near the posterior surface of the lobes of the thyroid, two on each side. The internal secretion which they furnish regulates calcium metabolism which is so essential in bones, blood, and other tissues, and is believed to aid in neutralizing certain toxic substances. Complete removal of the parathyroids is followed by acutely toxic results, muscular tetany, and death.

The thymus is located in the thorax posterior to the sternum and varies greatly in size in different individuals and at different ages. It is considered to consist of two lobes, one on each side of the midline, and to reach its maximum size in childhood. While it undergoes atrophy after puberty it does not entirely disappear. Its function is obscure but it is believed it exerts an influence on body growth and the development of the reproductive organs.

The suprarenals, or *adrenal glands*, are two flattened bodies situated in the back part of the abdomen which lie like caps over the upper pole of each kidney. These glands consist of two portions, an inner, highly vascular mass of tissue called the *medulla* enclosed within an outer portion, or capsule, of cortical substance called the *cortex*. The cortex in turn is surrounded by a capsule of fibrous tissue. Each portion has a separate secretion and function. The

secretion of the medulla, *adrenalin*, or *epinephrine*, is the better known and has a marked effect on the tone of the heart and the blood vessels. It increases blood pressure by constricting the blood vessels and slowing and increasing the force of the heart beat. Its constricting action on blood vessels causes it to be used in controlling hæmorrhage. *Cortin*, the secretion of the cortex, regulates important phases of the mineral and water metabolism of the body, and appears to be of great value in the treatment of Addison's disease. From the cortex was first isolated the substance known as *ascorbic acid*, which is the antiscorbutic vitamin C. Removal of the cortex results in death.

The pituitary body, or *hypophysis*, is a small, oval-shaped gland attached to the base of the brain and situated in a depression in the sphenoid bone. It consists of an anterior lobe of glandular structure and a posterior lobe composed chiefly of connective tissue, blood vessels, and nerve cells and to which a glandular portion, the *pars intermedia*, is attached. The anterior lobe is larger than the posterior, which it partly encircles, and has been called the "master gland" as it appears to influence the activity of most of the other glands of internal secretion. This gland, though its size is small and its gross structure simple, has the most complex function of the glands of internal secretion. In its secretion are a great number of hormones, some of which are far from being definitely identified. In the anterior lobe, hormones influencing sex, growth, thyroid metabolism, and carbohydrate metabolism are known to be present, and in the posterior lobe hormones stimulating contractions of non-striated muscles, constricting arteries and raising blood pressure, and with anti-diuretic action have been found. Over or under production of the growth principle in the secretion of the anterior lobe results in pituitary giants or dwarfs.

The pineal body, or *epiphysis*, is a small, fir-cone-shaped gland about the size of a cherry stone situated near the pituitary body but above and back of it. Little is known of the function of the pineal gland, but the general conclusion from evidence now at hand is that it has an internal secretion which counteracts at least some of the functions of the pituitary, particularly the stimulation of the gonads. It is also necessary for the development of the eyeball, very small eyes occurring in its absence.

The pancreas, mentioned elsewhere as producing digestive enzymes, also produces, from areas of specialized tissue called the Islands of Langerhans, a hormone called *insulin*, which like other products of the glands of internal secretion, is poured directly into the blood. Insulin is essential in the regulation of carbohydrate metabolism. An insufficiency, relative or absolute, results in the condition called *diabetes*.

The gonads, sex glands, male, *testes*, and female, *ovaries*, each produce, in addition to reproductive cells (spermatozoa and ova), an internal secretion which is responsible for the development of appropriate secondary sex characteristics in the individual.

THE EXCRETIONS.

The waste products resulting from the activities of the body are called *excretions* and are discharged to the exterior by organs known as *excretory organs*, some of which are arranged in systems. The discharge of the waste products of the body is called *excretion* and takes place by means of: 1. The *urinary system*, which eliminates water, and certain organic and inorganic waste products; 2. The *skin*, which eliminates water, organic and inorganic waste materials by means of perspiration; 3. The *lungs*, which eliminate certain gaseous waste products, such as carbon dioxide, water vapor, and small

amounts of nitrogen; and 4. The *alimentary canal*, which eliminates the residue remaining after digestion and the waste products discharged into it.

Normal urine of man varies in color from a pale yellow to a brownish hue, is acid in reaction, and has a specific gravity ranging from 1.015 to 1.025. The color varies according to the quantity excreted, being pale or light when the quantity is large, and dark when the quantity is small and the concentration of solids is greater. Various foods and medicinal substances also affect the

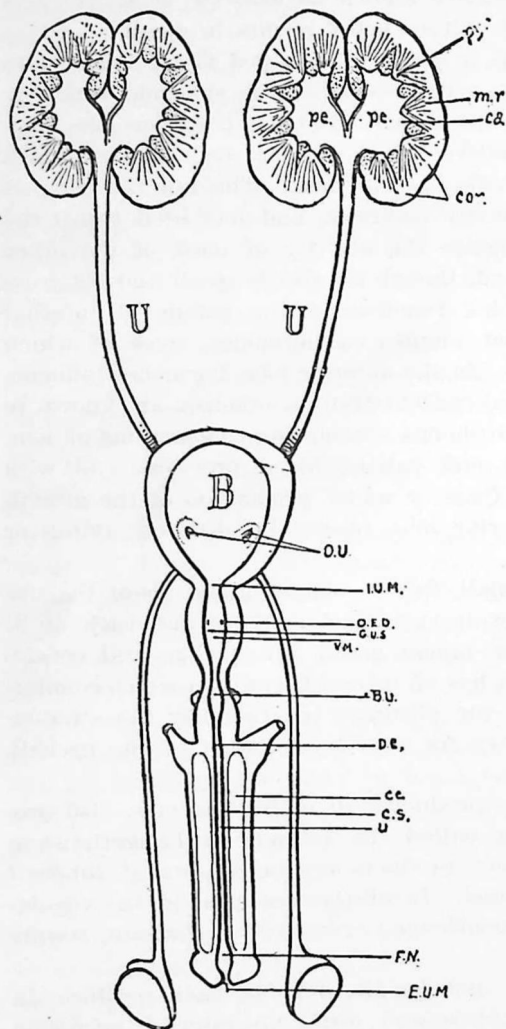


FIGURE 34.—Anterior view of the opened genitourinary tract in the male. (Guiteras.)

color of the urine. The degree of acidity varies at different periods of the day and is affected by the character of the individual's food or by medicinal substances taken. The average daily output is from 40 to 50 fluidounces but may be more or less, depending upon many factors, among which may be mentioned atmospheric temperature, the intake of fluids, disease, medicinal substances taken, and other types of elimination of fluids, as in hæmorrhage, perspiration, diarrhœa, and vomiting. Urine has a characteristic odor which is influenced by disease, vegetable foods, and other substances. The chemical composition of urine is very complex and is determined partly by tissue metabolism and partly by the quantity and quality of foods consumed and metabo-

- pe. The pelvis of the kidney.
 cor. The cortex, the part between the cortex and the pelvis being the medullary portion.
 pyr. Pyramid.
 ca. The calices.
 m. r. The medullary rays.
 U. The ureters.
 B. The bladder.
 o. u. The ureteral openings.
 i. u. m. The internal urinary meatus.
 o. e. d. The openings of the ejaculatory ducts in the prostatic urethra.
 g. u. s. The genitourinary sinus.
 v. m. The veru montanum.
 b. u. The bulbous urethra.
 d. c. Openings of the ducts of Cowper's glands.
 c. c. Corpus cavernosum.
 c. s. Corpus spongiosum.
 u. Urethra.
 f. n. Fossa navicularis.
 e. u. m. External urinary meatus.

lized. Ordinarily it is composed of about 95 per cent of water and 5 per cent of solids comprised of nitrogenous waste products and organic and inorganic salts. The chief nitrogenous constituent of urine is *urea* which is present to the extent of about 2 per cent. Other nitrogen compounds are present in minor quantities. The inorganic salts are those of sodium, calcium, ammonium, potassium, and magnesium, the organic salts are lactates, acetates, and small amounts of formates. Certain abnormal constituents as albumin, sugar, indican, acetone, casts, and blood may be found under pathological conditions.

The urinary system consists of the *kidneys*, the *ureters*, the *bladder*, and the *urethra* (fig. 34).

The kidneys are two large, glandular organs situated in the posterior part of the abdominal cavity, behind the peritoneum, one on each side of the lower,

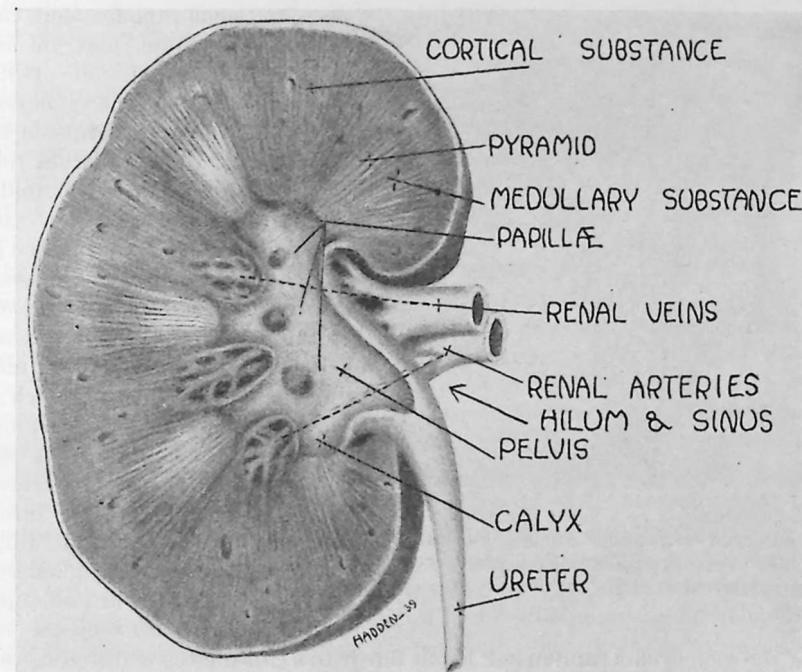


FIGURE 35.—Section of kidney. (U. S. Naval Medical School.)

movable portion of the spinal column. They extend from about the level of the twelfth thoracic to that of the third lumbar vertebrae, the inferior end usually being from $1\frac{1}{4}$ to 2 inches above the highest part of the crest of the ilium, and the right kidney slightly lower than the left. These organs (fig. 35) are bean-shaped and each is about $4\frac{1}{2}$ inches long, 2 inches wide, and $1\frac{1}{4}$ inches thick. On the concave side of each is a deep, notch-like depression called the *hilum*, through which the blood vessels and nerves enter and leave the kidney. The hilum extends inward into the kidney to form the narrow space known as the *sinus of the kidney*. Each kidney is surrounded by a thin fibrous capsule and lies embedded in a mass of soft fatty tissue. The *parenchyma*, or specialized glandular tissue, of the kidney is dense and friable, and consists of an inner portion called the *medullary substance*, or *medulla*, and an outer portion called the *cortical substance*, or *cortex*. The medullary substance surrounds the sinus of the kidney and appears largely in the form of conical masses known as *renal pyramids*, or *pyramids*, whose apices project into the sinus to form

small conical elevations called *renal papillæ*, or *papillæ*, whose rounded ends are pierced by minute openings called *foramina papillaria* that are the terminal apertures of the tubules of the kidney. Two or three and sometimes six or more pyramids end in one papilla, which number from 6 to 18 and cause the floor of the sinus to be uneven. The bases of the pyramids are covered and also separated from the surface of the kidney by a layer of the cortical substance of the kidney, which also extends inward towards the sinus, between the pyramids, in columns known as *renal columns*. In the cortical substance are an immense number of tubules called *uriniferous tubules* and thousands of small structures known as *Malpighian bodies* or *renal corpuscles* (fig. 36).

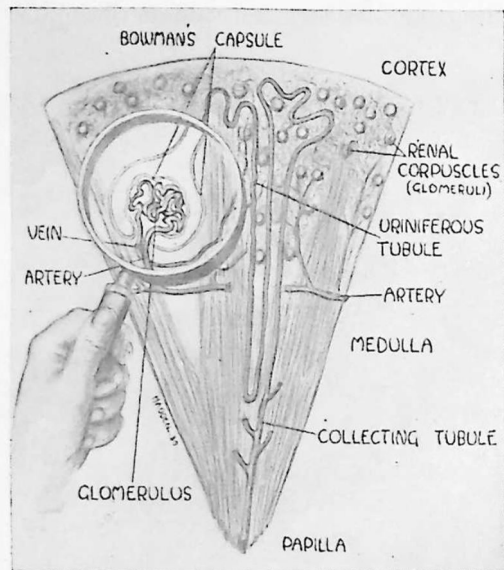


FIGURE 36.—Schema of a renal pyramid showing enlarged uriniferous tubule, glomeruli, and blood supply, with further magnification of a glomerulus. (U. S. Naval Medical School.)

These bodies are located in the cortical substance of the kidney and consist of an outer, spherical-shaped, membranous sac called *Bowman's capsule*, and an inner, minute, convoluted coil of blood capillaries called the *glomerulus* (fig. 36). Bowman's capsule is an expansion of the uriniferous tubule and its membranous wall folds in so that its outer surface becomes an inner surface, as when one part of a hollow rubber ball is pushed inward. Through the opening made by the infolding of the wall a small artery enters and divides into a number of capillaries which coil and twist about to form the glomerulus and later unite in a single small vein that passes out through the same opening. The infolded wall of Bowman's capsule adheres to the capillaries of the glomerulus, closely covering them and dipping into the spaces between the small coils of the glomerular capillaries. From Bowman's capsule the uriniferous tubule immediately continues through the cortical and medullary substances until it terminates in the opening in the papilla with which it communicates. The uriniferous tubules, which may be roughly separated into a secreting part lined with several types of epithelial cells and a collecting part, are partly convoluted and partly straight and regular, and run a very complicated course before the collecting part begins in the pyramids. The collecting part of the tubule in the pyramids is straight and empties into the kidney pelvis, there discharging the urine collected. The blood supply of the kidneys is through the renal arteries which give off branches that, as they pass through the kidney substance, divide repeatedly into smaller branches each of which, with a few exceptions, ends in a glomerulus. The venous return is by the renal veins.

The function of the kidneys is to remove certain waste materials from the blood and excrete them in the aqueous solution known as urine, thereby preventing the waste materials from accumulating in the blood and keeping its composition constant. They also play an important part in maintaining the normal, slightly alkaline reaction of the blood by excreting enough of substances in the blood that might alter its reaction to reduce their quantity to

the normal level. For example, should the reaction of the blood tend to become too alkaline, the kidneys will excrete more alkali in the salts in the urine. Also, when the presence of more acid substances in the blood tends to make its reaction less alkaline, they excrete more acid. Likewise, although its removal is not concerned with the reaction of the blood, the kidneys will remove all excess sugar present in the blood. Through the kidneys the greatest part of nitrogenous waste products is excreted, that excreted elsewhere being almost negligible in quantity.

The process by which substances are removed from the blood and excreted in the urine is not definitely known but the generally accepted theory is that it is a process of filtration, reabsorption, and secretion. All the substances present in the blood plasma except protein filter through the infolded wall of Bowman's capsule into the sac-like cavity communicating with the uriniferous tubule. The liquid that seeps through the capsule is known as the *filtrate* and consists of blood plasma without any protein. This filtrate as it passes along the course of the uriniferous tubule becomes altered in composition by the selective action of the epithelial cells lining the tubule.

The selective action of the epithelium of the tubule consists very largely of a reabsorption of those substances that, at the time, are needed by the blood to maintain its normal composition, i. e., a composition having the proper aqueous dilution, the proper acid-base balance, the proper sugar concentration, etc. Also, by this mechanism those substances that are not needed in the operation of the body metabolism are thrown off. Whether or not a certain substance is needed at a given time depends on conditions within the body at that time. Thus, when the body needs water, as may occur as a result of limited intake or from increased loss through sweating, diarrhoea, or copious vomiting, more water is reabsorbed from the filtrate and as a result the urine contains less water and its specific gravity rises. On the other hand, when the body has an excess of water, the urine contains more water and its specific gravity lowers. Similarly, if the body has need of sodium chloride that substance is selected out and reabsorbed from the filtrate in the tubule with the result that little is excreted in the urine. This occurs particularly when sodium chloride is absent from the diet. Also, all sugar in the filtrate is normally reabsorbed in the tubule with the result that none is excreted in the urine. In blood plasma there is normally about 0.03 per cent of urea present while in urine there is nearly 67 times as much, or about 2.0 per cent. This great increase is largely due to concentrating the urea contained in a very large amount of filtrate in a relatively small amount of urine.

In addition to the absorption taking place in the uriniferous tubule there is good experimental evidence showing that the epithelium which lines the tubule actually secretes some of the urinary constituents, particularly the ammonium salts found in urine.

Besides removing from the blood the waste products of normal body metabolism the kidneys also are able to remove surprisingly large amounts of foreign substances of a poisonous nature that may find their way into the blood stream. Outstanding examples of substances so removed are mercury, various barbituric-acid derivatives, and alcohol. Most medicinal substances given in treatment are ultimately eliminated from the body through the kidneys.

These activities of the kidneys show them to be organs extremely vital to the well-being of the body. If they fail to perform their vital functions, the composition of the urine changes, substances that should be are not removed from the blood, and those substances rapidly build up to a concentration in the blood that results in toxic conditions. One of the most familiar conditions

manifesting a disturbance of kidney function is *albuminuria* which occurs when Bowman's capsule fails to prevent protein from passing through it. When waste products are retained in the blood because of failure of the kidneys to remove them, they quickly build up to a concentration in the blood that produces toxic effects. The acid-base balance is seriously disturbed and an excess of urea and other waste products accumulates. This condition is known as *uræmia*.

The ureters (fig. 35) are two musculo-membranous tubes about 15 to 18 inches long, that begin above in a thin-walled, funnel-shaped expansion called the *pelvis* which lies partly within and partly without the sinus of the kidney. The part outside of the sinus gradually decreases in size until at about the level of the inferior end of the kidney its diameter is about that of a goose quill. The part within the sinus contains several cup-like divisions called *renal calyces*, or *calyces*, which enclose the papillæ and receive the urine, which enters them through the openings in the papillæ. The ureters connect the kidney and the bladder, leaving the kidney at the hilum and entering the bladder at the lower and back portion of the organ, where they deliver to the bladder the excretion of the kidneys. The course of the ureters through the muscular walls of the bladder is oblique so that when the bladder is distended the coats of the ureters are approximated in such a manner that regurgitation of urine from the bladder is prevented.

The urinary bladder (fig. 34) is a musculo-membranous sac situated in the pelvis just behind the pubis, and does not, under normal conditions, extend above the upper border of the symphysis. It acts as a reservoir for urine until such time as micturition is convenient. When moderately distended the bladder holds about 1 pint. Upon the inner surface of the bladder in the upper part, or *fundus*, the mucous membrane is thrown into folds or *rugæ*. The lower portion presents a comparatively smooth triangular surface, known as the *vesical trigone*, outlined by the openings of the two ureters and the urethra.

Micturition, or the act of voiding urine, is an involuntary mechanism controlled partly by volition.

The urethra (fig. 34) is a membranous tube passing from the bladder along the under surface of the penis to the distal end of that organ where it terminates in the *meatus*. It serves to convey the urine and, in the male, the secretions of the genital glands, to the exterior. In the male it is about 8 inches long, and is divided into three parts, the *prostatic*, the *membranous*, and the *penile* portions. The prostatic urethra, about 1 inch in length, is surrounded by the prostate gland and contains the orifices of the prostatic and the ejaculatory ducts. In this portion the diameter of the urethra is the largest. The membranous urethra is about one-half inch in length and consists of that portion which pierces the urogenital diaphragm. The penile urethra is the longest portion and lies along the base of the penis, extending to its external opening, the urinary meatus. (See section on Genito-urinary and Venereal Diseases.)

The perspiration, or *sweat*, excreted by the sweat glands of the skin, is a clear, colorless, water liquid with a specific gravity of about 1.004 and a slightly acid reaction. It has a salty taste and a distinctive, rancid odor or none at all. Perspiration is excreted continuously, taking place so gradually that it evaporates as fast as it is formed when it is known as *insensible perspiration*, or, under exposure to great heat and exercise, so rapidly that evaporation does not take care of it, and it is then known as *sensible perspiration*. Normally about 1 quart of this fluid is excreted daily, but the amount varies widely with atmospheric temperature and humidity, and the amount

of exercise taken. It consists chiefly of water with small quantities of salts, fatty acids, urea, and carbon dioxide.

The skin is a tough elastic membrane forming the outer covering of the body, and contains certain appendages as the hair and nails. Certain glands, as the sweat and the sebaceous glands, discharge their secretions upon the surface of the skin. (Fig. 37).

The skin is made up of two principal layers, the *epidermis*, or *cuticle*, and the *derma*, or *true skin (cutis vera)*. The epidermis consists of stratified squamous epithelium and may be divided into two layers, the superficial layer being horny and hard, and the inner layer, known as the germinative layer, consisting of soft protoplasmic cells.

The derma is a highly sensitive and vascular layer of connective tissue, containing blood vessels, hair follicles, sweat and sebaceous glands, and nerve endings.

The sweat glands are coiled tubular glands, the coils of which lie embedded in the derma and surround a small tuft of capillaries. These glands are located in the subcutaneous tissue and open by a duct upon the surface of the skin. The sweat glands

serve as excretory organs, excreting the sweat or perspiration. The sebaceous glands are compound sacular glands, the ducts of which open about the hair shaft. These glands secrete an oily substance, *sebum*, which keeps the skin soft and pliable. The true skin is well supplied with specialized nerve endings which carry impressions of touch, heat, cold, and pain. The true skin also contains motor nerves to blood vessels, and secretory nerve fibers to the glands.

The skin serves as a protective covering to aid in the preservation of body temperature, and as an excretory organ. It contains the nerve endings previously mentioned.

THE MALE REPRODUCTIVE ORGANS

The male genital organs consist of the *testes*, the *epididymis*, the *scrotum*, *ductus deferens*, *seminal vesicles*, *prostate*, *bulbo-urethral glands*, *urethra*, and the *penis*. (fig. 38).

The testes are two glandular organs suspended from the inguinal region by the spermatic cord and surrounded and supported by a musculo-membranous sac covered with skin, the *scrotum*. The testicle proper is somewhat oval in shape and is composed of tubular glands held together by connective tissue. These glands form the male generative cells, the *spermatozoa*. The interstitial cells of the testis produce an internal secretion which promotes the development of

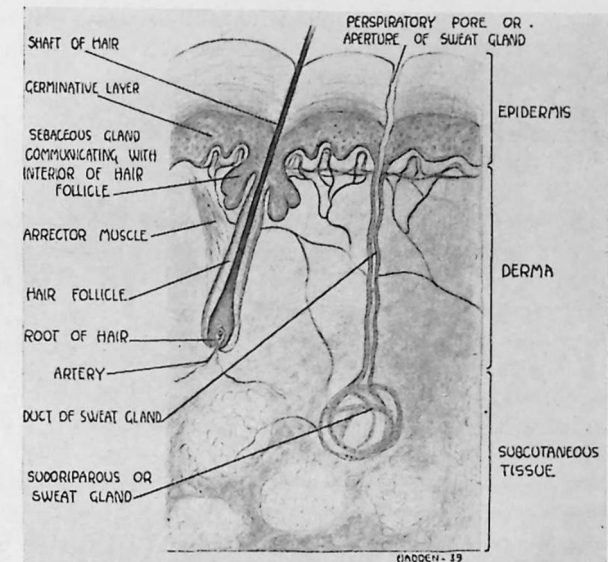


FIGURE 37.—Perpendicular section of skin. (Mason, modified.)

masculine characteristics. The tubules of the testicles unite to form a single tube which lies as a tortuous mass called the *epididymis* on the posterior surface of the testicle and connects with the ductus deferens.

The ductus deferens or *vas deferens*, is the excretory duct of the testicle and runs in the spermatic cord through the inguinal canal into the abdomen, thence extra-peritoneally on a convergent course to the seminal vesicles. The spermatic cord forms the pedicle of each testicle and extends from the internal abdominal ring to the back of the testis, and is made up of the ductus deferens, spermatic arteries and veins, lymphatics, nerves, cremasteric muscle and connective tissue.

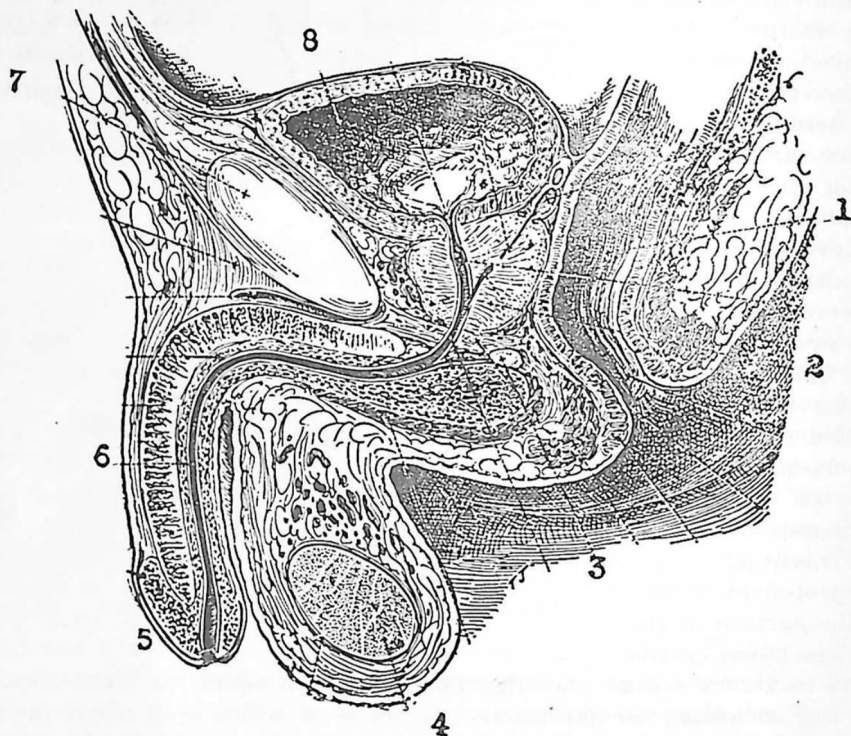


FIGURE 38.—Section through male generative organs and bladder. 1, Rectum, 2, prostate; 3, bulbo-urethral gland; 4, testicle; 5, glans penis; 6, urethra; 7, symphysis pubis; 8, bladder. (Manual of Surgical Anatomy, U. S. Army, modified.)

The seminal vesicles are two glandular pouches between the bladder and rectum and unite with the ductus deferens to form the *ejaculatory duct*. These vesicles serve as a reservoir for the *semen* and add a secretion of their own. The ejaculatory ducts pass from the seminal vesicles between the lobes of the prostate gland and open into the floor of the prostatic urethra.

The prostate gland is a partly glandular and partly muscular organ that surrounds the first portion of the urethra and resembles a horse-chestnut in form. The glandular and muscular tissue of this gland is surrounded by a dense fibrous capsule. It secretes a fluid which is an essential element of the semen. The *bulbo-urethral* or *Cowper's glands* are two small bodies about the size of a pea situated one on each side of the membranous urethra and opening into it. They secrete a fluid which forms part of the seminal fluid.

The penis consists of three more or less cylindrical bodies composed largely of erectile tissue. The two *corpora cavernosa* lie above the *corpus spongiosum* which contains the urethra. The *glans penis*, forming the distal end of the

penis, is continuous with the corpus spongiosum and contains the external opening of the urethra, the *meatus*, or *urinary meatus*. The covering of the shaft of the penis is loose skin, but that portion reflected over the glans penis is a thin layer of skin lined with mucous membrane, and is called the *prepuce*.

The semen is a fluid made up of the secretions of the bulbo-urethral glands, the prostate, the seminal vesicles, and the testes.

THE NERVOUS SYSTEM

In order that the subject matter which is to follow may perhaps be better understood it is considered advisable to briefly describe the means by which the lower forms of animal life react to different conditions.

The lowest form of animal life, the unicellular animal organism such as the *Amoeba*, possesses no distinctive nervous system but adapts itself to its surroundings by reason of the property of irritability which is inherent in the protoplasm of which it is composed. The single-cell animal moves about and carries out its processes of metabolism and reproduction entirely within and by itself and always reacts in the same way to any specific stimulus.

A little higher form of animal life, the *Metazoon*, has a soft, semifluid body of protoplasm consisting of groups of cells which stick together. Most of these cells, originally derived from a single parent cell, have lost their characteristics as individual cells and become specialized for certain functions. Some are specialized so that they link the different parts of the body of this water-dwelling animal together with a primitive nervous system which deals with outside impressions, brings about necessary movements, and controls various living activities. Other cells are specialized to form a supporting substance (primitive skeleton) and others are specialized to provide for movement (primitive muscles). In all parts of the outer supporting substance are cells which are specialized to receive external stimuli and are known as *sensory* or *receptor cells*. From the receptor cells extend two elongated portions called *processes*. One, the *peripheral process*, passes toward the surface and may even pass beyond it, the other, called the *central process*, passes inward into the body and connects with a network of cells of the nervous system called *connector cells*. The connector cells communicate with each other by processes and have other processes reaching still deeper into the body and connecting with *motor* or *effector cells* which have processes distributed to the primitive muscles of the animal. There is thus provided a means by which a sensation or impression of danger received by a receptor cell can be carried to a connector cell and thence, through the network of connector cells, to a number of motor cells. As a result of stimulation of the motor cells there occurs a general response of the primitive muscles and the animal moves away from the point of danger. Such a general muscular response to a local stimulus is always the same if conditions are the same.

In producing the movement just described three basic nerve elements have been shown to exist: 1. The *receptor* or *sensory cell*; 2. The network of *connector cells*; and 3. The *motor* or *effector cells*. These basic elements are found in the nervous systems of all forms of animal life higher than the Metazoon, with such modifications as are necessary to permit a particular type of animal to carry out its purpose in life.

When the higher stage in animal life represented by the earthworm, or *Lumbricus*, has been reached there has evolved from the primitive nervous system one in which there is a *central, controlling part* quite distinct from a *peripheral portion* of nerve fibers carrying impulses to or from the central part. In the earthworm this central part consists of a *nerve-cord* running

longitudinally through the entire length of the body, in each segment of which the nerve-cord is slightly swollen or enlarged on each side. These enlargements are collections of nerve cells called *ganglia* from each of which bundles of nerve fibers called *nerves* pass off to each side. Some of these nerves are *motor* and are connected with muscles; others are *sensory* and end in *receptor* or *sensory cells* in the covering of the body. Close to the front end of the worm is located a single pair of ganglia called the *cerebral ganglia* which are connected with each other by a bridge of nerve fibers. From the side of each cerebral ganglion a strand of nerve fibers curves around the side of the worm's alimentary canal and connects with the first ganglion of the nerve-cord. In the more highly developed animals the cerebral ganglia in the worm may be said to be represented by the brain, the nerve-cord by the spinal cord, and the ganglia on the nerve-cord by the pairs of spinal nerves.

In the higher animals modification and evolution of the primitive nervous system of the Metazoon has proceeded to the point where a *central nervous system* consisting of the *brain* and *spinal cord* and a *peripheral nervous system* consisting of the *spinal nerves* have been developed. The primitive connector cells and their processes and the primitive motor cells without their processes have collected to form the central nervous system and ganglia on sensory nerves. *Nerves* have evolved, the processes of the primitive receptor or sensory cells forming *sensory* or *afferent nerves* which pass into the central nervous system while the processes of the primitive motor or effector cells have formed *motor* or *efferent nerves* which pass out of the central nervous system. If, for convenience, both sensory and motor nerve fibers are carried in the same nerve trunk, that nerve trunk is known as a *mixed nerve*. The cranial nerves arising from the brain and the spinal nerves arising from the spinal cord are typical examples of mixed nerves. With this evolution of the nervous system there have been developed special receptors for the functions of sight, smell, hearing, etc., and in the highest forms of animal life certain parts of the brain have enlarged to enable it to properly control the many complex functions and movements of the body containing that brain.

The ability of the human organism to adapt itself to its surroundings or environment, to coordinate and regulate the activities of its various parts so that they work harmoniously together, and to reason, is due solely to the presence in it of nerve tissue, which, as previously stated, is the most highly specialized tissue in the body. This tissue is present in every part of the body in the form of *nerve cells*, small masses containing nerve cells called *nerve centers*, or *ganglia*, and conducting or connecting elements called *nerve fibers*, bundles of which are termed *nerves*. These forms collectively constitute the complex apparatus known as the nervous system, frequently spoken of as the "ruler of the body."

For purposes of study and description in this book, the nervous system will be considered as divided into three parts, the *cerebrospinal* or *central nervous system*, the *peripheral nervous system*, and the *sympathetic nervous system*. Also, for ease in study and description, the impulses carried by the afferent or sensory nerves will be termed *impressions* while those carried by the efferent or motor nerves will be termed *impulses*.

The *central nervous system* consists of the *brain*, or *encephalon*, contained within the cranial cavity, and the *spinal cord*, or *medulla spinalis*, which occupies the upper two-thirds of the spinal canal. Together the brain and the spinal cord dominate the entire nervous system.

The *peripheral nervous system* consists of 12 pairs of *cranial nerves* attached to the brain and 31 pairs of *spinal nerves* attached to the spinal cord.

These nerves are associated with the functions of the special and general senses and with the voluntary movements of the body.

The *sympathetic nervous system* is often considered as part of the peripheral nervous system with which it is intimately connected and closely intermingled. It is also known as the *autonomic*, *vegetative*, and *ganglionic* nervous system.

Nerve tissue is made up of *nerve cells*, or *neurones*, and their processes, held together, in the brain and spinal cord, by a special supporting tissue called the *neuroglia* and by ingrowths of the membrane covering the brain and spinal cord, the *pia mater*. The nerve cell, or *neurone*, is the unit of structure and of function in the nervous system, varies in size, shape, and structure, and consists of the cell-body, or *cyton*, and one or more processes extending out from the body. Nerve cells having but one process are called unipolar cells, those having more than one, multipolar cells. The cell body, made of nucleated protoplasm, is the seat of origin of the changes which give rise to nervous impulse, and presides over the nutrition of the cell. The processes of nerve cells are outgrowths of the cell-body and provide the paths along which nervous impulses are carried. They are of two kinds, the *axone*, or *axis-cylinder process*, a single, unbranched process which lengthens out to become the axis cylinder, or conducting part, of a nerve, and the *dendrone*, *dendrite*, or *protoplasmic process*, a short process that divides into smaller and smaller branches which terminate in free ends that become lost in the nervous tissue (fig. 39). The axones vary in length, some extending only a very short distance beyond the cell while others continue to distant parts of the body. The longer processes, which usually acquire protective sheaths, are known as *nerve fibers*, and these, arranged in bundles, form the *nerves*, or *nerve trunks*, that pass to every part of the body.

Nerve fibers are the conducting elements of the nervous system and bring the nerve cells into relation with each other and with the various tissues of the body. They constitute the greater part of the brain and the spinal cord, make up the nerves, and are known as *medullated* or *white fibers* and *nonmedullated* or *gray fibers*, the difference being due to the presence or absence of the white medullary sheath. The central and essential part of a nerve fiber is the *axis cylinder* which, in medullated fibers, is surrounded by the *medullary sheath* or *white substance of Schwann*, and the whole enclosed in a delicate membrane called the *primitive sheath* or *neurolemma*, and in nonmedullated fibers is surrounded by a delicate nucleated sheath corresponding with the neurolemma of the medullated fibers. Medullated nerve fibers form the white part of the brain and the spinal cord and the greater part of every cranial and spinal nerve; nonmedullated fibers compose most of the sympathetic nervous system and some of the central. The medullated fibers constitute the *white matter* of the nervous system; the non-medullated fibers the *gray matter*.

Nerves usually are classed according to the impressions or impulses they conduct and the direction in which the impression or impulse is carried. Afferent nerves conduct impressions of pain, hunger, feeling, etc., from all parts of the body into the central nervous system, and as these impressions are spoken of as sensations, afferent nerves are also known as *sensory nerves*.

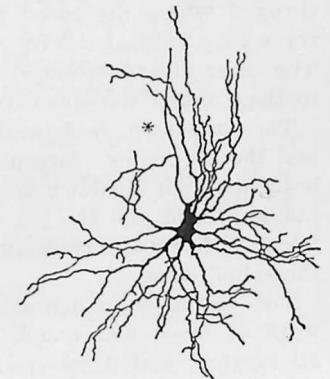


FIGURE 39.—Motor nerve cell. (Howell.) *is the axone; the other branches are dendrites.

Efferent nerves conduct impulses from the brain and spinal cord to the parts to which nerves are distributed. Most efferent nerves go to muscles and are commonly termed *motor nerves*; those that go to secreting glands are called *secretory nerves*; while those that restrain or check movement or secretion are called *inhibitory nerves*. Some nerves have both afferent and efferent fibers and are known as *mixed nerves*.

The cerebrospinal nervous system.

The brain, the largest and most complex mass of nervous tissue in the body, weighs about 3 pounds and fills the cranial cavity of the skull (fig. 40). It is continuous with the spinal cord at the *foramen magnum*, is very vascular, and when observed in life is seen to pulsate. The outer layer of the brain, the *cortex cerebri*, is made up of *gray matter* and the deeper parts of *white matter*. The gray matter, composed largely of nerve cells, receives and stores afferent impressions and transforms them into efferent impulses; the white matter, consisting principally of nerve fibers, conducts the efferent impulses. The brain is covered by three membranous coats, the *meninges*, which, named from without inward, are the *dura mater*, the *arachnoid*, and the *pia mater*.

The *dura mater*, a dense membrane of fibrous connective tissue, contains many blood vessels and is arranged in two layers, except in a few places. The outer layer of the *dura mater* is adherent to the inside surfaces of the bones of the skull where it forms their periosteum. The inner layer covers the brain and sends numerous prolongations inward for the support and protection of the lobes of the brain. These projections form the venous sinuses through which the blood is returned from the brain to the large veins of the neck. They also form the sheath for the nerves leaving the cranial cavity. The inner layer continues through the *foramen magnum* into the spinal canal to there invest the spinal cord.

The *arachnoid*, a delicate serous membrane, lies between the *dura mater* and the *pia mater*. Except in the longitudinal fissure of the brain this membrane does not dip down into the crevices and depressions of the brain. Between the *arachnoid* and the *pia mater* is a space called the *subarachnoid space*, in which is found a certain amount of cerebro-spinal fluid. It also continues into the spinal canal.

The *pia mater*, a delicate membrane of connective tissue containing a network of blood and lymph vessels, lies under the *arachnoid* and extends to all crevices and depressions of the brain. It contains the blood vessels of the brain and supplies blood to all parts of the brain. It frequently is called the nutritive membrane, and continues into the spinal canal.

The brain itself is divided into three main parts: The *forebrain*, containing the cerebral hemispheres and other bodies; the *midbrain*, a short constricted portion connecting the pons and cerebellum with the forebrain; and the *hind-brain*, consisting of the medulla oblongata, pons, and cerebellum (fig. 40).

The *cerebrum*, the largest part of the brain, fills the whole of the upper part of the cavity of the skull. It is composed of gray matter externally, which is the active part of the brain, and white matter internally, in which are embedded masses of gray matter. The outer portion of the cerebrum is made up of alternate elevations, called *convolutions*, and depressions, called *fissures*. The fissures divide the cerebrum into hemispheres and the hemispheres into lobes, the latter bearing names corresponding to the cranial bones near which they lie. The hemispheres are known as right and left.

The *great longitudinal fissure* extends from the front to the back of the cerebrum and completely divides it into two hemispheres except in the middle

portion where a broad transverse band of white fibers called the *corpus callosum* connects the hemispheres. The *transverse fissure* separates the cerebrum from the cerebellum. The fissures of the brain divide each hemisphere into sections called lobes, designated as the *frontal*, *parietal*, *temporal*, *occipital*, and *central*, or Island of Reil. Among the important fissures are the fissure of Rolando, called the *central sulcus*, running from the top and near the middle of each hemisphere downward and forward for two-thirds of its vertical measurement and separating the frontal lobe from the parietal lobe; the *lateral cerebral fissure* (Fissure of Sylvius), separating the frontal and parietal lobes from the temporal lobe; and the *parieto-occipital* fissure separating the parietal from the occipital lobe.

The function of the cerebrum is to govern all of the mental activities and coordinate body movements. This section of the brain contains the centers or seats of reason, intelligence, will, memory, and all of the higher emotions and feelings. Certain areas of the brain have a preponderance of control over certain functions, although all areas are more or less closely connected by *association fibers*; the frontal lobe is primarily the seat of reasoning or higher psychical thought; that portion just anterior to the central fissure is the motor area; the temporal lobe is the seat of hearing; and the occipital lobe is the seat of vision.

The white matter consists of fibers which run in three directions, from above downward, from the front backward, and from side to side.

They form a connection between the different parts of the brain and connect the brain with the spinal cord.

Within the brain there are four communicating cavities called *ventricles*. These are the two *lateral ventricles*, one situated within each cerebral hemisphere, the *third ventricle*, lying in the lower middle portion of the brain and communicating on each side with a lateral ventricle, and the *fourth ventricle*, situated between the pons and the cerebellum, connecting above with the third ventricle and continuous through the medulla with the minute central canal of the spinal cord. The ventricles contain a clear lymph-like fluid, the cerebro-spinal fluid. There are openings between the fourth ventricle and the space between the inner and middle layers of the meninges of the brain, which space is continuous with a similar space between the meninges of the spinal cord that also contains cerebrospinal fluid.

The *cerebellum*, sometimes called the "little brain," lies in the lower posterior part of the skull, between the occipital lobes of the cerebrum above, and behind the pons and medulla oblongata, with all of which it is connected. It is somewhat oval in form and consists of two lateral hemispheres and a central por-

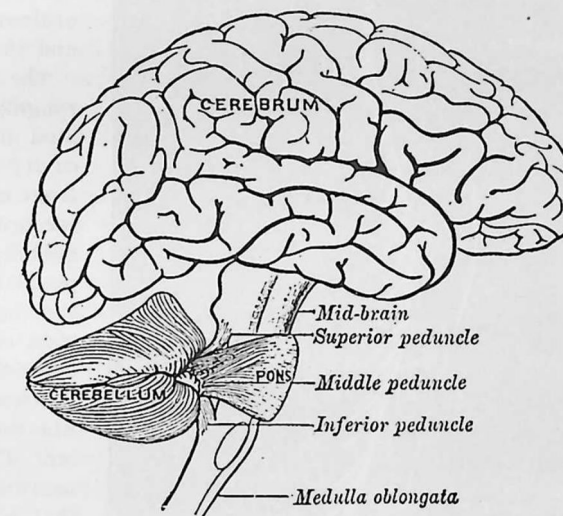


FIGURE 40.—Schema showing the connection of the several parts of the brain. (Gray.)

tion called the *vermis*, or *worm*, and sometimes the *middle lobe*. A large, deep fissure called the *horizontal fissure* incompletely divides the cerebellum into an upper and a lower portion. Other deep fissures separate the hemispheres into lobes, and numerous, curved fissures, varying in depth and roughly parallel with each other, separate the lobes into layers, or leaves, the edges of which appear as fine ridges. The surface of the cerebellum therefore presents a

slightly ridged and laminated, or leaf-like, appearance, instead of a convoluted one like that of the cerebrum. The substance of the cerebellum is composed of a solid, compact mass of white matter in the interior over which is a layer of gray matter, and its principal function is believed to be the regulation and coordination of ordinary movements and the maintenance of equilibrium.

The pons, or *pons Varolii*, is a roughly rounded, white mass situated in the midline of the cranial cavity at the base of the brain, in front of the cerebellum, beneath the cerebrum, and continuous with the medulla oblongata below. It is composed of a ventral, or anterior portion and a dorsal portion, and consists chiefly of rope-like bundles of nerve fibers connecting with the mid-brain above and the medulla oblongata below, and areas of gray matter. From its surfaces emerge the narrow white bands of nerve fibers that connect the medulla oblongata with the cerebrum and the cerebellum, the pons thus acting as the "bridge" which its name signifies. In the gray matter of the pons are located the nuclei from which arise some of the cranial nerves.

The medulla oblongata, or *spinal bulb*, extends in an almost vertical direction from the lower margin of the pons, above, through the foramen magnum to the level of the upper border of the first cervical vertebra, or atlas, below, where it

is continuous with the spinal cord. Shaped somewhat like a flattened pyramid or cone, it rests in and is supported by a shallow groove in the basilar portion of the occipital bone. It is divided into two lateral halves by two fissures continued into it from the spinal cord, the anterior one extending the entire length of the medulla and ending at the upper end, the posterior one ending in the lower half. The lateral halves are further divided longitudinally by grooves, and the surface of the medulla consequently appears convoluted. The

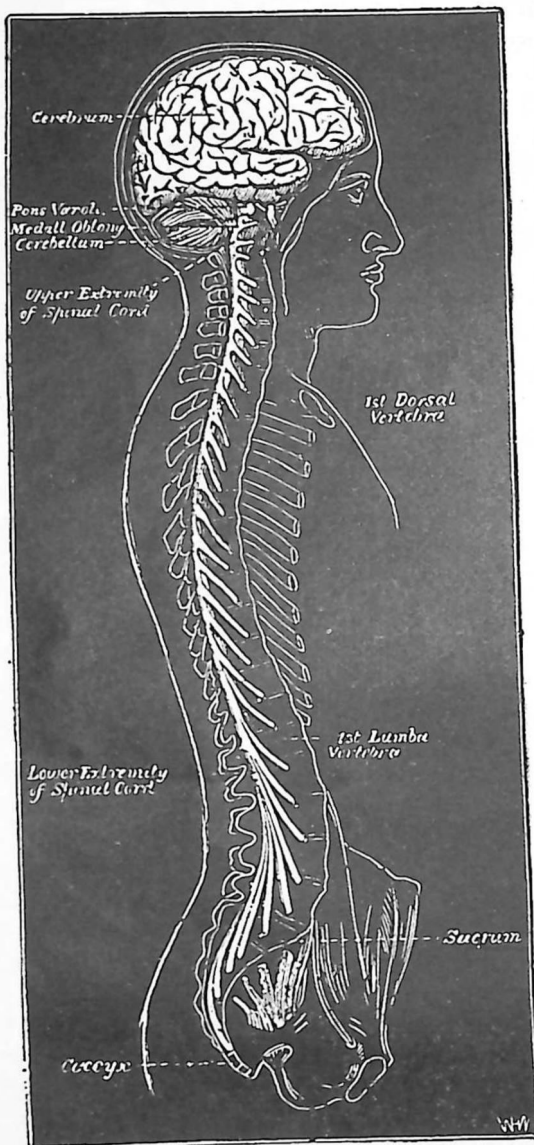


FIGURE 41.—Spinal cord and nerves. (Mason.)

upper portion of the posterior surface forms the lower part of the floor of the fourth ventricle of the brain, and the minute central canal of the spinal column passes through the lower half of the medulla and there opens out into the lower, tapered end of the fourth ventricle. The medulla is made up largely of a continuation of bundles of nerve fibers from the spinal cord, some of which end in the medulla while others pass on into the cerebellum. Much gray matter also is present in which are located numerous nerve nuclei and the reflex centers for regulating respiration, accelerating heart action, and maintaining vascular tone. In the lower part of the medulla a large part of the nerve fibers *decussate* (cross to the opposite side) which is the reason why one side of the brain controls nervous activity in the opposite side of the body. The functions of the medulla are largely conduction, reflex action, and automatic action, its function of conduction being especially important as it conducts all impressions passing between the brain and the spinal cord.

The spinal cord, or *medulla spinalis*, is that part of the central nervous system which occupies the upper two-thirds of the vertebral or spinal canal (fig. 41). It is nearly cylindrical in shape, being slightly flattened in front and behind, and extends from the level of the upper border of the atlas to the level of the lower border of the first lumbar vertebra, a distance of about 18 inches in the male. Above it is continuous with the medulla oblongata and below it ends in a cone-shaped extremity, the *conus medullaris*, from the point of which a slender filament, consisting mainly of fibrous tissue and called the *filum terminale*, extends downward about 8 inches where it is attached to the periosteum of the coccyx and so anchors the spinal cord. The nerve roots which spring from the lumbar and sacral portions of the spinal cord descend for a considerable distance in the spinal canal as a bunch of long nerve fibers which, from its resemblance to a horse's tail, is called the *cauda equina*. The three coats or membranes which cover the brain extend down and cover the spinal cord, and the subarachnoid space between the arachnoid and pia mater is likewise continued and also the cerebro-spinal fluid. Between the dura mater and the vertebral column is a protective covering of fatty tissue which also serves as a protection to the spinal cord. Two fissures, the *ventro-median fissure* anteriorly and the *dorso-median groove* posteriorly, almost completely divide the spinal cord, leaving only a narrow bridge of substance connecting the two halves. The bridge is called the *isthmus of the spinal cord* and in it is contained the minute cavity called the *central canal* which traverses the entire cord and communicates with the fourth ventricle of the brain. The spinal cord is made up of white matter surrounding an H-shaped section of gray matter (fig. 42). The anterior parts or horns of this H-shaped substance are short and bulky while the posterior ones are long and slender. The white matter is composed of bundles of nerve fibers running lengthwise of the cord, the gray of cell bodies, dendrites, axones, and collateral branches held together by neuroglia. The function of the bundles of nerve fibers is to conduct sensory impressions to and motor impulses from the brain.

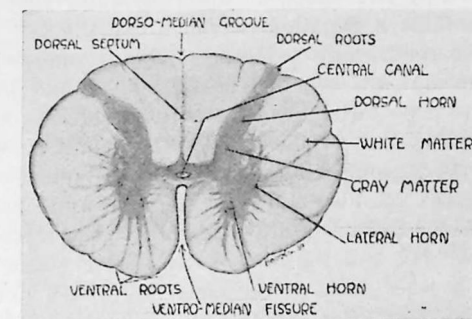


FIGURE 42.—Cross section of spinal cord at seventh thoracic vertebra. (U. S. Naval Medical School.)

The peripheral nervous system.

The cerebral or cranial nerves, consisting of 12 pairs, originate in the brain and supply certain definite areas of the body. They are of three varieties, sensory, motor, and mixed nerves which contain both sensory and motor nerve fibers. These cranial nerves after leaving the cranium through definite anatomical exits split up into branches and are widely distributed. They are numbered from before backward in the order in which they arise from the brain, and are named in accordance with their nature, function, or distribution.

NUMBER, NAME, TYPE, DISTRIBUTION, AND FUNCTION OF THE CRANIAL NERVES

Nerve No.	Nerve name	Type	Distribution	Function
1	Olfactory.....	Sensory..	Upper third of the nasal cavity.	Sense of smell.
2	Optic.....	do.....	Retina of eye.....	Sight.
3	Oculomotor.....	Motor...	All eye muscles except superior oblique and external rectus.	Movements of eye.
4	Trochlear.....	do.....	Superior oblique muscle of eye.	Do.
5	Trigeminal.....	Mixed...	Skin of face, eyeball, lacrimal glands, mucous lining of mouth and pharynx, teeth, and tongue, muscles of mastication.	Taste, mastication, secretion, and touch.
6	Abducens.....	Motor...	External rectus muscle of eye.	Movements of eye.
7	Facial.....	do.....	All muscles of expression of face; also supplies ear and part of neck.	Facial expression.
8	Acoustic.....	Sensory..	Internal ear.....	Hearing and equilibrium.
9	Glossopharyngeal.....	Mixed...	Tongue and pharynx.....	Taste, movement of pharyngeal muscles and sensation to mucous membrane of pharynx.
10	Vagus.....	do.....	Larynx, trachea, lungs, heart, pharynx, œsophagus, and stomach.	Both motor and sensory to lungs and larynx. Cardio-inhibitory. Motor to œsophagus and stomach.
11	Accessory.....	Motor...	Certain neck muscles.....	Movements of head.
12	Hypoglossal.....	do.....	Tongue.....	Movements of tongue.

The spinal nerves, 31 pairs in number, are named in accordance with the location of their exit from the spinal canal, there being 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 1 coccygeal (fig. 41). Each nerve arises from the spinal cord by two roots, an anterior *motor root* and a posterior *sensory root* which contains a ganglion in which are the cell bodies of the sensory neurone. The two roots unite to form a single trunk which emerges from the spinal canal through an *intervertebral foramen* and immediately divides into an anterior and a posterior branch, each of which contains fibers from both the motor and sensory roots. Thus all of the spinal nerves are mixed nerves, for they carry sensory impressions and motor impulses. The posterior branches of these nerves are distributed to the skin and muscles of the back and trunk; the anterior branches unite to form the three great *plexuses* known as the *cervical*, the *brachial*, and the *lumbosacral*, from which the nerve supply to the extremities and other parts of the body is derived. From the cervical plexus arise nerves whose branches supply the skin and muscles of the head, face, neck, upper back parts of the shoulders, and thorax, and certain organs within the thoracic cavity; from the brachial plexus arise nerves that supply the upper extremity among which are the *median*, *ulnar*, and *radial nerves*; and from the lumbosacral plexus arise nerves that supply the lower extremities, the chief ones being the *sciatic* (the largest nerve in the body), the *femoral*, and the *obturator nerves*.

The sympathetic nervous system.

This system, also called the autonomic and vegetative, innervates all the involuntary muscles and the various glands of the body, the striated muscles of the heart, and the skeletal muscles may receive some sympathetic fibers. It consists of two rows of central ganglia situated one on each side of the median line, partly in front and partly at the sides, of the vertebral column and extending from the base of the skull to the coccyx, other ganglia situated in different parts of the body, and a network of small nerve trunks connecting the ganglia and ramifying to various organs. The central ganglia are joined with each other by cords of nerve fibers and each ganglion is connected with the spinal nerve of that region and with the spinal cord. A group or collection of ganglia and nerves supplying organs and structures in the body with nerve influence is called a *plexus*. Among the many of this system in the body are the *cardiac plexus* supplying the heart, the *epigastric* or *solar plexus* supplying the stomach, the *pulmonary plexus*, supplying the lungs, and the *hypogastric plexus* supplying the organs in that region of the body. Through the sympathetic system the movements of the viscera are regulated, the caliber of the blood vessels determined, the phenomena of secretion controlled, and the metabolic processes of life maintained. The activity of this system does not excite the consciousness and is almost entirely involuntary.

Nerve action.

The outstanding physiological property of nerve fiber is its *conductivity*, by which is meant the capacity of the nerve fiber to conduct impulses. For ease in description and study the impulses carried by the afferent nerves have been termed impressions throughout this section, while those carried by the efferent nerves have been termed impulses. A nerve *impression* may then be said to be the influence or effect on feeling, sense, or consciousness resulting from stimulation or excitation, and a nerve *impulse* the influence or effect on muscular or other tissue that incites it to action. Under normal conditions afferent nerve fibers are stimulated or excited only at their endings, called *receptors*, in the skin, mucous membranes, sense organs, etc., while efferent nerve fibers are stimulated only through the nerve cells from which they spring. Sensory impressions are converted into motor impulses in the nerve cells or nerve centers and the conversion may be totally unconscious as well as involuntary, as the emptying of the gall-bladder during digestion, or there may be consciousness of the act, as the winking of the eyelid when the eye is touched. On reaching the central nervous system sensory impressions may be carried to the brain, there to give rise to a specific sensation in the consciousness, or they may be conducted by a direct or a devious path within the central nervous system to a nerve cell or nerve center which converts them into motor impulses and conducts them away to incite response in some distant muscle or gland cell. When such a response occurs without intervening consciousness it is called *reflex action*, the nervous activity involved a *reflex*, and the path over which the impression and impulse travelled a *reflex arc*. The reflex is the basis of all functional activity of the nervous system, and the nervous function necessary for the control of the most intricate movements and activities is probably only a compounding of reflexes. In reflex action it is essential that there be: 1. A receptor on which the stimulant or excitant is brought to bear; 2. A path to the central nervous system by which the sensory impression is carried; and 3. A path from the central nervous system by which the motor impulse is carried. Although

the sensory impressions may be sent to and the motor impulse received from the brain in reflex action, it is believed that in most cases the impressions are received in the spinal cord and the motor impulses originated therein.

Thus, in response to impressions received over the afferent or sensory nerves, the nerve cells in the spinal cord send out orders without waiting for the impression to be carried to the brain or central nervous system and the orders sent out from there. As an example, the hand is pricked by a tack (fig. 43). The receptor nerve ending receives the sensation and the afferent or

sensory nerves carry it to the spinal cord and brain. Before the sensation has reached the brain, however, an order to lift the hand has been originated by the nerve cells in the cord and sent out by the efferent or motor nerves. The hand is moved and the brain made conscious of the prick at about the same time.

Reflexes are classed as *simple reflexes*, in which a single muscle or gland is involved, as in the corneal reflex; *complex reflexes* in which several muscles or glands are involved, the action remaining perfectly coordinated, as in the patellar reflexes; *spreading reflexes* in which a large number of muscles are involved; *tonic reflexes* or continuous reflexes in which a

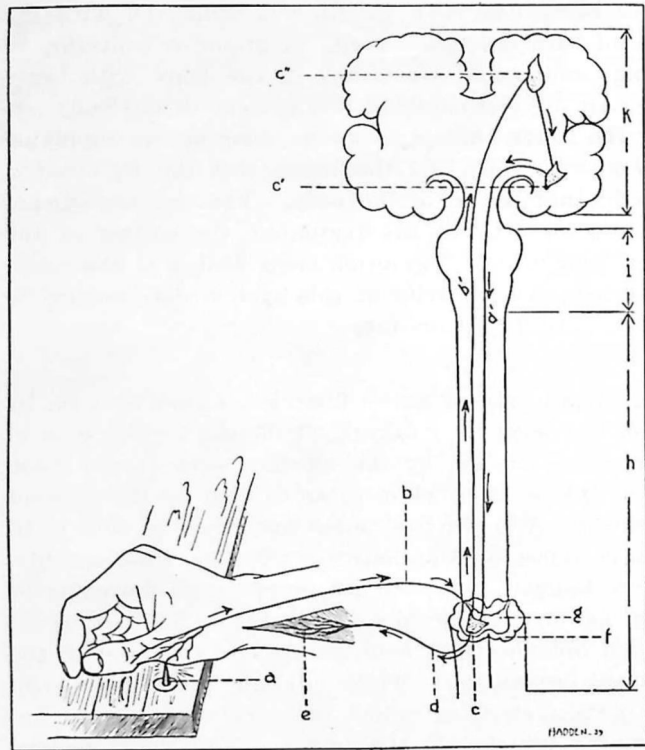


FIGURE 43.—Diagram of reflex action: a, Tack pricking hand; b, b', afferent nerves; c, c', c'', nerve cells; d, d', efferent nerves; e, muscle moving hand; f, white matter; g, gray matter; h, spinal cord; i, medulla oblongata; k, brain.

reaction is repeated a number of times as in swallowing, coughing, hiccupping, etc.; and *association* or *perception reflexes* in which a mental picture produces reaction, as in the flow of saliva or gastric juice when well-cooked food is seen or smelled, or when one person yawning causes others to do likewise.

The special senses.

Various kinds of external stimuli produce nerve impressions which give rise to the phenomenon in consciousness known as *sensation*. Stimuli within the body give rise to such sensations as *thirst*, *hunger*, *fatigue*, and many other less well-defined sensations. The body is equipped with various mechanisms especially adapted to receive specific forms of stimuli from external surroundings. These mechanisms are called the *organs of the special senses*. The skin contains various forms of sensory nerve endings, which, when acted upon by specific stimuli, give rise through the nerve impulses generated to such sensations as *heat*, *cold*, *pressure*, and *pain*. Other more elaborate mechanisms similarly provide for the senses of *sight*, *hearing*, *smell*, and *taste*.

The *visual apparatus* consists of the *eyeballs*, the *optic nerves*, and the *visual centers* in the brain, together with certain associated organs, as the *eyelids*, *eyebrows*, *muscles of the eyeball*, and the *lacrimal apparatus*.

The *eyelids* are two thin movable folds projecting from above and below, placed in front of the eye. They are covered externally by skin, and internally by a mucous membrane, the *conjunctiva*. This internal lining, the *conjunctiva*, is reflected over the front of the eyeball. The interior of the eyelid is composed chiefly of connective tissue, part of which is dense fibrous tissue which forms the *tarsal cartilage*. Several small glands, the *Meibomian glands*, are situated in this connective tissue. The upper eyelid contains a small muscle which acts to elevate or lower it. On the margin of each lid are double or triple rows of short hairs or cilia called the *eyelashes*. The function of the eyelids is to afford protection to the eyes. They are movable shades which may exclude light, dust, and other injurious substances.

The *lacrimal apparatus* consists of the *lacrimal glands*, the *canaliculi*, the *lacrimal sac*, and the *nasal duct*. The lacrimal gland is situated at the upper and outer angle of the orbit and secretes tears which flow to the surface of the conjunctiva via several small ducts. This secretion passes over the eyeball and is collected by the canaliculi at the inner angle of the conjunctiva. These canaliculi communicate with the lacrimal sac from which the tears are discharged into the nose through the nasal ducts.

The *orbits* are bony cavities in which the eyeball and its muscles are contained. They are shaped like a four-sided pyramid and are made up of seven bones, the *zygomatic*, *maxilla*, *palate*, *ethmoid*, *frontal*, *sphenoid*, and *lacrimal*. The orbit contains two openings posteriorly, the *optic foramen* for the passage of the optic nerve and the ophthalmic artery; and the *sphenoidal fissure* for passage of the ophthalmic veins and of nerves to the muscles of the eye.

There are six extrinsic muscles of the eye the function of which is to move the eyeball. These are the *internal*, *external*, *superior*, and *inferior recti* muscles, and the *inferior* and *superior oblique* muscles (fig. 44). The innervation of these muscles has been given under the cranial nerves.

The general shape of the eyeball is spherical, or, more exactly, it "is composed of the segments of two spheres of different sizes, the anterior being the segment of a small sphere forming about one-

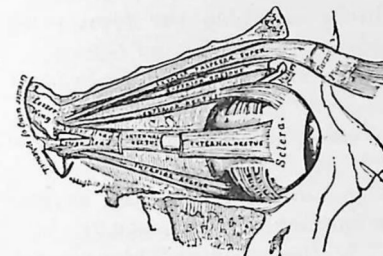


FIGURE 44.—Muscles of the right orbit. (Gray.)

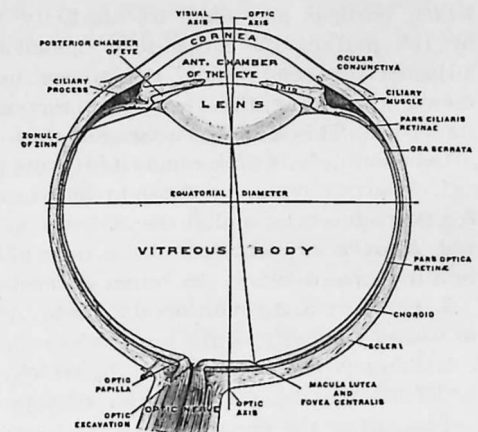


FIGURE 45.—The right eye in horizontal section. (Toldt.)

sixth of the eyeball and the posterior being the segment of a much larger sphere and forming about five-sixths of the globe" (fig. 45). The surface of the eyeball is made up of three distinct coats or layers. The outer layer consists of the sclera and the cornea. The sclera or "the white of the eye" is a dense, tough, fibrous

membrane covering the posterior five-sixths of the eyeball and pierced posteriorly by the optic nerve. In front where the light enters the eye the sclera changes to a transparent membrane having no blood vessels, which covers the remaining sixth of the eyeball and is known as the *cornea*.

The middle layer is composed of the choroid and the iris. The choroid is a thin, vascular, chocolate-colored membrane lining the sclera and containing a network of blood vessels and pierced in the back by the optic nerve. It is folded inward and arranged in radiating folds about the lens of the eye. These folds form the *ciliary processes* and are well supplied with nerves and blood vessels and the *ciliary muscle* is contained therein. The iris is a thin, circular, contractile disc directly back of the cornea and suspended in front of the lens but not in contact with it, and perforated near its center by a circular opening called the *pupil*. It divides the space between the cornea and the lens into *anterior* and *posterior chambers* which contain a watery substance called the *aqueous humor*. The iris is composed of connective tissue, pigment cells, blood vessels, and contains two sets of muscles. One set of muscle fibers contracts the pupil, the other dilates it. The function of the iris is to regulate the amount of light entering the eye—by contracting, it decreases the amount of light entering, by dilating, it increases it. This is the part that gives the eye its characteristic color.

The inner layer of the eye is the retina, which is essentially the expanded fibers of the optic nerve. It is the screen on which the images fall, is most essential to vision, and is a transparent, purplish-colored membrane situated between the inner surface of the choroid and the outer surface of the *vitreous body*, a transparent jelly-like substance nearly filling the cavity of the eyeball and separated from the retina by the *hyaloid membrane*. The retina consists of eight layers of cells, the most important of which is the first or external layer, called the "layer of rods and cones," in which the cells act as end organs to the optic nerve.

The crystalline lens is a solid transparent body enclosed in a transparent capsule or membrane and held in place by a ligament. It is situated between the iris in front and the vitreous body behind. The lens is an elastic body which hardens and loses its elasticity with age. It is kept normally tense by the pull of the suspensory ligament on the capsule. When the eye is adjusted for near vision, the ciliary muscle contracts, drawing the choroid forward, relaxing the suspensory ligament and allowing the lens to change its shape. This is called *accommodation*.

Common defects of accommodation are:

1. *Hypermetropia*, or farsightedness, a condition in which the focal point for near objects is behind the retina.
2. *Myopia*, or nearsightedness, a condition in which the rays are brought to a focal point before the retina is reached.
3. *Presbyopia*, a condition similar to hypermetropia, found in old age and due to loss of elasticity of the lens.
4. *Astigmatism*, a condition in which the curvature of the cornea or lens is defective, causing a dispersion of rays and a blurring of the image.

The ear or the *organ of hearing* is composed of three parts: The *external*, the *middle*, and the *internal ear* (Fig. 46). The *external ear* consists of the *auricle* and the *external auditory canal*, which extends from the outside to the *eardrum*, or *tympanic membrane*. This membrane separates the external from the middle ear. The middle ear (tympanic cavity) is a small, irregular, air-filled cavity located in the temporal bone. It communicates with the pharynx, by the Eustachian or auditory tube, and also with the mastoid air cells, and

is separated from the internal ear by a thin bony plate containing two small openings, one of which is closed by a thin membrane. The other opening, the *fenestra ovalis*, is the connection between the middle and the internal ear, and is occupied by the base of the stapes, one of the *ear ossicles* or bones located within the middle ear. These bones form a chain extending from the tympanic membrane to the fenestra ovalis. The internal ear contains the perceptive organ of hearing and consists of a *bony labyrinth* hollowed out of the petrous portion of the temporal bone. This labyrinth is lined with a membrane, contains a fluid called *endolymph*, and is divided into the *vestibule*, the *semicircular canals*, and the *cochlea*. The semicircular canals and vestibule receive nerve endings from the vestibular branch of the auditory nerve and have to do with the sensation of equilibrium.

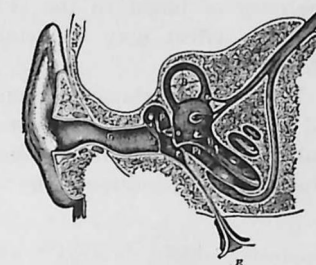


FIGURE 46.—Section through right, external, middle, and internal ear. (Howell.)

The end organs of hearing are located in the cochlea. Hearing is accomplished by sound waves which strike against the eardrum and are transmitted by the ear ossicles to the endolymph of the internal ear, the movement of which stimulates the end organs of hearing. The center of hearing is in the temporal lobes of the brain.

The sense of smell is accomplished by emanations from certain substances coming in contact with special nerve endings of the olfactory nerve which are distributed to the mucous membrane of the upper part of the nasal chambers.

Taste is accomplished by certain end organs known as *taste buds*, which are groups of modified epithelium cells of the tongue around which terminate nerve fibers. The perceptive portions of the tongue are the tip, the borders and the posterior portion of the dorsum. The nerves concerned with the sense of taste are the *chorda tympani* branch of the facial, the *lingual* branch of the trigeminal, and the *glossopharyngeal*. There are four fundamental tastes: *salt*, *sweet*, *acid*, and *bitter*. The pleasing variations which commonly are called taste are usually combinations of taste and smell. It is necessary for a substance to be in solution to stimulate the nerve endings concerned with taste.

Certain special functions and activities.

Speech, or the *expression of coherent thought* is brought about by a combination of several acts under control of a certain brain center. The center of speech is considered to be located deep in the left temporal lobe of the brain. The larynx contains folds of mucous membrane called *vocal chords*, which are controlled by muscles which separate or bring these folds together according to the pitch of tone desired. When air is forced from the lungs past these folds certain sounds are produced, and in conjunction with the movements of the pharynx, tongue, lips, and cheeks articulate speech results.

Sleep is a period of more or less unconsciousness, during which most of the higher psychical powers are quiescent, but during which the physiological activities continue. It usually is considered a period of rest, in which the *constructive processes* exceed the *disassimilatory* or *katabolic changes*. Certain changes take place during sleep; respiration is slowed, the pulse slowed, and less blood is sent to the brain and greater amounts to the extremities. The cause and necessity for definite periods of sleep is not thoroughly understood.

Heat regulation, or *maintenance of constant body temperature* is a two-sided process, and consists of controlling the loss of heat as well as the production of heat. Heat is lost through the excreta, through expired air, by

evaporation of sweat, and by radiation and conduction from the skin. Heat is produced by physiological oxidations within the body. This is effected by muscular exercises and partly by the variety and quantity of food.

The preservation or elimination of heat is controlled chiefly by the sympathetic nervous system, by nerves to sweat glands and vasomotor nerves. An increase of blood to the skin, increases the loss of heat by radiation. The opposite effect may be produced by vasoconstriction or decrease of blood to the skin.

Fever is an abnormal condition of increased temperature, the exact cause of which is unknown. Generally it is considered to be a metabolic disturbance caused by certain toxic substances which act upon a possible heat center in the brain and influence the sympathetic nervous system.

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Raymond Thomas Martin

CHAPTER III

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Section 1.—MINOR SURGERY AND FIRST AID

Minor surgery is that part of surgery which includes procedures not endangering life. The application of bandages, splints, dressings and sutures, counterirritation, cauterization, and similar simple surgical measures are all considered as being within the scope of minor surgery.

First aid is the emergency treatment of the sick or injured before regular medical or surgical attention can be given. It should neither supersede nor take the place of proper medical or surgical attention and should consist of furnishing temporary assistance to a sufferer pending the arrival of medical aid. In rendering first aid there are certain things that are to be done in all cases of injury or illness. After taking charge of the situation the hospital corpsman should:

1. Send for a medical officer or somebody capable of giving the proper treatment.
2. Have somebody keep bystanders far enough away to give room to work without hindrance.
3. Lay the patient on a blanket, or clothing spread out flat, with the head level with the body; do not permit him to sit or stand up.
4. Loosen the patient's clothing about the neck, chest, and abdomen.
5. Examine the patient to determine the nature of the injury or illness, paying particular attention to evidence of hæmorrhage, stoppage of breathing, poisoning, wounds, fractures, dislocations, burns, etc. If necessary, cut or rip clothing to get it away from the injured part. In making the examination look at or feel of the chest to determine whether the patient is breathing, note the color of the face, especially the lips and cheeks, look for bleeding from the nose and ears, determine if he is conscious by asking questions of him, examine the lips and mouth for burns, discoloration, or bloody froth and the tongue for cuts, smell the breath for evidence of alcohol or poisons, and feel for the pulse to determine the character of the circulation.
6. Proceed with first-aid treatment at once, treating serious hæmorrhage first, stoppage of breathing next, and other conditions in the order of their seriousness. Remember to keep the patient warm.
7. Note the location of the accident or of the patient; inquire of the patient or bystanders as to what happened; get the time the accident or illness occurred and the names of the patient and witnesses; be prepared to receive an ante-mortem statement and be sure to have at least two others hear such statement, it may be the patient's non-cupative or oral will.

A hospital corpsman giving first aid should do so with evident display of self-assurance and authority born of knowledge, with decision, calmness, alacrity, and alertness of mind, thereby obtaining the confidence of the patient and of interested bystanders.

INFLAMMATION

Inflammation may be described as the changes which occur in living tissue when it is injured, providing that the injury is not of such a degree as tends to destroy the structure and vitality of the patient. When tissue is injured, the following changes take place: Engorgement of the blood capillaries in the injured tissue and a seepage through the dilated capillary walls of blood fluids and blood cells, particularly white blood cells (phagocytes). Nature brings about these changes with the object in view of bringing aid of a reparative and a nutritive nature to the cells which make up the tissue injured. Inflammation manifests itself by certain local signs and symptoms which are produced by changes in the injured tissue. These symptoms are heat, pain, discoloration, swelling, and disordered function of the part involved. Heat and discoloration are due to the enlargement of the blood capillaries, the swelling to the throwing out of blood fluids and cells into the injured tissues, and the pain to the pressure of pent-up fluids on the nerve ends in the area affected. There may also be constitutional symptoms, as *increase of temperature* and *increase of white blood cells* (leucocytosis) which depend in a large measure upon the cause of the inflammation and the absorption into the general circulation of the broken-down products of this inflammation.

The causes of inflammation are: *Traumatic*, such as blows and mechanical irritation; *chemical*, such as stings of insects, mustard, venom of serpents, ivy poisoning, etc.; *thermal*, heat and cold; *microorganisms*, such as staphylococcus, streptococcus, etc.; and *agencies*, such as electricity, X-rays, actinic rays of the sun, etc.

The general principles involved in the treatment of inflammation are: 1. To remove the exciting cause; 2. To keep the inflamed part at rest; and 3. To reduce the local blood pressure by elevation of the part.

Other agencies employed in the treatment of inflammation are heat and cold, wet dressings, and ointments. Heat acts by softening the tissues and hastening the carrying away of the products of inflammation, thus decreasing the pressure on the nerve ends in the inflamed area. Cold acts by contracting the dilated blood capillaries and thus decreasing tension. Wet dressings and ointments act by softening the tissues and frequently contain some agent to rid the inflamed area of the specific cause of the inflammation—some microorganism, for instance.

The conditions in which inflammation plays a very important part are: Fractures, dislocations, sprains, strains, wounds, burns, frostbite, and many kinds of infection.

Inflammation due to microorganisms or bacteria differs from inflammation due to other causes in that the cause of septic inflammation, or inflammation due to bacteria, is a living organism which multiplies and throws off poisons in increasing quantities until such time as the white blood cells and blood fluids thrown out from the dilated capillaries can overpower it. In the case of aseptic inflammation the cause is other than bacterial.

The principal danger in a septic inflammation is that the white blood cells and blood fluids will not be able to overcome the microorganisms which may gain access to the circulation and set up areas of inflammation elsewhere in the body. The term applied in this condition is *sepsis*.

Bacteria which cause infection or sepsis are present in myriads on the surface of the body and on every article touched, unless it has been sterilized. The skin and mucous membranes protect from infection and sepsis, and it is only when there is a break in these tissues that the bacteria of sepsis gain entrance and start septic inflammation. All bacteria of infection and sepsis do not cause the same degree of inflammation, some causing mild and others very severe inflammation. In the case of some it is easy for blood fluids and white blood cells to limit the inflammation locally, while with others it is difficult for them to do so.

An abscess is a localized area of infective inflammation containing live and dead microorganisms, live and dead phagocytes (white blood cells which have been combating the microorganisms), fluids forced out from the blood capillaries, and the broken-down products of dead tissue cells. The content of an abscess is called *pus*.

The *treatment* of an abscess is in accordance with the rules for treating other inflammations, but with the added rule that the *pus when formed must be evacuated*. Abscesses should be incised and drainage instituted, in order to reduce pressure on the tissues, rid the tissues of the irritating products of infective inflammation, and lessen the chances of the infecting organism gaining access to the general circulation and causing further trouble. Strict care must be taken not to introduce further infective organisms when the incision is made; that is, an aseptic technique must be employed. The incision must be large enough to allow good drainage. Never squeeze an abscess as this tends to break down Nature's barrier and to spread the infection. Depending on the severity of the inflammation, more or less of this tissue may die, and this dead tissue is spoken of as *slough*. When the slough includes the skin or mucous membrane, an *ulcer* results.

A *boil*, or *furuncle*, is an abscess in the true skin in which the infecting microorganism generally gains access by way of a sebaceous or a sweat gland, and in which there is a small slough in or beneath the true skin. A boil at the end of the nose or within the nostrils is very dangerous because, as a result of handling, incision, or other trauma, the infection enters the blood and is very easily carried by veins to the large venous channels on each side of the sphenoid bone (the cavernous sinuses) and thence spreads to the brain to form abscesses, or to the meninges to cause meningitis, or into the general circulation to result in septicæmia and possibly death.

A *carbuncle* is a boil or furuncle, in which there are multiple sloughs often coalescing in one beneath the true skin. When the pus from these sloughs finds its way to the surface an opening occurs, hence the numerous foci of pointing (called "coming to a head"). Carbuncles, wherever they are located, are very dangerous, those about the face being especially so on account of the ease with which the infection can be carried to the cavernous sinuses and thence to other parts of the body as explained in the preceding paragraph. A patient suffering from one should be brought immediately under the care of a medical officer. If a furuncle breaks, one opening results; if a carbuncle breaks, numerous openings result. Diabetes, Bright's disease, and conditions of lowered resistance brought about by living in impure air, on improper foods, etc., render an individual particularly susceptible to boils.

Boils and carbuncles should be *treated* by first placing the site of the furuncle or carbuncle at rest, and putting the patient to bed is advisable. X-ray therapy is the ideal treatment when the boil or carbuncle is in the indurated state, that is, before it has "come to a head." If X-ray therapy is not available the treatment should be: 1. Rest and avoidance of trauma; 2. Applica-

tion of heat by hot wet-dressings; 3. Relief of pain (aspirin or codeine may be given); 4. Ample fluid intake and high-caloric diet; 5. When there is definite fluctuation make a small incision to evacuate the pus. When there is a medical officer present and in the absence of X-ray facilities, early, radical, and complete excision is curative. No attempt should ever be made to treat a boil at the end of the nose or within the nostrils as over or faulty treatment may result in death. The best treatment for boils in these areas, except that ordered by a medical officer, is to leave them strictly alone; they may be looked at but not touched or handled.

SHOCK

Shock is a sudden depression of the vital functions of the body. The nervous system, which controls these vital functions, may be likened to a system of electric wiring. If too heavy an electric current is made to traverse the wires in an electric system they are likely to be burned out, or fuses blown. Similarly, if too violent impulses traverse the nerve paths in the body, there may be death from complete nonfunctioning of the nervous system, or there may result a much milder condition in which there is only partial functioning of the same. As the nervous system controls all the vital functions, so in shock they are all more or less affected. Practically any impulse traversing the nerve paths, if severe enough, may cause shock. There is *emotional shock*, where the impulses originate in the brain; *traumatic shock*, which results from a severe blow in the solar plexus or testicle, or from crushing or cutting a large nerve trunk, or from some severe injury; and *electrical shock* resulting from a heavy electric current traversing the nerve paths.

One of the main effects of too violent impulses on the nerve track is the loss of nerve control over the blood vessels, resulting in the circulating blood collecting in the veins, especially the large veins of the abdomen and depriving the brain and other parts of the body of their normal supply. More or less shock occurs from all injuries. Depending upon the stability of the nervous systems of individuals, what might cause a mild case of shock in one could cause a severe case in another.

Symptoms.

A person suffering from severe shock lies in a drowsy condition, with the limbs limp, but generally is not totally unconscious. The skin is pale and cold; the temperature is subnormal; the pulse is feeble, fluttering, and rapid, and may be irregular and barely perceptible; the respirations are shallow and sighing; the pupils are generally dilated. Great thirst is frequently an accompaniment of shock.

The sensibility of these patients often is lowered and they do not feel pain as acutely as in a normal condition. Shock may result in immediate death from heart failure, or a condition known as *reaction* may be established. This state frequently is ushered in by vomiting and is characterized by a gradual return of color to the skin and a rise of body temperature accompanied by an improvement in the heart's action and fuller and deeper respirations. After reaction is established, it is not unusual for the patient to fall into a sound sleep. In a case of mild shock, there may be nothing more than momentary paleness, weakness, and perhaps some temporary confusion of the thought. Other names applied to conditions of shock are faintness and collapse.

Concealed hæmorrhage resembles shock very closely, and always must be kept in mind in all cases of severe shock.

Treatment.

The principle underlying the treatment of shock is to bring the blood which has accumulated in the large abdominal veins back into the general circulation, to bring the proper blood supply back to the brain where the vital centers are situated and to the surface of the body, and to administer proper stimulation. If the shock is at all severe, a medical officer should be summoned immediately, but treatment must be started at once without waiting for his arrival. This may be accomplished by placing the patient in the proper position, applying warmth and administering stimulants. The position in which the shocked person is to be placed is on the back with the head low in order that the blood will tend to run into the brain. A good way to do this is to raise the foot of the bed or bench on which lying. Never raise the head of a shocked person by placing it on a pillow. The application of warmth acts as a stimulant, and also tends to bring the blood to the surface of the body. Warmth should be applied both externally and internally. Externally, warmth is applied by friction and rubbing of legs and arms briskly toward the trunk, by putting the patient on a bed in a warm room, covering with blankets and surrounding with hot-water bags, hot bricks or stones. Care must be taken that the latter are properly covered and not so hot as to burn the patient. Loss of body heat always increases shock; therefore, never remove more clothing than necessary from a shocked person, and when possible spread blankets or coats over him. Be careful, while rubbing, that the patient is not uncovered. Warmth is applied internally by hot drinks such as coffee or hot beef tea in small amounts, given frequently, and hot enemas, such as 2 pints of hot saline solution. Care must be taken not to burn the patient. Stimulants used *by mouth* are one-half teaspoonful of aromatic spirit of ammonia in one-half glass of hot water, hot coffee, hot tea, hot beef tea, or plain hot water; *hypodermically*, one-thirtieth grain of strychnine, or caffeine and sodium benzoate, 2 to 5 grains; and by *inhalation*, smelling salts or ordinary water of ammonia. Unconscious persons or those unable to swallow should never be given anything by mouth. The inhalation method is particularly useful in such cases. The most important treatment in electrical shock is artificial respiration which should be continued at least 4 hours in all cases. Shocked patients who have resumed breathing often later stop breathing, and they should be watched closely for hours after treatment.

It must be borne in mind in the treatment of all severe injuries that they are accompanied by more or less shock, and that the treatment of this shock is perhaps just as important as the treatment of the injury itself.

HÆMORRHAGE

Hæmorrhage or bleeding is the escape of blood from the heart or blood vessels due to a break in their walls. Hæmorrhage is spoken of as *arterial*, *venous*, and *capillary*, depending upon whether the escape of blood is from arteries, veins, or capillaries. In *arterial hæmorrhage* the blood is bright red in color, and escapes in jets; in *venous hæmorrhage* there is a rapid flow of dark blood, a welling up, as it were, without any spurting; and in *capillary hæmorrhage* there is a steady oozing of red blood from the entire wounded surface.

Nature's method of arresting hæmorrhage is by the clotting of blood, thus forming a plug at the point of bleeding. In the average healthy person, it takes from 3 to 5 minutes for blood to clot. There are, however, some abnormal people whose blood-clotting time is very much lengthened and the

arrest of hæmorrhage in them is very difficult. These people are spoken of as *hæmophiliacs* or *bleeders*. The clot of blood which arrests the hæmorrhage eventually organizes and permanently plugs the break in the vessel wall if it remains undisturbed. Certain factors favor and hasten the formation of a clot at the point of bleeding, such as the stopping or slowing of the blood stream at that point, and the obliteration or decrease in size of the opening in the blood vessel where the hæmorrhage is occurring. When an artery is cut or torn, the muscular wall contracts, thus decreasing the size of the opening. With the increase in loss of blood, the pressure within the circulatory system becomes lower and lower. When the hæmorrhage occurs in a confined space, the pressure of exuding blood in the surrounding tissue and on the blood-vessel wall tends to slow the current of blood and close the opening in the blood-vessel wall.

Treatment.

It is possible to assist Nature in arresting hæmorrhage by elevation of the bleeding part, thus decreasing the pressure of blood at the point of hæmorrhage with the help of gravity; by keeping the patient at complete rest so that the blood clot at the point of bleeding will not be disturbed and so that the blood pressure at that point will be as low as possible, due to the slow beating of the heart; by the application of heat or cold, which tends to cause the blood-vessel wall to contract; by the use, at the point of hæmorrhage, of styptics, medicinal substances which act to hasten blood clotting or cause contraction of blood-vessel walls; by the use of pressure to close the bleeding vessel; and by the use of ligation or torsion, also to close the bleeding vessel. *Do not give stimulants* in treatment of hæmorrhage, as they increase the blood pressure and tend to cause the dislodgment of the clot at the bleeding point.

Capillary hæmorrhage is treated by elevating the part and applying very hot or very cold water, followed by the application of uniform pressure by means of a gauze compress and bandage. In some cases it may be necessary to apply a styptic, such as epinephrine (adrenalin). Epistaxis, or nosebleed, and bleeding from a tooth socket after extraction of the tooth are examples of capillary hæmorrhage.

In epistaxis, or nosebleed, keep the patient quiet and in a sitting position; remove collar or any constriction about the neck; apply cold or ice to the back of the neck, and instruct the patient to breathe through his mouth and *not to blow his nose*. The cold application to the back of the neck causes a reflex contraction of the blood vessels of the nose. Styptics, such as a solution of alum or of epinephrine, may be snuffed up the nose. Put a roll of paper under the upper lip, between it and the gum. If bleeding still continues, the nostril must be packed by taking some soft material—cotton, linen, or lint—and gently forcing it well back into the nose. If bleeding continues, the person is probably a hæmophiliac, and a medical officer should be summoned. In severe bleeding from a tooth socket, pack the cavity tightly with cotton or linen saturated with some styptic, such as epinephrine or alum; then have the jaws closed tightly and apply a Barton or a four-tailed bandage.

In venous hæmorrhage, elevate the part (so little velocity is there in the venous current that often this procedure alone will stop the bleeding). If bleeding continues, make pressure directly over the wound with a sterile compress. If venous hæmorrhage is from an extremity, the limb should be bandaged from toes or fingers up to the bleeding point in addition to pressure over the point. A common location for severe venous hæmorrhage is from varicose veins of the legs.

In the treatment of arterial hæmorrhage prompt and decisive measures are required, particularly in the case of hæmorrhage from the large arteries.

Hæmorrhage from the femoral artery may result fatally in a few minutes. The main reliance must be on the more strenuous methods, viz., *pressure*, *ligation*, and *torsion*. Ligation is the tying off of an artery with sutures, and torsion consists in twisting the end of the vessel with forceps or an artery clamp for five or six rotations; these two methods should be left to a medical officer ordinarily and should not be undertaken by the first-aid man unless absolutely necessary. This leaves the pressure methods available as the main reliance of the first-aid man.

Pressure to control arterial hæmorrhage always must be applied at some point between the bleeding point and the heart, preferably at a point where the bleeding artery can be compressed against bone. Pressure may be applied by means of the fingers, spoken of as digital pressure, or by means of compresses or by the application of a tourniquet. *Digital pressure* can serve only for a short time, as the fingers soon become tired. This pressure should be made with the thumbs and should be firm enough to arrest the bleeding; it should be made over the clothes, as too much time may be lost in removing them. One will know that he is pressing on the right place by feeling the artery beating beneath the thumbs and by the arrest of the bleeding; if the artery cannot be found, make pressure directly over the bleeding point. As pressure with the thumb soon becomes tiresome, an assistant should relieve the first-aid man who should prepare to apply other pressure methods, either tourniquet or compress. A *tourniquet* is a constricting band, and there are various kinds. The principle of all tourniquets is a pad over the artery to bring the pressure on the artery and take it off the veins, a band around the limb and over the pad, and some means of tightening the band. There are a number of special tourniquets, but as they are not usually at hand, a suitable one must be improvised. An excellent one may be improvised with a rubber bandage, a number of turns being made about the limb and the rolled portion of the bandage then placed under the last turn in such a position as to press directly on the artery. The most common improvised tourniquet is the so-called Spanish windlass, in which arrangement any rounded, smooth, hard object, such as a stone, a cork, or a roller bandage, is used as a compress; for the band, a handkerchief, a suspender, a waistbelt, a bandage, or anything of the sort may be used. To tighten the band, a stick, bayonet, or scabbard, or something of the kind, is passed under the band and twisted until the bleeding ceases, and the ends are then tied to the limb to prevent the band from becoming untwisted. *Pressure by means of compresses* may be effected as follows: A number of small pieces of gauze or linen, or a tampon, previously rendered sterile or antiseptic, are placed in the wound, one on top of the other, until there are a sufficient number to compress the bleeding vessel; a bandage then is applied firmly to hold them in place and exert the necessary pressure. Sometimes more effective pressure can be obtained by employing a compress of gradually increasing size (cone-shaped with apex nearest the vessel). Compresses may be applied in the same manner along the course of the vessel.

The dangers in the use of tourniquets and constricting bands for the control of hæmorrhage are that if applied tight enough to stop arterial hæmorrhage they cause pain and swelling of the limb, and if left long enough may cause gangrene or death of the part below the constriction. Therefore they should be watched and loosened from time to time, at about half-hour intervals. If on loosening the tourniquet the bleeding starts again, tighten it up; if there is no appearance of bleeding leave the loose tourniquet in place with an attendant instructed to tighten it should the bleeding recur. The tourniquet method is the most effective in the majority of cases, but due to the attendant after-

dangers, in all but the most severe hæmorrhages of the larger arteries arrest of the bleeding by elevation of the part and the compress method should be tried first. All possible care should be taken not to infect the tissue with dirty applications, but sometimes in tremendous hæmorrhages all these precautions have to be laid aside to save the person's life. In all cases of severe hæmorrhage the measures mentioned are only preliminary to arrival of a surgeon.

With great loss of blood the patient suffers severe collapse and must be given treatment for shock, except that stimulants must not be given unless the blood vessel has been safely secured against recurrence of the hæmorrhage. After severe hæmorrhage tremendous thirst generally is complained of and should be relieved with frequent, small drinks. This may be termed the *constitutional treatment* of hæmorrhage.

The specific treatment for hæmorrhage from certain parts of the body is described immediately following:

Bleeding from the scalp.—Apply pressure over wound with compress and bandage.

Arterial bleeding from the lips.—Grasp lips between thumb and fingers on each side of wound, as the arteries to the lips come from both sides.

Arterial hæmorrhage in other parts of the face.—Apply digital pressure on the facial artery against the lower jaw midway between the ear and chin where its pulsation can be felt (fig. 47).

Arterial hæmorrhage from neck.—Apply digital pressure with the thumb on the carotid artery against the vertebrae. (A tourniquet cannot be used in this location.) (Fig. 47.)

Arterial hæmorrhage from the armpit.—Place a compress in the armpit and bind the arm tightly to the side. If this fails, compress the subclavian artery behind the clavicle (collar bone) between the thumb and first rib, or compress it with a key, the handle of which has been padded (fig. 47).

Arterial hæmorrhage of arm, forearm, or hand.—Apply digital pressure on the

brachial artery on the inner side of the biceps, and then apply a tourniquet a little higher up. In case of arterial hæmorrhage of the forearm, a pad may be placed in the bend of the elbow and the forearm forcibly flexed on the arm. In case the hæmorrhage is from the palm, either of these two methods may be used, or a large firm compress may be placed in the hand with the fingers very tightly closed over it and bandaged in place (fig. 47).

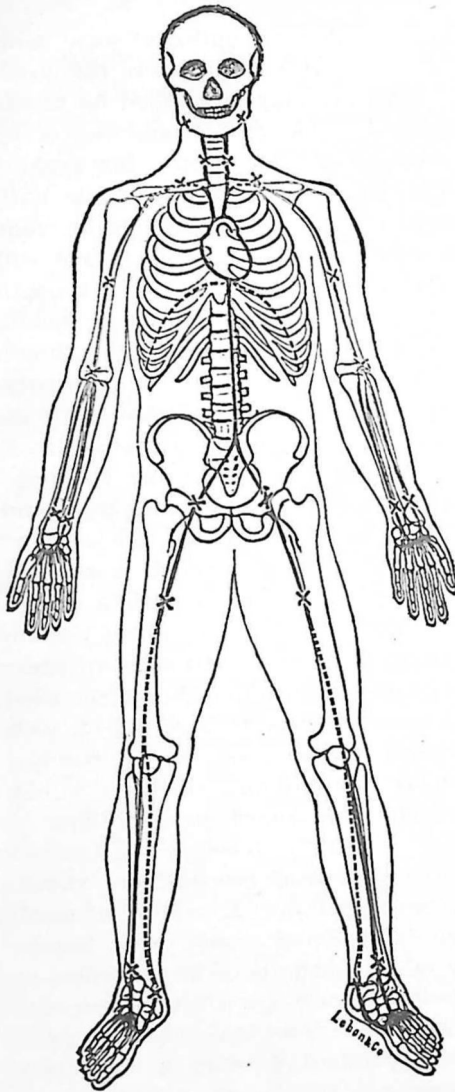


FIGURE 47.—Skeleton with black and dotted lines showing the course of the arteries and x indicating the pressure points. (Mason.)

Arterial hæmorrhage from the thigh, leg, or foot.—Compress the femoral artery against the head of the femur just below the middle of the groin with both thumbs, then apply a tourniquet to replace the thumbs. In case the hæmorrhage is in the leg or foot, another method is to put a pad behind the knee, flex the leg forcibly, and tie it in that position. With arterial hæmorrhage in the foot, in place of these two methods, compression can be made, when the bleeding point is on the dorsal surface, on the anterior tibial artery at the instep; and, when the bleeding is on the plantar surface, on the posterior tibial artery behind the internal malleolus (fig. 47).

Hæmoptysis is hæmorrhage from the lungs. It may result from wounds of the lung but more often is due to disease of these organs. The patient usually is seized by a fit of coughing and spits up bright red, frothy blood. Unfortunately, nothing can be done to arrest the hæmorrhage quickly. The treatment consists of immediately summoning a medical officer, and in the meantime keeping the patient absolutely quiet, at rest, and giving ice by mouth. Listen over the chest, and where rattling is heard, apply an ice bag. Avoid all stimulants.

Hæmorrhage from the stomach.—The vomited blood is usually dark in color and may be mixed with food. It always should be remembered that vomited blood does not necessarily indicate hæmorrhage from the stomach; blood coming from the back of the nose and throat may have been swallowed, and inquiry should be made to find out if there has been any nosebleed. The blood from pulmonary hæmorrhage contains air and is frothy while blood from the stomach is not. The treatment is the same as for hæmorrhage from the lungs, except that the ice bag is applied over the upper abdomen.

Internal hæmorrhage, also called concealed hæmorrhage, may occur in any of the cavities and from any of the organs of the body as the result of injuries or disease. It is a condition which may be very difficult to diagnose, as the bleeding cannot be seen. Frequently the only symptoms are those of shock. In such cases summon a medical officer immediately; in the meantime, place the patient flat on his back and keep him absolutely quiet. Opiates are indicated in hæmorrhage of this nature, their purpose being to produce quietness.

Primary hæmorrhage occurs immediately on receipt of a wound or injury. After the arrest of primary hæmorrhage, a recurrence may occur, caused by dislodgement of the clot, the slipping of a ligature, or from the opening of a blood vessel by separation of a slough. Recurrence of hæmorrhage within 24 hours is spoken of as consecutive or intermediate, and recurrence after that time is spoken of as secondary hæmorrhage.

WOUNDS

A wound is defined as the forcible solution of continuity of any of the tissues of the body. The principal kinds of wounds are: *Clean* or *aseptic wounds*; *infected* or *septic wounds*; and *poisoned wounds*. A clean or aseptic wound is one to which no germs have gained access; the best example of it being a wound made by the surgeon's knife. An infected or septic wound is one in which there have been introduced pus-producing organisms (*see inflammation*), or such organisms as produce tetanus or lockjaw, gas gangrene, or hydrophobia. A poisoned wound is one in which some nonliving poison, as distinguished from bacteria or microorganisms, has been introduced by the agent causing the wound; e. g., bites of insects, scorpions, snakes, etc.

An incised wound is one made by a sharp cutting instrument, the class of wounds commonly known as cuts. A lacerated wound is the result of the tear-

ing of the skin and underlying tissues by blunt instruments or machinery and presents ragged edges, which do not retract much, and which, as a rule, consist of masses of torn tissues, frequently with dirt ground into them. A contused wound is one in which the division of tissue is accompanied by more or less severe crushing. A punctured wound is deep and narrow; e. g., stabs are punctured wounds. Crushed wounds are more serious than they first appear, due to the fact that the dead tissues are an excellent culture medium for the growth of microorganisms of infective inflammation, resulting sometimes not only in loss of the part but also in general infection of the body, that is, septicæmia or blood poisoning. The term gunshot wound is applied to any wound inflicted by the missile of a weapon of warfare, such as by rifles, pistols, cannon, etc.

When the skin and underlying tissues are divided, blood vessels, generally capillaries, also are divided, and there is more or less bleeding from the cut surfaces of the tissue, a clot forming between the cut surfaces. Young connective-tissue cells and capillary buds grow into this clot from the edges of the wound, replacing the blood elements. These young connective-tissue cells and the young capillaries form what is known as granulation tissue or "proud flesh." Later the young connective-tissue cells and capillary buds develop into the mature connective tissue, and the epithelium of the skin grows over it from the edges of the wound. When the cut surfaces are so close together that there is very little granulation tissue required to heal the wound, healing is said to be by *first intention*; when the wound is gaping and considerable granulation tissue is required, healing is said to be by *second intention*. Pus infection causes gaping of wounds, therefore in wounds infected with pus bacteria, healing is by second intention. Connective tissue filling in a gaping wound forms the so-called "scar."

Unless cut ends of tendons are brought together, the two ends will be so retracted, and there will be so much connective tissue formed between them in the healing of the wound, that the function of the tendon will be lost. Unless the cut ends of a nerve trunk are brought together, the function of that nerve will be lost forever. Nerve fibrils making up a nerve trunk regenerate centrifugally, and if the pathway for this regeneration is blocked by a wall of connective tissue, these fibrils can never reach the part they are supposed to innervate.

The local factors preventing and delaying the healing of wounds are: Infection with pus bacteria; the presence in the wound of foreign bodies, such as dirt, bits of clothing, etc.; and a lowered vitality of the edges of the wound due to crushing and tearing of the tissues, etc. General and constitutional factors also prevent and delay healing, among these factors being poor circulation of blood, diabetes, Bright's disease and syphilis.

General principles underlying the treatment of wounds.

Stop hæmorrhage and treat shock; so handle the wound as not to introduce fresh bacteria of infection; remove foreign bodies, such as dirt, bits of clothing, etc., from the wound; if infective bacteria already have been introduced into the wound, take measures to eliminate them or prevent their development. If the wound is an aseptic one, bring the edges together so that it can heal by first intention; if the wound is an infected one, keep the wound open and furnish drainage (*see inflammation*); if the wound is a poisoned one, neutralize the poison in it and prevent its entrance into the general circulation; treat any constitutional condition which may delay or prevent healing.

There are two main types of bacteria commonly causing infection in wounds: *Aërobic* and *anaërobic*. The former are bacteria that live and multiply in the

presence of air, while the latter are bacteria that live and multiply in the *absence* of air. The principal bacteria which cause infective inflammation and *septicæmia* or blood poisoning are *Streptococci*, some varieties of which are hæmolytic (destroy red blood cells), *Staphylococci*, and *Pseudomonas aëruginosa* (Bacillus pyocyaneus), frequently called the bacillus of green or blue pus; these are aërobic. There are several anaërobic bacteria which are frequently present in wounds. They commonly inhabit the intestinal tracts of man and other animals and are often found in soils which have been fertilized with animal manure. Among those occurring in wounds, especially in war wounds, are the *Clostridium welchii*, commonly termed the "gas bacillus" and causing gas gangrene, the *Clostridium sporogenes*, the *Clostridium adematians*, and the *Clostridium histolyticum*. The *Clostridium tetani*, or tetanus bacillus, is common in the fæces of horses and cattle and consequently is found with great frequency in soils fertilized with manure from those animals. It is often associated with *Clostridium welchii* in wounds and it produces a toxin which is one of the most powerful poisons known, being said to be 20 times as poisonous as dried cobra venom. The filtrable virus causing rabies, often termed hydrophobia (fear of water, and a common symptom of the disease) is nonpathogenic and perhaps anaërobic in character.

Inasmuch as the bacteria of pus infection are present everywhere, any wound is likely to be infected with them. However, contused and lacerated wounds are most likely to suffer from infective inflammation, owing to the lowered vitality of the tissues. The bacteria of tetanus or lockjaw and of gas gangrene are found in exceptional numbers in the intestinal contents of herbivorous animals, such as horses and cattle, and, for that reason, wounds inflicted by objects which have been contaminated by manure or by heavily fertilized soil are most liable to have introduced into them the bacteria of these diseases. In badly lacerated wounds and in punctured wounds there is great likelihood of absence of air due to the flapping back of the torn tissues after infliction of the wound, and for this reason these types of wounds afford a very favorable environment for the development of tetanus or gas gangrene. Tetanus, or lockjaw, frequently occurs after stepping on a nail near a barn or a stable, the nail previously having become infected with *Clostridium tetani* from the excretions of horses or cattle. The virus of rabies is found in the saliva of a rabid animal and is introduced by its bite. These bites generally are either lacerated or punctured wounds, with their associated anaërobic conditions.

A wound dressing consists of everything used to cover or dress a wound. The pad which is put directly over the wound is called a *compress*. In ordinary emergency treatment a wound dressing consists of a compress with bandage to hold it on. A dressing may be either dry or wet, aseptic or antiseptic. An *aseptic dressing* is one which is sterile, that is, one with no bacteria on it. An *antiseptic dressing* is one which, in addition to being sterile, contains some substance for killing bacteria. A *wet dressing* generally is an antiseptic dressing. A *wet antiseptic dressing* generally is used in wounds where infective inflammation is going on, whereas a *dry sterile dressing* is used to cover a recent wound which is considered to be free from infection. The purpose of a wound dressing is to stop hæmorrhage, to prevent introduction of bacteria, and to prevent further injury to the wound.

The Navy supplies a first-aid packet which is a hermetically sealed tin can containing a dry sterile dressing. This is excellent for a small wound. The directions for its use are contained in the packet. For large wounds, sick bays aboard ship are furnished with large and small shell-wound dressings. All these dressings consist of a sterile gauze compress with bandage attached. Any

piece of cloth, such as gauze, cotton, linen, muslin, or a handkerchief, is suitable for a compress in case of emergency, *provided it is rendered sterile*, and anything that can be used for bandaging is suitable as a bandage. The most vital point about material used as the compress of a wound dressing is that, before it is applied to a wound, it should be rendered sterile.

The part of the dressing which is to come in contact with the wound must be kept absolutely sterile; i. e., it must not be touched with any part of the body or anything else except sterile instruments before its application to the wound. In an emergency, material to be used in a wound dressing may be sterilized by boiling it for 10 minutes.

When a patient can be brought under the care of a medical officer in the very near future, the procedure necessary in the first-aid treatment in the case of ordinary wounds is: Stop the hæmorrhage, treat the shock, and apply a sterile dressing to the wound. If a surgeon is not available, the wound must be further treated as described hereafter.

In treating a freshly made wound suspected of being contaminated (all wounds should be suspected of contamination by infective organisms unless made under strictly aseptic precautions) the following procedure is recommended: Cleanse one's own hands as thoroughly as possible by a thorough scrubbing with soap and hot water, followed, if possible, by immersion of the hands in hot 1-2,000 bichloride of mercury solution and then in 70 per cent alcohol. Sterilize all instruments to be used in removing foreign bodies such as dirt, glass, splinters, etc., or for shaving the skin about the wound. If there is much bleeding, arrest the hæmorrhage. If there is much hair about the part, remove it by cutting or shaving for a distance of several inches from the cut edges. If there is much grease in and about the wound, remove it with turpentine or gasoline. Remove all foreign particles with sterile forceps. Clean the skin about the wound with a sterile damp cloth, and, while doing this, protect the wound with a piece of sterile gauze. Dry the wound and skin about it with sterile dry cloth or cotton. Apply tincture of iodine to all parts of the wound and to the skin about the wound for a distance of about one-half inch beyond the wound edges. After the skin has been well dried, the wound edges are brought together and a dry wound dressing applied.

There is no substance which should be used by the first-aid man to wash a wound. In the first place, he only washes in more dirt than he washes out, and, secondly, ordinary water is dangerous, as it contains many bacteria; this applies equally to soap and water. Strong antiseptics such as bichloride of mercury or phenol (carbolic acid) will destroy the cells of the body which dispose of the pus bacteria before they kill the latter, and should never be used except in certain wounds described later. Peroxide of hydrogen is not strong enough to kill all bacteria, and in a large or deep wound it washes some of these bacteria to uninfected parts which then become infected. Therefore, use none of these preparations in a wound, which should be covered with a sterile cloth, while cleaning the skin around the wound as described before. If, however, there is much greasy dirt rubbed into the wound, the latter should be gently swabbed out with sterile gauze or a cotton applicator, saturated with benzine or gasoline, and foreign bodies picked out with sterile forceps. *Tincture of iodine is the only substance to be used in an ordinary fresh wound by the first-aid man, aside from benzine and gasoline to cut grease, if present.* The tincture of iodine should be used within two hours after the wound is inflicted, as after that time it is probably valueless. Tincture of iodine is best applied with a camel's-hair brush, but a bit of cotton on a stick answers the purpose very well; the brush or cotton need not be sterilized, as the iodine accomplishes this. The tincture

of iodine may be poured into a wound. Iodine can be used in wounds practically anywhere in the body except in or near the eyes, *where it must never be used.* It must not be used in conjunction with bichloride of mercury.

Attempts to bring the wound edges together should not be made when the patient can be brought under the care of a surgeon in the very near future, but if hours or days must elapse before the service of a medical officer can be obtained, coaptation should be done in cases requiring it. The edges of a wound should not be brought together before foreign bodies and dirt have been removed and wound edges cleaned. Wounds in which infective inflammation is going on should be left open and allowed to drain. The two methods by which coaptation may be accomplished are by means of *sutures* and by means of *adhesive strips*. The former is preferable, as by the latter method bacteria of infective inflammation most probably will be introduced. As a rule, the edges of large deep wounds should not be too tightly apposed. Some chance of escape should be left for the serum and blood which are sure to be present, that is, means for drainage should be supplied. This may be done by the use of small pieces of sterile rubber tubing, strands of catgut or silkworm gut, or a narrow strip of gauze which has been sterilized by boiling. These drains should be placed in the lower angle of the wound. Wounds which are dirty and look badly should be left wide open.

The materials ordinarily used for sutures are *plain catgut, chromicized catgut, kangaroo tendon, silkworm gut, silk, or linen*; sometimes *horsehair* also is used. *Suture material*, also called *ligatures*, is divided into absorbable and nonabsorbable ligatures. *Absorbable ligatures* are those which can be left in a wound, inasmuch as the tissues absorb them, and included in this class are catgut and kangaroo tendon. Silkworm gut, silk, linen, and horsehair are *non-absorbable ligatures* and must be removed after 6 or 7 days. *Chromicized catgut* is catgut which has been so treated that it is not as quickly absorbed as plain catgut. Catgut is the ligature to be preferred in the suturing of wounds. *Needles* used in the suturing of wounds are: *Curved, straight, and round, or cutting.* Where the skin must be pierced, the curved cutting needle is preferable. The main point about all suture material to be used in a wound is that it must be sterile. In case of emergency, an ordinary sewing needle with cotton or silk thread, well sterilized by boiling, may be used. This suture is nonabsorbable and must be removed after 6 or 7 days. With the operator's hands, and also the wound, well cleansed, the needle, threaded with the suture, is passed through the skin about one-eighth of an inch from the cut edge and on out through the opposite side at a corresponding point. The suture then is tied, and the ends cut, leaving about one-quarter of an inch remaining; care should be taken in tying the suture to use but little tension, sufficient only to bring the cut edges in accurate approximation. The remaining stitches are inserted in the same manner at a distance of from one-quarter to one-half of an inch apart until the wound is closed. When a tendon or large nerve has been cut, the ends must be brought together and sutured with catgut before the wound is closed. Suturing of tendons and nerves should be done by medical officers.

The manner in which a wound showing evidence of infective inflammation is treated, is: Elevate the part; put it at rest; remove foreign bodies, if present; remove enough sutures, if present, to obtain good drainage; insert drain; apply a wet antiseptic dressing; and treat the constitutional symptoms.

Wet antiseptic dressings generally are made up of a layer of sterile gauze, saturated with an antiseptic solution, to be applied directly on the wound. A layer of sterile cotton is then applied, some impervious material such as oiled

silk or waxed paper put over the dressing in order to retain the moisture, and a bandage over all. The dressing should be kept wet with the antiseptic solution, either by frequent changing or by having perforated rubber tubes between the gauze and cotton through which the dressing can be periodically moistened with the antiseptic solution. The antiseptic solutions usually employed in wet dressings are: Bichloride of mercury solution 1-5,000; saturated solution of boric acid; and Dakin's solution. *Bichloride of mercury solution* should not be applied on a wound freshly painted with tincture of iodine, as a corrosive iodide of mercury is formed which causes a very severe inflammation followed by ulceration.

If the symptoms of an infected wound are severe, put the patient to bed, clear out the bowels with a brisk purgative, and apply an ice cap to the head to reduce the fever.

The measures taken in fresh wounds suspected of being infected with tetanus or gas gangrene are: The wound is cleaned and treated as has been described, and kept freely open for a time in order that anaërobic conditions may not exist for the growth of these bacteria. As a further precautionary measure, tetanus antitoxin is given. A punctured wound suspected of being infected is frequently cauterized and a dry wound dressing applied.

Symptoms and treatment of special types of wounds.

Wounds inflicted by an animal suspected of being rabid or of having rabies are to be treated in the following manner: Thoroughly cauterize the wound with fuming nitric acid and neutralize with sodium hydrate solution, 1 per cent, or sodium bicarbonate solution, 10 per cent. The Pasteur treatment may be given later. In the absence of fuming nitric acid, a red-hot needle may be used to cauterize the wound. *Do not use silver nitrate or phenol for cauterizing these wounds* as they coagulate the albumin in the tissues thereby producing the anaërobic conditions necessary for infective organisms and retarding their destruction. Apply a dry wound dressing.

Poisoned wounds due to causes other than to bites of poisonous snakes include ordinary insect bites, such as those produced by mosquitoes, fleas, ants and bees. These bites require but little treatment. Sometimes the sting of a bee is broken off and remains in the skin. In treating these cases always search for the sting and remove it if it be present. As the poison of insects is composed chiefly of an acid, the local application of some alkali should be employed; either water of ammonia or a solution of washing soda affords great relief. Bites of the more poisonous spiders, centipedes, tarantulas, and scorpions require prompt treatment. Tie a ligature or tourniquet about the injured part between the wound and the heart to prevent the absorption into the general circulation; enlarge the bite by making an incision at its site, suck out the wound to produce bleeding, and apply crystals of potassium permanganate or tincture of iodine. If there be abrasions or open lesions in the mouth, it is not advisable to suck the wound. Release the tourniquet after a time to permit temporary restoration of circulation, replace it and repeat this process every half hour as long as may be necessary. Apply a wound dressing to the wound and treat shock which sometimes occurs in these cases.

Poisonous snakes are classified into *viperine snakes* and *colubrine snakes*. To the viperine family belong the *rattlesnake*, the *copperhead*, the *water moccasin*, and the *viper*; to the colubrines belong the *cobra* and the *coral snake*. In poisonous snakes the teeth are arranged in two rows, with a fang on each side, outside the teeth near the point of the jaw. Nonpoisonous snakes have four rows of teeth without fangs (fig. 48). The imprint of the wound often

will tell whether a person has been bitten by a poisonous or a nonpoisonous snake. The venom of different poisonous snakes differs in its action. The poisonous constituents are *neurotoxin*, a nerve poison, and *hæmorrhagin*, which injures the lining of the blood vessels so that an escape of blood occurs into the surrounding tissues; a third constituent is *hæmolysin*, which destroys red blood cells. The venom of colubrine snakes is made up principally of neurotoxin and that of viperine snakes of hæmorrhagin. In *colubrine poisoning*, the local symptoms are not marked, though there are at times severe pain and some

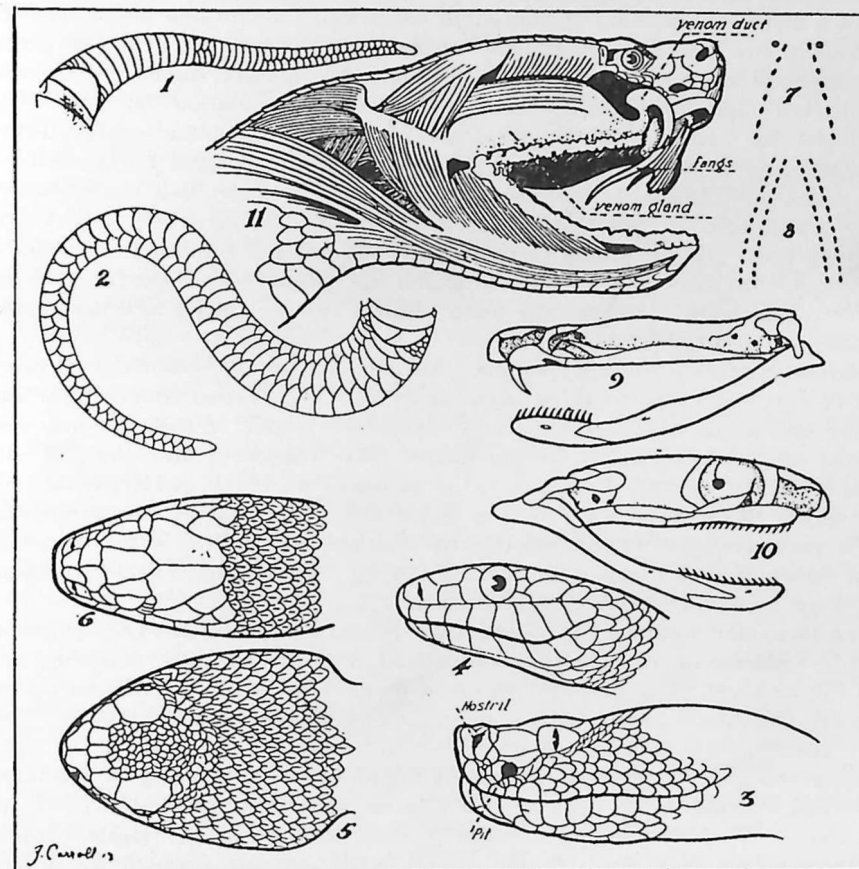


FIGURE 48.—1, Single row of scales, posterior to vent (poisonous snake—water moccasin); 2, double row of scales of harmless snake (*Natrix*); 3, side view of head of pit viper; 4, side view of head of harmless snake; 5, dorsal view of pit viper; 6, dorsal view of harmless snake; 7 and 9, bite puncture and skull of *Elaps*; 8 and 10, the same of harmless snake; 11, poison apparatus of rattlesnake. (Stitt.)

tenderness, swelling, and discoloration at the site of the bite; then in 1½ to 2½ hours the patient begins to feel tired and drowsy, there often being some nausea and vomiting; paralysis sets in, generally affecting the extremities first and then becoming more generalized, finally affecting respiration, so that the patient's breathing becomes slow and shallow and finally ceases; convulsions also may be present. In *viperine poisoning* there is pain at the seat of the bite, which soon becomes excruciating, with rapid swelling and discoloration; there is at the same time a feeling of nausea and faintness, while a sense of depression takes hold of the individual; the pulse becomes rapid and feeble.

and the breathing is labored; in fatal cases, death may occur in 24 to 48 hours. The severity of the symptoms and final outcome depend upon the amount of venom injected and absorbed into the general circulation, which in a large measure depends on the size of the snake.

The treatment of wounds inflicted by a poisonous snake follows: If the wound is in an extremity, tie a bandage or handkerchief tightly about the single-bone part of the limb between the wound and the heart; incise the wound freely and suck out as much of the poison as possible. If there be abrasions or open lesions in the mouth it is not advisable to suck the wound. With a hypodermic syringe, inject a 2-per cent solution of potassium permanganate into and about the bite to destroy any poison which is left. Meanwhile, give stimulants in the shape of coffee and strychnine, one-thirtieth grain. The ligature should be loosened about every half hour to allow restoration of the circulation, but should be tightened up immediately if symptoms of general poisoning occur. There are antivenin serums available for the treatment of poisoning by snake bite, one which neutralizes neurotoxin and another which neutralizes hæmorrhagin. They are injected hypodermically or intravenously and are very effective if properly used; that is, serum to combat the venom of a colubrine snake must be used against that type of snake bite, and the specific serum for the viperine snake venom used to combat the toxin of that type of snake, in order to get results.

Gunshot wounds inflicted by bullets.—Always look for the wounds of entrance and of exit and apply a sterile dressing to each. Concealed hæmorrhage and injury to internal organs are the most dangerous results of these wounds and depend on the course taken by the bullet. The wounds of entrance and exit caused by high-velocity bullets may be so small as to be hardly visible, or the wound of entrance may be very small and the wound of exit large, due to the explosive effect of the bullet on the tissues. *Never probe a bullet wound*, as a bullet is very likely to be sterile, and by probing one is almost sure to introduce germs of infective inflammation.

Symptoms and treatment of penetrating wounds of the chest.—The symptoms are the presence of air bubbles in the wound, difficult breathing, coughing, and spitting of blood. The first-aid treatment consists in laying the patient on the injured side, firmly bandaging the chest, summoning medical aid, and the general treatment for wounds.

Symptoms and treatment of wounds of the abdomen with injury to the intestines and stomach.—The signs of injury to the intestines are the escape of gas or fæces through the wound and the passage of blood in the stools. Injury of the stomach may result in the escape of its contents through the wound and the presence of bloody vomitus. Keep the patient absolutely quiet and place under the care of a surgeon as soon as possible, as every moment's delay in surgical treatment lowers his chance of recovery. With a large abdominal wound from which more or less of the abdominal contents escape, place a sterile cloth over the wound and the extruded intestines; bandage in place and keep the dressing wet with sterile physiological salt solution until the patient can be placed under the care of a surgeon.

Treatment for wounds of the eye.—Remove the foreign body, if present, as described under removal of foreign bodies. Never use tincture of iodine or other strong antiseptics in the eye. Boric acid solution or an organic silver preparation (silvol or argyrol) are the only antiseptics to be used in the eye. All eye wounds should be brought under the care of a medical officer as soon as possible. In the meantime cover both eyes with absorbent cotton or soft cloths so as to keep the eyelids still, and hold the dressing in place with bandages

around the head. Be careful not to put on these bandages so tightly that they will cause pressure on the eyeball. In case some time must elapse before the services of a medical official can be obtained, the dressing should be kept wet with cool saturated solution of boric acid, and if secretions are present, the eye should be irrigated at frequent intervals with warm saturated solution of boric acid. In lifting the eyelid do not press on the lid, but lift the upper lid by traction on the region above it; this prevents scratching of the cornea by pressure.

CONTUSIONS, STRAINS, AND SPRAINS

A contusion, or as it is commonly termed, a *bruise*, is a crushing and tearing of the tissues, usually without a break in the skin. It is characterized by swelling, tenderness, and discoloration, due to the rupture of blood vessels in the neighborhood of the injury. At first the discoloration is red, then blue or black, and finally turns yellow or green, commonly called black and blue spots. The change in color is due to the chemical change in the coloring matter of the blood hæmoglobin. The rapidity in the formation of the swelling and its size depends on the number and size of the blood vessels ruptured. Contusions vary in extent from an ordinary black and blue spot to the almost complete pulpification of a limb with laceration of blood vessels and nerves such as sometimes occurs in railway or other accidents. A "black eye" is an example of a contusion.

Slight contusions as a rule require no treatment. With severe contusions there is more or less shock which must be treated. For the contusion itself, the treatment is to stop the subcutaneous hæmorrhage; this can be done by rest and elevation of the part; by very hot or cold applications; and if the injury is in a limb, firm, even pressure of a bandage may be effective. Later, when the bleeding has ceased, the absorption of the extravasated blood may be hastened by hot fomentations and massage. In the case of severe contusions and in contusions in elderly people, hot water is much better than cold, as the latter tends to lower the vitality of injured tissue.

A strain is the overstretching of a muscle or tendon with an attendant rupture of the muscle or tendon fibers. In severe strains, small blood vessels often are ruptured, resulting in the escape of blood into the muscles in the same way that, in the case of a bruise, blood escapes beneath the skin. It is generally the result of violent exertion or sudden unexpected movement. The symptoms are pain in the affected muscle, stiffness, lameness, and more or less swelling. If complete rupture occurs, there will be loss of power of the affected muscle and on examination there will be found a distinct gap with considerable swelling above it, due to retraction of the muscle fibers.

For slight strain, the treatment consists of strapping with adhesive plaster or bandages, which, with rest, gives the most comfort. After 2 or 3 days, graduated massage may be given. If rupture occurs, in the absence of surgical assistance immobilize the part by splints or bandages and place the part in such a position that the muscles are relaxed, thus allowing the torn fibers to come together.

A sprain is an injury to a joint due to wrenching or twisting its ligaments and adjacent soft parts. There usually is a momentary dislocation and automatic reduction of the joint affected. There also may be injury to cartilages, and even portions of bone to which the ligaments are attached may be torn away. Accompanying these injuries there is more or less escape of blood into the joint itself and surrounding tissues, resulting in severe pain and marked swelling of the injured part. Later, discoloration develops at the site

of injury. Sprains of the ankle and wrist are the most common. Frequently it is difficult to determine whether or not a sprain is not complicated with fracture. An X-ray examination is always advisable to determine the presence of a fracture in these cases.

In the treatment of sprains all severe cases should be brought under the care of a medical officer, particularly as the condition may be complicated with fracture. Elevate the joint and apply very hot or very cold water for one-half

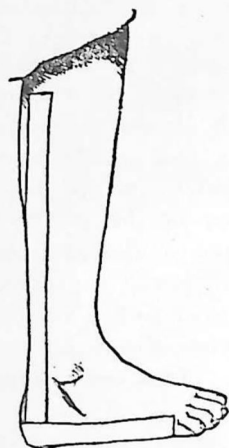


FIGURE 49.—Strapping of ankle; first step. (Owen.)

an hour to an hour to stop the subcutaneous hæmorrhage; then apply a tight bandage and keep the joint at rest in order to give the torn ligaments and tissues a chance to heal and the effused blood to be absorbed. Treatment of a sprain of the ankle by immediate strapping of the joint and allowing the patient to walk about may be practiced in the less severe uncomplicated cases. For this purpose strips of adhesive plaster 1 to 1½ inches wide and about 18 inches long should be obtained. A strip is started well behind at the junction of the lower and middle third of the leg of the injured

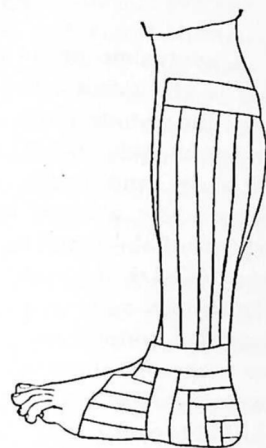


FIGURE 50.—Strapping of ankle; completed. (Owen.)

side, and is carried down under the heel with considerable tension, across the sole and up the other side of the joint. (Fig. 49.) The middle of another strip is applied to the point of the heel and the two ends are carried forward over the foot, but not far enough to meet. Leg strips and foot strips alternate, interlacing with each other and overlapping about one-third of the previous strip each time until the ankle joint is covered. (Fig. 50.) Strapping in this manner furnishes pressure and at the same time fixes the joint and gives support to the torn ligaments. If any individual is unable to walk immediately after injury to the ankle, the injury should be considered as a fracture until proved otherwise.

DISLOCATIONS

A dislocation is a slipping away from each other of the bones which form a joint, resulting usually in a locking of the bones in a new position. Necessarily the dislocation is attended with tearing of the ligaments, and often with rupture of the muscular attachments as well, except in a joint which, on account of frequent prior dislocations, has had its ligaments so stretched that not only is dislocation easy but no tearing of the ligaments results. As a result of the tearing of structure about the joint, there is also rupturing of the blood vessels, with consequent swelling and discoloration.

Dislocations must be differentiated from fractures and sprains. In all three conditions there may be swelling and pain in the neighborhood of a joint. In fracture there is an unnatural movement of the bone between the joints instead of immobility at the joints as in dislocations, and the movement is attended with a grating sound and sensation; the deformity is in the bone between the joints in fractures, whereas the deformity is at the joint in dislocations. In dislocations there is immobility at the joint and between

the joints, and the head of the dislocated bone may be felt in an abnormal position. In sprains there is absence of any of the symptoms of dislocation except swelling and pain. As a rule sprains are momentary dislocations in which the head of the bone has slipped back into place. All cases, if facilities are available, should be X-rayed before and after treatment.

The treatment consists in restoring the bones to their normal positions, spoken of as "reducing the dislocation," and then so confining the parts that a recurrence of the trouble will be improbable. The joint should be immobilized until the rents in the ligaments have healed. While some dislocations slip easily back into place, to properly reduce the majority requires considerable knowledge, skill, and either local or general anæsthesia. Without careful manipulation blood vessels and nerves not only may be injured but a simple dislocation may become complicated with fracture. In view of this, if surgical aid can be obtained within a day or two, do not attempt to reduce a dislocation, except perhaps in case of the jaw and finger; loosen the clothing about the injured part and support it as comfortably as possible in the new position, or if the patient must be moved, support the limb in a sling or by splints and bandages, and summon surgical assistance. If, however, surgical assistance cannot be had for some time, 3 or 4 days, careful attempts should be made to reduce the dislocation, as the head of the bones concerned most probably will become bound by connective tissue formation and then reduction will become next to impossible without an operation. Shock is often present with major dislocations and should be treated.

Treatment of certain dislocations.

Dislocation of the jaw.—In this condition the patient cannot speak or close his jaws. The dislocation is due generally to a blow upon the mouth when open or by yawning or laughing. This dislocation usually is reduced without much difficulty, but there is great danger of the thumbs of the operator being bitten. Wrap the thumbs well with a handkerchief or bandage, stand in front of the patient, and while pressing with the thumbs in the mouth just back of the last lower molars, at the same time lift up the chin with the fingers. The jaw usually will snap at once into place, and the thumbs must be quickly withdrawn to prevent them from being bitten. After reduction, no further treatment is indicated, but the patient should be advised to open the mouth no oftener than necessary.



FIGURE 51.—Backward dislocation of finger; reduction by extension. (Hamilton.)

Dislocation of finger joints.—With a dislocated finger joint, pull on the dislocated end, at the same time bending it backward if the dislocation is forward, or forward if the dislocation is backward, and pushing the joint into place; strap or splint the finger (fig. 51).

Dislocation of the shoulder.—In this dislocation the arm is held rigid, the elbow stands off a distance of 3 or 4 inches from the body, and the shoulder appears flat with a marked depression beneath the point of the shoulder. In addition there is pain and swelling at the site of injury, and the head of the humerus can be felt in an abnormal position as compared with the other side. Do not try to reduce this dislocation if surgical assistance can be had in a few days; if not, try one of the three methods following.



FIGURE 52.—Subglenoid dislocation of the shoulder. (Mason.)

(a) *Stimson's method*.—Place the patient on a canvas cot or stretcher lying on the injured side, arm hanging through a hole made in the cot or stretcher in the median line at a distance of about 18 inches from the head end. The cot or stretcher first should be elevated from the floor by means of chairs or blocks so that the arm does not touch the floor. Fasten a 10-pound weight on the dependent arm, and, in from 5 to 10 minutes, the muscles usually have become sufficiently relaxed to allow the head of the bone to slip into its proper place of its own accord. If it should not do so, the weights should be removed and the arm carefully brought to the patient's side against the operator's fist, held in the armpit. This should force the head of the bone back in place. Apply a Velpeau or Desault bandage without the pad in the armpit and keep the arm bandaged for a week.

(b) *Kocher's method*.—The patient should be in either the sitting or standing posture, preferably the former. Grasping the affected arm at the elbow and wrist, flex the elbow to a right angle and press the arm against the chest (fig. 53). Turn the forearm as far as possible from the chest by external



FIGURE 53.—Kocher's method of reduction by manipulation: a, First movement, outward rotation; b, second movement, elevation of the elbow; c, third movement, inward rotation and lowering of the elbow. (Ceppi.)

(outward) rotation of the humerus. Maintaining this external rotation, carry the elbow slowly inward across the front of the chest to the center line of the body. With the arm in this position quickly rotate the forearm inward until the hand touches the sound shoulder. Lower the elbow. Immobilize the entire arm by the application of a special bandage of the chest or a Velpeau bandage without the axillary pad.

(c) *Reduction by traction or extension*.—Place the patient upon his back on the deck or table. The operator takes off one shoe, inserts his heel under the armpit of the dislocated side, and makes traction upon the arm downward and slightly toward the patient's body. In doing this, care must be taken not to employ too great leverage action upon the arms, as a fracture might be produced. After reduction, immobilize the joint with a Velpeau or Desault bandage without the pad in the armpit, and keep the arm bandaged for a week.

If a dislocation fails to be reduced by these methods, do not persist in attempting reduction, as it is then a case for operative surgery.

Dislocation of the elbow, hip, and knee.—These dislocations are not as common as shoulder dislocations. The bones may be displaced in various directions and their reduction is difficult and often dangerous. First-aid treatment consists in obtaining surgical assistance, making the patient comfortable with pillows, etc., and treating for shock, if present.

Compound dislocations are those in which the head of the bone has been forced through the skin and underlying tissues. Here not only the dislocation

but also the wound must be treated. A **complicated dislocation** is one in which a large blood vessel or nerve has been injured.

FRACTURES

A **fracture** is the forcible solution of the continuity of a bone. Fractures are classified as *simple* or *closed*, and *open* or *compound*. A simple or closed fracture is one in which there is no opening to the outside air. An open or compound fracture is one in which, by a break in the overlying skin and other tissues, there is direct communication between the outside air and the broken bone. A compound fracture is always very serious, owing to the likelihood of infection. In an infected compound fracture not only is it difficult to obtain union of the bones but there is danger to life from the infection itself. This element of infection is absent in simple fractures.

Careless handling of fractures may convert a simple into a compound fracture, and there is grave danger of injuring blood vessels, nerves, and other tissues in the neighborhood of the fracture (complicated fracture).



FIGURE 54.—Green-stick fracture.



FIGURE 55.—Comminuted fracture.



FIGURE 56.—Impacted fracture of femur. (Wharton.)

A **complete fracture** is one in which the bone is severed through its entire thickness. An **incomplete** or **green-stick fracture** is one in which the bone is broken or bent, but not broken entirely through (fig. 54). (It resembles the condition obtained from an effort to break a green stick.) A **multiple fracture** is one in which the bone is broken into more than two fragments, the lines of fracture not, however, communicating with each other. A **comminuted fracture** is one in which the bone is broken into several pieces, the lines of fracture communicating with one another (fig. 55). A **complicated fracture** is one accompanied by an injury to some surrounding part, as an injury to a joint, muscle, nerve, or blood vessel. An **impacted fracture** is one in which one fragment of the bone is driven into the other, the two remaining tightly wedged (fig. 56).

When a bone breaks, there is always an injury to the periosteum, or bone covering, and to the surrounding tissues. There is also hæmorrhage about the ends of the fragments, and the space between the two fragments rapidly becomes filled with a blood clot. This blood clot becomes organized as described in the healing of wounds, forming a callus which surrounds the ends of the

fragments, and, as it were, glues them together. At first the callus consists only of fibrous tissue, but later there is growth of bone cells, and a deposit of lime salts which changes the callus into dense bone.

The following factors may prevent the union of fractures: Infection preventing the formation of a callus; the interposition between the fragments of muscle or other tissue; improper reduction of the fracture; general constitutional conditions such as syphilis, tuberculosis, diabetes, Bright's disease, and an inability on the part of the patient's body to deposit bone in the callus. This latter condition in which fibrous tissue, but not bone, is deposited in the callus is spoken of as "fibrous union."

In the diagnosis of fracture the following conditions usually will be found: 1. There is a loss of power in the part, for example, if the leg is broken, the man has fallen and cannot arise; 2. The part is in unnatural position, and comparison of a fractured limb with the uninjured one will show that there is a deformity between the joints and that the injured limb is probably shorter; 3. Movement can be obtained where normally there is no motion, with grating of the broken ends of the bone (if an attempt to move the limb is made it will be found that there is movement in the bone between the joints where there should be none, and the broken ends of the bone grating together (*crepitus*) can be felt and heard); 4. There is history of violence and the patient will say that he heard the bone crack and give way; and 5. The patient complains of great pain and tenderness at the seat of fracture and there is swelling present, due to bleeding from the broken ends. Whenever a fracture is suspected or doubtful, an X-ray picture of the part should be obtained, as this is the surest means of determining fracture.

General principles for the treatment of simple fractures.

The patient should be brought under the care of a medical officer as soon as possible. The object of treatment before a medical officer can take charge of the case, if his services cannot be had promptly, is to prevent further injury, especially to blood vessels and nerves, and puncture of the skin by the sharp, knife-like edges of the broken bone, and to treat shock if it is present. The patient should be placed in a comfortable position while waiting for the medical officer or surgeon, and if it is necessary to move the fractured part in doing this or in treating shock, one hand should support the broken bone on each side of the break. The bone must not bend at the break while the patient changes his position to a more comfortable one. Support the broken bone in a natural position on a pillow or folded coat, great care being taken that it is not bent or does not drag on the point of fracture. If there is doubt as to whether or not a fracture is present, do not manipulate the part, but treat it as a fracture until the arrival of a surgeon. Do not move the patient more than is necessary before the fracture has been set and secured. If the injured person is wearing thin summer clothing, it will not always be necessary to remove it; if thick clothing is worn, however, it is difficult to determine whether or not a fracture has occurred or the character of the injury. In the latter case, never try to take off the clothing, but cut it in the seams with a sharp knife or scissors. If the patient cannot be brought under the care of a surgeon for a day or more, the fracture must be set and immobilized as described hereafter. If a fracture is not set, it will unite in bad position and the bone will have to be refractured to secure proper alinement.

In the treatment of *compound fractures* the services of a medical officer should be obtained as soon as possible. In the meantime, treat the shock and the wound as described in the section on wounds. After treatment of the

wound, treat the fracture as described before. In case no surgeon is available for a day or more, the fracture may be set as described hereafter, always keeping in mind the proper treatment of the wound while so doing, thus preventing, as far as possible, infection which is a serious complication in fractures.

The setting of a fracture consists of bringing the two fragments in apposition and in holding them in that position. The force which keeps the fragments out of apposition and which must be overcome in order to bring them into apposition is muscular contraction. This muscular contraction is overcome by extension and counterextension. *Extension* is pulling the far or distal end of the limb, and *counterextension* is merely holding the near or proximal end next the trunk. Extension and counterextension must be applied until the deformity and shortening disappear and the two limbs look alike. Where the muscular contraction is great, as in fractures of the thigh, the fragments frequently cannot be brought into apposition without relaxation of the muscles by a general anæsthetic or by gradual tiring out of the muscles by a steady pull with weights and pulley. In these cases extension and counterextension frequently have to be applied for some time after the fracture has been set in order to maintain the fragments in apposition. The fragments of a fractured bone are held in apposition by means of splints, plaster of Paris bandages, ordinary bandages, etc.

Splints are agents for immobilizing a fractured part. There are two general classifications of splints, *traction splints*, and *coaptation splints*. Traction splints are those which, in addition to immobilizing a fracture, are constructed in such a manner that by their use extension and counterextension can be applied without the use of other apparatus for this purpose. Coaptation splints are those which are used solely to immobilize the fracture. Traction splints are indicated in fractures where there is much muscle pull tending to displace the fragments. The most common traction splints are: The *Thomas leg splint* and modifications of the same, the *Jones humerus traction splint*, the *Army hinged half-ring thigh and leg splint (Keller)*, the *wire ladder splint*, and the *Cabot posterior wire splint*. To obtain extension by use of these splints, adhesive strips or tapes are fastened to the skin and attached to the distal end of the splint, while counterextension is obtained by the push of the other end of the splint against the body.

In emergency any material which has sufficient firmness to give support to a limb will answer for coaptation splints. Examples are umbrellas, canes, swords, scabbards, guns, cigar boxes, wire, leather, laths, tent pins, pillows, or a folded coat. In fractures of the thigh and leg, the sound limb may be used as a splint. Plaster of Paris bandage may be used. Adhesive plaster generally is used to splint a fractured rib. The materials used for splints must be light but sufficiently rigid to prevent bending; long enough to fix into the joints above and below the fracture; broad enough to prevent pinching of the limb in bandaging; and sufficiently padded to protect the part from undue pressure.

Coaptation splints may be applied temporarily over the clothing and should always be well padded, as a hard board against an injured limb soon becomes very painful. Oakum, cotton, grass, moss, portions of clothing, or any soft material will answer for the padding. If possible, two splints should be applied to a limb, while in fractures of the leg three generally are used, one on each side and one behind. In applying splints, have an assistant hold them in position and then firmly fasten them to the limb by several turns of a roller bandage, adhesive strips, handkerchiefs, pieces of rope, or portions of clothing. While splints should be applied snugly, care should be taken