A. AUERBACH

ANATOMY AND PHYSIOLOGY FOR NURSES

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TEXT-BOOK

OF

ANATOMY AND PHYSIOLOGY

FOR NURSES

COMPILED BY

DIANA CLIFFORD KIMBER

GRADUATE OF BELLEVUE TRAINING SCHOOL; FORMERLY ASSISTANT SUPERINTENDENT NEW YORK CITY TRAINING SCHOOL FOR NURSES, BLACKWELL'S ISLAND, N.Y.; FORMERLY ASSISTANT SUPERINTENDENT ILLINOIS TRAINING SCHOOL, CHICAGO, ILL.

FOURTH EDITION, COMPLETELY REVISED, WITH ADDITIONS
AND MANY NEW ILLUSTRATIONS

BY

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Affectionately Dedicated

TO MY

FRIEND, SCHOOLMATE, AND SUPERINTENDENT

Louise Darche

GRADUATE OF BELLEVUE TRAINING SCHOOL

AND

SUPERINTENDENT NEW YORK CITY TRAINING SCHOOL

BLACKWELL'S ISLAND, N.Y.

PREFACE

Once more this book has been thoroughly revised. This revision represents an effort to simplify the most difficult portions, to introduce more physiology, and to present more fully the subject of the generative organs. Much of the book has been rewritten, a number of new illustrations have been introduced, and several that seemed to have outlived their usefulness have been discarded.

As in the previous revision, many Superintendents and Teachers of Training Schools have been consulted both personally and by letter. The suggestions offered by them have been of very great value, and have been carried out as far as possible. It is a privilege and pleasure to acknowledge this indebtedness.

My thanks are due to Miss Charlotte A. Francis, Instructor of Chemistry in Teachers College, Columbia University, for rewriting the first chapter, also to Dr. R. J. E. Scott of New York, who supervised the entire revision and made the index.

I am also indebted to the authors whose works I have consulted, and to the various publishers who have granted me permission to use illustrations from their books.

Miss Kimber, while not actively engaged in Training School work, is still keenly interested in all that pertains to nursing progress, and derives much satisfaction from the thought that her text-book is of real service to nurses. That its service and usefulness may be increased by the present edition is the sincere wish of the reviser.

C. E. G.

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CHAPTER I

EXPLANATIONS AND DEFINITIONS OF SOME CHEMICAL AND PHYSICAL TERMS

An intelligent discussion of the various functions of the human body cannot be given without some elementary considerations in the field of chemistry and its intimately related science of physics. Probably the briefest method for presenting the essential points is in the way of definitions with accompanying illustrations, and explanations where necessary.

THE PHYSICAL SCIENCES

1. **Physics** deals with mechanics, heat, light, sound, and electricity, and their relations to matter.

2. **Chemistry** deals with change in the composition of matter, the energy change involved therein, and the principles controlling chemical change.

MATTER

1. **Defined.** — *Matter* is usually defined as anything that occupies space, as wood, air, water.

2. **Forms in which matter exists.**

Elements. — An element is a substance which cannot be separated into more simple substances by any means known to science at present. Elements are supposed to be made up of *atoms* which are alike for the same element and cannot be divided.

There are about eighty of these elements, less than half of which are well known. Some of the most common are carbon, iron, sulphur, mercury, and oxygen.

Compounds. — A compound is a substance which can be separated into simpler substances. Compounds are supposed to be made up of *molecules* which are composed of groups of *atoms*. Molecules are alike for the same compound and can be divided, giving elements or simpler compounds. For example, water is composed of hydrogen and oxygen, each molecule having in it two hydrogen atoms and one oxygen atom (H_2O), when separated, water gives the two elements hydrogen and oxygen. Again, sugar is composed of hydrogen, carbon, and oxygen, each molecule having in it twelve atoms of carbon, twenty-two atoms of hydrogen, and eleven atoms of oxygen ($C_{12}H_{22}O_{11}$), when separated it gives several compounds with simpler molecules, as carbon dioxide (CO_2), water (H_2O), methane (CH_4), etc.

Mixtures. — A mixture can be made up of either or both elements and compounds. These can often be separated by simple physical means, as filtration or evaporation. Milk is a mixture of several compounds, — water, cream, proteins, sugar, and salts. The cream can be separated by allowing the milk to stand, when it will rise to the top, and can be skimmed off. Salt solution is a mixture of the compounds, salt and water. They can be separated by evaporating the water. Air is a mixture of compounds and elements, carbon dioxide (compound), nitrogen and oxygen (elements). They cannot be separated by any simple means.

3. **Matter undergoes changes.**

Physical change. — When matter has been subjected to a change which does not affect the composition of the matter, the change is said to be a physical one only. The following are given by way of illustration: —

Water can solidify (freeze) or it can vaporize; whether it exists in the state of a solid, a liquid, or a gas, depends upon the temperature, but the composition in all these *states* is identical. Sugar melts, but the solid sugar and the liquid sugar are exactly the same in composition; the change is only one in *physical state.*

Other physical changes besides change in *physical state* are, change in *size, position, magnetic* or *electric* condition, and change in *temperature.*

Chemical change. — When matter undergoes a change in composition, it is said to have undergone a chemical change. The following are illustrations: when an electric current is passed through water, the water is separated into two distinct substances, hydrogen and oxygen. In this case we start with a single compound (water) of definite composition, and as a result of the change, obtain two different substances (oxygen and hydrogen). Again, in a bar of iron there is nothing but the element iron, but if it is left exposed to the air, it is converted into a red solid which has iron and oxygen in it, the iron having combined with some of the oxygen from the air. The iron and the iron rust are evidently different in composition.

ELEMENTS FOUND IN THE BODY

The elements found in the body are: —

Carbon,	13.5	(C)	form 97 per cent of total weight of body.
Hydrogen,	9.1	(H)	
Nitrogen,	2.5	(N)	
Oxygen,	72.	(O)	
Sulphur,		(S)	
Phosphorus,		(P)	
Fluorine,		(F)	
Chlorine		(Cl)	
Iodine,		(I)	
Silicon,		(Si)	
Sodium,		(Na)	
Potassium,		(K)	
Calcium,		(Ca)	
Magnesium,		(Mg)	
Lithium,		(Li)	
Iron,		(Fe)	
Manganese,		(Mn)	
Copper,		(Cu)	
Lead,		(Pb)	

These elements are not, of course, found uncombined in the body, but rather combined, usually in the form of rather complex compounds. *Protoplasm,* for instance, is a compound of carbon, hydrogen, nitrogen, oxygen, and phosphorus.

ORGANIC AND INORGANIC COMPOUNDS

The distinction between organic and inorganic compounds dates back to an early period, when there was a belief that certain compounds of carbon found in living organisms could only be built up through the agency of a vital force possessed by the organism, which prevented their being synthesized in the chemical laboratory. In distinguishing such they were spoken of as organic compounds. However, when urea, one of these substances, was prepared in the laboratory, this theory was abandoned, but the distinctive terms *organic* and *inorganic* persisted. Under the present classification organic compounds are compounds that contain carbon.

Because of the fact that there are numerous carbon compounds and also because many of these can be grouped into classes with well-defined characteristics, the study of the carbon compounds has become a separate phase of the general study of chemistry and is called *organic chemistry.*

SOME CHEMICAL TERMS

Atom. — An atom is the smallest part into which an element can be divided. Atoms are alike for the same element, but different for different elements.

Molecule. — A molecule is a group of atoms in chemical combination. Compounds are made up of multitudes of molecules, all of which are alike for the same compound.

Chemical formula. — A chemical formula is a simple means for representing the composition of the molecule. *Symbols* are made use of to represent the elements and small subscript figures to represent the number of atoms of the respective elements. For example, the formula for the sulphuric acid molecule (H_2SO_4) shows it to be made up of two atoms of hydrogen, one atom of sulphur, and four atoms of oxygen; the formula for the sodium chloride molecule ($NaCl$) shows it to be made up of one atom of sodium and one of chlorine.

Chemical equation. — A chemical equation is a simple means for representing the matter change that takes place in a chemical action. When carbon burns it combines with oxygen to form carbon dioxide. The equation that expresses this,

$$C + O_2 \rightarrow CO_2,$$

tells that during the process of combination, one atom of carbon combines with one molecule of oxygen (composed of two atoms) to give one molecule of carbon dioxide. In the action of sodium hydroxide with hydrochloric acid, water and sodium chloride are formed. The equation to represent this,

$$NaOH + HCl \rightarrow H_2O + NaCl,$$

shows that one molecule of sodium hydroxide reacts with one molecule of hydrochloric acid to give one molecule of water and one molecule of sodium chloride.

Oxide. — An oxide is a compound in which another element is in combination with oxygen, as water (H_2O), carbon dioxide (CO_2), sulphur dioxide (SO_2), and iron oxide (Fe_2O_3).

Acid oxide. — An acid oxide (or acid anhydride) is an oxide of a non-metal which in combination with water will form an acid, as carbon dioxide and sulphur dioxide, as shown in the following: —

$$CO_2 + H_2O \rightarrow H_2CO_3 \text{ (carbonic acid)},$$
$$SO_3 + H_2O \rightarrow H_2SO_4 \text{ (sulphuric acid)}.$$

Basic oxide. — A basic oxide (or basic anhydride) is an oxide of a metal which in combination with water will give a base, as calcium oxide (CaO) and sodium oxide (Na_2O), shown in the following: —

$$CaO + H_2O \rightarrow Ca(OH)_2 \text{ (calcium hydroxide)},$$
$$Na_2O + H_2O \rightarrow 2\,NaOH \text{ (sodium hydroxide)}.$$

Acid. — An acid is a substance which contains hydrogen and an acid radical. The acid radical must contain a non-metal and may contain oxygen. Examples are hydrochloric acid (HCl), sulphuric acid (H_2SO_4), carbonic acid (H_2CO_3), hydrobromic acid (HBr), nitric acid (HNO_3).

Base. — A base is a substance which contains a metal and the hydroxyl (OH) radical. Examples are sodium hydroxide (NaOH) and calcium hydroxide ($Ca(OH)_2$). One exception to this is ammonium hydroxide (NH_4OH), which contains the ammonium radical (NH_4) instead of a metal.

The *alkalies* are the bases of sodium, potassium, and ammonium; they give very strong basic action.

Both acids and bases give distinctive characteristic actions.

Salt. — A salt is a substance containing the metal from a base and the acid radical from an acid. Salts may be obtained by the neutralization of an acid by a base, the characteristic hydrogen of the acid combining with the characteristic hydroxyl of the base to form water, leaving the salt as shown in the following: —

$$\text{Base} + \text{Acid} \rightarrow \text{Water} + \text{Salt}$$
$$NaOH + HCl \rightarrow H_2O + NaCl \text{ (sodium chloride)},$$
$$Ca(OH)_2 + H_2SO_4 \rightarrow 2\,H_2O + CaSO_4 \text{ (calcium sulphate)}.$$

SOME GENERAL CHEMICAL ACTIONS

Oxidation. — Oxidation is the process in which the element oxygen combines chemically with another substance, heat being evolved in the process. The heat evolved may not be perceptible unless the oxidation takes place rapidly, as in the burning of gas, wood, coal, etc. If the substance combines slowly with oxygen, heat may be imperceptible; for example, iron allowed to lie in moist air is covered with rust due to the union of the iron and oxygen. Also in our bodies some of the carbon from the cells unites with oxygen, and thus the temperature of the body is kept up. It is for this reason that oxygen must be taken into the body, which is accomplished by the act of breathing.

Neutralization. — Neutralization is the process that takes place in the action of an acid with a base. Water and salt are the products of the reaction. (See Salt.)

Hydrolysis. — Hydrolysis can be defined as the chemical change that takes place when a compound in its action with water splits into two other compounds, fixing the elements of water in the process. The action of water with some salts, also the formation of glucose and fructose from cane sugar, may be given as examples, as represented in the following reaction equations: —

$$\begin{array}{lclcl} \text{(Sodium carbonate)} & & \text{(Sodium hydroxide)} & & \text{(Carbonic acid)} \\ Na_2CO_3 + 2\,H_2O & \rightarrow & 2\,NaOH & + & H_2CO_3, \\ \text{(Cane sugar)} & & \text{(Fructose)} & & \text{(Glucose)} \\ C_{12}H_{22}O_{11} + H_2O & \rightarrow & C_6H_{12}O_6 & + & C_6H_{12}O_6. \end{array}$$

Hydration. — Hydration is the process by which water enters into direct combination with another compound to form a single compound which is called a *hydrate*. As examples might be given, sulphuric acid as a hydrate of sulphur trioxide, calcium hydroxide as a hydrate of calcium oxide, and crystalline copper sulphate as a hydrate of anhydrous copper sulphate. The formation of these hydrates in the process of hydration is represented in the following: —

$$\begin{array}{lcllc} \text{Anhydrous substances} & & & & \text{Hydrates} \\ SO_3 & + & H_2O & \rightleftarrows & H_2SO_4 \\ CaO & + & H_2O & \rightleftarrows & Ca(OH)_2 \\ CuSO_4 & + & 5\,H_2O & \rightleftarrows & CuSO_4 \cdot 5\,H_2O. \end{array}$$

The reverse process by which a compound is split up into water and an anhydrous compound is called *dehydration.* This process is represented in the equations by the reverse arrows.

ENERGY

Energy is ordinarily defined as the power of doing work. As examples of various types of energy might be mentioned: mechanical energy, heat energy, electrical energy, and chemical energy. These can be transformed from one form to another. To illustrate: (1) electrical energy can be converted into energy of motion, as evidenced in the motor; (2) electrical energy can be converted into heat energy, as in the electric stove; (3) mechanical energy of motion can be converted into electrical energy, as in the dynamo; also, (4) chemical energy can be transformed into heat energy, as is true in the burning of wood.

SOME PHYSICAL TERMS

Specific gravity. — By specific gravity is meant the comparison between the weight of a substance and the weight of an equal volume of some other substance taken as a standard. The standards usually referred to are air for gases, and water for liquids and solids. For instance, the specific gravity (sp. gr.) of mercury is 13.6, meaning that mercury is 13.6 times as heavy as an equal volume of water. Again, the specific gravity of carbon dioxide (air standard) is 1.5, meaning that it is 1.5 times as heavy as an equal volume of air.

The specific gravity of solutions, as a salt solution, will necessarily vary with the concentration.

Diffusion. — This term in its ordinary use has to do with the tendency of two liquids or two gases of different densities to mix uniformly. Diffusion can take place either when the substances are simply superimposed, or when they are separated by a permeable membrane. The following illustrations may help to make this clear.

1. When the gases or liquids are not separated by a membrane.

(*a*) If a bottle of hydrogen is inverted over a bottle of chlorine gas, the lighter hydrogen molecules will move down among the chlorine molecules, while the heavier chlorine molecules will move up to mix with the hydrogen molecules, so that the two will eventually be mixed uniformly.

(*b*) If a layer of water is placed carefully over a layer of sulphuric acid, in such a way that the two do not mix, two distinct layers will be formed with the heavier sulphuric acid at the bottom. The acid molecules will begin to move up and mix with the water molecules, while the water molecules will move down to mix with the sulphuric acid molecules. The action is much slower than with the gases.

2. When the gases or liquids are separated by certain membranes.

(*c*) In the illustration given in (*a*) if a membrane, permeable to gases, be stretched over the mouth of the bottle, the gases will mix evenly through it. Also, if a membranous sac of carbon dioxide is placed in a vessel containing oxygen, the two gases will diffuse through the membrane, until the mixture of gases inside and outside is uniform.

(*d*) When a bladder of alcohol is immersed in water, the two liquids will diffuse through the membrane; the water diffusing more rapidly than the alcohol, the bladder will become distended.

This subject of diffusion is an important one, as it has a great deal to do with life and with physiological processes. Because of diffusion the heavier carbon dioxide in the atmosphere is prevented from settling to the bottom of the atmosphere, thereby forming a layer of the same next to the earth, a condition which would seem to make life impossible. Diffusion of gases through membranes makes possible the exchange of carbon dioxide and oxygen through the walls of the lungs. (See page 246.)

The explanation of the process is found in the suppositions of the *kinetic theory* that: —

1. There are spaces between the molecules making up all bodies.
2. Molecules are in rapid motion in straight lines, the motion of gas molecules being much more rapid and unrestrained than in the case of liquid molecules.

Two forms of diffusion are spoken of distinctively as *osmosis* and *dialysis*.

Osmosis. — If a solution is separated from the clear solvent by a membrane, which is permeable to the liquid but not to the substance in solution, the liquid will pass through the membrane and the volume on the side of the solution will be increased. Also, if two solutions of different concentrations are used with the separating membrane, the volume on the side of the solution of greater concentration will be increased.

For example, if a carrot with the inside hollowed out is filled with a sugar solution, a long glass tube secured in the opening and the carrot then placed in a vessel of water or a solution of less concentration, the volume of the solution inside the carrot will increase as indicated by the rise in the glass tube. If conditions are reversed and the less concentrated solution is placed in the membrane, the increase in volume will be in the outer vessel. This phenomenon of osmosis, therefore, accounts for the swelling of dried fruits in water and the rising of water into the stems and leaves of plants. (See page 154.)

No completely satisfactory explanation is given for this process of osmosis. A most acceptable one, however, is found in the *kinetic theory*. According to this theory, the molecules of liquid and solute are both bombarding the membrane on each side. The molecules of the liquid can pass through, but the molecules of the solute cannot, the membrane, therefore, being called *semi-permeable*. The number of liquid molecules bombarding the membrane, per unit area, on the side of the clear solvent, or less concentrated solution, will be greater than the number of liquid molecules bombarding the membrane on the side of the more concentrated solution, hence, more liquid molecules will pass from the less concentrated to the more concentrated solution and the volume of the latter will be thereby increased. This increase will continue until the pressure in both directions is the same.

Osmotic pressure. — This is a term that is used indefinitely, and to express a fact rather than an understood force. A possible explanation is as follows: the molecules in their vibratory motion in the process of diffusion exert a certain force which is evident as a pressure when striking against anything in their path. This force or pressure is spoken of as osmotic pressure. When therefore a solution is held confined the vibratory force or osmotic pressure of the molecules within the mass produces an evident pressure against the sides of the containing vessel. It is to this pressure that the process of osmosis is due, for if the side of a vessel is a permeable membrane, the molecules in pressing against it will pass through.

Dialysis. — In this process a permeable membrane is selected which will admit of the passage of a substance in solution. For example, if a tumbler is completely divided vertically into two compartments by a moist piece of membrane and a water solution of common salt is placed in one compartment and a water solution of sugar in the other, it will be found after a time that some of the salt has passed into the solution of sugar, and *vice versa* some of the sugar into the salt solution. Such an interchange is said to be due to dialysis, and if the process is allowed to go on for some hours, the same proportion of salt and sugar will be found in the solution on each side of the dividing membrane. (See page 154.)

Emulsion. — When a substance scatters evenly throughout a liquid in such a finely divided form that it cannot be separated from the liquid by filtration, but has a tendency to separate like matter in suspension, the system is spoken of as an emulsion. This separation may take place in a brief time, or it may require a week, or month, or even a year. Oil shaken thoroughly in water furnishes an example.

UNIT FOR MEASURING HEAT

Inasmuch as heat is a form of energy, it is not as simple an undertaking to speak of it in comparative terms as in the case of matter. It is easy for one to visualize five quarts of milk as five times a certain volume that has been taken as a standard and called one quart. So it is also with weights and distances, and the measurement of weights, distances, and volumes is a necessary part of our experience. It is quite as urgent that there should be a basis for the comparison of energy values as well as for matter values, else the coal dealer could not place the value of his coal on a basis of its heat-producing qualities, nor could the dietitian plan the meals on a basis of the ultimate energy-producing qualities to the individual. We are only conscious of energy as a result of the effect it produces, consequently, if it is to be measured, it must be on this basis. The units most used for measuring heat are the *small calorie* and the *large calorie.*

Small calorie. — The small calorie (cal.) is the amount of heat that is necessary to raise one gram of water through one degree centigrade.

In the complete combustion of 12 grams of carbon, 94,300 cal.

are liberated, or sufficient heat energy to raise 943 grams of water through 100 degrees.

When 25 grams of sugar are oxidized, 100 calories of heat energy are produced; therefore, if the sugar is used as a food, the energy produced by the same can be expected to be proportionate to this estimate.

Large calorie. — The large calorie (cal.) is the amount of heat that is necessary to raise 1000 grams of water through one degree centigrade. This shows the large calorie to be equal to 1000 small calories. (See page 311.)

CHAPTER II

DEFINITIONS. — CAVITIES OF THE BODY

DEFINITIONS

Before taking up the subjects of anatomy and physiology in detail, it is well first of all to consider the definitions of these terms as follows: —

Anatomy refers to the structure of the body.

Physiology refers to the functions of the different parts of the body, in a state of health.

Anatomy teaches us what organs a plant or animal has, and how they are arranged with reference to one another. Physiology teaches us the uses to which these organs are put. Anatomy shows what an organ is; physiology shows what an organ does. Anatomy may be, and usually is, studied upon the dead creature; physiology can be studied only upon the living creature.

Anatomy is sometimes divided into the following branches: —

Osteology is the anatomy of the bones.
Syndesmology is the anatomy of the joints.
Myology is the anatomy of the muscles.
Angiology is the anatomy of the vessels.
Neurology is the anatomy of the nerves.
Splanchnology is the anatomy of the internal viscera.
Adenology is the anatomy of the glands.
Dermatology is the anatomy of the skin.
Genesiology is the anatomy of the generative organs.

The Anatomical Position. — In describing the body, anatomists always consider it as being in the erect position, with the face toward the observer, the arms hanging at the sides, and the palms of the hands turned forward.

Surfaces of the Body. — When the body is in the anatomical position, the front, or surface facing the observer, is named the anterior or *ventral* surface. (See Fig. 1.) The back, or surface directed away from the observer, is named the posterior or *dorsal* surface. (See Fig. 2.)

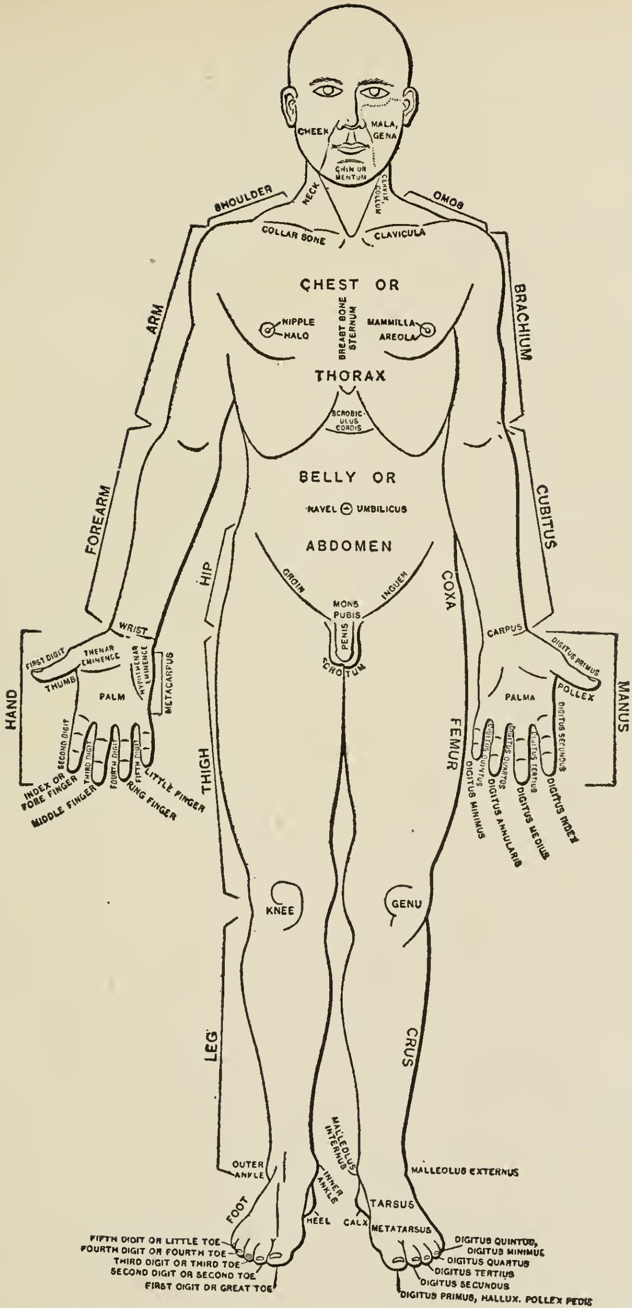

FIG. 1.—FRONT VIEW OF A MAN IN THE ANATOMICAL POSITION. On the right lateral half the parts are labelled in English, on the left in Latin. The right upper limb is drawn away from the trunk in order to show the arm more fully than is possible when it hangs perpendicularly. (Gerrish.)

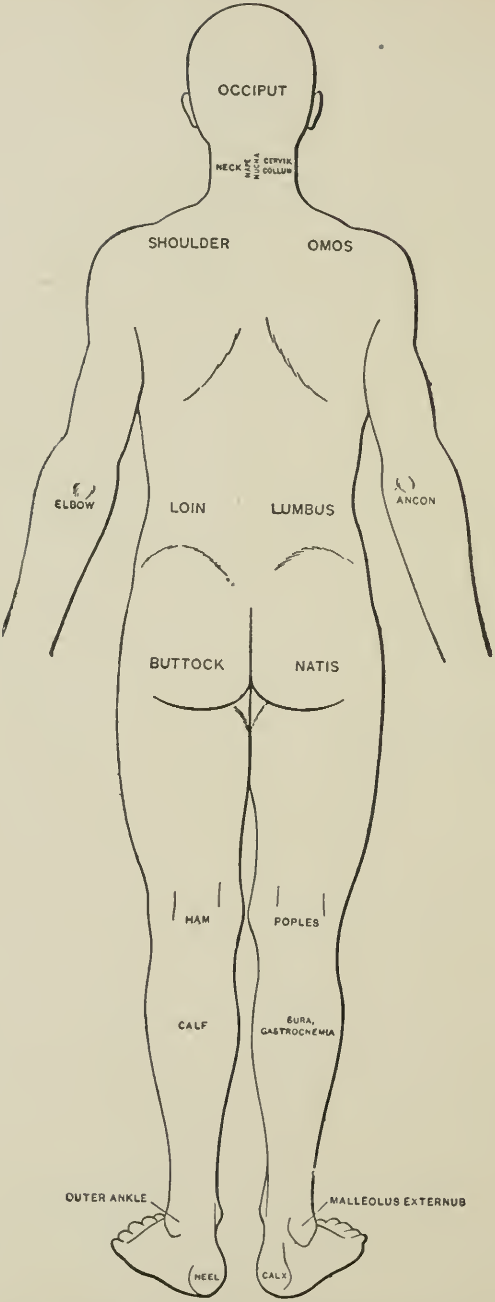

FIG. 2. — BACK VIEW OF A MAN. On the left lateral half the names of the parts are given in English, on the right in Latin. (Gerrish.)

The Median Line. — This refers to an imaginary line drawn through the middle of the body, from the top of the head to the middle of the floor between the feet; The parts nearest this line are described as *medial*, the parts farthest from this line are described as *lateral*.

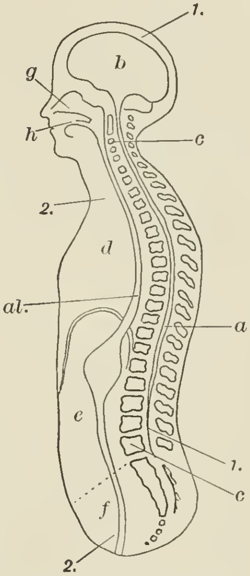

Fig. 3. — Diagrammatic Longitudinal Section of the Trunk and Head. 1, 1, the dorsal cavity; *a*, the spinal portion; *b*, the cranial enlargement; *c*, *c*, the bodies of the vertebræ forming the partition between the dorsal and ventral cavities; 2, 2, the ventral cavity, subdivided into thoracic cavity (*d*), abdominal cavity (*e*), and pelvic cavity (*f*); *g*, the nasal cavity; *h*, the mouth, or buccal cavity. The alimentary canal (*al*) is represented running through the whole length of the ventral cavity.

Internal and External. — These terms are used to designate within and without the body itself, also within and without the body cavities.

Proximal and Distal. — Proximal is used to describe a position near the head or source of any part. Distal is used to describe a position distant, or farthest away from the head or source of any part.

Periphery. — This term is used to describe the circumference of a circle, hence in anatomy it means the part farthest from the centre.

THE HUMAN BODY

It is necessary to have the clearest possible conception of the main divisions and the positions of the different parts of the body, and we shall therefore outline the structure of the body as a whole. It is readily seen that the human body is separable into **trunk, head,** and **limbs**; the **trunk** and **head** are cavities, and contain the internal organs, or viscera,[1] while the **limbs** are solid, contain no viscera, and are merely appendages of the trunk.

Cavities of the body. — The trunk and head contain two main cavities, and looking at the body from the outside we should naturally imagine that these two cavities were the cavity of the head and the cavity of the trunk, respectively. If, however, we divide the trunk and head lengthwise into two halves, by cutting

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[1] *Viscera* is the plural of the Latin word viscus, which means an organ; hence viscera are organs contained within the body cavities. Example: heart, stomach, etc. Each of these may be called a *viscus*.

them through the middle line from before backwards, we find the **trunk** and **head** are divided by the bones of the spine into dorsal and ventral cavities, and not into upper and lower. (See Fig. 3.)

1. **Dorsal cavity.** — The dorsal or back cavity is a complete bony cavity, and is formed by the bones of the skull, and the vertebræ (bones of the spine). It may be subdivided into: —

a. The *cranial cavity.* — This cavity contains the brain.

b. The *spinal canal.* — This canal contains the spinal cord, which is continuous with the brain.

2. **Ventral cavity.** — The ventral or front cavity is not a complete bony cavity, part of its walls being formed of muscular and other tissue; it is much larger than the dorsal cavity, and may be subdivided into: —

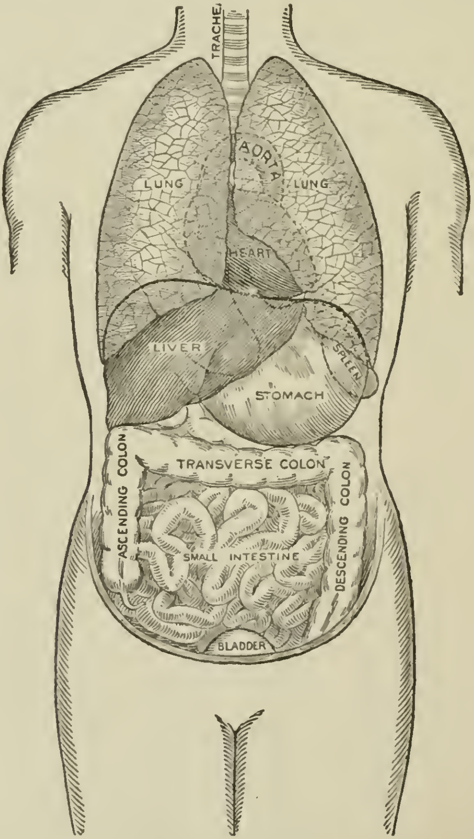

FIG. 4. — POSITION OF THE THORACIC AND ABDOMINAL ORGANS (FRONT VIEW). (Morrow.)

a. Orbital cavity. — The orbital cavity contains the eye, the optic nerve, the muscles of the eyeball, and the lacrimal apparatus.

b. Nasal cavity. — The nasal cavity is filled in with the structures forming the nose.

c. Buccal cavity. — The buccal cavity or mouth contains the tongue, teeth, and salivary glands.

d. Thoracic cavity. — The thoracic cavity, or chest, contains the trachea or windpipe, the lungs, œsophagus or gullet, heart, and the great vessels springing from, and entering into, the heart.

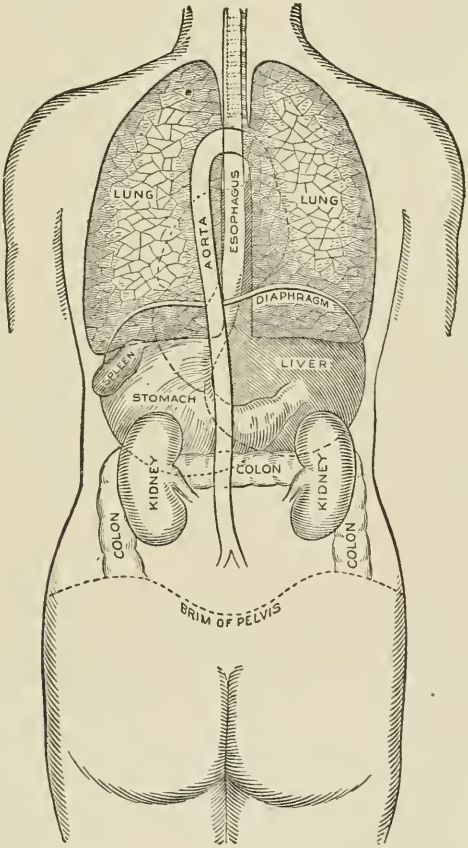

Fig. 5. — Position of the Thoracic and Abdominal Organs (Rear View). (Morrow.)

Diaphragm. — The diaphragm is a dome-shaped muscle, and forms a transverse partition between the thoracic and adbominal cavities.

e. Abdominal cavity. — The abdominal cavity contains the stomach, liver, gall-bladder, pancreas, spleen, kidneys, small and large intestines, etc.

f. Pelvic cavity. — The pelvic cavity is that portion of the abdomen lying below an imaginary line drawn across the prominent crests of the hip bones. It is more completely bounded by bony walls than the rest of the abdominal cavity. It contains the bladder, rectum, and some of the generative organs.

The **limbs**, or **extremities**, upper and lower, are in pairs, and bear a rough resemblance to one another, the shape of the bones, and the disposition of the muscles in the thigh and arm, leg and forearm, ankle and wrist, foot and hand, being very similar. There is, however, a marked difference between the mobility of the upper and the lower limbs. The shoulder is freely movable, not so the hip.

SUMMARY

HUMAN BODY

- **Dorsal Cavity**
  - *a.* **Cranial cavity** — Brain.
  - *b.* **Spinal canal** — Spinal cord.
- **Ventral Cavity**
  - *a.* **Orbital cavity**
    - Eye.
    - Optic nerve.
    - Muscles of the eyeball.
    - Lacrimal apparatus.
  - *b.* **Nasal cavity**
    - Structures forming the nose.
  - *c.* **Buccal cavity**
    - Tongue.
    - Teeth.
    - Salivary glands.
  - *d.* **Thoracic cavity**
    - Œsophagus—Trachea.
    - Lungs — Heart.
    - Blood-vessels.
  - The **Diaphragm** muscle separates the thoracic and abdominal cavities.
  - *e.* **Abdominal cavity**
    - Stomach — Spleen — Pancreas.
    - Liver—Gall-bladder.
    - Kidneys — Large and small intestines.
  - *f.* **Pelvic cavity**
    - Bladder — Rectum.
    - Some of the generative organs.

CHAPTER III

CELLS, TISSUES, ORGANS, AND SYSTEMS.—EPITHELIAL TISSUE: SIMPLE, TRANSITIONAL, STRATIFIED

FROM the standpoint of the chemist the body is composed of **elements.** (See page 3.) From the standpoint of the anatomist the body is composed of **cells**, and they are regarded as the structural units out of which either directly or indirectly it is built. If the substance of any part of the body, *i.e.* skin, muscle, or blood, is examined with the unaided eye, it appears homogeneous, but if examined with the microscope it is found to be composed of an innumerable number of these minute cells. It is helpful to recall that low down in the scale of life we find animals so simple that they are described as consisting of just one cell. As we ascend in the scale of life, we find animals that consist of a greater number of cells, until the human body may be properly described as an enormous aggregate of cells.

All the varied activities of the body are the result of the activity of the cells which compose it, and it is very desirable that we early acquire some definite conception of these tiny elementary bodies.

CELLS

A cell[1] is a minute portion of living substance or protoplasm which is sometimes enclosed in a cell membrane or cell wall. Within the protoplasm lies a body of definite rounded form, called the nucleus, and this in turn often contains one or more smaller bodies or nucleoli. As the substance of the entire cell is protoplasm, that portion which surrounds the nucleus is given the name cytoplasm, and the substance of the nucleus is named karyoplasm.

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[1] The word cell is from the Latin *cella* — a cavity — and was first used by botanists to describe plant cells, like those of cork and elder pith, which have cavities in their substance. It is now known that most animal cells, and many plant cells, do not have cavities, so that the name is not especially appropriate, but it is too firmly fixed in our language to be abandoned.

Cytoplasm. — The cytoplasm is a viscid semi-fluid substance, sometimes homogeneous, often granular, and has the appearance of a meshwork. In this meshwork are often suspended various passive bodies, such as food granules, pigment bodies, drops of oil or water. These may represent reserve food matters, or waste matters, and are collectively designated as metaplasm.

Nucleus. — The structure of the nucleus is similar to that of the cytoplasm, but it is more solid, and differs in chemical composition. It is bounded by a membrane which separates it from the surrounding cytoplasm, and may or may not contain the minute spherical bodies termed nucleoli. In some cells no nucleus can be found. It may be assumed as true that at some period of its life every cell had a nucleus, though it may have been lost in the course of development.

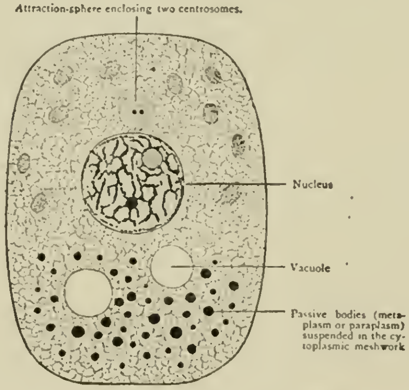

FIG. 6. — Diagram of a cell. (Wilson.)

Centrosome. — The centrosome is an extremely minute body or pair of bodies usually surrounded by a mass of cytoplasm known as the *attraction sphere*. As a rule it lies in the cytoplasm, not far from the nucleus, and plays an important part in nuclear division.

Life activities in cells. — Since the body is composed of cells, it follows that all the activities of the body are the result of the activities of the cells. These activities produce changes in the protoplasm, the chief of which may be enumerated as follows: —

(1) *Respiration.* — Each cell coming in contact with oxygen absorbs it and combines with it. Whenever this combination takes

place, a certain amount of the protoplasm is burned or oxidized, and as a result of this oxidation heat and other kinds of energy are produced, and carbon dioxide, which is a waste product, is evolved. Thus it will be seen that the real purpose of respiration is to furnish oxygen to each individual cell, and to take from the cell the carbon dioxide which it does not need.

(2) *Metabolism.* — Each cell is able to take to itself, and eventually convert into its own substance, certain materials (foods) that are non-living; in this way the protoplasm may increase in amount, or in other words, the cell may grow. The amount of protoplasm is not permanently increased, because just as much protoplasm is being broken down by the process of oxidation, and removed from the cell, as is added by the process of assimilation. Chemical changes which involve the building up of living material within the cell have received the general name of **anabolic** changes, or **anabolism**; on the other hand, those which involve the breaking down of such material into other and simpler products are known as **katabolic** changes, or **katabolism**, while the sum of all the anabolic and katabolic changes which are proceeding within the cell is spoken of as the **metabolism** of a cell. These chemical changes are always more marked as the activity of the cell is promoted by warmth, electrical, or other stimulation, the action of certain drugs, etc.

(3) *Amœboid movement.* — The most obvious physical changes that can sometimes be seen in living protoplasm, by the aid of the microscope, are those which are termed "**amœboid**." This term is derived from the *amœba*, a single-celled organism which has long been observed to exhibit spontaneous changes of form, accompanied by a flowing of its soft semi-fluid substance. By virtue of this property, the cells can move from one place to another. If one of these cells be observed under a high-power lens of the microscope, it will be seen gradually to protrude a portion of its protoplasm; this protrusion extends itself, and the main part or body of the cell passes by degrees into the elongated protrusion. By a repetition of this process, the cell may glide slowly away from its original situation and move bodily along the field of the microscope, so that an actual locomotion takes place. When the surface of these free cells comes in contact with any foreign particles, the protoplasm, by

virtue of its amœboid movements, tends to flow round and enwrap the particles, and particles thus enwrapped or incepted may then be conveyed by the cell from one place to another.

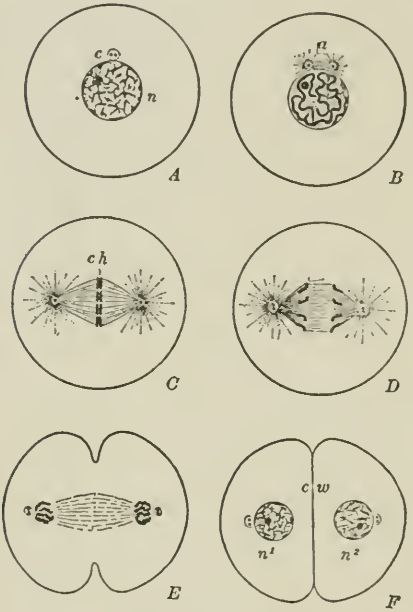

Fig. 7. — Diagrams illustrating division of a cell. *A*, resting cell with nucleus (*n*) and centrosome (*c*). *B*, preparing to divide, two asters (*a*) near nucleus, each with a centrosome, chromatin becoming massed into chromosomes. *C*, two asters have formed a spindle with chromosomes (*ch*) in centre. *D*, each chromosome divided and two halves being moved toward the asters. *E*, chromosomes forming the two new nuclei, and cell body beginning to divide. *F*, division complete, two-cell stage, each cell has the same structure as the one cell in *A*. *cw*, cell-wall. (Bigelow from Wilson.)

(4) *Reproduction.* — Like all living organisms, each cell grows, produces other cells, and dies, so that each cell has a life cycle comparable to, but much shorter than the body itself. As the cells are constantly dying, the need for constant reproduction is apparent. This reproduction is accomplished in two ways, (*a*) simple, direct division or akinesis, and (*b*) indirect division or karyokinesis, which is the almost universal method.

(*a*) In *akinesis* or direct division the cell elongates, the nucleus and cytoplasm become constricted in the centre, and the cell divides and forms two cells which soon grow to the size of the original cell.

(*b*) In *karyokinesis* or indirect division the nucleus passes through a series of remarkable changes which are rather complicated. A careful study of Fig. 7 will give the student some idea of these changes.[1]

Differences in cells. — Cells differ in (1) size, (2) form, (3) chemical composition, and (4) function. (1) They vary in size from $\frac{1}{3000}$ to $\frac{1}{300}$ of an inch (0.008 to 0.08 mm.) in diameter.[2]

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[1] For a detailed description of karyokinesis the student is referred to "The Cell in Development and Inheritance," by Wilson.

[2] On page 469 will be found accurate ratios between the metric system and the system of length, weights, and measures used in the United States. For the sake

(2) The simplest form of cell is spherical, but this is seldom realized except in unicellular plants and animals. In the human body the form of the cell is modified by the pressure of the surrounding structures, by active movements of the cell substance, and by growth and differentiation. (3) It is assumed that the marked difference in the appearance of cells is an expression of a chemical difference, which in turn shows the difference in function. (4) A unicellular animal is in itself a complete living thing, and thus one cell must perform all the essential activities of life, and is self-sufficient. In the human animal the individual cells have become specialized as it were, and certain groups of them perform certain functions, *i.e.* the function of muscle cells is to contract, and the combined contraction of a group of muscles cells results in the contraction of a muscle.

TISSUE

A collection of cells of like substance arranged together form what is known as a tissue. In many tissues, all the substance is not inside the cell walls, some of it is between the cells or *intercellular.* In the muscles there is a cement substance between the cells which holds them together. In some tissues there is very little intercellular substance, in others there is a large proportion of it.

ORGAN

When two or more different tissues are associated in performing some special office in the body, the part so adapted is termed an organ. Thus, the lungs are organs specially adapted for assisting in the function of respiration, the bones are organs adapted for support and locomotion, the kidneys for secreting urine, etc. As the structure of an organ depends upon the properties of the tissues composing it, so the characteristics of each tissue depend upon their ultimate structural units — the cells and the intercellular substance.

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of simplicity in converting figures in the text, from one system to the other, we have assumed

1 cm. to equal $\frac{2}{5}$ in. (25 mm. = 1 in.).
1 cc. to equal 15 minims.
30 gm. to equal 1 oz. (dry or liquid measure).
30 cc. to equal 1 oz. (dry or liquid measure).
1 litre to equal 1.75 pt. (dry measure).
1 litre to equal 2.11 pt. (liquid measure).

SYSTEM

An arrangement of organs closely allied to each other and set apart to perform some general function is spoken of as a system. Eight systems are found in the human body. Their names with the functions of each are briefly expressed as follows: —

Skeletal system. — Support and locomotion.

Muscular system. — Irritability and motion.

Vascular system. — Distribution of the body fluids to all the cells.

Respiratory system. — To provide oxygen and get rid of carbon dioxide.

Alimentary system. — To receive, digest, and absorb the food so as to provide heat, energy, and materials to replace worn-out tissues.

Excretory system. — To eliminate the waste products that result from the activities of life.

Nervous system. — To control and insure coördination in the working of all the systems in the body. Contains the centres for all the sensations, intelligence, and thought that we recognize as the highest functions of life.

Reproductive system. — To insure the continuance of the race by the production of another being.

It is important for the student to remember that these different systems are closely related and dependent on each other. While each forms a complete unit, specially adapted for the performance of some function, yet that function cannot be properly performed without the assistance and coöperation of other systems. The most perfect skeleton is not capable of locomotion, unless assisted by the muscular and nervous systems. Any interference with the circulatory system also affects the work of the excretory system, etc.

CLASSIFICATION

By the aid of the microscope the different distinct tissues of which the body is formed are found to be comparatively few in number, and some of these, although at first sight apparently distinct, yet have so much in common in their structure and origin, one with another, that the number becomes still further reduced, until we can distinguish only four distinct tissues, viz.: —

1. The epithelial tissues.
2. The connective tissues.
3. The muscular tissues.
4. The nervous tissues.

Such fluids as blood and lymph are frequently described as liquid tissues.

Origin of tissues. — It has been stated that the cell is the structural unit of the body, and in the beginning the body develops from a single cell named the ovum. The ovum is developed in the ovary and is made fertile by the entrance into it of a cell, known as the spermatozoön formed in the testes of the male. After fertilization or impregnation takes place, the cells divide and subdivide until their number is enormously increased.

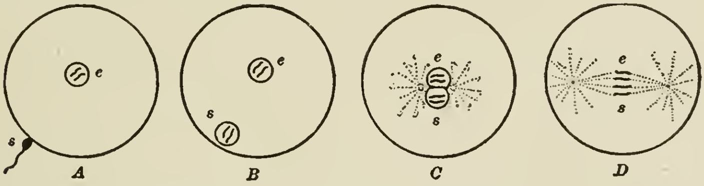

FIG. 8. — DIAGRAMS TO ILLUSTRATE FERTILIZATION OF AN EGG-CELL (OVUM) BY A SPERM-CELL (SPERMATOZOÖN). *A*, *e*, nucleus of a matured egg-cell; *s*, a sperm-cell ready to enter. *B*, sperm-cell entered and transformed into sperm-nucleus (*s*). *C*, sperm-nucleus and egg-nucleus united, fertilization complete. *D*, division leading to two-cell stage. (Bigelow.)

The cells thus formed eventually arrange themselves in the form of a membrane, *blastoderm,* which is composed of three layers. These layers are known respectively as *ectoderm, mesoderm,* and *entoderm.*

The *ectoderm,* or outer layer, forms the epidermis and the nervous system.

The *mesoderm,* or middle layer, forms the circulatory and urinogenital systems, also the muscles, bones, and other connective tissues.

The *entoderm* or inner layer forms the greater part of the alimentary and respiratory tracts, also the liver, pancreas, and other glands.

EPITHELIAL TISSUE

Epithelial tissue is composed entirely of cells united together by adhesive matter or cement substance. The cells are generally so arranged as to form a skin, or membrane, covering the external surfaces, and lining the internal parts of the body. This membrane is seen when the skin is blistered, the thin and nearly transparent membrane raised from the surface being epithelial tissue — in this situation called **epidermis**, because it lies upon the surface of the true skin. In other situations, epithelial tissue usually receives the general name of **epithelium.**

We may classify the varieties of epithelium according to the shape of the cells which compose them, or according to the arrangement of these cells in layers. Adopting the latter and simpler classification, we distinguish three main varieties: —

1. **The simple, consisting of a single layer of cells.**
2. **The transitional, consisting of two or three layers.**
3. **The stratified, consisting of many layers.**

1. **Simple epithelium.** — This is composed of a single layer of cells. The cells forming single layers are of distinctive shape, and have distinctive functions in different parts of the body. The chief varieties are: —

a. pavement *b. columnar* *c. ciliated*

(*a*) *Pavement epithelium.* — This is also called squamous or scaly epithelium. The cells form flat, many-sided plates or scales, which fit together like the tiles of a mosaic pavement. It forms very smooth surfaces, and lines the heart, blood-vessels, and lymphatics, the mammary ducts, the serous cavities, etc.

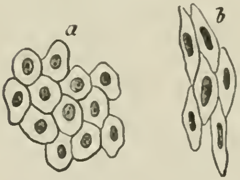

Fig. 9. — Simple Pavement Epithelium. *a*, from a serous membrane; *b*, from a blood-vessel.

(*b*) *Columnar epithelium.* — The columnar epithelium is a variety of simple epithelium in which the cells have a prismatic shape, and are set upright on the surface which they cover. In profile these cells look somewhat like a close palisade. They taper somewhat toward their attached end, which is set upon a basement membrane. Columnar epithelium is found in its most characteristic form lining the intestinal canal.

Fig. 10.—Simple Columnar Epithelium. *a*, the cells; *b*, intercellular substance between the lower end of cells.

(*c*) *Ciliated epithelium.* — In ciliated epithelium the cells, which are generally columnar in shape, bear at their free surface little hair-like processes (strongly suggestive of eyelashes), which are agitated incessantly with a lashing or vibrating motion. These minute and delicate processes are named **cilia,** and may be regarded as active prolongations of the cell-protoplasm. The manner in which cilia move is best seen when they are not acting very quickly. The motion of an individual cilium may be compared to the lash-like motion of a short-handled whip, the cilium being rapidly bent in one direction. The motion does not involve the whole of the ciliated surface at the same moment, but is performed by the cilia in regular succession, giving rise to the appearance of a series of waves travelling along the surface like the waves tossed by the wind in a field of wheat. When they are in very rapid action, their motion conveys the idea of swiftly running water. As they all move in one direction, a current of much power is produced.

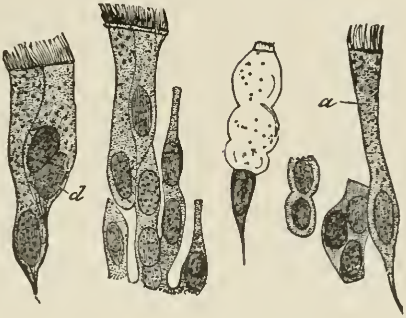

FIG. 11. — CILIATED EPITHELIUM FROM THE HUMAN TRACHEA. (Highly magnified.) *a*, large ciliated cell; *d*, cell with two nuclei.

Function. — Cilia have been shown to exist in almost every class of animal, from the highest to the lowest. In man their use is to impel secreted fluids, or other matters, along the surfaces to which they are attached; as, for example, the mucus of the trachea and nasal chambers, which they carry toward the outlet of these passages, and thus keep out foreign matter.

2. **Transitional epithelium.** — This consists of two or three layers of cells. The superficial cells are large and flattened, having on their under surface depressions into which fit the larger ends of

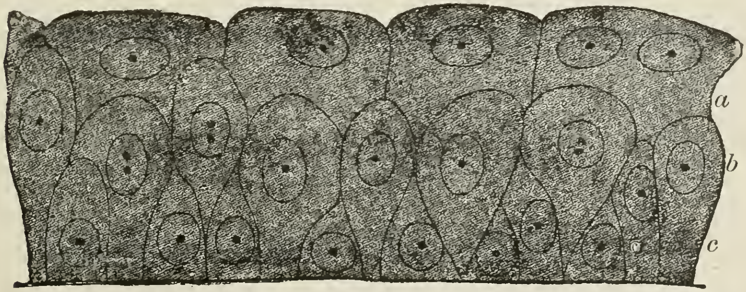

FIG. 12. — SECTION OF THE TRANSITIONAL EPITHELIUM LINING THE BLADDER. (Highly magnified.) *a*, superficial; *b*, intermediate; *c*, deep layer of cells. (Schäfer.)

the pear-shaped cells which form the next layer. Between the tapering ends of these pear-shaped cells are one or two layers of smaller, many-sided cells, the epithelium being renewed by division of these deeper cells. This kind of epithelium lines the bladder and ureters.

3. **Stratified epithelium.** — This consists of many layers of cells. The cells composing the different layers differ in shape. As a rule, the cells of the deepest layer are columnar in shape; the next, rounded or many-sided, whilst those nearest the surface are always flattened and scale-like. The deeper soft cells of a stratified epithelium are separated from one another by a system of channels, which are bridged across by numerous fibres. These cells are often described as **prickle cells**, as when separated they appear beset with spines. They are continually multiplying by cell-division, and as the new cells which are thus produced in the deeper parts increase in size, they compress and push outward those previously formed.

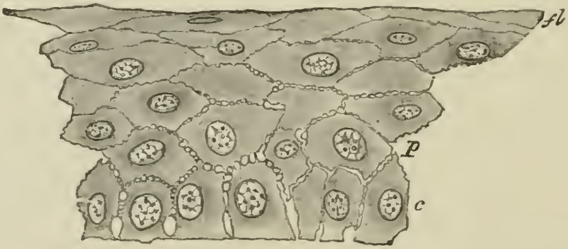

FIG. 13. — SECTION OF STRATIFIED EPITHELIUM. *c*, lowermost columnar cells; *P*, polygonal cells above these; *fl*, flattened cells near the surface. Between the cells are seen intercellular channels, bridged over by processes which pass from cell to cell. (Schäfer.)

In this way cells which were at first deeply seated are gradually shifted outward and upward, growing harder as they approach the surface. The older superficial cells are being continually rubbed off as the new ones continually rise up to supply their places.

Stratified epithelium covers the anterior surface of the eye, lines the mouth, the chief part of the pharynx, the œsophagus, the anal canal, part of the urethra, and in the female the vagina and neck of the uterus.

Its most extensive distribution is over the surface of the skin, where it forms the epidermis. Whenever a surface is exposed to friction, we find stratified scaly epithelium, and we may therefore classify it as a protective epithelium.

Function. — The most important functions of epithelial tissue are as follows:

1. *Protection.* — Some varieties are specially modified so as to form protective membranes. Example — skin. Other varieties form the top layer of the mucous membranes, and mucous membranes are found lining passages that communicate with the exterior of the body. Serous membranes are also lined by epithelial cells. These serous membranes line passages that do not communicate with the exterior of the body.

2. *Motion.* — This is seen in the cilia, which tend to keep the passages to which they are attached clean, and free from foreign material.

3. *Absorption.* — This is particularly well seen in the digestive tract. To some extent the skin also is capable of absorption.

4. *Secretion.* — Every secreting organ must contain epithelial cells. Mucous and serous membranes are examples of secreting organs.

5. *Special Sensation.* — The organs of the special senses contain epithelial cells. Examples — eye, ear, nose, etc.

SUMMARY

The Human body is an enormous aggregate of cells.

Cell
- Cell membrane — may or may not be present.
- Cytoplasm — distinctive name given to protoplasm that surrounds nucleus.
- Nucleus — a more solid central portion surrounded by a membrane. The protoplasm of the nucleus is called karyoplasm.
- Nucleolus — minute, spherical bodies found in nucleus.
- Centrosome — one or two extremely small bodies, surrounded by *attraction sphere*, which is made up of cytoplasm. Always located near nucleus.

Life activities in cells
1. Respiration
    - Combines with oxygen = oxidation.
    - Liberates heat.
    - Carbon dioxide formed.
2. Metabolism
    - Anabolism = building up process.
    - Katabolism = breaking down process.
3. Amœboid movements.
4. Reproduction
    - Akinesis or direct division.
    - Karyokinesis or indirect division.

Differences in cells
- Size $\frac{1}{3000}$ to $\frac{1}{300}$ of an inch (0.008 to 0.08 mm.).
- Form depends on
    - Pressure.
    - Movements of cell.
    - Growth and differentiation.
- Chemical composition — dependent on special work of cell.
- Function — assist in work of tissue or organ of which it forms a part.

Tissues — are made up of a collection of cells of like substance, with more or less intercellular substance between the cells.

Organs — are made up of two or more tissues associated to perform a common function.

System
- System — a group of organs set apart to perform some special function.
- Skeletal, Muscular, Vascular, Respiratory, Alimentary, Excretory, Nervous — All interdependent.
    - Skeletal
    - Muscular
    - Vascular
    - Respiratory
    - Alimentary
    - Excretory
    - Nervous

Classification of tissues
1. Epithelial.
2. Connective.
3. Muscular.
4. Nervous.

Origin of tissues
- Impregnation — Multiplication of cells — Blastoderm
  - Ectoderm
    - Epidermis.
    - Nervous system.
  - Mesoderm
    - Circulatory. system.
    - Urino-genital system.
    - Muscles.
    - Connective tissues.
  - Entoderm
    - Respiratory tract.
    - Alimentary tract.
    - Liver, Pancreas.

Epithelial — a tissue of cells and little intercellular substance.

Classification of Epithelial Tissue
- **Simple**, consisting of a single layer
  - Pavement or scaly.
  - Columnar.
  - Ciliated.
- **Transitional**, consisting of 2 or 3 layers.
- **Stratified**, consisting of many layers.

Function . .
- Protection.
- Motion.
- Absorption.
- Secretion.
- Special sensation.

CHAPTER IV

CONNECTIVE TISSUES: AREOLAR, FIBROUS, ELASTIC, ADIPOSE, RECTICULAR, LYMPHOID, CARTILAGE, BONE

Following the classification of tissues we have adopted, the next group to be studied is that known as the connective tissue group.

Our description of epithelial tissue was briefly this: a skin or membrane formed of cells, which cells may be of a variety of shapes, and be arranged in one or more layers. It is distinctly a tissue of cells with very little of what we call intermediate or intercellular substance lying between the cells. Connective tissue differs from epithelial tissue in having a great deal of intercellular substance lying between the cells. It may be interesting to note that in this form of tissue, the intercellular substance is supposed to develop from the cells.

CONNECTIVE TISSUE GROUP

These tissues differ considerably in their external characteristics, but are alike (1) in that they all serve to connect and support the other tissues of the body; (2) they are all developed from the mesoderm; (3) the cellular element is at a minimum, and the intercellular material is at a maximum; (4) they originate no action, but are acted upon by the other tissues. We may therefore group them together as follows: —

1. **Areolar** tissue.
2. **Fibrous** tissue.
3. **Elastic** tissue.
4. **Adipose** tissue.
5. **Reticular** tissue.
6. **Lymphoid** tissue.
7. **Cartilage.**
8. **Bone** or **osseous** tissue.

Areolar tissue. — This tissue appears to be composed of a multitude of fine threads or films, called fibres. Viewed with a microscope, these fibres are seen to be principally made up of wavy bundles of exquisitely fine, transparent, white fibres, and these bundles intersect in all directions. Mixed with the white fibres are a certain number of yellow elastic fibres, which do not form bundles, and have a straight instead of a wavy outline. Between these fibres are open spaces, called areolæ,[1] that communicate freely with one another. Lying in the areolæ between the bundles of fibres are seen the tissue-cells, of which there are many varieties.

If we make a cut through the skin of some part of the body where there is no subcutaneous fat, as in the upper eyelid, and proceed to raise it from the parts lying beneath, we observe that it is loosely connected to them by a soft, filmy substance of considerable tenacity and elasticity. This is areolar tissue.

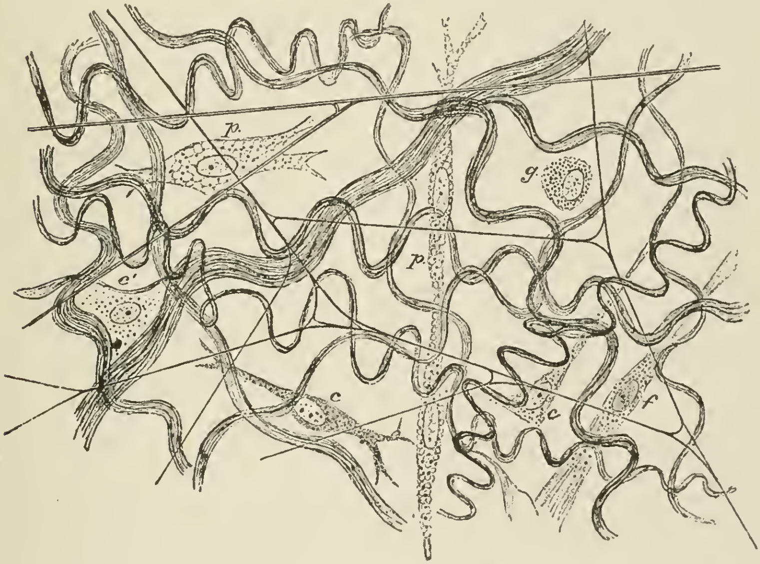

FIG. 14. — SUBCUTANEOUS AREOLAR TISSUE FROM A YOUNG RABBIT. (Highly magnified.) The white fibres are in wavy bundles, the elastic fibres form an open network. *p*, *p*, vacuolated cells; *g*, granular cell; *c*, *c*, branching lamellar cells; *c'*, a flattened cell, of which only the nucleus and some scattered granules are visible; *f*, fibrillated cell. (Schäfer.)

Fibrous tissue. — This tissue is intimately allied in structure to the areolar tissue. It consists almost wholly of wavy white fibres, which cohere very closely and are arranged side by side in bundles which have an undulating outline. The spaces between the bundles are occupied by cells arranged in rows, but the cells are

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[1] Areola is the Latin word for "a small space." Areolar tissue gets its name from appearing full of minute spaces.

not a prominent feature of this tissue. The fibres may be some inches long, do not branch, and confer a distinctly fibrous aspect on the parts which they compose.

Fig. 15. — Fibrous Tissue, from the Longitudinal Section of a Tendon. The spaces between the bundles of fibres are occupied by rows of cells. (Gegenbauer.)

Fibrous tissue is white, with a peculiarly shining, silvery aspect. It is exceedingly strong and tough, yet perfectly pliant; but it is almost devoid of extensibility and is very sparingly supplied with nerves and blood-vessels.

Elastic tissue. — In elastic tissue the wavy white bundles are comparatively few and indistinct, and there is a proportionate development of the elastic fibres. When present in large numbers, they give a yellowish color to the tissue. This form of connective tissue is extensile and elastic in the highest degree, and wherever located, does such work as India rubber would do. It is not so strong as the fibrous variety, and breaks across the direction of its fibres when forcibly stretched.

Function. — These three varieties of connective tissue (areolar, fibrous, elastic) agree closely with one another in elementary structure. It is the different arrangement of the cells and fibres, and the relative proportion of one kind of fibre to the other, that gives them their different characteristics. They are used for purely mechanical purposes.

Areolar tissue forms web-like binding and supporting material and serves to connect and insulate entire organs. It is one of the most general and most extensively distributed of the tissues. It is, moreover, continuous throughout the body, and from one region it may be traced without interruption into any other, however distant, — a fact not without interest in practical medicine, seeing that in this way air, water, pus and other fluids, effused into the areolar tissue, may spread far from the spot where they were first introduced or deposited.

Fibrous tissue is met with in the form of: —

(1) *Ligaments.* — Ligaments are strong flexible bands, or capsules, of fibrous tissue that help to hold the bones together at the joints.

(2) *Tendons* or *sinews.* — Tendons are white glistening cords or bands which serve to attach the muscles to the bones. They are usually composed of white fibres, but may contain some yellow fibres.

(3) *Aponeuroses.* — Aponeuroses are flat, wide bands of fibrous tissue which serve to connect one muscle with another.

(4) *Protecting sheaths* or *membranes.* — Fibrous tissue is found investing and protecting different organs of the body. Examples — heart and kidneys.

(5) *Fasciæ.* — The word fascia means a band or bandage. It is most frequently applied to sheets of fibrous membrane which are wrapped around muscles, and serve to hold them in place. Fasciæ are divided into two groups, which are associated with the skin and the muscles. They are called: —

a. Superficial.

b. Deep.

a. Superficial fascia. — The subcutaneous areolar tissue, which forms a nearly continuous covering beneath the skin, is classed as superficial fascia. It varies in thickness, and usually permits free movement of the skin on the subjacent parts.

The fascia covering the palms of the hands is named palmar fascia, and the fascia covering the soles of the feet is named plantar fascia. The palmar and plantar fascia are much thicker, stronger, and more closely attached than the superficial fascia in other parts of the body.

b. Deep fasciæ. — The deep fasciæ are sheets of white, flexible fibrous tissue, employed to envelop and bind down the muscles, also to separate them into groups. The term fascia, unless limited by an adjective, is usually employed to designate the *deep fasciæ.* Subcutaneous areolar tissue is rarely called by the name fascia, though it is correctly classed as such.

Elastic tissue, being extensile and elastic, has a most important use in assisting muscular tissue, and so lessening the wear and tear of muscle. It is found: —

(1) Between the transverse processes of the vertebra in elastic bands. (Ligamenta flava.)

(2) In the walls of the blood-vessels (especially arteries), air tubes, and vocal cords.

(3) Entering into the formation of the lungs and uniting the cartilages of the larynx.

Adipose tissue. — When fat begins to be formed, it is deposited in tiny droplets[1] in some of the cells of the areolar tissue; these droplets increase in size, and eventually run together so as to form one large drop in each cell. By further deposition of fat the cell becomes swollen out to a size far beyond that which it possessed originally, until the protoplasm remains as a delicate envelope surrounding the fat drop. The nucleus is crowded off to one side and attached to the cell wall. As these cells increase in number they collect into small groups or lobules, which lobules are for the most part lodged in the meshes of the areolar tissue, and are also supported by a fine network of blood-vessels. This fatty tissue exists very generally throughout the body, accompanying the still more widely distributed areolar tissue in most parts, though not in all, in which the latter is found. Still, its distribution is not

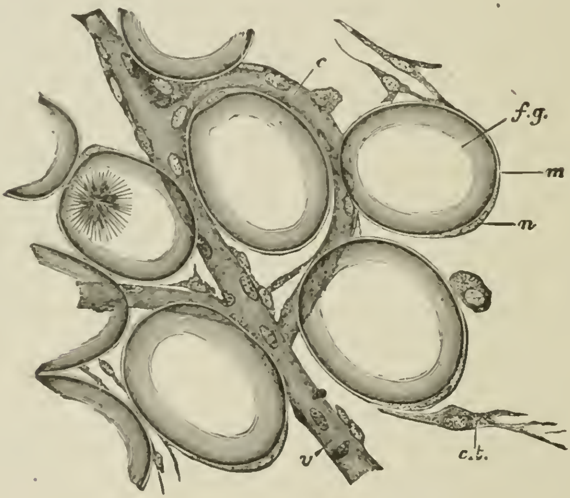

FIG. 16. — A FEW FAT CELLS FROM THE MARGIN OF A FAT LOBULE. (Very highly magnified.) *f.g.* fat globules distending a fat cell; *n*, nucleus; *m*, membranous envelope of the fat cell; *c*, capillary vessel; *v*, veinlet; *c.t.* connective-tissue cell; the fibres of the connective tissue are not shown. (Schäfer.)

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[1] The contents of the fat cells of adipose tissue are fluid during life, as the normal temperature of the body is considerably above the melting point of the mixture of fats found there.

uniform, and there are some situations in which it is collected more abundantly. This tissue is found chiefly: —

(1) Underneath the skin, in the subcutaneous layer.

(2) Beneath the serous membranes or in their folds.

(3) Collected in large quantities around certain internal organs, especially the kidneys, which it helps to hold in place.

(4) Filling up furrows on the surface of the heart.

(5) As padding around the joints.

(6) In large quantities in the marrow of the long bones.

Function. — Adipose tissue serves several important purposes. (1) Unless formed in abnormal quantities it confers graceful outlines. (2) It constitutes an important reserve fund, which when required can be returned to the blood and oxidized, thus producing heat and energy. (3) It serves as a jacket or covering under the skin, and being a non-conductor of heat, prevents the too rapid loss of heat through the skin. (4) It is an admirable packing material, and serves to fill up spaces in the tissues, and thus affords support for delicate structures such as blood-vessels and nerves.

Reticular or retiform [1] tissue. — This variety of connective tissue consists of a close network of white fibres with few, if any, yellow fibres. The meshes of the network are small and close in some parts, more open and like areolar tissue in other parts. The fibres are nearly covered by fibrous tissue cells in the form of broad, thin

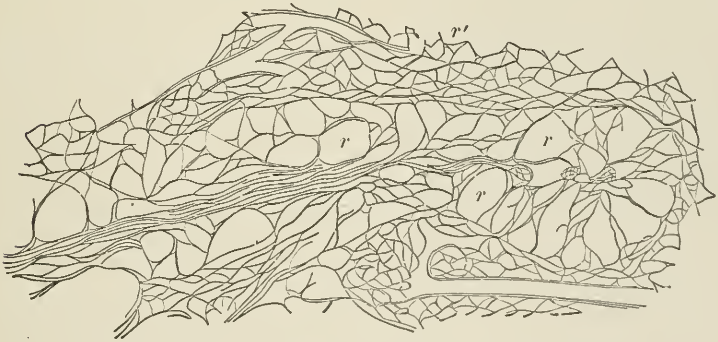

Fig. 17. — Retiform Tissue from a Lymph Node. *r*, *r*, *r*, represent open meshes of this tissue. (Quain.)

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[1] Reticulum (from the Latin *reticulum* "a small net"). Resembling a small net.

plates wrapped around them. It forms a fine framework in many organs.

Lymphoid or adenoid [1] tissue. — This is reticular tissue in which the meshes of the network are occupied by lymph corpuscles. This is the most common condition of retiform tissue.

Function. — Lymphoid tissue forms the principal part of the substance of the spleen and lymph nodes. It also enters into the composition of the tonsils and some of the intestinal glands.

Cartilage. — This is the well-known substance called "gristle." Although cartilage can be readily cut with a sharp knife, it is nevertheless of very **firm** consistence, but at the same time highly **elastic**, so that it readily yields to extension or pressure, and immediately recovers its original shape when the constraining force is withdrawn. When a very thin section is examined with a microscope, it is seen to consist of nucleated cells disposed in small groups in a mass of intercellular substance. This intercellular substance is sometimes transparent, and to all appearances structureless; sometimes it is pervaded with white fibres and sometimes with yellow fibres. According to the amount and texture of the intercellular substance, we distinguish three principal varieties: —

FIG. 18. — ARTICULAR HYALINE CARTILAGE FROM THE FEMUR OF AN OX. *s*, intercellular substance; *p*, protoplasmic cell; *n*, nucleus. (Ranvier.)

(1) *Hyaline* or *true cartilage.*
(2) *White fibro-cartilage.*
(3) *Yellow* or *elastic fibro-cartilage.*

Hyaline cartilage. — This variety is named from the Greek word for glass. A comparatively small number of cells are embedded in an abundant quantity of intercellular substance which has the appearance of ground glass.

White fibro-cartilage. — The intercellular substance is pervaded

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[1] Adenoid (from the Greek *aden*, "a gland," and *eiodos*, "form" or "resemblance." Pertaining to or resembling a gland.

with bundles of white fibres, between which are scattered cartilage cells. It closely resembles white fibrous tissue, and is found wherever great strength, combined with a certain amount of rigidity, is required.

Yellow, or *elastic, fibro-cartilage.* — The intercellular substance is pervaded with yellow elastic fibres which form a network. In the meshes of the network the cartilage cells are found.

Function. — The function of cartilage is roughly the same throughout, the qualifying terms are used to denote differences in structure and appearance rather than in function.

1. *Hyaline cartilage* covers the ends of the bones in the joints, where it is known as articular cartilage.

2. *Hyaline cartilage* forms the rib cartilages, where it is known as costal cartilage.

In both these situations the cartilages are in immediate connection with bone, and may be said to form part of the skeleton, hence frequently described as skeletal cartilages.

The articular cartilages, in covering the ends or surfaces of bones in the joints, provide these harder parts with a thick, springy coating, which breaks the force of concussion, and gives ease to the motion of the joint. The costal cartilages, in forming part of the solid framework of the thorax or chest, impart elasticity to its walls. Hyaline cartilage also enters into the formation of the nose, ear, larynx, and trachea. It strengthens the substance of these parts without making them unduly rigid, maintains their shape, keeps open the passages through them where such exist, and gives attachment to moving muscles and connecting ligaments.

White fibro-cartilage is found joining bones together, the most familiar instance being the flat, round plates or disks of fibro-cartilage connecting the bones of the spine and the pubic bones. In these cases the part in contact with the bone is always hyaline cartilage, which passes gradually into the fibro-cartilage.

Yellow, or elastic, fibro-cartilage is found in the epiglottis, cartilages of the larynx, Eustachian tube, and external ear.

Cartilage is not supplied with nerves, and very rarely with blood-vessels. Being so meagrely supplied with blood, the vital processes in cartilage are very slow, and when a portion of it is absorbed in disease or removed by the knife, it is regenerated very slowly. A wound in cartilage is usually at first healed by connective tissue proper, which may or may not become gradually transformed into cartilage. Nearly all cartilages receive their nourishment from the **perichondrium** which covers them, and which is a moderately vascular fibrous membrane.

Bone, or osseous tissue. — Bone is connective tissue in which the intercellular substance which is derived from the cells is rendered hard by being impregnated with mineral salts.

The mineral, or earthy, substance which is deposited in bone, and which makes it hard, consists chiefly of phosphate of calcium, with about a fifth part of carbonate of calcium, and a small portion of other salts.

The organic, or soft, matter consists chiefly of blood-vessels and connective tissue, and may be resolved by boiling almost entirely into gelatine.

It is possible to separate each of these substances. The **mineral** matter may be removed by soaking a bone in dilute acid for several days. The result will be a tough, flexible, elastic substance, consisting only of organic matter. The shape of the bone will be preserved, but the specimen will be so free from stiffness that it may be tied in a knot.

The **organic** matter may be driven off by heat. As before, the shape of the bone will be preserved. The specimen will consist only of mineral matter, will appear white, rigid, and so brittle it can be crushed between the fingers.

Amount of organic and inorganic matter. — The comparative amount of organic and inorganic matter found in bone is dependent on the age of the individual. In the fœtus the tissues that later become bone are either fibrous or cartilaginous. By absorption of mineral substances from the blood, these tissues gradually become ossified. Thus it follows that in youth the organic matter is in excess. In adult life the organic matter constitutes about one-third of the weight of the bone, and the inorganic matter two-thirds. In old age the amount of inorganic matter is increased.

Fracture. — The term "fracture" is applied to the breaking of a bone. As a result of the greater amount of organic matter in the bones of children, they are flexible, bend easily, and do not break readily. In some cases the bone bends like a bough of green wood. Some of the fibres may break, but not the whole bone, hence the name "green-stick fracture." It is also true that the greater amount of inorganic matter in the bones of the aged renders the bones more brittle, so that they break easily and heal with difficulty.

Rachitis or Rickets. — In the disease called rickets, quite common among poorly nourished children, there is not sufficient mineral matter, so that the bones are flexible, bend easily, and may be permanently misshapen.

Structure of Bone. — On sawing a bone it will be seen that in some parts it is open and spongy, whilst in others it is dense and close in texture, appearing like ivory. We thus distinguish two forms of bony tissue: —

(1) *The cancellated, or spongy.*

(2) *The dense, or compact.*

On closer examination, however, it will be seen that the bony matter is everywhere porous, and that the difference between the two varieties of tissue arises from the fact that the compact tissue has fewer spaces and more solid matter between them, while the cancellated has larger cavities and more slender intervening bony partitions. In all bones the compact tissue is the stronger; it lies on the surface of the bone and forms an outer shell or crust, whilst the lighter, spongy tissue is contained within. The shafts of the long bones are almost entirely made up of the compact substance, except that they are hollowed out to form a central canal, — the medullary canal, — which has a fibrous lining called **endosteum**, and contains marrow.

The hard substance of both varieties is arranged in bundles of bony fibres, or **lamellæ** (layers).

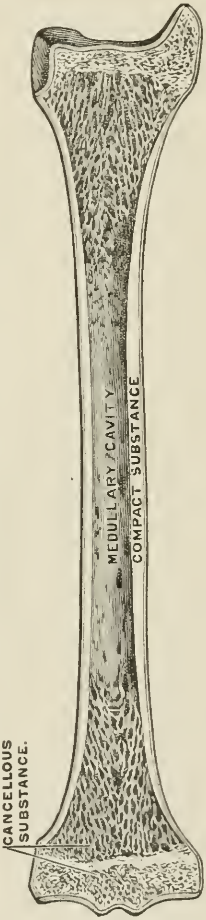

Fig. 19. — Vertical Section of a Long Bone. (Gerrish.)

Cancellated bone. — In cancellated bone the lamellæ join and meet together so as to form a structure resembling lattice-work (*cancelli*), whence this tissue receives its name. In the interstices of this kind of bone we find the blood-vessels supported by the marrow.

Compact bone.—In compact bone the lamellæ are usually arranged in rings around canals, — Haversian canals, — which carry blood-vessels in a longitudinal direction through the bones. Between the lamellæ are branched cells which lie in cell-spaces, or cavities, called **lacunæ** (little lakes), and running out in a wheel-like or radial direction from each lacuna are numerous tiny wavy canals called **canaliculi**, connecting one lacuna with another, and forming a system of minute channels which communicate with each other and with the Haversian canal. This constitutes an **Haversian System**, so named from Havers, a celebrated anatomist. Many such systems may be found in the shaft of a long bone. The spaces between these systems are filled by lamellæ arranged at irregular angles.

Marrow. — Marrow consists of fibrous tissue with blood-vessels, fat-cells, marrow-cells and red corpuscles. There are two distinct kinds of marrow, yellow and red. Yellow marrow contains a larger per cent of fat, and is found in the medullary canals of the long bones. Red marrow contains less fat, but is highly vascular and occupies the spaces in cancellous bone. The function of marrow is (1) to support the blood-vessels, lymphatics, and nerves; (2) to serve as a source of nourishment for bone; and (3) as a location for the formation of red corpuscles. (See page 143.)

Periosteum. — All bones are covered, except at the joints, by a vascular fibrous membrane, the periosteum (around the bone). It consists of an outer fibrous layer and an inner vascular layer. The attachment of the periosteum to bone is rendered firmer by inward prolongations of the fibrous layer called the **fibres of Sharpey.**

Blood-vessels. — Unlike cartilage, the bones are plentifully supplied with blood. If we strip the periosteum from a fresh bone, we see many bleeding points representing the canals (Volkman's) through which the blood-vessels enter and where they leave the bone. These blood-vessels proceed from the periosteum to join the system of Haversian canals. Around the Haversian canals the lamellæ are disposed, while lying between them, arranged in circles, are found the lacunæ, which contain the bone-cells. Running from one lacuna to another in a radial direction through the lamellæ towards the centre are the canaliculi. Following this scheme, it will be seen that the innermost canaliculi run into the Haversian canals, and thus is established a direct communication between the blood in these canals and the cells in the lacunæ connected with and surrounding each Haversian canal. In this way the whole sub-

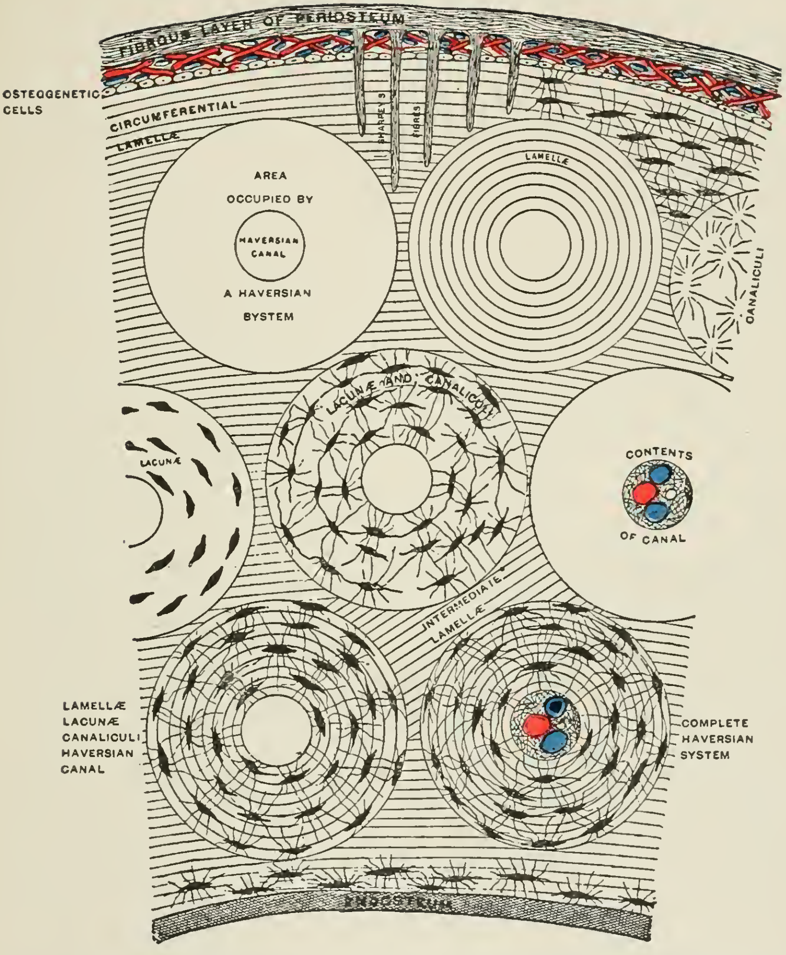

Fig. 20. — Diagram of the Structure of Osseous Tissue. A small part of a transverse section of the shaft of a long bone is shown. At the uppermost part is the periosteum covering the outside of the bone; at the lowermost part is the endosteum lining the marrow cavity. Between these is the compact tissue consisting largely of a series of Haversian systems, each being circular in outline and perforated by a central canal. In the first one is shown only the area occupied by a system; in the second is seen the concentric arrangement of the lamellæ; in the others, respectively, canaliculi; lacunæ; lacunæ and canaliculi; the contents of the canal, artery, vein, lymphatic, and areolar tissue; lamellæ, lacunæ, and canaliculi; and finally all of the structures composing a complete system. Between the systems are circumferential and intermediate lamellæ, only a few of which are represented as lodging lacunæ, though it is to be understood that lacunæ are in all parts. The periosteum is seen to be made up of a fibrous layer and a vascular layer, and to have upon its attached surface a stratum of cells. From the fibrous layer project inward the rivet-like fibres of Sharpey. (Gerrish.)

stance of the bone is penetrated by intercommunicating channels, and the nutrient matters and mineral salts from the blood in the Haversian canals can find their way to every part.

Function of periosteum in growth of bone. — In the embryo the foundation of the skeleton is laid in cartilage, or in primitive connective tissue, ossification of the bones occurring later. The hardening or ossification of the bones is accomplished by the penetration of blood-vessels and bone-cells, called osteoblasts, from the periosteum. As they penetrate into the cartilaginous or membranous models, they absorb the cartilage and connective tissue and deposit the true bone tissue at various points until they form the particular bony structure with which we are familiar.

Regeneration of bone. — A fracture is usually accompanied by injury to the periosteum and tissues. This results in inflammation, which means an increased amount of blood is sent to the part. The plasma and white blood corpuscles from the blood exude into the tissues and form a viscid substance, which sticks the ends of the bone together, and is called *callus*. Usually bone-cells from the periosteum and lime salts are gradually deposited in the callus, which eventually becomes hardened and forms new bone. Occasionally the callus does not ossify and a condition known as *fibrous union* results. The periosteum is largely concerned in this process of repair; for if a portion of the periosteum be stripped off, the subjacent bone will be liable to die, while if a large part or the whole of a bone be removed, and the periosteum at the same time left intact, the bone will wholly or in a great measure be regenerated.

SUMMARY

CONNECTIVE TISSUE — A tissue of cells with a great deal of intercellular substance, which is derived from the cells.

Reasons for Classification
1. Resemble each other in function.
2. Resemble each other in origin.
3. Resemble each other in structure.

Classification
Areolar, Reticular,
Fibrous, Lymphoid,
Elastic, Cartilage,
Adipose, Bone.

Areolar tissue. — Formed by interlacing of wavy bundles of white fibres and some straight elastic fibres with cells lying in the spaces.

Fibrous tissue. — Formed of wavy bundles of white fibres only, with cells in rows between bundles. Very strong and tough but pliant.

Elastic tissue. — Formed of yellow elastic fibres with few bundles of white fibres. It is extensile and elastic.

Function
- **Areolar tissue** connects, insulates, forms protecting sheaths, and is continuous throughout the whole body.
- **Fibrous tissue** is found in form of ligaments, tendons, aponeuroses, protecting sheaths, and fasciæ.
- **Elastic tissue** serves same purpose as India rubber. Saves wear and tear of muscles. Found in **ligamenta flava**, blood-vessels, air-tubes, vocal cords, lungs, and larynx.

Adipose tissue. — Modification of areolar tissue, with cells enlarged and filled with fat. Distribution quite general but not uniform.

Function
1. Confers graceful outlines.
2. Forms a reserve fund for the production of heat and energy.
3. Prevents the too rapid loss of heat.
4. Serves to protect and support delicate organs.

Reticular tissue. — Network of white fibres with few yellow fibres. Cells wrapped around fibres.

Lymphoid tissue. — Reticular tissue with meshes of network occupied by lymph corpuscles.

Function. — Lymphoid tissue forms the structure of the spleen and lymph-nodes. Also enters into composition of glands and mucous membranes.

Cartilage. — Cartilage or gristle is a bluish white tissue, firm and elastic, covered and nourished by perichondrium.

Varieties
1. **Hyaline cartilage** — Articular, Costal } Skeletal.
2. **White fibro-cartilage.**
3. **Yellow fibro-cartilage.**

Hyaline — Small number of cells in an abundant quantity of intercellular substance. Found as articular cartilage, covering ends of bones in joints. Found as costal cartilage, connecting ribs and sternum, or one rib with another.

White Fibro — Intercellular substance pervaded with white fibres. Resembles fibrous tissue. Found between spinal and pubic bones.

Yellow Fibro — Intercellular substance pervaded with network of yellow elastic fibres. Found in parts of throat and ear.

Function
- Hyaline Cartilage
  - Serves as cushions for ends of bones.
  - Makes a flexible connection between the ribs and the sternum, or between one rib and another.
  - Strengthens and maintains shape of certain organs without rigidity.
- White Fibro-cartilage
  - Serves as strong, flexible connecting material between bones, and around some joints.
- Yellow Fibro-cartilage
  - Strengthens and maintains shape of certain organs, and yet allows of certain amount of elasticity.

BONES OR OSSEOUS TISSUE

- **Composition**
  - Mineral matter
    - Calcium phosphate.
    - Calcium carbonate.
    - Small portion of other salts.
  - Organic matter
    - Blood-vessels.
    - Connective tissue.
    - Marrow.
- **Varieties**
  - Cancellated or spongy.
  - Dense or compact like ivory.
- **Canals**
  - Medullary — Yellow Marrow.
  - Haversian
    - Blood-vessels.
    - Lymphatics.
- **Haversian System**
  - Haversian canal.
  - Lamellæ — bony fibres arranged in rings around Haversian canal.
  - Lacunæ — small spaces between lamellæ occupied by bone cells.
  - Canaliculi — canals which radiate from lacunæ to the Haversian canal.
- **Endosteum** — A fibrous membrane that lines the medullary canal.
- **Marrow**
  - **Consists of**
    - Fibrous tissue, blood-vessels, fat-cells, marrow cells, and red corpuscles.
  - **Varieties**
    - Yellow — found in medullary canals of long bones.
    - Red — occupies spaces in cancellous bone.
  - **Function**
    - 1. Supports blood-vessels, lymphatics, and nerves.
    - 2. Serves as a source of nourishment for bone.
    - 3. Serves as location for formation of red corpuscles.
- **Periosteum** — A vascular fibrous membrane that covers the bones and serves to nourish them. Important in reunion of broken bone and growth of new bone.
- **Fibres of Sharpey** — Inward prolongations of periosteum.

CHAPTER V

THE SKELETON

Function. — The **bones** are the principal organs of support, and the passive instruments of locomotion. Connected together in the skeleton, they form a framework of hard material, affording attachment to the soft parts, maintaining them in their due position, sheltering such as are of delicate structure, giving stability to the whole fabric, and preserving its shape.

The entire skeleton in the adult consists of two hundred and six named bones. These are: —

Cranium		8
Face		14
Ear	Malleus 2 Incus 2 Stapes 2	6
Hyoid		1
The spine, or vertebral column (sacrum and coccyx included)		26
Sternum and ribs		25
Upper extremities		64
Lower extremities		62
		206

In this enumeration the sesamoid[1] bones, which are found embedded in tendons covering the bones of the knee, hand, and foot, are not included.

CLASSIFICATION

The bones may be divided, according to their shape, into four classes: 1. **Long**, 2. **Short**, 3. **Flat**, and 4. **Irregular**.

Long bones. — A long bone consists of a shaft, and two extremities. The shaft is formed mainly of compact tissue, this compact tissue being thickest in the middle, where the bone is most slender

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[1] Ses′amoid [from the Greek *sēsamon*, a "seed of the sesamum" and *eidos*, "form," "resemblance"], resembling a grain of sesamum.

and the strain greatest, and it is hollowed out in the interior to form the **medullary canal**. The extremities are made up of cancellated tissue with only a thin coating of compact substance, and are more or less expanded for greater convenience of mutual connection, and to afford a broad surface for muscular attachment. All long bones are more or less curved, which gives them greater strength and a more graceful outline.

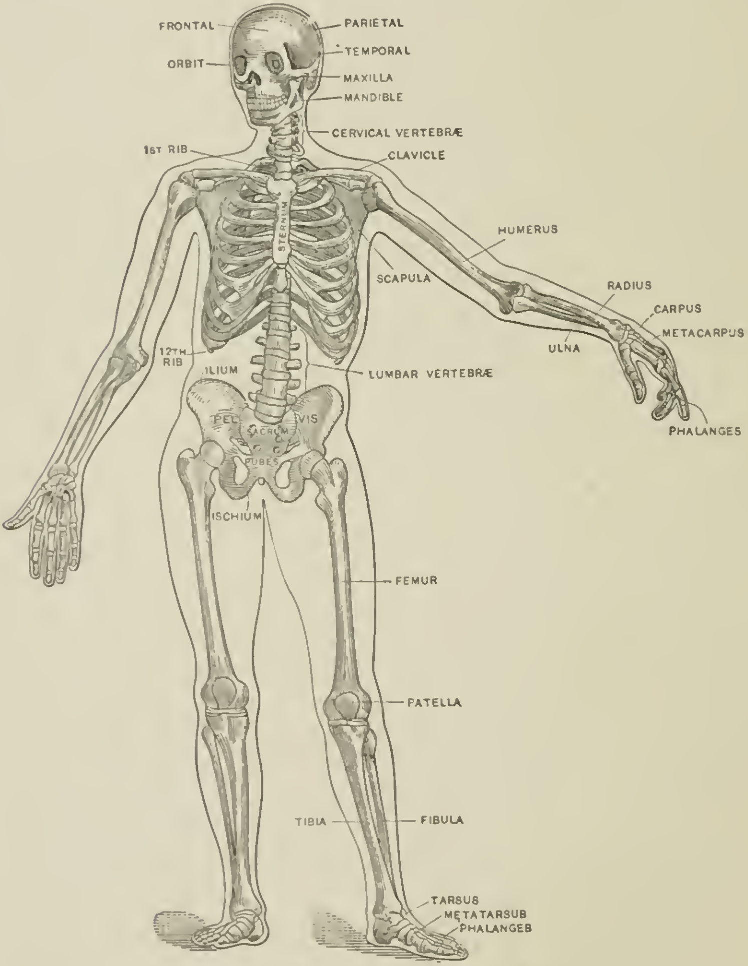

Fig. 21. — The Human Skeleton. (Morrow.)

The long bones are as follows: —

2 Clavicle
2 Humerus
2 Radius
2 Ulna
2 Femur
2 Tibia
2 Fibula
10 Metacarpals
10 Metatarsals
56 Phalanges
90

Short bones. — The short bones are small pieces of bone irregularly shaped. Their texture is spongy throughout, excepting at their surface, where there is a thin crust of compact substance. The short bones are the sixteen bones of the carpus, and the fourteen bones of the tarsus. Some authors include the two patellæ.

Flat bones. — Where the principal requirement is either extensive protection or the provision of broad surfaces for muscular attachment, the bony tissue expands into broad or elongated flat plates which are composed of two thin layers of compact tissue, enclosing between them a variable quantity of cancellous tissue.

The flat bones are as follows: —

1 Occipital
2 Parietal
1 Frontal
2 Nasal
1 Vomer
2 Lacrimal
2 Scapula
1 Sternum
24 Ribs
2 Hip bones
38

Irregular bones. — The irregular bones are those which, on account of their peculiar shape, cannot be grouped under either of the preceding heads.

The irregular bones are as follows: —

24 Vertebræ
1 Sacrum
1 Coccyx
2 Temporal
1 Sphenoid
1 Ethmoid
2 Malar
2 Maxillæ
1 Mandible
2 Palate
2 Inferior turbinated
1 Hyoid
40

The bones of the ear are so small that they are described as *ossicles* and do not fit in any of these groups.

Processes and Depressions. — If the surface of any bone is examined, certain projections and depressions are seen. The projections are called **processes**. The depressions are called **fossæ** or **cavities**, and either a qualifying adjective is used to describe them, or a special name given to them. Processes and depressions are classified as: 1. **Articular**, 2. **Non-articular**. The articular are provided for the mutual connection of bones to form joints. The non-articular serve for the attachment of ligaments and muscles. The following terms are used: —

Process. — Any marked bony prominence.

Tuberosity. — A large process.

Tubercle. — A small process.

Spinous. — A sharp, slender process.

Crest. — A narrow ridge of bone.

Condyle. — A rounded or knuckle-like process.

Head. — A portion supported on a constricted part or neck.

Fossa. — A depression in or upon a bone.

Cavities. — The terms *sinus*[1] and *antrum* are applied to cavities within certain bones.

Meatus or Canal. — A long tube-like passageway.

Fissure. — A narrow slit.

Foramen. — A hole or orifice through which blood-vessels, nerves, and ligaments are transmitted.

DIVISIONS OF THE SKELETON

In taking up the various divisions of the skeleton, we will consider it as consisting of —

1. Head or skull . . .	Cranium. Face.
2. Hyoid.	
3. Trunk	Vertebræ. Sternum. Ribs.
4. Upper extremities.	
5. Lower extremities.	

The head or skull. — The head or skull rests upon the spinal column, and is formed by the union of the cranial and facial bones. It is divisible into — 1. **Cranium** or **brain** case, and 2. **Anterior region**, or **face**.

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[1] The term "sinus" is also used in surgery to denote a narrow tract leading from the surface down to a cavity.

BONES OF THE CRANIUM

Occipital	1
Parietal	2
Frontal	1
Temporal	2
Ethmoid	1
Sphenoid	1

Occipital bone. — It is situated at the back and base of the skull. At birth the bone consists of four parts, which do not unite into a single bone until the sixth year. The internal surface is deeply concave, and presents many eminences and depressions for the reception of parts of the brain. There is a large hole — the **foramen magnum** — in the inferior portion of the bone, for the transmission of the medulla oblongata (the constricted portion of the brain) where it narrows down to join the spinal cord. At the sides of the foramen magnum it presents

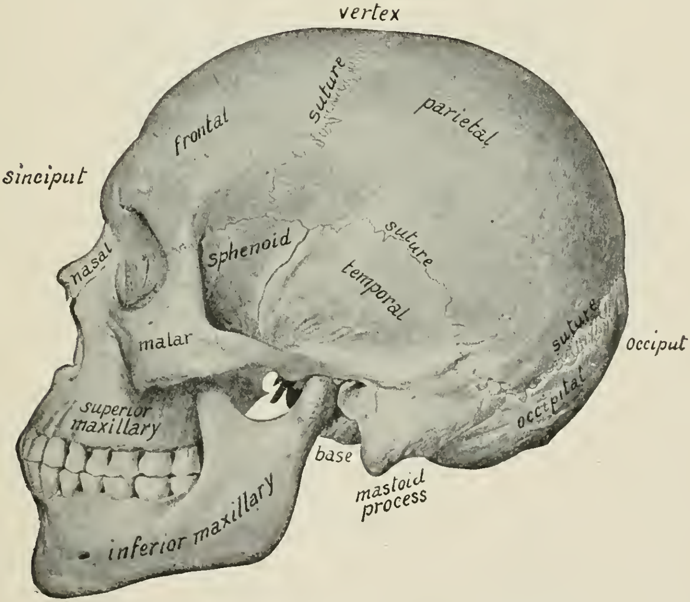

FIG. 22. — SIDE VIEW OF THE SKULL. (Morrow.)

Attention of the student is called to the text, page 54, where the word *Mandible* is used in preference to the term *Inferiòr Maxillary* which is found on the illustration. The word *Maxilla* is also used in preference to *Superior Maxillary.*

two processes called condyles, which articulate with the first vertebra.

Parietal bones. — The right and left form by their union the greater part of the sides and roof of the skull. The external surface is convex and smooth; the internal surface is concave, and presents eminences and depressions for lodging the convolutions of the brain, and numerous furrows for the ramifications of arteries which supply the dura mater (membrane which covers the brain) with blood.

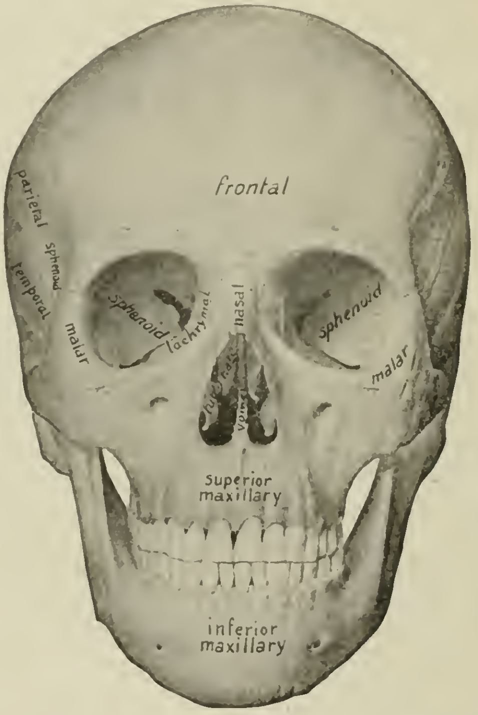

FIG. 23. — FRONT VIEW OF THE SKULL. (Morrow.)

See note under Figure 22 regarding use of *Mandible* and *Maxilla* in preference to *Inferior Maxillary* and *Superior Maxillary*. Note also that the spelling of the word *Lachrymal* differs from the more correct spelling found in the text, as per the B. N. A.

Frontal bone. — It resembles a cockle shell, and not only forms the forehead, but also enters into the formation of the roof of the orbits, and of the nasal cavity. The arch formed by part of the frontal bone over the eye is sharp and prominent, and is known as the supraorbital margin. Just above the supraorbital margins are hollow spaces called the **frontal sinuses** (see Fig. 33) which are filled with air and open into the nose. In the upper and outer angle of each orbit are two depressions called lacrimal fossæ for the reception of the glands of the same name, which secrete the tears. At birth the bone consists of two pieces, which afterwards become united along the middle line, by a suture[1] which runs from the vertex of the bone to the root of the nose. This suture usually becomes obliterated within a few years after birth, but it occasionally remains throughout life.

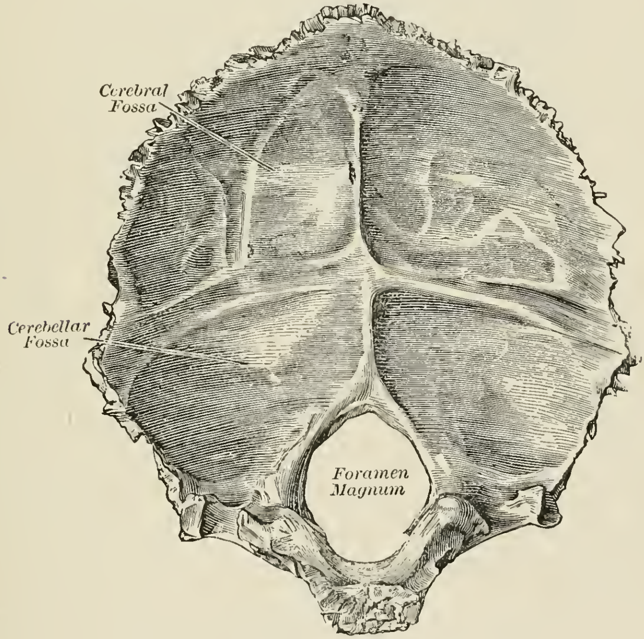

Fig. 24. — Occipital Bone. Inner surface.

Temporal bones. — The right and left are situated at the sides and base of the skull. They are named temporal from the Latin word *tempus,* time, as it is on the temple the hair first becomes gray and thin, and thus shows the ravages of time. The temporal bones are divided into three parts — the hard, dense portion, called **petrous**; a thin and expanded scale-like portion, called **squamous**; and a mastoid portion, which is prolonged down-

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[1] See Figs. 61 and 62.

Fig. 25. — Parietal Bone. Inner surface. *A*, parietal depression; *E*, furrow for ramification of arteries.

ward and forms the **mastoid process**. This process is filled with a number of connected cancellous spaces, containing air, and called **mastoid cells**.[1] They communicate with the cavity of the middle ear. The condition known as mastoiditis means inflammation of the lining of these cells.

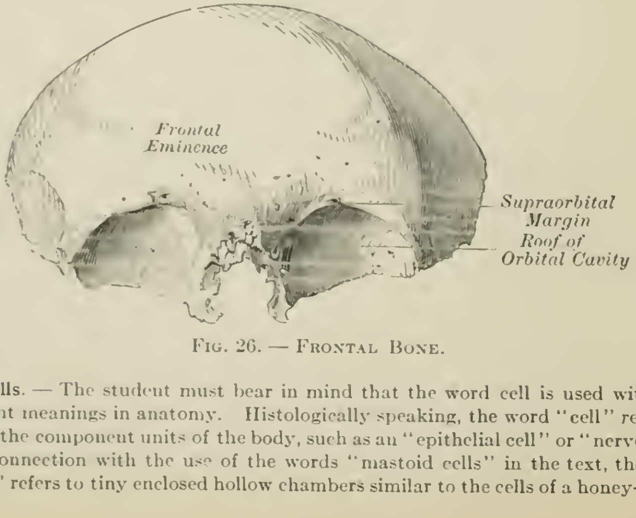

Fig. 26. — Frontal Bone.

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[1] **Cells**. — The student must bear in mind that the word cell is used with two different meanings in anatomy. Histologically speaking, the word "cell" refers to one of the component units of the body, such as an "epithelial cell" or "nerve cell."

In connection with the use of the words "mastoid cells" in the text, the word "cells" refers to tiny enclosed hollow chambers similar to the cells of a honey-comb.

The internal ear, the essential part of the organ of hearing, is contained in a series of cavities, channelled out of the substance of the petrous portion. Between the squamous and petrous portions is a socket, called the **glenoid fossa**, for the reception of the condyle of the lower jaw.

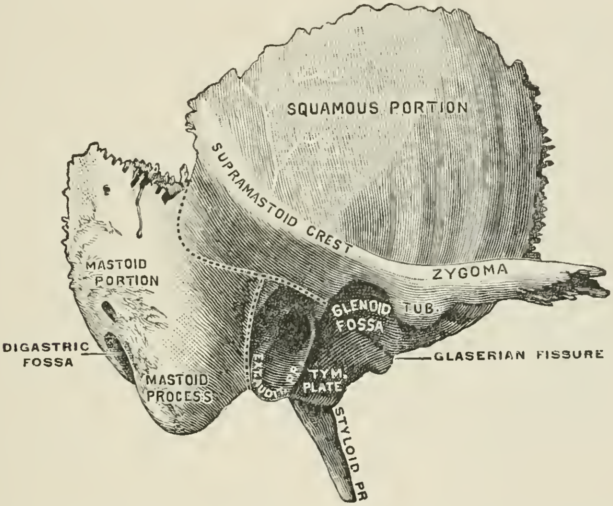

FIG. 27. — THE RIGHT TEMPORAL BONE. Outer surface. The dotted lines indicate the lines of suture between squamous, mastoid, and petrous portions. (Gerrish.)

Ethmoid bone. — It is an exceedingly light cancellous bone that forms part of the orbits, nasal fossæ, and base of the cranium. It consists of a horizontal plate, a vertical plate, and two lateral masses. The horizontal plate forms the roof of the nasal fossæ, and also closes the anterior part of the base of the cranium. It is pierced by numerous foramina or holes, through which the nerves conveying the sense of smell pass. Descending from the horizontal plate is the vertical plate which helps to form the nasal septum, and on either side the lateral masses help to form the side walls of the nasal fossæ. The lateral masses contain a number of thin-walled cavities called

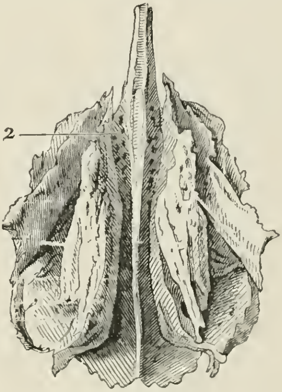

FIG. 28. — ETHMOID BONE. Seen from under surface. 2, cribriform or perforated plate.

the ethmoidal sinuses, which communicate with the nasal fossæ. Descending from the horizontal plate on either side of the septum are two processes of very thin, cancellous, bony tissue, named the superior and middle turbinated processes.

Fig. 29. — Parietal, Temporal, and Sphenoid Bones. Posterior aspect. 1, body of sphenoid bone; 2, 2, greater wings of sphenoid bone; 3, 3, parietal bones; 4, 4, mastoid process of temporal bones. (Gould's Dictionary.)

Sphenoid bone. — It is situated at the anterior part of the base of the skull and binds the other cranial bones together. It helps to form the cavities of the cranium, orbits, and nasal fossæ. In form it somewhat resembles a bat with extended wings, and is described as consisting of a body, two pairs of wings, and two pterygoid processes. The body is joined to the ethmoid in front and the occipital behind. It contains cavities which are called sphenoidal sinuses. They communicate with the nasal fossæ.

THE SKULL AS A WHOLE

The cranium is a firm case or covering for the brain. Four of the eight bones which form this bony covering are classed as flat bones. They consist of two layers of compact tissue, the outer one thick and tough, the inner one thinner and more brittle. The cancellated tissue lying between these two layers, or " tables of the skull," is called the *diploë*. The base of the skull is much thicker and stronger than the walls and roof; it presents a number of openings for the passage of the cranial nerves, blood-vessels, etc.

The bones of the cranium begin to develop at a very early period of fœtal life. Thus, before birth the bones at the top and sides of the skull are separated from each other by membranous tissue in which bone is not yet formed, and being then imperfectly ossified, they are readily **moulded**, and they overlap one another more or less during parturition. The spaces at the angles of the bone occupied by the membranous tissue are termed the fontanelles, so named from the pulsations of the brain, which can be seen in some of them and which the early anatomists likened to the rise and fall of water in a fountain. There are six of these fontanelles.

FIG. 30. — SKULL OF NEW-BORN CHILD. To show moulding. (Edgar.)

Anterior Fontanelle. — The anterior fontanelle is the largest, and is a lozenge-shaped space between the angles of the two parietal bones and the two segments of the frontal bone. It remains open until the second year, and occasionally persists throughout life.

Posterior Fontanelle. — The posterior fontanelle is much smaller in size, and is a triangular space between the occipital and two parietal bones. This is closed by an extension of the ossifying proccss a few months after birth. (See Figs. 61 and 62.)

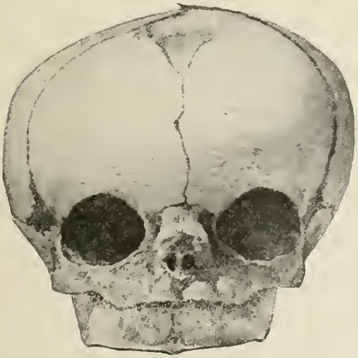

FIG. 31. — SKULL OF NEW-BORN CHILD. To show moulding. (Edgar.)

The other four fontanelles, two on each side of the skull, are placed at the inferior angles of the parietal bones; they are unimportant. Small, irregular ossicles called sutural bones (Wormian bones) are found in the sutures of the head, chiefly near the fontanelles, and often assist in the closure of the fontanelles.

Sinuses of the head. — Four sinuses communicate with each nasal cavity: the frontal, ethmoid, sphenoid, and maxillary or antrum of Highmore. The mucous membrane which lines the nose also lines all of these sinuses, and inflammation of this membrane may extend into any of them and cause *sinusitis*. (See Fig. 90.)

BONES OF THE FACE

Nasal	2
Vomer	1
Inf. Turbinated	2
Lacrimal	2
Malar	2
Palate	2
Maxillæ	2
Mandible	1
	14

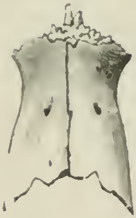

Fig. 32. — Nasal Bones. Viewed from before. (Gerrish.)

Nasal bones. — They are two small oblong bones placed side by side at the middle and upper part of the face, forming by their junction " the bridge " of the nose.

Vomer. — It is a single bone placed at the lower and back part of the nasal cavity, and forms part of the central septum of the nasal fossæ. It is thin, and shaped somewhat like a ploughshare, but varies in different individuals, being frequently bent to one or the other side, thus making the nasal chambers of unequal size.

Inferior turbinated bones. — They are situated in the nostril,

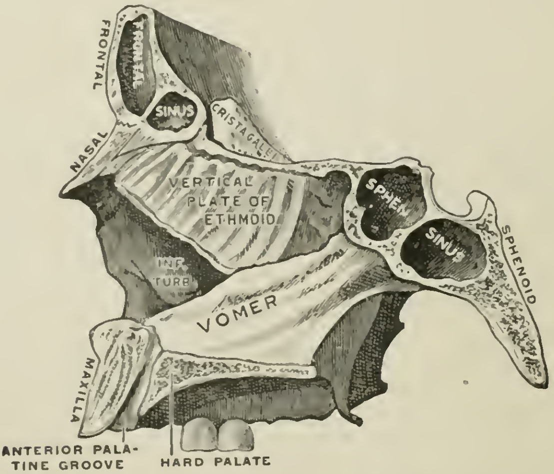

Fig. 33. — Sagittal Section of Face, a Little to the Left of the Middle Line, showing the Vomer and its Relations. (Gerrish.)

on the outer wall of each side. Each consists of a layer of thin, cancellous bone, curled upon itself like a scroll; hence its name, "turbinated." They are below the superior and middle turbinated processes of the ethmoid bone. Abnormal conditions of these bones and the membranes covering them cause some of the more common nasal diseases. (See Fig. 140.)

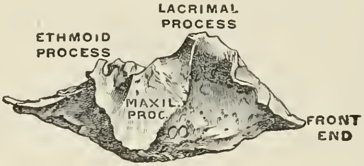

Fig. 34. — Right Inferior Turbinate Bone. External surface. (Gerrish.)

Lacrimal bones. — Are the smallest and most fragile bones of the face. They are situated at the front part of the inner wall of the orbit, and resemble somewhat in form, thinness, and size, a finger-nail. They are named lacrimal because they contain part of the canal through which the tear duct runs.

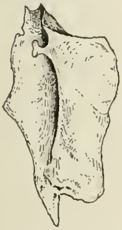

Fig. 35. — Lacrimal Bone.

Malar, or yoke bone.—Forms the prominence of the cheek, and part of the outer wall and floor of the orbit. A prominent spine of bone projects backward from the body of the malar, and articulates by its free extremity with the corresponding spine projecting forward from the temporal bone, thus making the two members of the true arch known as the zygomatic arch.

Palate bones. — They are shaped like an "L," and form (1) the back part of the roof of the mouth; (2) part of the floor and outer wall of the nasal fossæ; (3) a very small portion of the floor of the orbit.

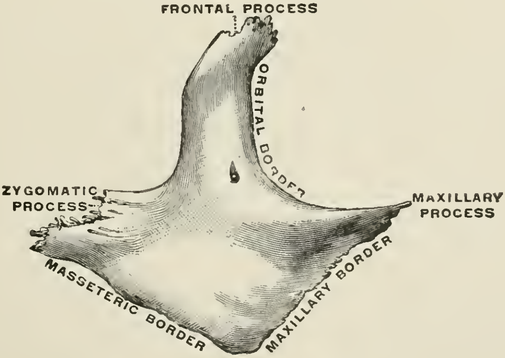

Fig. 36. — Right Malar Bone. Outer surface. (Gerrish.)

Maxillae, or upper jaw-bones, also known as superior maxillary. — The maxillæ are two in number (right and left) and are the principal bones of the face. Each bone assists in forming (1) part of the floor of the orbit, (2) the floor and outer wall of the nasal fossæ, (3) the greater part of the roof of the mouth. These bones usually unite before birth to form one bone. When they fail to do so we have the condition known as cleft palate. From a surgical point of view, it is the most important bone of the face, on account of the number of diseases to which it is liable.

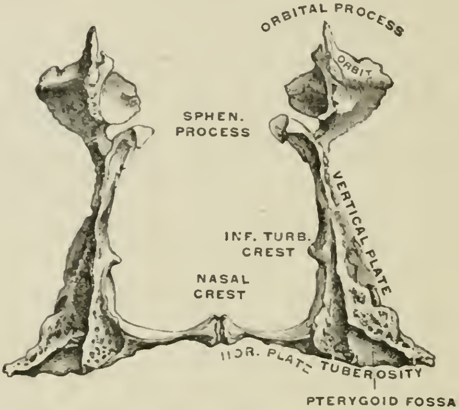

Fig. 37. — The Two Palate Bones in their Natural Position. Dorsal view. (Gerrish.)

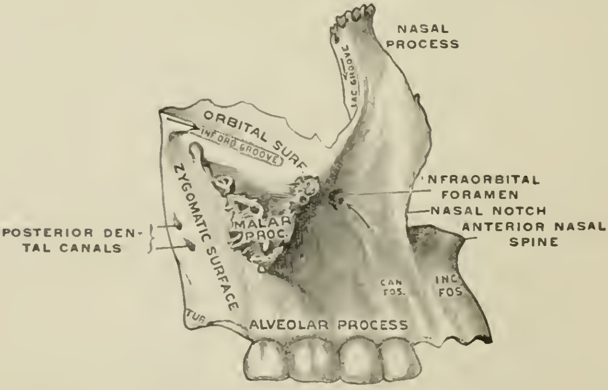

Fig. 38. — The Right Maxilla. Outer surface. (Gerrish.)

That part of the bone which contains the teeth is called the alveolar process, and is excavated into cavities, varying in depth and size according to the size of the teeth they contain. The body of the bone is hollowed out into a large cavity known as the **antrum** of **Highmore**, which opens into the nose. Abnormal conditions of either the nose or teeth may cause an infection of these antrums.

Mandible, or lower jaw-bone, also known as inferior maxillary. — It is the largest and strongest bone of the face. At birth, it consists of two lateral halves, which join and form one bone during the first or second year. It serves for the reception of the lower teeth, and undergoes several changes in shape during life, owing mainly (1) to the first and second dentition, (2) to the loss of teeth in the aged, and (3) the subsequent absorption of that part of the bone which contained them. It articulates, by its condyles, with the sockets in the temporal bones, which allows for free movement in mastication.

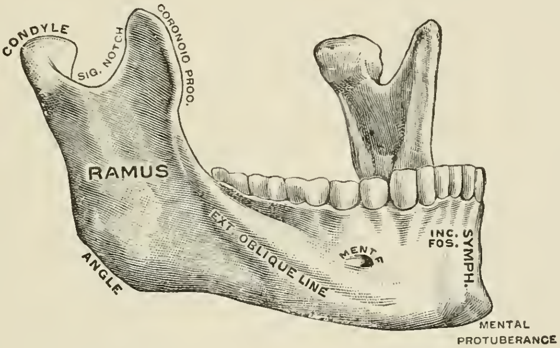

Fig. 39. — The Mandible. Viewed from the right and a little in front. (Gerrish.)

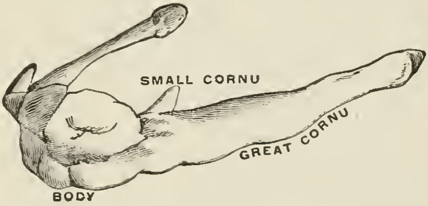

Fig. 40. — The Hyoid Bone. Viewed from the left and in front. (Gerrish.)

Hyoid bone (os hyoideum). — Is an isolated U-shaped bone lying in front of the throat, just above the laryngeal prominence (Adam's apple). It supports the tongue, and gives attachment to some of its numerous muscles.

TRUNK

The bones which enter into the formation of the **trunk** consist of the **vertebræ**, **sternum**, and **ribs**.

The vertebral column as a whole. — It is formed of a series of bones called vertebræ, and in a man of average height is about twenty-eight inches long. In youth the vertebræ are **thirty-three** in number, and according to the position they occupy are named: —

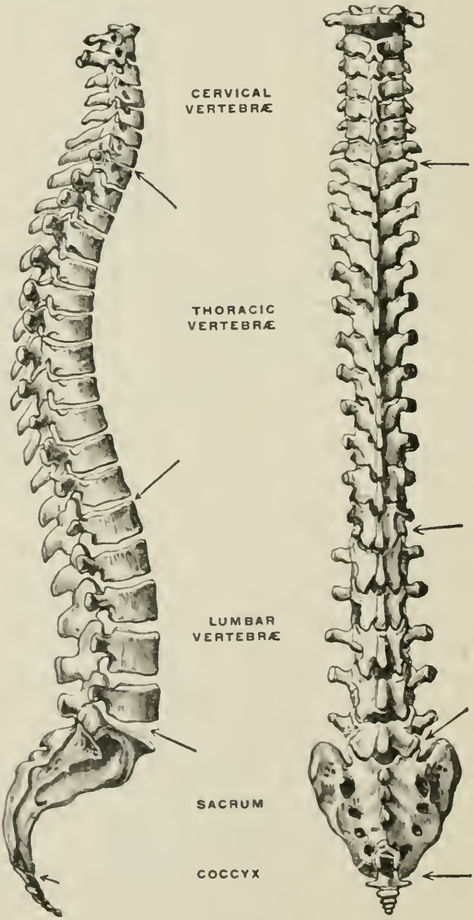

FIG. 41. — THE VERTEBRAL COLUMN. Right lateral view and dorsal view. (Gerrish.)

Cervical, in the neck	7
Thoracic, in the thorax	12
Lumbar, in the loins	5
Sacral, in the pelvis	5
Coccygeal, in the pelvis	4

The vertebræ in the three upper portions of the spine are separate and movable throughout the whole of life, and are known as **true** vertebræ. Those found in the sacral and coccygeal regions are, in the adult, firmly united, so as to form two bones, five entering into the upper bone, or sacrum, and four into the terminal bone of the spine, or coccyx. They are known as **false** vertebræ, and on account of their union the number of vertebræ in the adult is twenty-six. The bodies of the vertebræ are piled one upon another, forming a strong, solid pillar, for the support of the cranium and trunk, the arches forming a hollow cylinder behind for the protection of the spinal cord. Viewed from the side, it presents four curves which are alternately convex and concave. The two concave ones are called primary curves because they exist in fœtal life and are designed for the accommodation of viscera. The other two are called secondary or compensatory curves because they enable the child to assume the erect attitude.

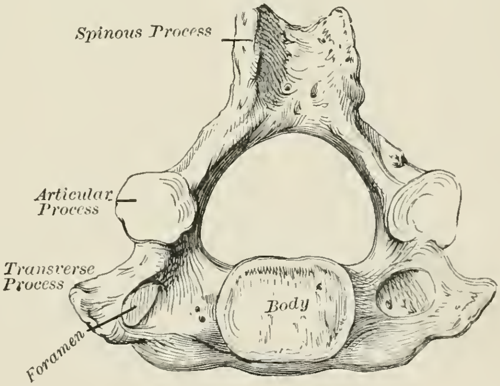

Fig. 42. — A Cervical Vertebra.

The vertebræ. — Each vertebra consists of two essential parts, an anterior solid portion or body, and a posterior portion or arch. Each arch has seven processes: four articular, two to connect with bone above, two for bone below; two transverse, one at each side, and one spinous process, projecting backward.

Cervical vertebræ. — In the cervical region of the vertebral column the bodies of the vertebræ are smaller than in the thoracic, but the arches are larger. The spinous processes are short, and

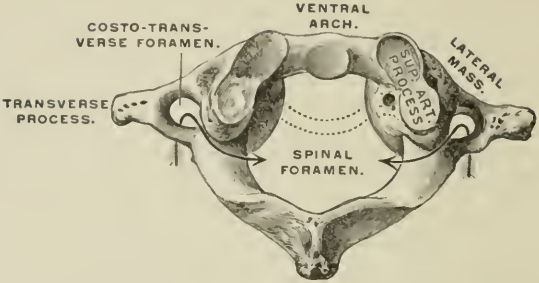

Fig. 43. — The Atlas. Viewed from above. (Gerrish.)

are often cleft in two, or bifid. The transverse processes are pierced by a foramen for the passage of blood vessels and nerves.

The first and second cervical vertebræ differ considerably from the rest. The first, or **atlas**, so named from supporting the head, has practically no body, and may be described as a bony ring divided into two sections by a transverse ligament. The dorsal section of this ring contains the spinal cord, and the ventral or front section contains the bony projection which arises from the upper surface of the body of the second cervical vertebra, **axis** (epistropheus). This bony projection, called the **odontoid** process, forms a pivot, and around this pivot the atlas rotates when the head is turned from side to side, carrying the skull, to which it is firmly articulated, with it.

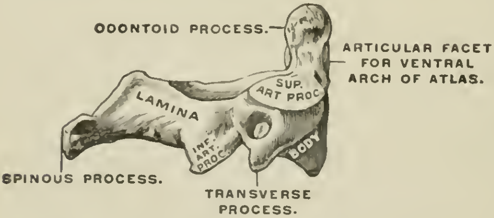

Fig. 44. — The Axis (Epistropheus). Its right side. (Gerrish.)

Thoracic vertebræ. — The bodies of the thoracic vertebræ are larger and stronger than those of the cervical; and have a facet or demi-facet for articulation with the vertebral end of a rib.

Lumbar vertebræ. — The bodies of the lumbar vertebræ are the largest and heaviest in the whole spine.

Structure of vertebral column. — The different vertebræ are connected together (1) by means of the articular processes, (2) by disks of intervertebral fibro-cartilage placed between the vertebral bodies, and (3) by broad thin ligaments called the *ligamenta* *flava* which connect the transverse processes. The spinal curves confer a considerable amount of springiness and strength upon the spinal column, which would be lacking were it straight, and the elasticity is further increased by the ligamenta flava, and the disks of fibro-cartilage. These disks or pads also mitigate the effects of concussion arising from falls or blows, and allow of a certain amount of motion between the vertebræ. The amount of motion permitted is greatest in the cervical region.

Abnormal conditions. — As a result of injury or disease the normal curves may become exaggerated and are then spoken of as *curvatures*. Curvatures may be lateral, dorsal, or ventral.

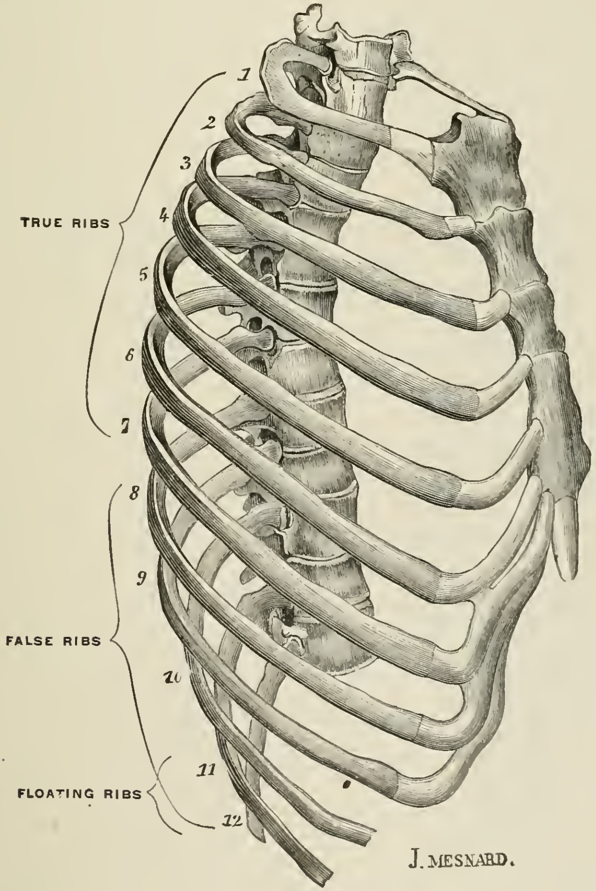

Fig. 45. — Thorax. (10th rib is defective; it should be attached to the costal cartilage above.)

It occasionally happens that the arch of one of the vertebræ does not develop properly, and as a result the membranes and fluid of the spinal cord will protrude, forming a tumor upon the child's back. This condition is called *spina bifida*.

Sacrum (os sacrum). — The sacrum is formed by the union of the five sacral vertebræ. It is a large triangular bone situated like a wedge between the coxal bones, and is curved upon itself in such a way as to give increased capacity to the pelvic cavity.

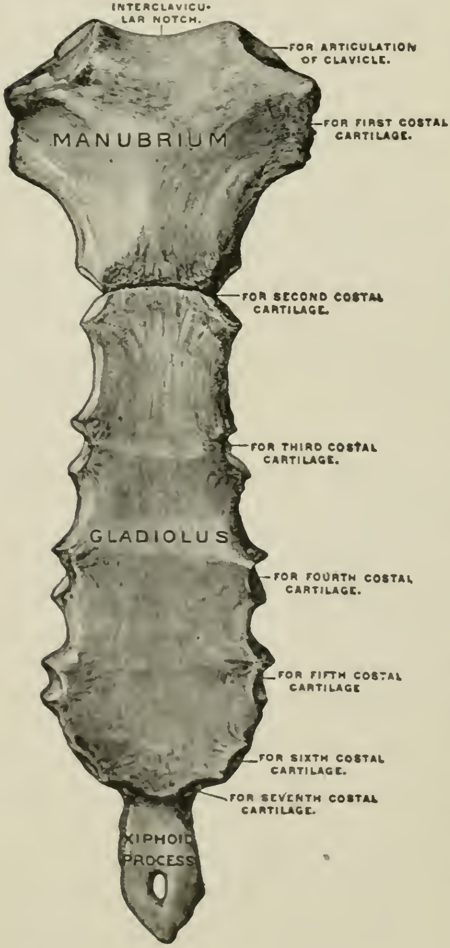

Fig. 46. — The Sternum. Ventral aspect. (Gerrish.)

Coccyx (os coccygis). — The coccyx is usually formed of four small segments of bone, and is the most rudimentary part of the vertebral column.

THORAX

The thorax is an elongated bony cage formed by the sternum and costal cartilages in front, the twelve ribs on each side, and the bodies of the twelve thoracic vertebræ behind. It contains and protects the principal organs of respiration and circulation.

Sternum, or breast bone. — It is a flat, narrow bone about six inches long, situated in the median line in the front of the chest, and may be likened to a short, flat sword. It consists of three portions. The upper part is termed the handle, or manubrium; the middle and largest piece is termed the body, or gladiolus; the inferior portion is termed the ensiform, or the xiphoid process. On both sides of the upper and middle pieces are notches for the reception of the sternal ends of the costal cartilages. The ensiform or xiphoid process is cartilaginous in structure in early life, but is more or less ossified at the upper part in the adult; it has no ribs attached to it, but affords attachment for some of the abdominal muscles.

Ribs (costæ). — They are elastic arches of bone, forming the chief part of the thoracic wall (*vide* Fig. 45). They are usually twelve in number on each side. They are all connected behind with the vertebræ, and the first seven pairs are connected with the sternum in front through the intervention of the costal cartilages; these first seven pairs are called from their attachment the **true ribs**. The remaining five pairs are termed **false ribs**; of these, the first three, eight, nine, and ten are attached in front to the costal cartilages of the next rib above. The two remaining, being unattached in front, are termed **floating ribs**.

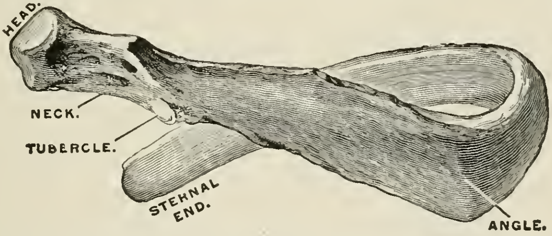

Fig. 47. — The Eighth Rib of the Right Side. Viewed from behind. (Gerrish.)

The convexity of the ribs is turned outwards so as to give roundness to the sides of the chest and increase the size of its cavity; each rib slopes downwards from its vertebral attachment, so that its sternal end is considerably lower than its dorsal, and the lower border is grooved for the accommodation of the intercostal nerves and blood-vessels. The spaces left between the ribs are called the intercostal spaces.

BONES OF THE UPPER EXTREMITIES

Clavicle (clavicula, or collar bone) . . .	2
Scapula (shoulder blade)	2
Humerus (arm)	2

Ulna — 2 Radius — 2 } (forearm)	4
Carpus (wrist)	16
Metacarpus (palm of hand)	10
Phalanges (fingers)	28
	64

Clavicle, or collar bone. — It is a long bone, placed horizontally above the thorax. It articulates with the sternum by its inner extremity, which is called the sternal extremity. Its outer or acromial extremity articulates with the scapula. In the female,

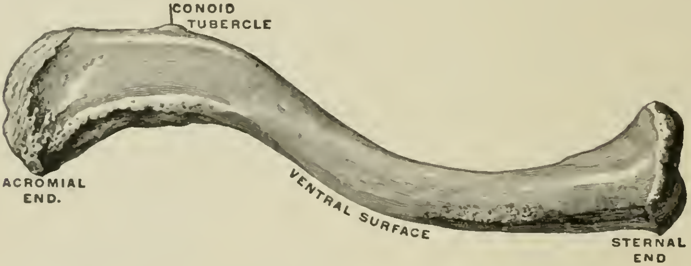

Fig. 48. — The Right Clavicle. Upper surface. (Gerrish.)

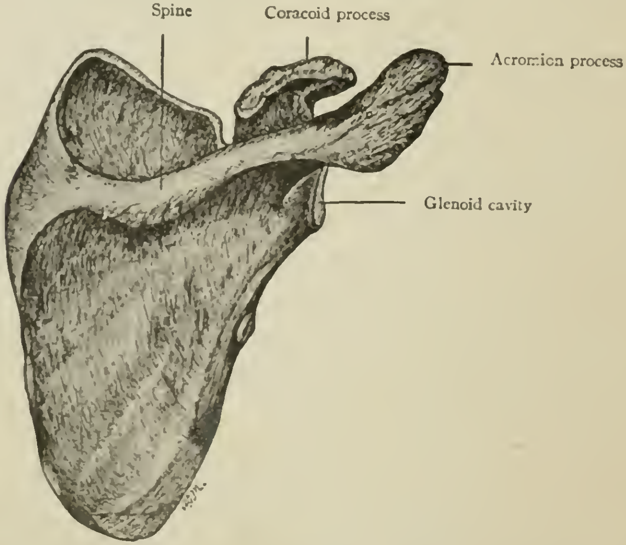

Fig. 49. — The Right Scapula, or Shoulder Blade. Viewed from behind. (Morrow.)

the clavicle is generally less curved, smoother, shorter, and more slender than in the male. In those persons who perform considerable manual labor, which brings into constant action the muscles connected with this bone, it acquires considerable bulk.

Scapula, or shoulder blade. — It is a large, flat bone, triangular in shape, placed between the second and seventh, or sometimes eighth, ribs on the back part of the thorax. It is unevenly divided on its dorsal surface by a very prominent ridge, the spine of the scapula, which terminates in a large triangular projection called the **acromion process**, or summit of the shoulder. Below the acromion process, at the head of the shoulder blade, is a shallow socket, the **glenoid cavity**, which receives the head of the humerus.

Humerus, or arm bone. — The humerus is the longest and largest bone of the upper limb. The upper extremity of the bone consists of a rounded head joined to the shaft by a constricted neck, and of two eminences called the larger and smaller tubercles, also known as tuberosities. The head articulates with the glenoid cavity of the scapula. The constricted neck above the tubercles is called the anatomical neck, and that below the tubercles, the surgical neck, because it is so often fractured. The lower extremity of the bone is flattened from before backward into a broad articular surface called the trochlea which is divided by a slight ridge so

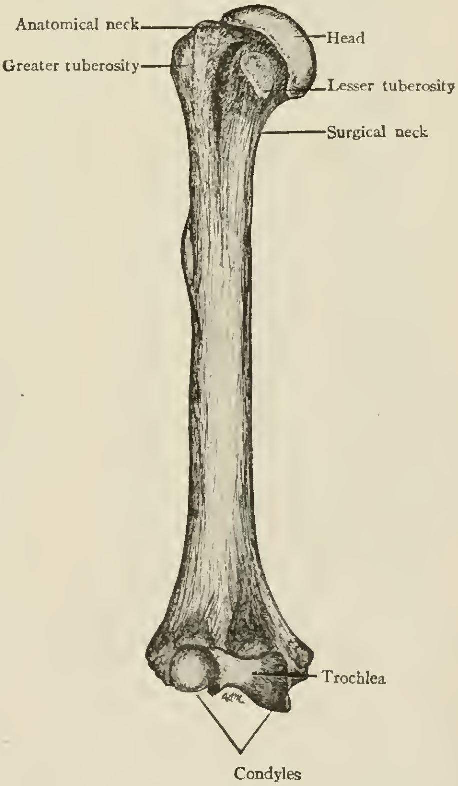

FIG. 50. — THE LEFT HUMERUS, OR ARM BONE. (MORROW.)

that it ends in two condyles by means of which it articulates with the radius and ulna.

Ulna, or elbow bone. — It is placed at the inner side (little finger side) of the forearm, parallel with the radius. Its upper extremity presents for examination two large curved processes and two concave cavities; the larger process forms the head of the elbow, and is called the olecranon process. The smaller process on the front surface is termed the coronoid, and the trochlea of the humerus fits into the cavity — the great sigmoid cavity — between these two processes. The lesser sigmoid cavity is on the outer side of the coronoid, and receives the head of the radius. The lower extremity of the ulna is of small size and ends in two prominences; the outer one, called the head, articulates with the radius, the inner one, named the styloid process, serves for the attachment of ligaments from the wrist; but the ulna is excluded from the wrist by a piece of fibro-cartilage.

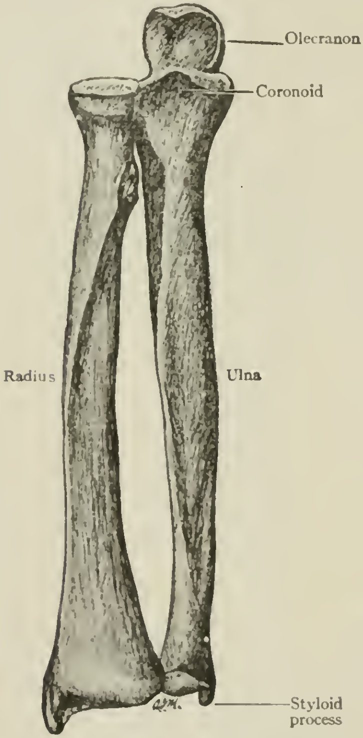

Fig. 51. — The Bones of the Right Forearm. Anterior view. (Morrow.)

Radius. — It is situated on the outer side of the forearm. The upper end is small and rounded, with a shallow depression on its upper surface for articulation with the humerus, and a prominent ridge about it, like the head of a nail, by means of which it rotates within the lesser sigmoid cavity of the ulna. The lower end of the radius is large, and forms the chief part of the wrist.

Carpus, or wrist. — The wrist joint is composed of eight small bones (ossa carpi) united by ligaments; they are arranged in two rows, and are closely welded together, yet by the arrangement of their ligaments allow of a certain amount of motion. They

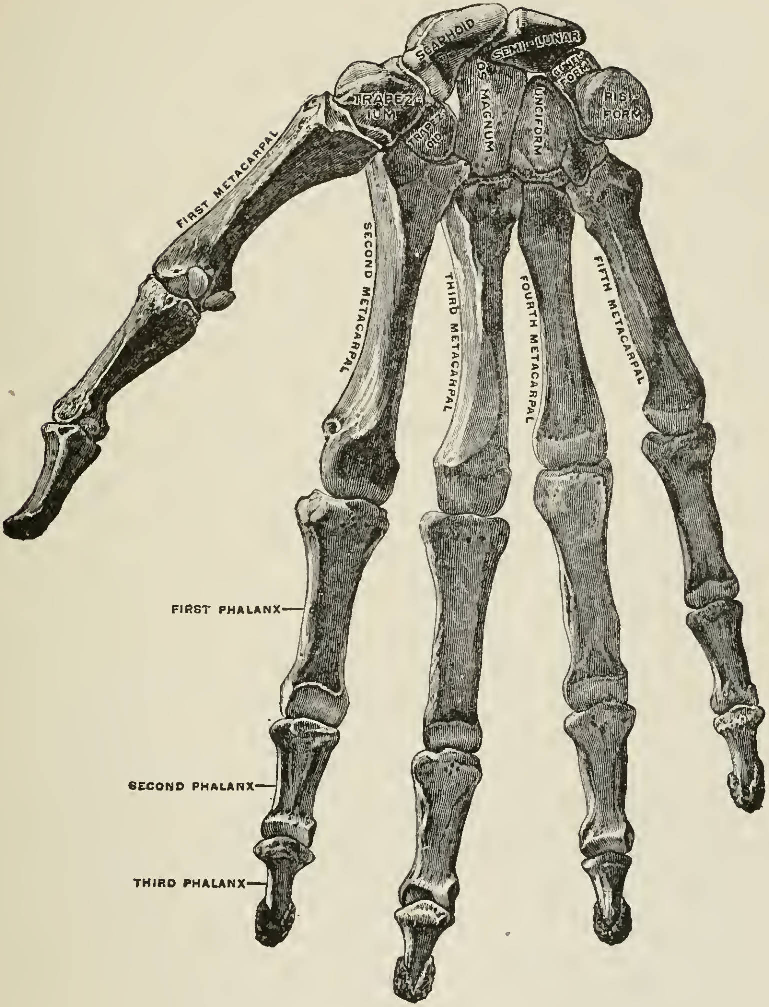

FIG. 52. — THE BONES OF THE RIGHT HAND. Palmar aspect. (Gerrish.)

afford origin by their palmar surface to most of the short muscles of the thumb and little finger, and are named as follows: —

1st row.	Scaphoid . .	1	2d row.	Trapezium . .	1
	Semilunar . .	1		Trapezoid . .	1
	Cuneiform . .	1		Os Magnum . .	1
	Pisiform . .	1		Unciform . .	1
					8

Metacarpus, or body of hand. — Each metacarpus is formed by five bones (ossa metacarpalia). The bones are curved longitudinally, so as to be convex behind, and concave in front. They articulate at their bases with the second row of carpal bones and with each other. The heads of the bones articulate with the bases of the first row of the phalanges.

Phalanges, or digits. — They are the bones of the fingers; and are fourteen in number in each hand, three for each finger, and two for the thumb. The first row articulates with the metacarpal bones and the second row of phalanges; the second row, with the first and third; and the third, with the second row.

BONES OF THE LOWER EXTREMITIES

Hip bones (ossa coxæ or ossa innominata)	2
Femur (thigh bone)	2
Patella (knee-cap)	2
Tibia (shin bone) 2 Fibula (calf bone) 2 } leg	4
Tarsus (ankle, or root of foot)	14
Metatarsus (sole and instep)	10
Phalanges (toes)	28
	62

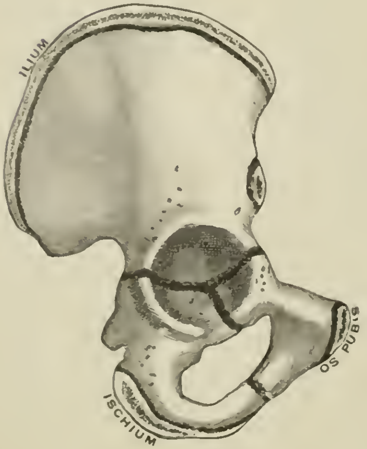

FIG. 53. — DEVELOPMENT OF THE HIP BONE. Showing the union of the three portions in the acetabulum. (Gerrish.)

The bones of the lower extremities correspond to a great extent with those of the upper extremities, and bear a rough resemblance to them, but are heavier and more firmly knit together.

Hip bone, or os coxæ.— It is a large, irregular-shaped bone, which, with its fellow of the opposite side, forms the sides and front wall of the pelvic cavity. In young subjects it consists of three separate parts, and although in the adult these have become united, it is usual to describe the bone as divisible into three portions: (1) the ilium (plural *ilia*), (2) the ischium (plural *ischia*), (3) the pubis (plural *pubes*).

The **ilium** is the upper broad and expanded portion which forms the prominence of the hip. The **ischium** is the lower and strongest portion of the bone, while the **pubes** is that portion which forms the front of the pelvis. Where these three portions of the bone meet and finally ankylose is a deep socket, called the **acetabulum**, into which the head of the femur fits. Other points of special interest to note in the hip bones are: —

(1) The spinous process formed by the projection of the **crest** of the ilium in front, which is called the **anterior superior spinous process**, and which is a well-known and convenient landmark in making anatomical and surgical measurements.

(2) The largest foramen in the skeleton, known as the **thyroid foramen**, situated between the ischium and pubis.

(3) The **symphysis pubis**, or pubic articulation, which also serves for a convenient landmark in making measurements.

The pelvis. — The pelvis, so called from its resemblance to a basin, is stronger and more massively constructed than either the cranial or the thoracic cavity. It is composed of four bones, the two hip bones forming the sides and front, the sacrum and coccyx completing it behind. It is divided by a narrowed bony ring into

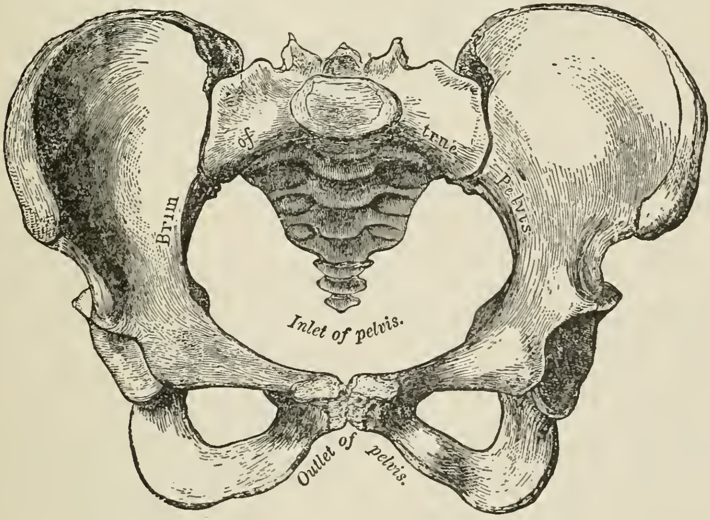

Fig. 54. — Female Pelvis.

the **large** (false), and **small** (true) pelvis. The narrowed bony ring which is the dividing line is spoken of as the *brim of the pelvis*, the *ilio-pectineal line*, and the *strait*. The large pelvis is all that expanded portion of the pelvis situated above the brim; it forms an incomplete or *false* basin. The small pelvis is all that portion situated below the brim. Its cavity is a little wider in every direction than the brim itself, while the large pelvis is a great deal wider. The small bony pelvis is a basin with incomplete walls of bone, the bottom of which is composed of the softer tissues, muscles, and ligaments. The opening of the small pelvis, *i.e.* the space just above the brim, is called the *inlet*, and the opening below is called the *inferior strait*, or *outlet*.

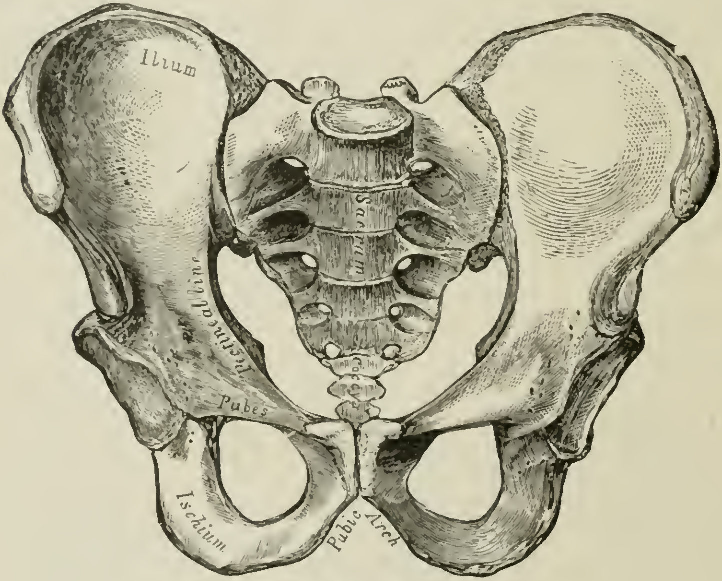

Fig. 55. — Male Pelvis.

The female pelvis differs from that of the male in those particulars which render it better adapted to pregnancy and parturition. It is more shallow than the male pelvis, but wider in every direction. The inlet and outlet are larger, the bones are lighter and smoother, and the coccyx is more movable. As can be seen by looking at Fig. 54 and Fig. 55 a distinctive anatomical difference is that the sub-pubic angle in a male is less than a right angle, and in the female it is greater than a right angle.

Fig. 56. — The Right Femur, or Thigh Bone. Anterior view. (Morrow.)

Femur, or thigh bone. — It is the longest, largest, and strongest bone in the skeleton. The upper extremity of the femur, like that of the humerus, consists of a rounded head joined to the shaft by a constricted neck, and of two eminences, called the greater and lesser **trochanters**. The head articulates with the cavity in the hip bone, called the acetabulum. The lower extremity of the femur is larger than the upper, is flattened from before backwards, and divided into two large eminences or **condyles** by an intervening notch. It articulates with the tibia and the patella, or knee-cap. In the erect position it is not vertical, being separated from its fellow by a considerable interval, which corresponds to the entire breadth of the pelvis, but the bone inclines gradually downward and inward, so as to approach its fellow towards its lower part, in order to bring the knee-joint near the line of gravity of the body. The degree of inclination varies in different persons, and is greater in the female than the male, on account of the greater breadth of the pelvis.

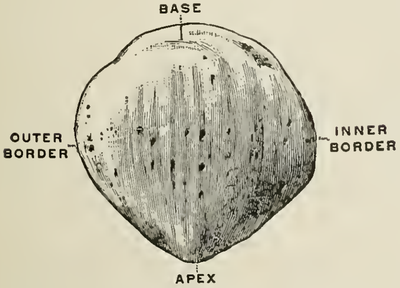

Fig. 57. — The Right Patella. Ventral surface. (Gerrish.)

Patella, or knee-cap. — It

is the largest sesamoid bone in the body. It is small, flat, triangular in shape, and placed in front of the knee-joint, which it serves to protect. It articulates with the two condyles of the femur, and is separated from the skin by a bursa. (See page 131.)

Tibia, or shin bone. — Is situated at the front and inner side of the leg. The upper extremity is large, and expanded into two lateral eminences with concave surfaces, which receive the condyles of the femur. The lower extremity is much smaller than the upper; it is prolonged downwards on its inner side into a strong process, the **medial** (or inner) **malleolus.** It articulates with the fibula and one of the bones of the ankle. (In the male, its direction is vertical and parallel with the bone of the opposite side; but in the female it has a slight oblique direction outwards, to compensate for the oblique direction of the femur inwards.)

Fibula, or calf bone. — Is situated at the outer side of the leg. It is the smaller of the two bones, and, in proportion to its length, the most slender of all the long bones; it is placed nearly parallel with the tibia. The upper extremity consists of an irregular quadrate head by means of which it articulates with the tibia. The lower extremity is prolonged downwards into a pointed process, the **lateral** (or external) **malleolus**, which lies just beneath the skin. It articulates with the tibia and one of the bones of the ankle.

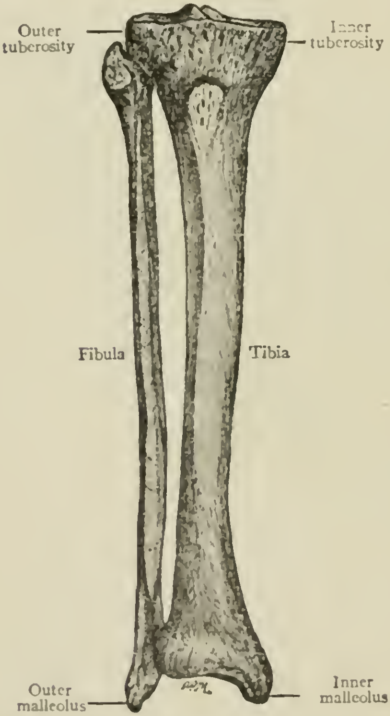

Fig. 58. — The Bones of the Right Leg. (Morrow.)

Tarsus. — The tarsus is composed of seven small bones united by ligaments, but the tarsal bones differ from the carpal in being larger and more irregularly shaped. The largest and strongest

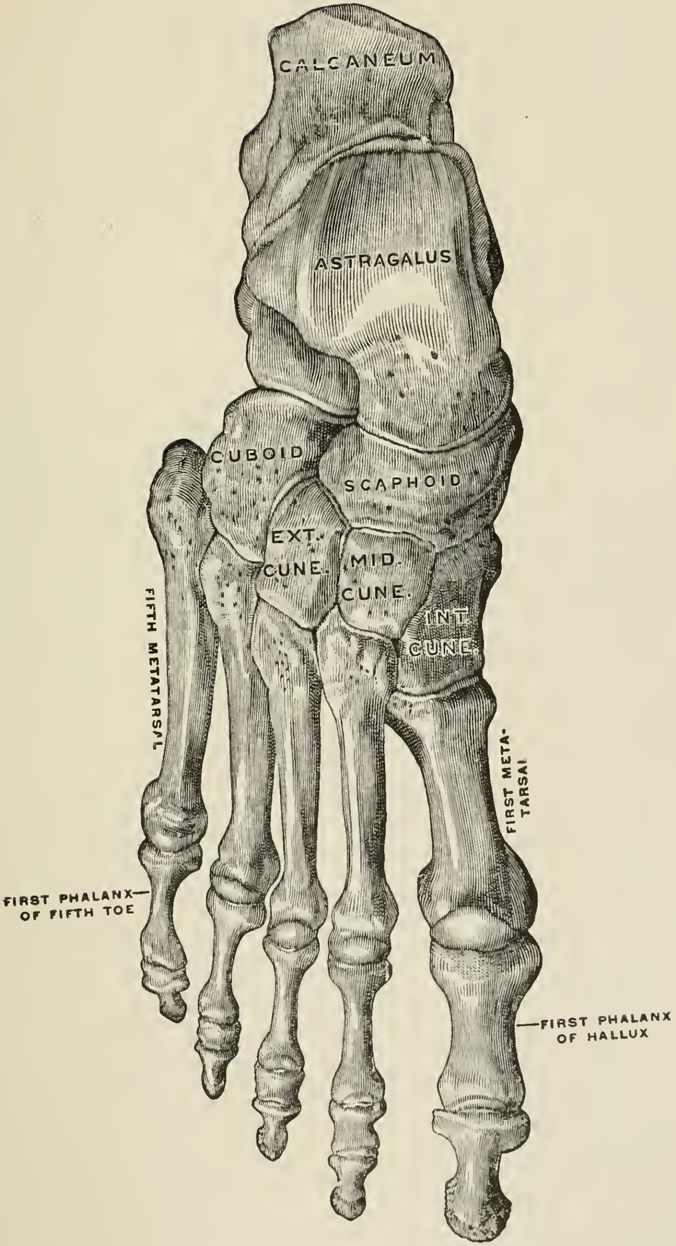

Fig. 59. — The Bones of the Right Foot. Viewed from above. (Gerrish.)

of the tarsal bones is called the **calcaneum, or heel bone**; it serves to transmit the weight of the body to the ground, and forms a strong lever for the muscles of the calf of the leg.

The names are as follows: —

Calcaneum	1
Astragalus	1
Cuboid	1
Scaphoid	1
External cuneiform	1
Middle cuneiform	1
Internal cuneiform	1
	7

Metatarsus, or sole and instep of foot, is formed by five bones. These metatarsal bones closely resemble the metacarpal bones of the hand. Each bone articulates with the tarsal bones by one extremity, and by the other with the first row of phalanges.

Phalanges, or digits. — Both in number and general arrangement resemble those in the hand, there being two in the great toe and three in each of the other toes.

SUMMARY

- **Bones**
  - Function
    - 1. Organs of support.
    - 2. Instruments of locomotion.
    - 3. Framework of hard material.
    - 4. Afford attachment to soft parts.
    - 5. Shelter delicate structures.
    - 6. Shape to whole body.
  - Classification
    - 1. Long.
    - 2. Short.
    - 3. Flat.
    - 4. Irregular.

TABLE OF THE BONES

HEAD

Cranium		Face	
Occipital	1	Nasal	2
Parietal	2	Lacrimal	2
Frontal	1	Vomer	1
Temporal	2	Malar	2
Sphenoid	1	Palate	2
Ethmoid	1	Inferior turbinated	2
	8	Maxilla	2
		Mandible	1
			14

Ear	Malleus	2
	Incus	2
	Stapes	2
		6
	Hyoid bone in the neck	1

TRUNK

		Child	Adult
Vertebræ	Cervical	7	7
	Thoracic	12	12
	Lumbar	5	5
	Sacral	5	1
	Coccygeal	4 = 33	1 = 26
	Ribs		24
	Sternum		1
			51

Upper Extremity		
	Clavicle	1
	Scapula	1
	Humerus	1
	Ulna	1
	Radius	1
Carpus	Scaphoid	1
	Semilunar	1
	Cuneiform	1
	Pisiform	1
	Trapezium	1
	Trapezoid	1
	Os magnum	1
	Unciform	1
	Metacarpus	5
	Phalanges	14
		32

32 × 2 = 64

Lower Extremity		
	Hip bone (os coxæ)	1
	Femur	1
	Patella	1
	Tibia	1
	Fibula	1
Tarsus	Calcaneum	1
	Astragalus	1
	Cuboid	1
	Scaphoid	1
	External cuneiform	1
	Middle cuneiform	1
	Internal cuneiform	1
	Metatarsus	5
	Phalanges	14
		31

31 × 2 = 62

CHAPTER VI

ARTICULATIONS

Articulations or joints. — The various bones of which the skeleton consists are connected together at different parts of their surfaces, and such connections are called articulations or joints.

CLASSIFICATION

Joints are classified as: —

1. Synarthroses, or immovable joints.
2. Amphiarthroses, or slightly movable joints.
3. Diarthroses, or freely movable joints.

In all instances some softer substance is placed between the bones, uniting them together or clothing the opposed surfaces; but the manner in which the several pieces of the skeleton are thus connected varies to a great degree.

SYNARTHROSES, OR IMMOVABLE JOINTS

The bones are connected by fibrous tissue or cartilage.

The bones of the cranium and the facial bones (with the exception of the lower jaw) have their adjacent surfaces applied in close contact, with only a thin layer of fibrous tissue placed between their margins.

Fig. 60. — A Toothed, or Dentated, Suture.

In most of the cranial bones this union occurs by means of toothed edges which dovetail into one another and form jagged lines of union known as **sutures**.

The three most important sutures are as follows: —

(1) **Coronal.** — The line of union between the frontal and parietal bones.

(2) **Lambdoidal.** — The line of union between the parietal and occipital bones.

(3) **Sagittal suture.** — This begins at the base of the nose, extends along the middle line on the top of the crown, separates the frontal bone into two parts,[1] the parietal bones from each other, and ends at the posterior fontanelle.

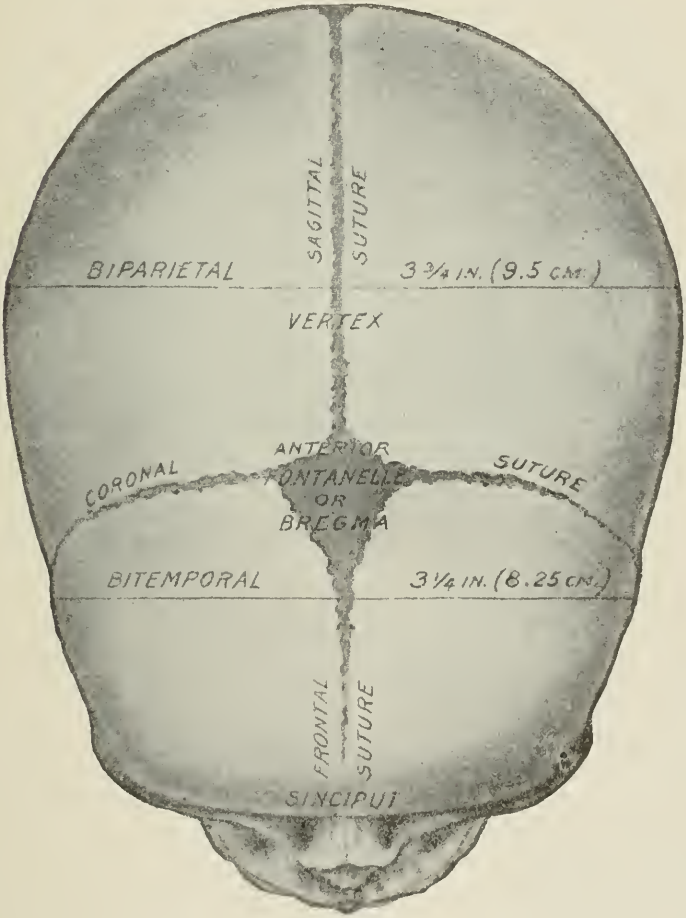

Fig. 61. — Diameters and Landmarks of the Fœtal Skull. Upper surface. (Edgar.)

Synchondrosis is usually a temporary form of joint. The cartilage between the bones ossifies before adult life. Example: the union of the sphenoid and occipital bones.

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[1] That portion of the sagittal suture which separates the frontal bone into two parts is often called the *frontal suture.* (See Fig. 61.)

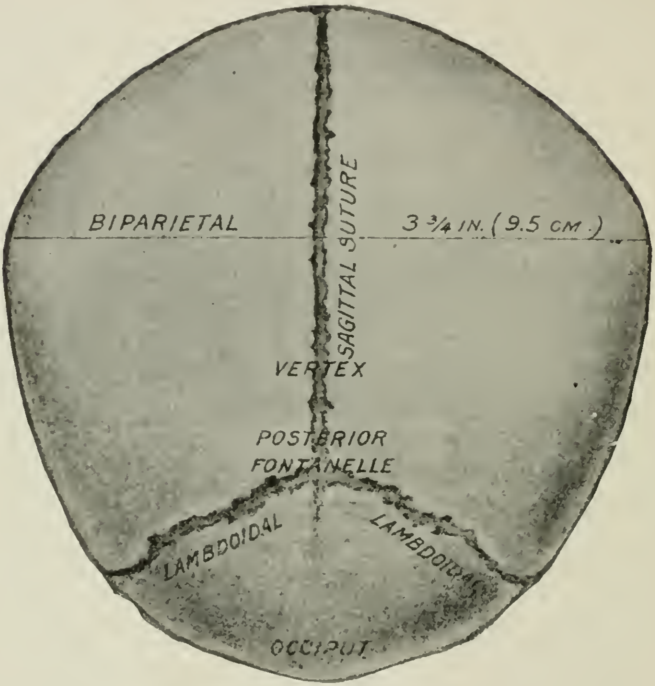

Fig. 62. — Diameters and Landmarks of the Fœtal Skull. Posterior surface. (Edgar.)

AMPHIARTHROSES, OR SLIGHTLY MOVABLE JOINTS

The above terms apply to joints that permit of slight movement and include two varieties: (1) symphysis, and (2) syndesmosis.

Symphysis. — In this form of articulation the bony surfaces are joined together by broad, flattened disks of fibro-cartilage, as in the articulations between the bodies of the vertebræ. These intervertebral disks being compressible and extensile, the spine can be moved to a limited extent in every direction. In the pelvis the articulation between the two pubic bones (symphysis pubis), and between the sacrum and ilia (sacro-iliac articulation), are slightly movable. The pubic bones are united by a disk of fibro-cartilage and by ligaments. In the sacro-iliac articulation the sacrum is united more closely to the

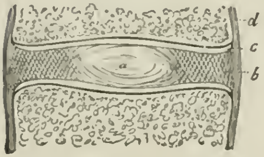

Fig. 63. — A Slightly Movable Joint. *a*, *b*, disk of fibro-cartilage; *c*, articular cartilage; *d*, bone.

ilia, the articular surfaces being covered by cartilage and held together by ligaments.

The fibro-cartilage between these joints (symphysis pubis and sacro-iliac) becomes thickened and softened during pregnancy and allows of a certain limited motion which is essential to a normal parturition.

Syndesmosis. — When the bony surfaces are united by an interosseous ligament, as in the lower tibio-fibular articulation, it is called syndesmosis.

DIARTHROSES, OR FREELY MOVABLE JOINTS

This division includes the complete joints, and are the only joints in which the three following conditions are found: —

(1) The bones are united by fibrous ligaments, forming more or less perfect capsules. The ligaments are not always so tight as to maintain the bones in close contact in all positions of the joint, but are rather tightened in some positions and relaxed in others, so that in many cases they are to be looked on chiefly as controllers of movements, and not as serving solely to hold the bones together. The bones are partly held together in these joints by atmospheric pressure and largely by the surrounding muscles.

(2) A secreting membrane (synovial) lines the capsule and is so arranged that it dips in between the edges of the opposing articular cartilages. (See Fig. 64.)

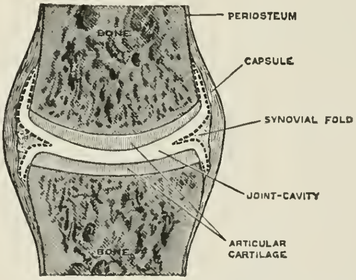

FIG. 64. — A COMPLETE JOINT. The synovial membrane is represented by dotted lines.

(3) Each articular end of the bone is covered by hyaline cartilage, which provides surfaces of remarkable smoothness, and these surfaces are lubricated by the synovial fluid secreted from the delicate synovial membrane which lines the cavity of the joint.

The varieties of joints in this class have been determined by the kind of motion permitted in each. They are as follows: —

(1) **Gliding joint.** — The articular surfaces are nearly flat, and

admit of only a limited amount of gliding movement, as in the joints between the articular processes of the vertebræ.

(2) **Hinge joint.** — The articular surfaces are of such shape as to permit of movement to and fro in one plane only, like a door on its hinges. These movements are called flexion and extension, and may be seen in the articulation of the arm with the forearm, in the ankle joint, and in the articulations of the phalanges.

(3) **Ball and socket joint.** — In this form of joint a more or less rounded head is received into a cup-like cavity, as the head of the femur into the acetabulum, and the head of the humerus into the glenoid cavity of the scapula. Movement can take place freely in any direction, but the shallower the cup, the greater the extent of motion. The shoulder joint is the most freely movable joint in the body.

(4) **Pivot joint.** — In this form, one bone rotates around another which remains stationary, as in the articulation of the atlas with the axis (epistropheus) and in the articulation of the ulna and radius. In the articulation of the ulna and radius the ulna remains stationary, and the radius rotates freely around its upper end. The hand is attached to the lower end of the radius, and the radius, in rotating, carries the hand with it; thus, the palm of the hand is alternately turned forward and backward. When the palm is turned forward, or upward, the attitude is called supination; when backward, or downward, pronation.

(5) **Condyloid joint.** — When an oval-shaped head, or condyle, of a bone is received into an elliptical cavity, it is said to form a condyloid joint. An example of this kind of joint is found in the metacarpo-phalangeal articulations. The rounded heads of the metacarpal bones are received in the elliptical-shaped bases of the phalanges.

(6) **Saddle joint.** — In this joint the articular surface of each bone is concave in one direction, and convex in another, at right angles to the former. A man seated in a saddle is "articulated" with the saddle by such a joint. For the saddle is concave from before backwards, and convex from side to side, while the man presents to it the concavity of his legs astride, from side to side, and the convexity of his seat, from before backwards. The metacarpal bone of the thumb is articulated with the trapezius of the carpus by a saddle joint. Both the condy-

loid and the saddle joints admit of motion in every direction except that of axial rotation.

The **different kinds of movement** of which bones thus connected are capable are: —

1. **Flexion.** — A limb is flexed, when it is bent.
2. **Extension.** — A limb is extended, when it is straightened out.
3. **Abduction.** — This term generally means drawn away from the middle line of the body.
4. **Adduction.** — This term generally means brought to or nearer the middle line of the body.

Both abduction and adduction have a different meaning when used with reference to the fingers and toes. In the hand the imaginary line is supposed to be drawn through the middle finger; and in the foot through the second toe.

5. **Rotation.** — Means made to turn on its own axis.
6. **Circumduction.** — Means made to describe a conical space by rotation around an imaginary axis.

No part of the body is capable of perfect rotation, as a wheel, for the simple reason that such motion would necessarily tear asunder all the vessels, nerves, muscles, etc., which unite it with other parts.

Sprain. — A wrenching or twisting of a joint accompanied by a stretching or tearing of the ligaments or tendons is called a sprain.

Dislocation. — If in addition to a sprain, the bone is displaced, the injury is called a dislocation.

SUMMARY

Articulations or Joints — connections existing between bones.

Synarthrosis, or Immovable Joint	Bones are connected by fibrous tissue or cartilage.	1. *Sutura.* — Articulations by processes and indentations interlocked together. A thin layer of fibrous tissue is interposed between the bones. Sutures may be dentated, dove-tailed; serrated, saw-like; squamous, scale-like; harmonic, smooth; and grooved, for the reception of thin plates of bone. 2. *Synchondrosis.* — Temporary joint. Cartilage between bones ossifies in adult life.

Amphiarthrosis, or Slightly Movable Joint	Bones are connected by disks of cartilage or interosseous ligaments.	1. *Symphysis.* — The bones are united by a plate or disk of fibro-cartilage of considerable thickness. 2. *Syndesmosis.* — The bony surfaces are united by an interosseous ligament, as in the lower tibio-fibular articulation.
Diarthrosis, or Movable Joint	1. Fibrous ligaments forming a capsule. 2. Synovial membrane lining fibrous capsule. 3. Hyaline cartilage covering articular ends of bones.	1. *Arthrodia.* — Gliding joint; articulates by plane surfaces which glide upon each other. 2. *Ginglymus.* — Hinge or angular joint; moves backward and forward in one plane. 3. *Enarthrosis.* — Ball and socket joint; articulates by a globular head in a cup-like cavity. 4. *Trochoides.* — Pivot joint; articulates by a pivot process turning within a ring, or by a ring turning round a pivot. 5. *Condylarthrosis.* — Condyloid joint; ovoid head received into elliptical cavity. 6. *Reciprocal Reception.* — Saddle joint; articular surfaces are concavo-convex.
Movement . .	Flexion. Extension. Abduction. Adduction. Rotation. Circumduction.	

CHAPTER VII

MUSCULAR TISSUE: CLASSIFICATION; PROMINENT SKELETAL MUSCLES

MUSCULAR TISSUE

This is the tissue by means of which the movements of the body and its component parts are produced. It constitutes the fleshy parts, enters into the structure of many of the internal organs, and forms a large proportion of the weight of the whole body. The following has been calculated for a man of one hundred and fifty pounds' weight from the tables of Liebig: —

Skeleton	28 pounds.
Blood	12 pounds.
Viscera	48 pounds.
Skin	
Fat	
Muscles	62 pounds.

Muscular tissue, like every other tissue, is composed of cells and intercellular substance, with this special difference that the cells become elongated and develop into fibres. The intercellular substance consists of a small amount of cement, which helps to hold the fibres together. The fibres are really bound into bundles by connective tissue which forms a supporting framework.

CLASSIFICATION

Muscle fibres are of three distinct kinds, and we therefore distinguish three varieties of muscular tissue: —

1. Striated or cross-striped;
2. Non-striated or plain;
3. Cardiac.

Striated or cross-striped muscular tissue. — This tissue is called striated because it is distinctly marked by striæ, or parallel cross stripes. It is also called *skeletal* because it forms the muscles which are attached to the skeleton, and *voluntary* because it is nearly always under the control of the will. It is composed of long, slender fibres measuring on an average $\frac{1}{500}$ inch (0.050 mm.) in diameter, but having a length of an inch or more.

Fig. 65. — Diagram of Muscle Fibre with Sarcolemma Attached.

Each fibre consists of three distinct elements: —

(1) *Contractile substance*, forming the centre and making up most of the bulk of the fibres;

(2) *Nuclei*, which lie scattered upon the surface of the contractile substance;

(3) *The sarcolemma*, a thin, structureless tube which tightly encloses the contractile substance and the nuclei.

As each fibre is developed from a single cell and contains a number of nuclei, we may regard it as a multinuclear cell of elongated form. The muscle fibres lie closely packed, their ends lapping over on to adjacent fibres and forming bundles. A delicate connective tissue penetrates between the fibres, surrounds the small bundles and groups them into larger bundles. Connective tissue also surrounds the larger bundles and forms a covering for the whole muscle. Thus it will be seen that connective tissue forms a supporting framework for muscular tissue.

All of the muscles described in this chapter are striated or skeletal.

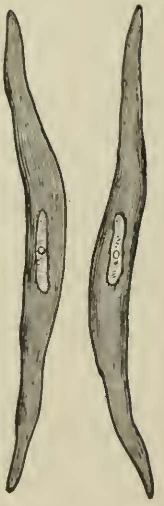

Fig. 66. — Fibre-cells of Plain Muscular Tissue. (Highly magnified.)

Non-striated or plain muscular tissue. — This tissue is called plain or non-striated because it does not exhibit parallel transverse *striæ* or stripes. It is also called *visceral* because it constitutes a large portion of the substance of many of the viscera, and *involuntary* because it is usually withdrawn from the control of the will. It is composed of elongated fibre-cells containing a single elongated nucleus. These fibre-cells are always shorter than the fibres of striated tissue. They lie side by side or lay over one another at the ends and are joined together by a small amount of cement substance. The fibre-cells are variously grouped in different parts of the body; sometimes crowded together in solid bundles which are arranged in layers and surrounded by connective tissue, as in the intestines; sometimes arranged in narrow, interlacing bundles, as in the bladder; sometimes wound in single or double layers around the blood-vessels; and again running in various directions and associated with bands of connective tissue, they form large, compact masses, as in the uterus.

Cardiac muscular tissue. — This variety of muscular tissue is found only in the heart substance. It is involuntary, but is striated, though not as distinctly as skeletal muscle. It is made up of fibres which are short, contain just one nucleus, and no sarcolemma. The fibres are grouped in bundles which are nearly square, and fine fibrils from each cell help to hold the bundles together. The bundles are really held together by connective tissue, which forms a supporting framework in the heart, just as it does in skeletal and visceral muscle.

Stimuli. — This term is used to describe influences which stimulate muscle fibres. They may be chemical, mechanical, thermal, electrical, or nervous. From the standpoint of physiology the nervous impulse is the most important.

Characteristics. — Muscular tissue is highly specialized and exhibits irritability, contractility, extensibility, elasticity, and tonicity.

Irritability has been defined as the response of a tissue to a stimulus. Nervous tissue and certain epithelial cells as well as muscular tissue possess this property. The response of any tissue to stimulation is to perform its special function, and in the case of muscular tissue this response takes the form of contraction and is known as *muscular contractility.* Each individual fibre becomes shorter and thicker, and thus the whole muscle becomes shorter and thicker. The function of the connective tissue framework is passive and may be likened to that of a harness, through which all the numerous contractile fibres are enabled to unite their efforts. Contraction of the muscle tends to bring together its two ends with whatever may be attached to them. Thus the contraction of certain muscles of the arm will shorten the muscles, shorten the distance between their ends, and flex the forearm.

Extensibility of a living muscle means that it can be stretched or extended, and *elasticity* means that it readily returns to its original form. Normally, the skeletal muscles are in a condition of slight tension, being stretched from bone to bone. This condition is of importance in two ways: (1) smoothness of movement is dependent upon it; (2) a stretched muscle will contract more quickly than one that is relaxed. To understand the first statement it is important to remember that skeletal muscles are usually arranged in antagonistic groups, one of which opposes another. Thus the muscles located on the anterior surface of the arm and forearm are called flexors, and those located on the posterior surface are called extensors. The action of the flexors is to bend the arm, the action of the extensors is to extend or straighten the arm. When stimulated, either group of muscles must overcome the resistance of the opposing group. Therefore contraction takes place more slowly and evenly, and smoothness of movement is the result.

Under normal conditions there is a constant and insensible tendency to contract called *tonicity.* It is really a mild, sustained contraction, and though it may vary in degree, it is rarely absent altogether. Tone in the skeletal muscles gives them a certain firmness and maintains a slight steady pull upon their attachments. It is not likely to result in movement on account of the action of an antagonistic muscle. In fractures the over-riding of the broken ends of a bone is often due to the contraction of the muscle, that is the result of its tonicity. This property is of importance in several ways: (1) in connection with elasticity it promotes a quicker response to stimulation, (2) it assists in maintaining the circulation of the blood and lymph, and (3) it assists in the regulation of nutrition and body heat. As previously stated tonicity may vary in degree. Increase in the degree may follow (1) muscular exercise, (2) mental exercise, and (3) lowering of the surrounding temperature. The effect of a cold bath is a familiar example of the last.

Blood-vessels and nerves. — All varieties of muscular tissue are well supplied with blood-vessels and nerves. The blood-vessels that supply blood to the muscles are supported and carried by the connective tissue. They do not penetrate into the cells, but each cell is bathed in lymph which exudes from the blood-vessels. The cells take from the lymph the materials they need and give up to the lymph the waste substances that are the result of their activities.

In order to understand the nerve supply it is necessary to become familiar with a few facts regarding the *nervous system.* The name nervous system includes all the structures in the body that are made of nerve tissue. For purposes of study the nervous system is arbitrarily divided into the central nervous system, and the sympathetic system. The *central nervous system* consists of the brain, the spinal cord, and their nerves. The *sympathetic system* consists of masses of nerve cell-bodies called *ganglia,* and the nerves connected with them. These two systems differ slightly in function, but are intimately connected and are really interdependent. Most of the nerves that are connected with the skeletal muscles belong to the central nervous system, but the majority of those supplying the visceral muscles belong to the sympathetic system. Nerves that carry impulses *from* the periphery (in this connection the muscles) to the brain, spinal cord or ganglia, are called *afferent.* Nerves that carry impulses *to* the periphery from the brain, spinal cord or ganglia, are called *efferent.* Afferent nerves that are connected with muscle fibres are spoken of as *sensory.* Efferent nerves that end in muscle fibres are spoken of as *motor.* For the purposes of this chapter, each of the terms in these pairs, *i.e.* motor and efferent, sensory and afferent, may be considered interchangeable. It should be remembered, however, that the terms efferent and afferent are applied to other types of nerves besides motor and sensory nerves.[1]

Differences in, and results of, contraction. — Skeletal muscle is essentially a quick-acting tissue. It contracts quickly and relaxes promptly. Even prolonged contractions are compounded of successive twitches that follow each other too rapidly to permit of relaxation. In sharp contrast to this the contractions of visceral muscle develop slowly, are maintained for some time, and fade out slowly. In addition to the contractions that are the result of stimulation from the nerves, visceral and cardiac tissue are also *automatic.* This means that there is a tendency to rhythmic contraction and relaxation inherent in the tissue itself.

Contractions of all kinds of muscular tissue cause a chemical change in the substance of the muscle fibre. The complex sub-

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[1] For a more detailed description, see Chap. XIX.

stances of which it is composed are split and oxidized into simpler substances, *i.e.* water, carbon dioxide, and sarcolactic acid. At the same time heat is generated, energy is set free, and various waste products are formed. Heat is a familiar result of muscular exercise. The liberation of energy enables the muscle to do its required work. The waste compounds must be eliminated, and, except in cases of prolonged contractions, the system is able to get rid of them readily. Prolonged contractions result in *fatigue,* and this means two things: (1) an accumulation of waste substances, known as fatigue poisons, (2) a loss of nutrient material. A period of rest furnishes opportunity for these poisons to be carried to the excretory organs by the blood, and fresh nutritive materials from the digestive organs carried by the blood to the muscle. In cases of extreme fatigue that are the result of prolonged overwork of a muscle or muscles, the fatigue poisons have the same effect that the toxins of tetanus have, and the over-contracted condition is spoken of as *tetanus of the muscle.* Writer's cramp with its accompanying stiffness and pain is an example of this condition. In such cases massage improves the circulation of the blood and lymph, thus helping the elimination of fatigue poisons, and brings about a condition of relaxation.

Skeletal Muscles. — The muscles are separate organs, each muscle having its own sheath of connective tissue, called epimysium. They vary in size from a fraction of an inch to nearly twenty-four inches (600 mm.) and are very diverse in form. In the trunk the muscles are broad, flattened, and expanded, forming the walls of the cavities which they enclose. In the limbs they are of considerable length, forming more or less elongated straps. A typical muscle is described as consisting of a body and two extremities. The body is the red contracting part, and the extremities are the ends where they are attached.

Attachment of the muscles to the skeleton. — Muscles are attached to the bones, cartilages, ligaments, and skin in various ways, the most common mode of attachment being by means of **tendons.** The muscular fibres converge as they approach their tendinous extremities, and gradually blend with the fibres of the tendons, the tendons in their turn inserting their fibres into the bones. Where one muscle connects with another, each muscle ends in expanded form in a flat, fibrous membrane called **aponeurosis.**

Again, in some cases, the muscles are connected with the bones, cartilages, and skin, without the intervention of tendons or aponeuroses.

Origin and insertion. — It is customary to speak of the attachments of the opposite ends of muscles under the names of origin and insertion, the first term **origin** being usually applied to the more fixed attachment; the second term **insertion** being applied to the more movable attachment. The origin is, however, absolutely fixed in only a very small number of muscles, such as those of the face, which are attached by one end to the bone, and by the other to the movable skin. In the greater number, the muscle can act from either end.

Names of muscles. — The skeletal muscles are usually called by their Latin names, and it is helpful to understand the meaning of these names, as they are often descriptive of some distinctive characteristic, such as their form, size, attachment, location, function, etc.[1]

The majority occur in pairs. Only a few are single, and they are located about the median line. Muscles may be classified in several ways. The most helpful way is to classify them according to their location and function. It is not necessary for nurses to distinguish more than a few of the most prominent.

CHIEF MUSCLES OF HEAD, FACE, TONGUE, AND NECK

Muscles of the Head — Occipito-frontalis.

Muscles of the Face	Orbital Muscles	Four recti.
		Two oblique.
		Levator palpebræ superioris.
	Muscles of Mastication	Masseter.
		Temporal.
		Internal pterygoid.
		External pterygoid.
	Muscles of Expression	Orbicularis oris.
		Buccinator.
Muscles of the Tongue	Genioglossus.	
	Styloglossus.	
Muscles of the Neck	Platysma.	
	Sterno-cleido-mastoid.	

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[1] The student will find the Latin derivations and their meaning in the *Glossary* at the back of the book.

Occipito-frontalis. — The chief muscle of the head is the occipito-frontalis, which may be considered as two muscles united together by a thin aponeurosis extending over and covering the whole of the upper part of the cranium. The occipital takes its origin from the occipital bone and is inserted into the aponeurosis. The frontal takes its origin from the tissues in the region of the eyebrows, and is also inserted into the aponeurosis.

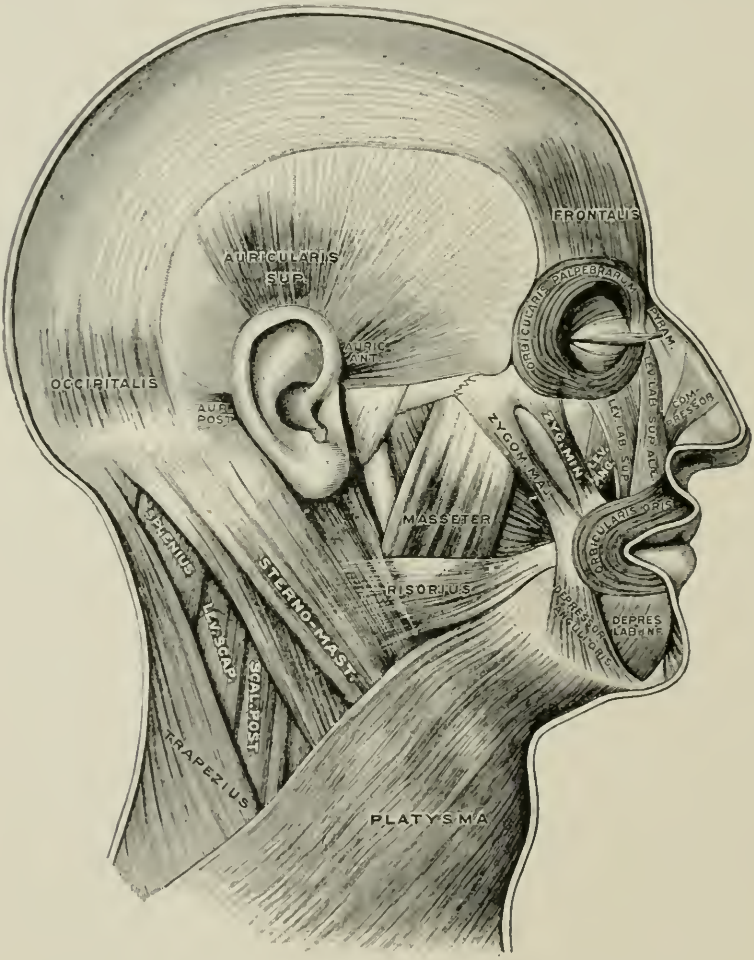

Fig. 67. — Superficial Muscles of Head and Neck. (Gerrish.)

Action. — The frontal portion of this muscle is the more powerful; by its contraction the eyebrows are elevated, the skin of the forehead thrown into transverse wrinkles, and the scalp drawn forward. The occipital acts in direct line with the frontal, and emphasizes its action.

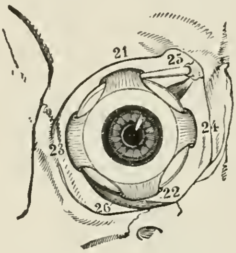

Fig. 68. — Muscles of Right Eyeball within the Orbit. Seen from the front. 21, superior rectus; 22, inferior rectus; 23, external rectus; 24, internal rectus; 25, superior oblique; 26, inferior oblique.

Muscles of the face. — There are about thirty facial muscles; they are chiefly small, and only a few are considered. We group them as: (1) Orbital muscles, (2) Muscles of mastication, and (3) Muscles of expression.

Orbital muscles. — The orbit contains seven muscles; six of them are attached to the eyeball, and the seventh is attached to the upper lid. The six muscles attached to the eyeball are arranged in three opposing pairs.

The superior and inferior recti. — These two muscles have their origin at the apex of the orbital cavity and pass straight forward to their insertion into the eyeball, the superior rectus in the middle line above, and the inferior rectus opposite it below.

Action. — Contraction of the superior rectus rolls the eye upward; contraction of the inferior rolls the eye downward.

The internal and external recti. — These two muscles have their origin at the apex of the orbital cavity, and pass forward to their insertion into the eyeball, the internal on the inner side, the external on the outer side.

Action. — Contraction of the internal rectus draws the eye inward toward the nose. Contraction of the external rectus draws the eye outward.

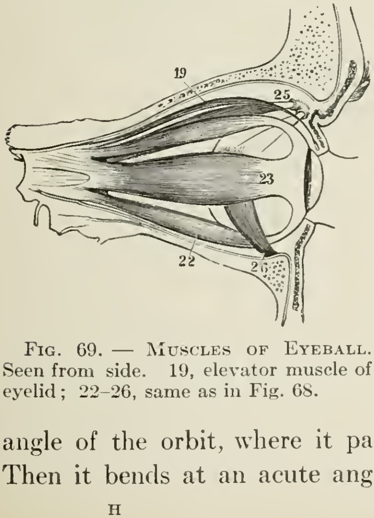

Fig. 69. — Muscles of Eyeball. Seen from side. 19, elevator muscle of eyelid; 22–26, same as in Fig. 68.

Superior oblique. — The superior oblique muscle arises from the apex of the orbit (the same as the four recti), courses forward to the upper and inner angle of the orbit, where it passes through a loop of cartilage. Then it bends at an acute angle, passes around the upper part of the eyeball, and is inserted between the superior and external recti.

Inferior oblique. — The inferior oblique arises from the orbital plate of the maxilla, and courses around the under portion of the eyeball to its attachment near the external rectus.

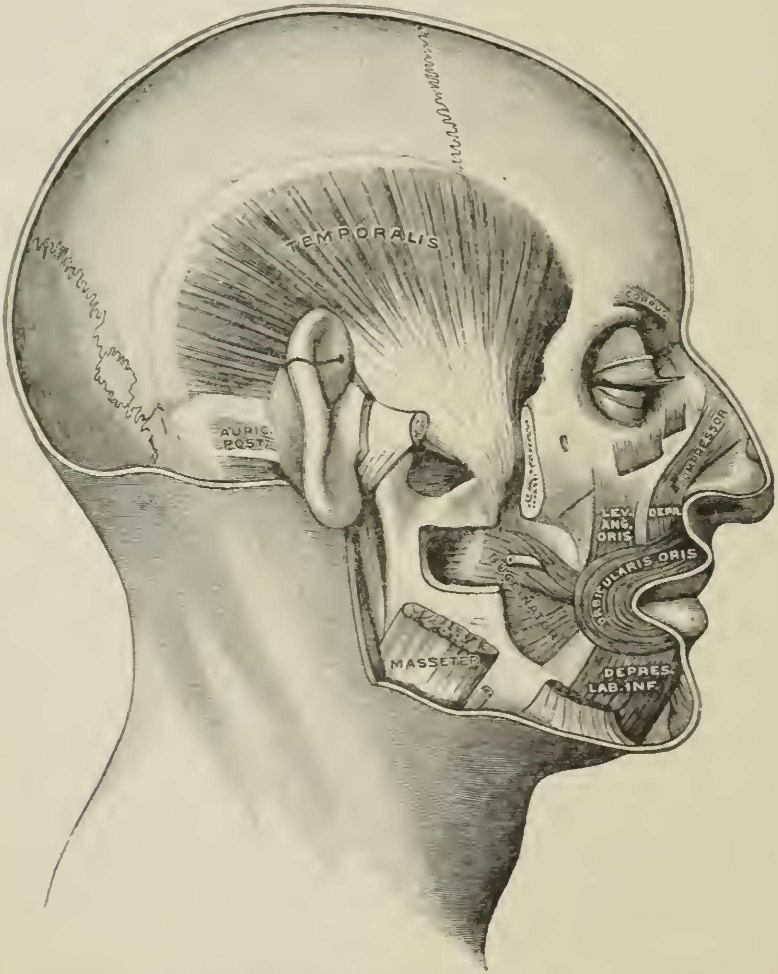

Fig. 70. — Temporal and Deep Muscles about the Mouth. (Gerrish.)

Action. — The action of the two oblique muscles is somewhat complicated, but their general tendency is to roll the eyeball on its axis.

In most cases the movements of the eye are somewhat complex and more than one muscle is involved.

Levator palpebræ superioris (lifter of the upper lid). — It arises from the sphenoid bone, passes forward, and is inserted into the tarsal cartilage of the upper lid.

Action. — It elevates the upper lid and opens the eye.

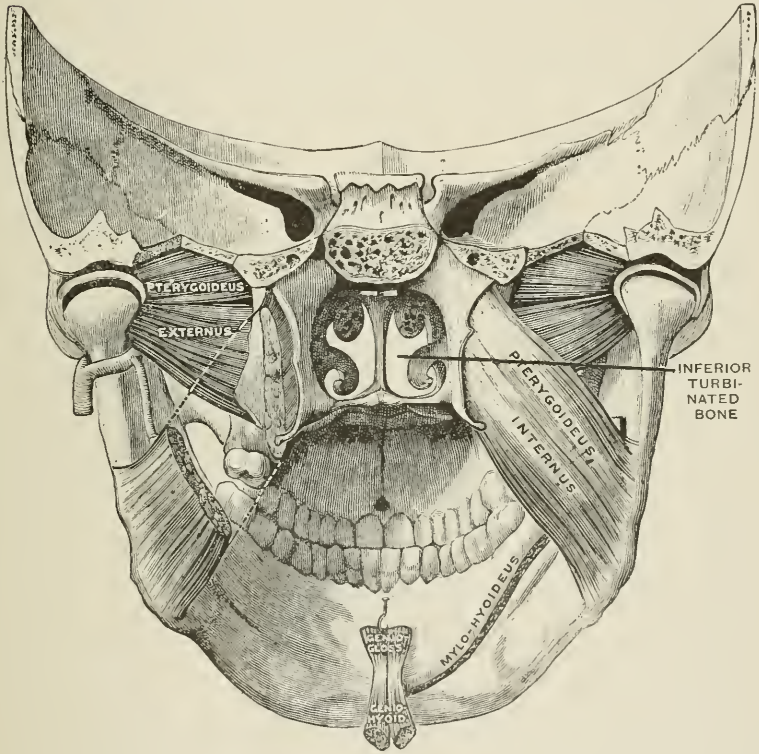

Fig. 71. — Pterygoid Muscles. Viewed from behind, the back portion of the skull having been removed. (Gerrish.)

Muscles of mastication. — They are: (1) the masseter (chewing muscle), (2) the temporal (temple muscle), (3) the internal pterygoid, and (4) the external pterygoid. These muscles can be located on the illustrations. They have their origin in one or more of the immovable bones of the skull, and are inserted into the movable lower jaw.

Action. — The muscles of mastication generally act in concert, bringing the lower teeth forcibly into contact with the upper; they also move the lower jaw forward upon the upper, and in every direction necessary to the process of grinding the food.

Muscles of expression. — These muscles are sometimes called mind muscles from the indications that they afford of the mental state of the individual. They are closely connected with the under surface of the skin or with each other, and therefore their slightest contraction is shown on the face. They include the muscles of the forehead, eyelids, nose, and all those related to the orifice of the mouth. We shall only consider two important muscles related to the orifice of the mouth.

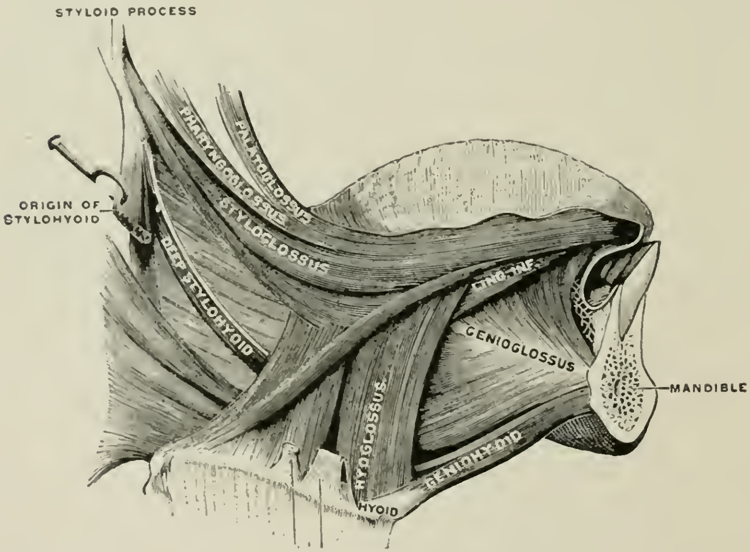

FIG. 72. — MUSCLES OF THE TONGUE. Viewed from the right side. (Gerrish.)

Orbicularis oris. — The ring muscle surrounds the opening of the mouth, extending from the nose above to the chin below. It forms a great part of the bulk of the lips, and constitutes a sphincter to the mouth. It is attached above to the partition between the nostrils and the upper jaw bones, and below to the mandible.

Action. — It closes the mouth.

Buccinator (trumpeter's muscle). — This muscle arises from the alveolar processes of the maxilla and mandible. Its different parts converge to the angle of the mouth, and are inserted into the orbicularis oris.

Action. — It compresses the cheeks, helps to close the mouth, and assists in such motions as blowing a trumpet.

Chief muscles of the tongue. — The chief muscles connecting the tongue and hyoid bone to the lower jaw are the **genioglossus** and the **styloglossus.**

Genioglossus. — The genioglossus has its origin in the front part of the mandible, and is inserted in the whole length of the tongue in and at the side of the mid line.

Action. — It thrusts the tongue forward, retracts it, and also depresses it.

Styloglossus. — The styloglossus has its origin in the styloid process[1] of the temporal bone, and is inserted in the whole length of the side and under part of the tongue.

Action. — It draws the tongue backward.

These muscles are interesting to us from the fact that during general anæsthesia they, together with the other muscles, become relaxed, and it is necessary to press the angle of the lower jaw upward and forward in order to prevent the tongue from falling backward and obstructing the larynx.

Muscles of the neck. — The two superficial muscles of the neck are: (1) platysma, (2) sterno-cleido-mastoid.

Platysma (broad sheet muscle). — It arises from the skin and areolar tissue covering the pectoral, deltoid, and trapezius muscles, and is inserted in the mandible and muscles about the angle of the mouth.

Action. — It draws the angle of the mouth down and contracts the skin of the neck.

Sterno-cleido-mastoid. — The most prominent muscle of the neck is the sterno-cleido-mastoid. It is named from its **origin** and **insertion**, arising from part of the sternum and clavicle, and being inserted into the mastoid portion of the temporal bone. This muscle is easily recognized in thin persons by its forming a cord-like prominence obliquely situated along each side of the neck.

Action. — Both sterno-cleido-mastoid muscles acting together flex the head on the chest or neck. They serve as convenient landmarks in locating the great vessels carrying the blood to and

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[1] See Fig. 27.

from the head. If one of these muscles be either abnormally contracted or paralyzed, we get the deformity called *Torticollis* or wry neck.

CHIEF MUSCLES OF THE TRUNK

They may be arranged in four groups: —

1. **Muscles of the Back**	Trapezius. Latissimus dorsi.
2. **Muscles of the Chest**	Pectoralis major. Pectoralis minor.
3. **Muscles of the Thorax**	External intercostals. Internal intercostals. Levatores costarum.
4. **Muscles of the Abdomen**	External oblique. Internal oblique. Rectus abdominis. Transversalis.

Muscles of the back. — The muscles of the back are disposed in five layers, one beneath another. The two largest and most superficial muscles are: (1) the trapezius, (2) the latissimus dorsi.

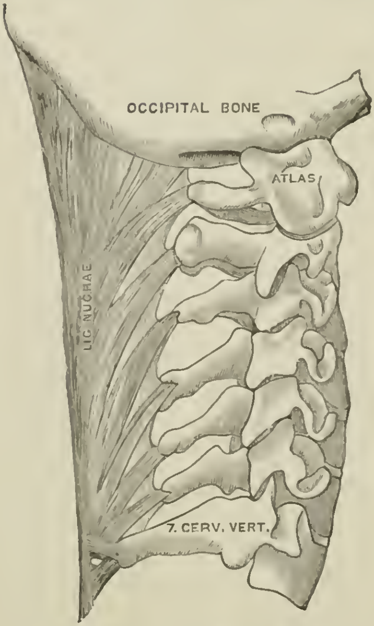

Fig. 73. — The Ligamentum Nuchæ. Seen from the right side. (Gerrish.)

Trapezius. — The trapezius, so called because right and left together make a large diamond-shaped sheet, arises from the middle of the occipital bone, from all the cervical and all the thoracic vertebræ. The connection with the cervical vertebræ is through the medium of the *ligamentum nuchæ*, which is a form of ligament that stretches from the protuberance of the occiput to the spinous processes of the seven cervical vertebræ. (See Fig. 73.) From this extended line of origin the fibres converge to their insertion in the clavicle, the acromion process, and the spine of the scapula. It is a very large muscle, and covers the other muscles of the upper part of the back and neck, also the upper portion of the latissimus dorsi.

Action. — It lifts the shoulder and rotates the angle of the scapula backward.

Latissimus dorsi. — The latissimus dorsi arises from the last six thoracic vertebræ, and through the medium of the lumbar aponeurosis, from the lumbar and sacral part of the spine and from the crest of the ilium. It covers the lower part of the back. The fibres pass upward and converge into a thick, narrow band, which winds around and finally terminates in a flat tendon, which is inserted into the front of the humerus just below its head.

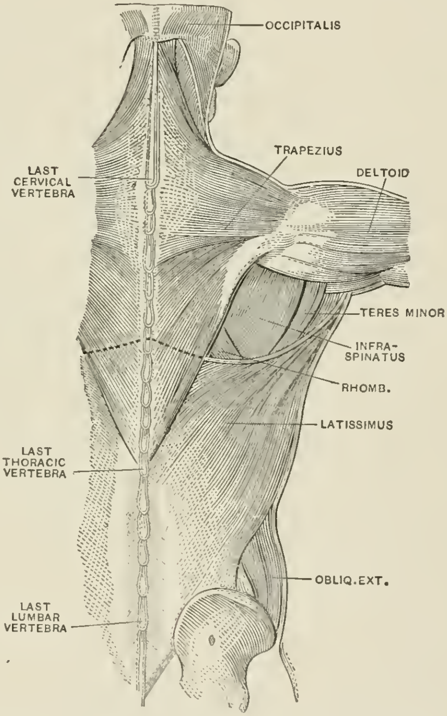

Fig. 74. — Muscles in the Superficial Layer of the Back. (Gerrish.)

Action. — It draws the humerus backward, the body forward, and keeps the scapula close to the chest, as in using crutches or climbing. If the arm is elevated, it draws it down, back, and rotates it in, as in swimming.

Muscles of the chest. — The chief bulk of the anterior muscular wall of the chest is made up of the **pectoral** muscles.

Pectoralis major. — The pectoralis major arises from the sternal end of the clavicle, the sternum, and the six upper ribs. The fibres converging form a thick mass, which is inserted by a tendon of considerable breadth into the upper part of the humerus.

Action. — It draws the arm downward and forward.

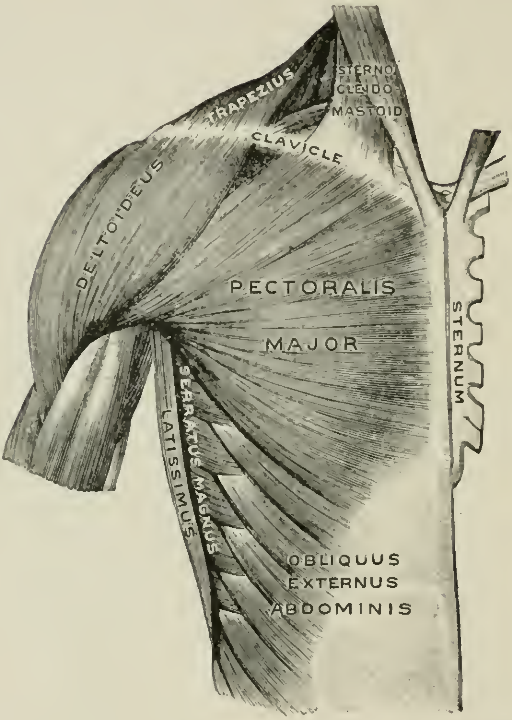

FIG. 75. — FRONT OF CHEST AND SHOULDER OF RIGHT SIDE, SUPERFICIAL MUSCLES. (Gerrish.)

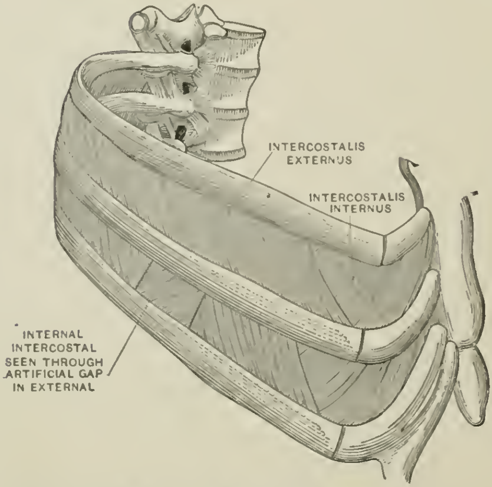

FIG. 76. — INTERCOSTAL MUSCLES IN RIGHT WALL OF THORAX. (Gerrish.)

Pectoralis minor. — The pectoralis minor is underneath and entirely covered by the major. It arises from the surface of the third, fourth, and fifth ribs, near the cartilages, and is inserted in the coracoid[1] process of the scapula.

Action. — It pulls the shoulder downward and assists in the elevation of the ribs during inspiration.

Muscles of the thorax. — The muscles of the thorax are chiefly concerned with the movements of the ribs during respiration. They are the: (1) intercostals, and (2) levatores costarum.

Intercostals. — The intercostals are found filling the spaces between the ribs. Each muscle consists of two layers, one external and one internal, and as there are eleven intercostal spaces on each side, and two muscles in each space, it follows there are forty-four intercostal muscles. The fibres of these muscles run in opposite directions.

External intercostals. — The external fibres arise from the lower border of a rib, run downward, forward, and inward, and are inserted into the upper border of the next lower rib.

Action. — They pull the ribs upward and outward, thereby increasing the chest cavity.

Internal intercostals. — The internal fibres arise from the lower border of a rib, run downward, outward, and backward, and are inserted into the upper border of the next lower rib.

Action. — They depress the ribs.

Levatores costarum (lifters of the ribs). — They arise from the transverse processes of the vertebræ from the seventh cervical to the eleventh thoracic, and are inserted into the outer surface of the ribs between the tubercles and angles.

Action. — They assist in elevation of the first ten ribs, and with other muscles draw the lower ribs backward.

Diaphragm. — The diaphragm is a thin, musculo-fibrous partition placed obliquely between the abdominal and thoracic cavities. It is dome-shaped, and consists of muscle fibres arising from the whole of the internal circumference of the thorax, and of a central aponeurotic tendon, shaped somewhat like a trefoil leaf, into which the muscle fibres are inserted. It has three large openings for the passage of the aorta, the large artery of the body, the inferior vena cava, one of the largest veins of the body, and the

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[1] See Fig. 49 for coracoid process of scapula.

œsophagus, or gullet; it has also some smaller openings for the passage of blood-vessels, nerves, etc. The upper or thoracic surface of the diaphragm is highly arched; the heart is supported by the central tendinous portion of the arch, the right and left lungs by the lateral portions, the right portion of the arch being slightly higher than the left. The lower or under surface of the diaphragm is deeply concave, and covers the liver, stomach, pancreas, spleen, and kidneys.

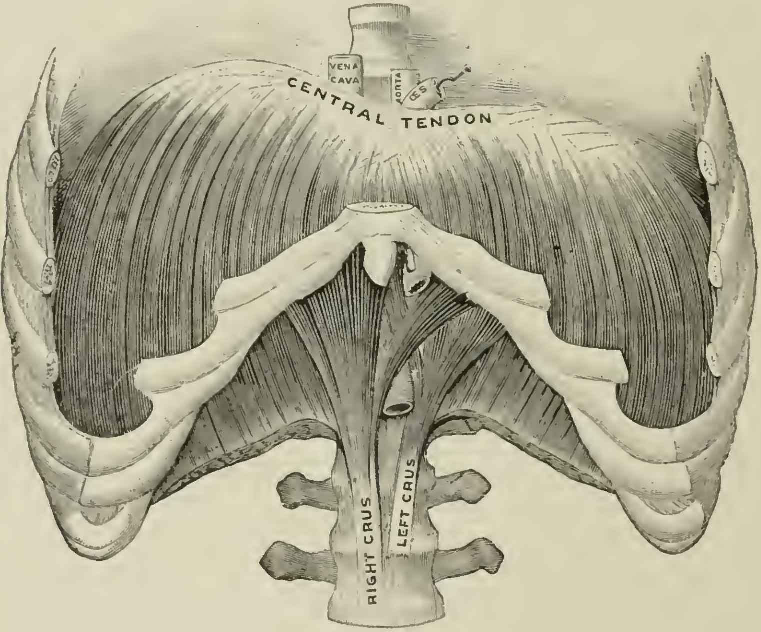

Fig. 77. — Diaphragm. Viewed from in front. (Gerrish.)

Action. — The diaphragm is probably the most important voluntary muscle in the body, as well as the chief respiratory and expulsive muscle. In the act of inspiration the diaphragm contracts, and in contracting flattens out and descends, the abdominal viscera are pressed downwards, and the thorax is expanded vertically. In forcible acts of expiration, and in efforts of expulsion from the thoracic and abdominal cavities, the diaphragm and all the other muscles which tend to depress the ribs, and those which compress the abdominal cavity, concur in powerful action to empty the lungs, to fix the trunk, and to expel the contents of the abdominal viscera. Thus it follows that the action of the diaphragm is of assistance in expelling the fœtus from the uterus, the fæces from the rectum, the urine from the bladder, and its contents from the stomach in vomiting.

Muscles of the abdomen. — The chief muscles of the abdomen are: (1) external oblique, (2) internal oblique, (3) rectus abdominis, and (4) transversalis.

External oblique. — The strongest and most superficial of the abdominal muscles is the external oblique. It arises from the outer surface of the eight lower ribs. The fibres incline downward and forward and terminate in the broad aponeurosis, which, meeting its fellow of the opposite side in the linea alba, covers the whole of the front of the abdomen. The lowest fibres of the aponeurosis are gathered together in the shape of a thickened band, which extends from the anterior superior spinous process of the ilium to the pubic bone, and forms the well-known and important landmark, the **inguinal ligament,** more commonly known as Poupart's ligament from the anatomist who first described it.

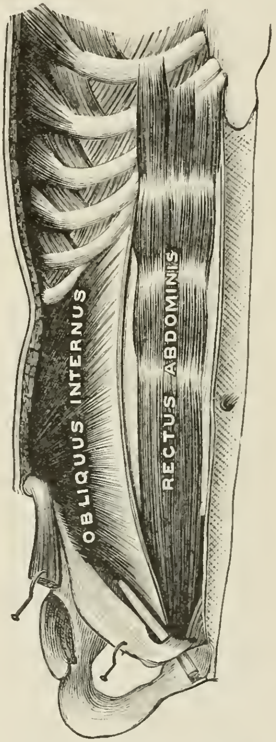

FIG. 78. — RECTUS ABDOMINIS AND OBLIQUUS INTERNUS OF RIGHT SIDE. (Gerrish.)

Internal oblique. — The internal oblique muscle lies just beneath the external oblique. It arises from the inguinal ligament, the outer crest of the ilium, and slightly from the lumbar fascia.[1]

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[1] The *lumbar fascia* springs from the vertebral column in three layers: —

(1) Outer, or posterior.
(2) Middle.
(3) Inner, or anterior.

(1) The outer layer begins at the spinous process of the lumbar and sacral vertebræ. It is attached above to the last rib, and below to the outer tip of the iliac crest and the ilio-lumbar ligament.

(2) The middle layer starts from the transverse processes of the lumbar vertebræ

(3) The inner layer starts from the front of the bases of the same processes.

The fascia resulting from the combination of these three layers gives rise to the internal oblique and transversalis muscles.

Its most posterior fibres run upward and forward and are inserted in the costal cartilages of the four lower ribs. At the outer border of the rectus muscle the remaining muscle fibres expand into a broad aponeurosis. This aponeurosis divides into two layers, one passing before, the other behind, the rectus muscle; they reunite at its inner border in the linea alba, and thus form a sheath for the rectus, extending from the xiphoid process to the crest of the pubes. At the lower part of the rectus the posterior layer of the aponeurosis is deficient.

Rectus abdominis. — The rectus is a long, flat muscle, consisting of vertical fibres situated at the fore part of the abdomen, and enclosed in the fibrous sheath formed by the aponeurosis of the internal oblique. It arises from the pubic bone, and is inserted into the cartilages of the fifth, sixth, and seventh ribs; it is separated from the muscle of the other side by a narrow interval which is occupied by the linea alba.

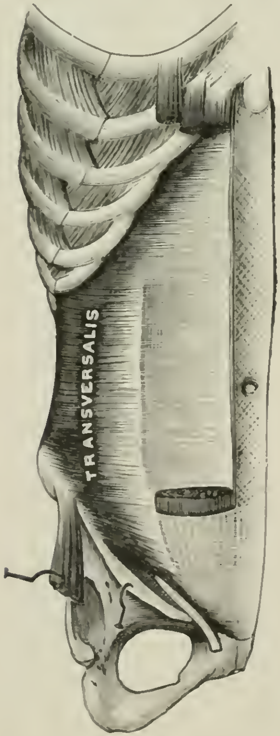

Fig. 79. — Transversalis Abdominis of Right Side. (Gerrish.)

Transversalis. — The transversalis muscle lies beneath the internal oblique. The fibres arise from the six lower costal cartilages, the lumbar fascia, the crest of the ilium, and the outer third of the inguinal ligament. The greater part of its fibres have a horizontal direction, and are inserted in the linea alba and the crest of the pubes.

Linea alba. — The linea alba, or white line, is a tendinous band formed by the union of the aponeuroses of the two oblique and transverse muscles, the tendinous fibres crossing one another from side to side. It extends perpendicularly, in the middle line, from the xiphoid portion of the sternum to the pubes. It is a little broader above than below, and a little below the middle it is widened into a flat, circular space, in the centre of which is situated the umbilicus.

Action of the abdominal muscles. — When these muscles contract, they compress the abdominal viscera, and constrict the cavity of the abdomen, in which action they are much assisted by the descent of the diaphragm. By these means they give assistance in parturition, defecation, micturition, and vomiting. They also assist in respiration, and in various movements, such as climbing, flexing the thorax upon the pelvis, rotation of the trunk, etc.

The inguinal canal. — Between the abdominal muscles, parallel to, and about one-half inch above the inguinal ligament, is a tiny canal, about one and one-half inches long, called the inguinal canal. The internal opening of the canal is called the *internal abdominal ring,* and is situated in the fascia of the transversalis muscle, midway between the spine of the ilium and the crest of the pubic bone. The canal ends in the *external abdominal ring,* which is in the tendon of the external oblique muscle. This canal transmits the spermatic cord in the male, or the round ligament of the uterus in the female.

Weak places in the abdominal walls. — The *internal* and *external abdominal rings,* described above, the *umbilicus,* and another ring situated just below the inguinal ligament, and called the *femoral ring,* are considered weak places because they are so often the seat of *hernia.* Hernia,[1] or rupture, is a protrusion of a portion of the contents of a body cavity, and in this instance would mean a protrusion of a portion of the intestine or mesentery through one of these weak places. If it occurs in the umbilicus, it is called *umbilical hernia;* in the inguinal rings, *inguinal hernia;* and in the femoral ring, *femoral hernia.* The inguinal canal is larger in the male than in the female, hence inguinal hernia is more common in the male than in the female.

MUSCLES OF THE UPPER EXTREMITIES

A certain number of muscles situated superficially on the trunk are frequently grouped with the muscles of the upper extremities, as their function is to attach the upper limbs to the trunk and move the shoulders and arms. Of these, the two superficial

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[1] If the skull is injured so that a portion of the brain protrudes, it would also be correctly spoken of as hernia of the brain. Of course this is more unusual than abdominal hernia.

muscles we have mentioned as covering the back, the trapezius and latissimus dorsi, and the pectoral muscles covering the front of the chest, are the chief.

The muscles of the extremities are arranged in antagonistic groups, the action of one group opposing the action of the other. The movements of which the extremities are capable are flexion and extension, abduction and adduction, supination and pronation, circumduction and rotation. (See page 87.)

Functionally we might group the muscles of the upper extremities as follows.

	Name of Muscle	Location	Function
Moving the Shoulder	Trapezius	Upper portion of back	Moves shoulder upward and backward.
	Pectoralis minor	Chest, under pectoralis major	Moves shoulder downward and assists in the elevation of the ribs during inspiration.
Moving the Arm	Deltoid	Covers the top of the shoulder	Abduction.
	Pectoralis major	Chest, from sternum to humerus	Adduction.
	Latissimus dorsi	Lower portion of back	Adduction.
Moving the Forearm	Biceps	Anterior surface of arm	Flexion.
	Triceps	Posterior surface of arm	Extension.
	Pronators	Anterior surface of forearm	Pronation.
	Supinators	Posterior surface of forearm	Supination.

Deltoid. — The deltoid is a coarse, triangular muscle covering the top of the shoulder. It arises from the clavicle, acromion process, and spine of the scapula, extends downward, and is inserted into the middle of the shaft of the humerus, on the outer side. (See Fig. 81.)

Action. — It abducts — raises the arm from the side so as to bring it at right angles to the trunk. This action is opposed by the pectoralis major and latissimus dorsi, which have been described.

Biceps. — The biceps is a long fusiform muscle, occupying the whole of the anterior surface of the arm; it is divided above into two portions or heads, from which circumstance it has received its name. It arises by these two heads from the scapula, and is inserted into the radius.

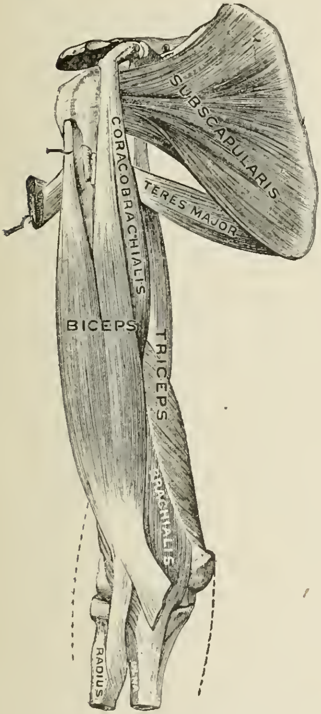

Fig. 80. — Muscles of the Front of the Right Shoulder and Arm. (Gerrish.)

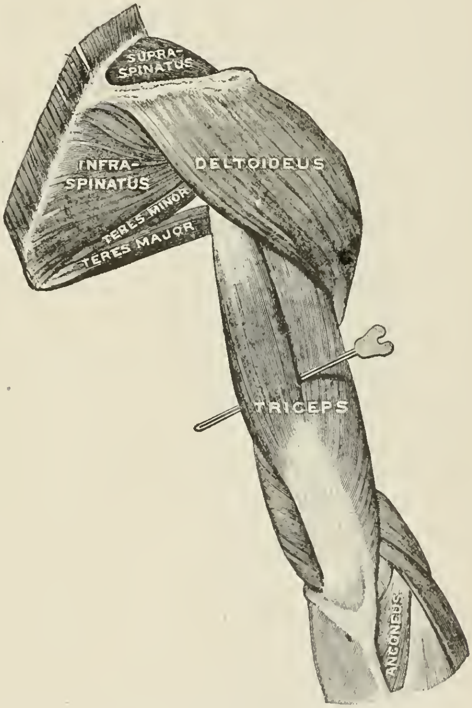

Fig. 81. — Muscles on the Dorsum of the Right Shoulder and Arm. (Gerrish.)

Action. — It flexes the forearm on the arm.

Triceps. — The triceps is situated on the back of the arm, extending the whole length of the posterior surface of the humerus. It is of large size, and divided above into three heads; hence its name. Two of the heads have their origin in the scapula and one in the humerus. The three heads unite in a common tendon which is inserted into the ulna.

Action. — It is the great extensor muscle of the forearm, and is the direct antagonist of the biceps.

Muscles of the forearm. — The muscles covering the forearm are disposed in groups, the **pronators** and **flexors** being placed on the front and inner part of the forearm, and the **supinators** and **extensors** on the outer side and back of the forearm: they antagonize one another. The pronators turn the palm of the hand backward and, when the elbow is flexed, downward or prone. The supinators turn the palm of the hand forward, and, when the elbow is flexed, upward or into the supine position. The flexors and extensors have long tendons, some of which are inserted into the bones of the wrist, and some into the bones of the fingers: they serve to flex and extend the wrist and fingers.

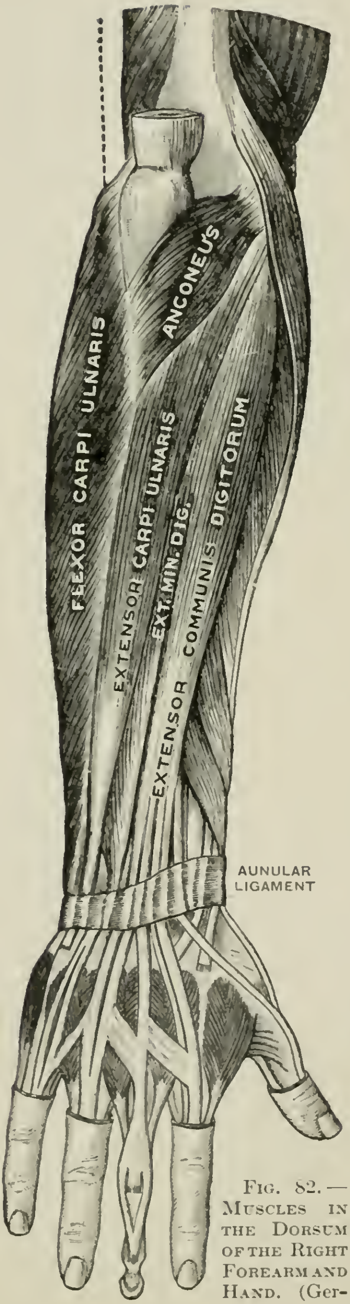

Fig. 82. — Muscles in the Dorsum of the Right Forearm and Hand. (Gerrish.)

MUSCLES OF THE LOWER EXTREMITIES

If we compare the muscles of the shoulder, arm, and forearm with those of the hip, thigh, and leg, we shall see that the anterior muscles of the former correspond roughly with the posterior muscles of the latter, the muscles of the hip, thigh, and leg, however, being larger and coarser in texture than those of the shoulder, arm, and forearm.

Functionally we might group the most important muscles of the lower extremities as follows: —

	Name of Muscle	Location	Function
Moving the Thigh	Psoas magnus Iliacus	In the pelvis and upper part of thigh	*Flexion* and outward rotation
	Gluteus maximus	Region of buttocks	*Extension*, outward rotation and adduction.
	Gluteus medius	Under gluteus maximus	*Abduction* and inward rotation.
	Gluteus minimus	Under gluteus medius	
	Adductor magnus Adductor longus Adductor brevis	Mesial part of thigh	*Adduct*, rotate and flex thigh.
	Adductor gracilis	Mesial part of thigh	*Adducts* thigh and flexes the leg.
Moving the Leg	Sartorius	Front of thigh	*Flexes* leg, helps in rotation and abduction of thigh.
	Biceps Semitendinosus Semimembranosus	Hamstring Back of thigh	*Flexors* of knee, rotate leg inward, extend thigh.
	Rectus femoris Vastus externus Vastus internus Vastus intermedius	Quadriceps Front of thigh	*Extension of* leg, flexes the thigh.
Moving the Foot	Tibialis anterior Peroneus tertius	Front of leg	*Flexors.*
	Tibialis posterior Gastrocnemius Soleus	Back of leg	Extensors.
	Peroneus longus Peroneus brevis	Outer part of leg	

Psoas magnus. — The great loin muscle arises from the last thoracic and all the lumbar vertebræ with the included intervertebral cartilages. It extends down and forward, then down and backward, to its insertion in the small trochanter of the femur.

Iliacus. — This muscle and its relation to the psoas magnus is well shown in Fig. 83. It arises from the iliac fossa and is inserted partly into the tendon of the psoas and partly into the small trochanter of the femur.

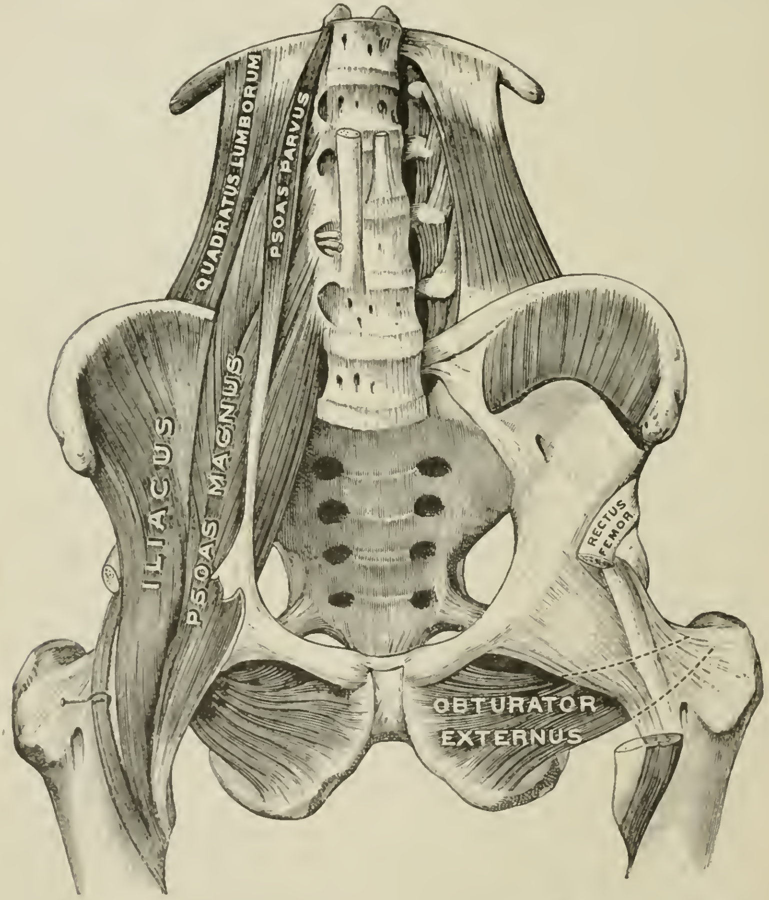

FIG. 83. — PSOAS, ILIACUS, AND OBTURATOR EXTERNUS MUSCLES. (Gerrish.)

Action. — The psoas magnus and iliacus act as one muscle to flex the thigh on the pelvis, and rotate the femur outward.

Glutei muscles. — The three gluteal muscles are coarse in texture, and form the chief prominence of the buttocks.

Gluteus maximus arises from the ilium, sacrum, and coccyx, and is inserted into the great trochanter of the femur.

Action. — It is a powerful extensor of the hip-joint. It also rotates the femur outward, and adducts the thigh.

Gluteus medius and gluteus minimus are under the gluteus maximus and almost entirely covered by it. They arise from the outer surface of the ilium and are inserted into the great trochanter.

Action. — Abduction of the thigh, and when the thigh is flexed, inward rotation.

Adductors. — The four adductor muscles are called respectively *magnus* (great), *longus* (long), *brevis* (short), and *gracilis* (slender). They are situated on the inner side of the thigh. They arise from different portions of the pubic bone, and the first three are inserted into the inner side of the femur. The gracilis is inserted into the shaft of the tibia.

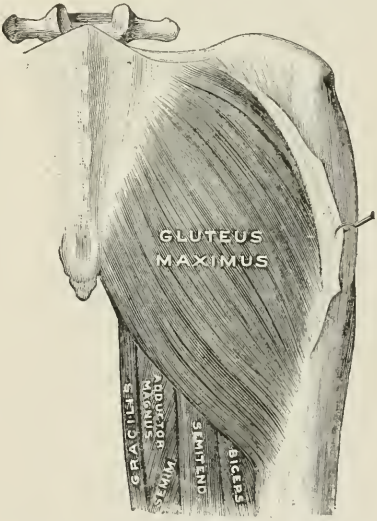

Fig. 84. — Gluteus Maximus of Right Side. (Gerrish.)

Action. — The magnus, longus, and brevis adduct, rotate, and flex the thigh. The gracilis adducts the thigh and flexes the leg.

Sartorius. — The sartorius, or tailor's muscle, is a long, ribbon-like muscle situated on the front of the thigh. It crosses the thigh obliquely from its origin in the ilium to its insertion in the tibia. It was formerly supposed to be the muscle principally concerned in producing the posture assumed by the tailor in sitting cross-legged, hence its name.

Action. — It flexes the leg, and helps in rotation and abduction of the thigh.

Biceps. — The biceps arises by two heads, one from the ischium, and the other from the posterior surface of the femur. It is inserted into the head of the fibula and the outer tubercle of the tibia.

Semitendinosus and Semimembranosus. — They arise from the ischium, and are inserted into the upper and inner part of the tibia. These three muscles, the biceps, semitendinosus, and semimembranosus, cover the back of the thigh, hence are named *posterior femoral*, or hamstring muscles.

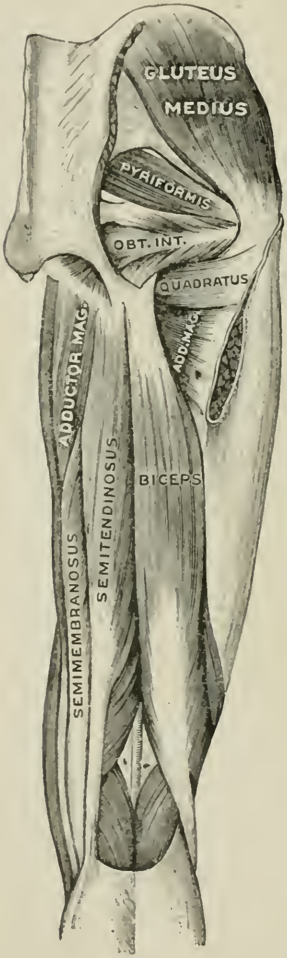

Fig. 85. — Muscles in the Dorsum of the Right Thigh. (Gerrish.)

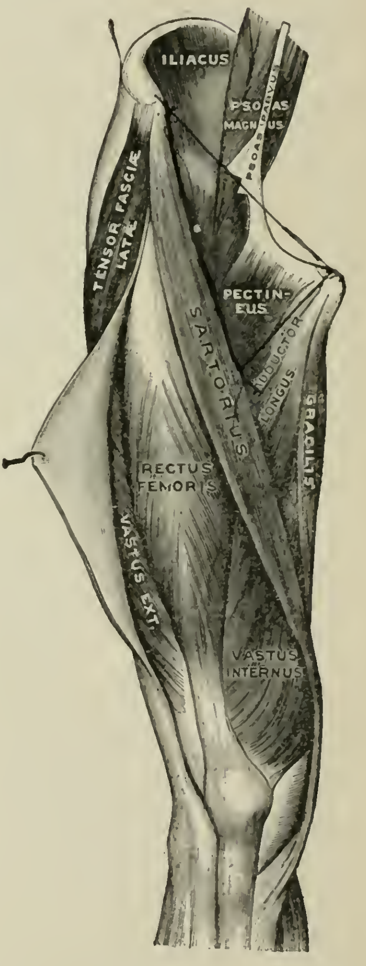

Fig. 86. — Superficial Muscles in Front Part of the Right Thigh. (Gerrish.)

Action. — They flex the knee, rotate the leg inward, and extend the thigh.

Quadriceps. — The quadriceps is a four-headed muscle that covers the front of the thigh, and is analogous to the triceps cover-

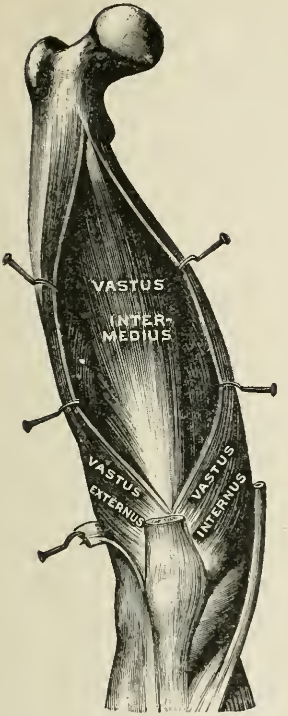

FIG. 87.—VASTUS INTERMEDIUS OF RIGHT SIDE. (Gerrish.)

ing the back of the arm. Each head is described as a separate muscle: (1) rectus femoris, (2) vastus externus, (3) vastus internus, (4) vastus intermedius.

The rectus femoris arises from the ilium, the other three arise from the femur. They pass downward, and are inserted by one tendon to the tubercle of the tibia. The tendon passes in front of the knee-joint, and the patella is a sesamoid bone developed in it.

Action. — The quadriceps is the great extensor of the leg; it also flexes the thigh, and antagonizes the action of the hamstring muscles.

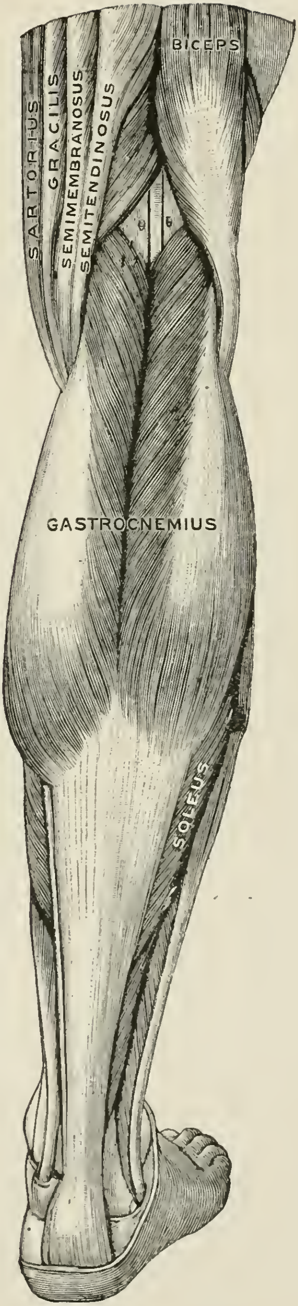

FIG. 88. — GASTROCNEMIUS OF RIGHT SIDE. (Gerrish.)

Gastrocnemius and soleus. — The gastrocnemius and soleus form the calf of the leg. The gastrocnemius arises by two heads from the two condyles of the femur. The soleus is in front of the gastrocnemius. It arises from the tibia and fibula. The direction of both is downward, and they are inserted into a common tendon, the tendon of the heel (tendo Achillis), which is the thickest and strongest tendon in the body, and is inserted into the calcaneum, or heel bone.

Action. — Extension of the foot, and when the ankle joint is fixed, extension of the leg. These muscles possess considerable power, and are constantly called into use in standing, walking, dancing, and leaping; hence the large size they usually present.[1]

Fasciæ. — As previously stated (page 37) most of the muscles are closely covered by sheets of fibrous tissue called fasciæ. These fasciæ not only envelop and bind down the muscles, but also separate them into groups. Such groups are named according to the parts of the body where they are found, viz.: cervical fascia, thoracic fascia, abdominal fascia, pelvic fascia, etc. Individual fascia are frequently given the name of the muscle which they envelop and bind down, viz.: temporal fascia, pectoral fascia, deltoid fascia, etc. It is important for the student to realize the continuity of the fibrous membranes. Tendons, ligaments, and fasciæ blend with periosteum, tendons and fasciæ serve as ligaments, tendons lose themselves in fasciæ, and tendons of some muscles serve as fasciæ for others.

Annular ligaments. — In the vicinity of the wrist and ankle, parts of the deep fascia become blended into tight transverse bands, which serve to hold the tendons close to the bones. These bands are called annular ligaments. (See Fig. 82.)

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[1] Additional muscles included in Summary.

SUMMARY

- **Muscular Tissue**
  - Cells develop into fibres.
  - Intercellular substance at a minimum.
  - Connective tissue — supporting framework.
- **Classification**
  - **Striated**
    - Voluntary
    - Skeletal
      1. Marked with transverse striæ.
      2. Under control of will.
      3. Attached to bones.
      4. Composed of bundles of fibres.
      5. Fibres are multinuclear elongated cells.
      6. Connective tissue framework.
      7. Outer sheath of connective tissue — Epimysium.
      8. Well supplied with nerves.
         - Sensory.
         - Motor.
      9. Majority of nerves connect with central nervous system.
         - Brain.
         - Spinal cord.
      10. Well supplied with blood-vessels and lymphatics.
      11. Contracts quickly, relaxes promptly.
  - **Non-striated**
    - Involuntary
    - Visceral
      1. Not marked with transverse striæ.
      2. Not under control of will.
      3. Found in walls of blood-vessels and viscera.
      4. Composed of bundles of fibre-cells.
      5. Fibre-cells contain just one nucleus.
      6. Connective tissue framework.
      7. Outer sheath of connective tissue — Epimysium.
      8. Well supplied with nerves.
         - Sensory.
         - Motor.
      9. Majority of nerves connect with sympathetic nervous system.
      10. Well supplied with blood-vessels and lymphatics.
      11. Contracts slowly and continuously for long periods of time.
      12. Possesses inherent power of automatic contraction.

- **Classification**
  - **Cardiac**
    - Striated
    - Involuntary
    - Visceral
      1. Striated but not distinctly.
      2. Not under control of will.
      3. Made of square bundles of fibres.
      4. Fibres are elongated cells, contain just one nucleus, no sarcolemma.
      5. Fine fibrils from cells form a network.
      6. Connective tissue framework.
      7. Contracts and relaxes quickly and unceasingly during life.
- **Stimuli**
  - Term used to describe influences which irritate or stimulate.
  - Varieties
    1. Chemical.
    2. Mechanical.
    3. Thermal.
    4. Electrical.
    5. Nervous — important one.
- **Characteristics**
  1. Irritability — response to a stiumlus.
  2. Contractility — muscle becomes shorter and thicker.
  3. Extensibility — muscle can be stretched.
  4. Elasticity — muscle readily returns to original shape.
  5. Tonicity — mild, sustained contraction.
- **Contraction**
  - Physical Change
    - Fibres shorten.
    - Fibres thicken.
  - Chemical Change
    - Take up oxygen.
    - Formation of
      - Carbon dioxide.
      - Sarcolactic acid.
      - Various other wastes.
    - Heat is liberated.
    - Energy is set free.
- **Fatigue** . . .
  - Accumulation of waste poisons.
  - Loss of nutritive material.
- **Skeletal Muscles**
  - Origin — more fixed attachment.
  - Insertion — more movable attachment.

Name of Muscle and where found		Origin	Insertion	Function
	Head			
Occipito-frontalis	Occipital	Occipital bone	Aponeurosis — top of skull	Elevate the eyebrows, cause transverse wrinkles of forehead. Draw scalp forward.
	Frontal	Tissues of the eyebrows	Aponeurosis — top of skull	
	Face			
Orbital Muscles	Superior rectus	Apex of orbit	Upper and central portion of eyeball	Rolls the eyeball upward.
	Inferior rectus	Apex of orbit	Lower and central portion of eyeball	Rolls the eyeball downward.
	Internal rectus	Apex of orbit	Midway on inner side of eyeball	Rolls the eyeball to which it is attached inward, the opposite one outward.
	External rectus	Apex of orbit	Midway on outer side of eyeball	Rolls the eyeball to which it is attached outward, the opposite one inward.
	Superior oblique	Apex of orbit	Eyeball — between superior and external recti	Rolls the pupil downward and outward.
	Inferior oblique	Orbital plate of maxilla	Eyeball — near external recti	Rolls the pupil upward and outward.
	Levator palpebræ superioris	Sphenoid bone	Tarsal cartilage of upper lid	Elevates upper lid and opens eye.
Muscles of Mastication	Masseter	Zygomatic process of malar bone	Mandible	Closes the mouth. Draws the mandible forward.
	Temporal	Temporal bone	Mandible	Closes the mouth. Draws the mandible backward.
	Internal pterygoid	Sphenoid, palate, and maxilla	Mandible	Closes the mouth. Moves jaw forward and sideways.
	External pterygoid	Sphenoid bone	Mandible	Moves the jaw forward and sideways.

Name of Muscle and where found		Origin	Insertion	Function
Muscles of Expression	Orbicularis oris	Partition between nostrils and maxillæ	Mandible	Closes the lips. Sphincter of mouth.
	Buccinator	Alveolar processes of maxilla and mandible	Orbicularis oris	Compresses the cheeks and helps to close the mouth.
Muscles of the Tongue	Genioglossus	Front part of mandible	Whole length of tongue in and at the side of the mid line	Thrusts the tongue forward, retracts it, and also depresses it.
	Styloglossus	Styloid process of temporal bone	Whole length of side and under part of tongue	Draws the tongue backward.
Muscles of the Neck	Platysma	Skin and fascia of the pectoral, deltoid, and trapezius muscles	Mandible and muscles about the angle of the mouth	Draws the angle of the mouth and lower lip down and outward. Contracts the skin of the neck.
	Sterno-cleido-mastoid	Sternum and clavicle	Mastoid portion of temporal bone	Both acting together flex the head on the chest or neck.
	Muscles of the Trunk			
Muscles of the Back	Trapezius	Occipital bone, ligamentum nuchæ, and spinous processes of the last cervical and all the thoracic vertebræ	Clavicle, acromion process, and spine of scapula	Lifts the shoulder and rotates the lower angle of the scapula backward.
	Latissimus dorsi	Last six thoracic vertebræ, lumbar, and sacral part of spine and crest of ilium	Front of the humerus	Draws humerus backward, body forward. If arm is elevated, draws it down, back, and rotates it in.

Name of Muscle and where found		Origin	Insertion	Function
Chest	Pectoralis major	Clavicle, sternum, and cartilages of six upper ribs	Upper part of humerus	It draws the arm downward and forward.
	Pectoralis minor	Outer surfaces of 3d, 4th, and 5th ribs	Scapula	Pulls the shoulder downward and assists in the elevation of the ribs during inspiration.
Thorax	External intercostals	Arise from lower border of each upper rib	Upper border of each lower rib	Pull the ribs upward and outward.
	Internal intercostals	Arise from lower border of each upper rib	Upper border of each lower rib	Depress the ribs.
	Levatores costarum	Transverse processes of vertebræ from 7th cervical to the 11th thoracic	Outer surface of the ribs between the tubercles and angles	Assist in elevation of the first ten ribs, and with other muscles draw the lower ribs backward. Aid in respiration.
	Diaphragm	Internal circumference of the thorax	A central aponeurotic tendon	Modifies size of chest cavity. Aids in expulsion.
Abdomen	External oblique	Outer surface of lower eight ribs	Outer lip of iliac crest, pubic spine and crest, the iliopectineal line, front of the symphysis and the linea alba	Compression of abdominal viscera, rotation of the pelvis to the same side, and flexion of the pelvis on the chest.
	Internal oblique	Inguinal ligament, outer crest of the ilium, and the lumbar fascia	Costal cartilages of four lower ribs, end of sternum, linea alba, and crest of pubis	Compresses the abdominal viscera, depresses the ribs, and flexes the chest upon the pelvis.
	Rectus abdominis	Pubic bone	Costal cartilages of 5th, 6th, and 7th ribs	Depression of the thorax and compression of the abdominal viscera.
	Transversalis	Lower six costal cartilages, lumbar fascia, crest of ilium, and outer third of the inguinal ligament	Linea alba and crest of the pubis	Compression of the abdominal viscera.

Name of Muscle and where found			Origin	Insertion	Function
Upper Extremity		Deltoid	Clavicle, acromion process, and spine of scapula	Middle of shaft of humerus	Abducts — raises the arm from the side.
		Biceps	Scapula	Radius	Flexes the forearm on the arm.
		Triceps	Scapula and posterior surface of the humerus	Ulna	Extension of forearm.
	Pronators	Pronator teres (front of forearm)	Humerus and ulna	Radius	Pronation of the hand.
		Pronator quadratus (lower quarter, front of forearm, close to the bones)	Inner and lower portion of ulna	Front and lower fourth of radius	Pronation of the hand.
	Flexors	Flexor carpi radialis (front of forearm)	Humerus	Base of 2d metacarpal bone on its palmar aspect	Flexion and slight pronation of hand.
		Flexor palmaris longus (front of forearm)	Humerus	Palmar fascia and anterior annular ligament	Tightens the fascia of the palm, then flexes the hand.
		Flexor carpi ulnaris (front and inner border of forearm)	Humerus and ulna	Pisiform, unciform, and base of 5th metacarpal	Flexion of the hand.
	Supinators	Brachio-radialis or long supinator) outer and front part of lower fourth of arm and forearm)	Humerus	Lower portion of radius	Flexion of forearm and supination of hand.
		Supinator brevis (deep in upper third of outer part of forearm)	External condyle of humerus	Radius	Supination.

Name of Muscle and where found			Origin	Insertion	Function
Upper Extremity	Extensors	Extensor carpi radialis longus (outer border of forearm)	Humerus	2d metacarpal bone	Extension of the hand.
		Extensor carpi radialis brevis (outer border of forearm)	Humerus	3d metacarpal bone	Extension of the hand.
		Extensor carpi ulnaris	Humerus and ulna	5th metacarpal bone	Extension of the hand.
Lower Extremity		Psoas magnus (in the pelvic and upper part of thigh)	Last thoracic and all the lumbar vertebræ with included intervertebral cartilages	Small trochanter of femur	Flexion and external rotation of thigh.
		Iliacus	Iliac fossa	Partly in tendon of psoas, and partly in small trochanter of femur	Same as psoas magnus.
		Gluteus maximus (largest)	Ilium, sacrum, and coccyx	Great trochanter of femur	Extension of the hip joint, external rotation and abduction of the thigh.
		Gluteus medius (middle)	External surface of the ilium	Great trochanter of femur	Abduction of the thigh, and when the thigh is flexed, inward rotation.
		Gluteus minimus (smallest)	External surface of the ilium	Great trochanter of femur	Abduction of the thigh when it is extended, inward rotation when it is flexed.
	Internal femoral	Adductor magnus	Pubic arch and ischium	Inner side of femur	They adduct, rotate, and flex the thigh.
		Adductor longus	Pubic bone		
		Adductor brevis	Upper part of pubic arch		
		Adductor gracilis	Lower part of pubic arch		Adducts thigh and flexes the leg.

Name of Muscle and where found			Origin	Insertion	Function
Lower Extremity	Anterior femoral	Quadriceps arises by four heads: —			
		1. Rectus femoris	Ilium	Tibia	Extends the leg and flexes the thigh.
		2. Vastus externus	Femur		
		3. Vastus internus	Femur		
		4. Vastus intermedius	Femur		
		Sartorius (front and inner side of thigh between ilium and tibia)	Anterior superior iliac spine	Inner surface of the tibia	Flexion of the leg and helps in rotation and abduction of the thigh.
	Posterior femoral	Biceps	Ischium and femur	Fibula and tibia	Flexes the knee, rotates leg inward, and extends thigh.
		Semitendinosus	Ischium	Tibia	
		Semimembranosus	Ischium	Tibia	
	Flexors	Tibialis anterior (front and outer side of leg)	Tibia and interosseous membrane	Internal cuneiform and 1st metatarsal bone	Flexion of the foot and adduction of its distal end.
		Peroneus tertius (front of leg, dorsum of foot)	Fibula and interosseous membrane	5th metatarsal bone	Flexion of the foot and abduction of its distal end.
	Extensors	Tibialis posterior (back of leg and inner part of foot)	Tibia and fibula	Scaphoid, three cuneiform, cuboid, 2d, 3d, and 4th metatarsal bones	Extension of the foot and abduction of its distal end.
		Peroneus longus (outer side of leg and sole of foot)	Tibia and fibula	Base of 1st metatarsal and internal cuneiform bones	Extension of the foot and abduction of its distal end.
		Peroneus brevis (outer side of leg and foot)	Fibula	5th metatarsal bone	Extension of the foot and abduction of its distal end.
		Gastrocnemius	Femur	Tuberosity of the calcaneum	Extension of the foot; also when the ankle joint is fixed, extension of the leg.
		Soleus	Fibula and tibia	Tuberosity of the calcaneum	Same as gastrocnemius.

CHAPTER VIII

SPECIAL MEMBRANES AND GLANDS

MEMBRANE

The word "membrane" in its widest sense is used to designate any thin expansion of tissue. Thus we speak of the periosteum as a fibrous membrane; and the layer of cells beneath the epithelium of free surfaces is called a basement membrane. In a restricted, although the commonest sense, the word "membrane" is used to denote an enveloping or a lining tissue of the body.

Classification of membranes. — The chief membranes of the body are classified as follows: —

1. Serous.
2. Synovial.
3. Mucous.
4. Cutaneous.

SEROUS MEMBRANES

Serous membranes are thin, transparent, tolerably strong, and elastic. The surfaces are moistened by a fluid resembling serum, from which the membranes obtain their name of serous membranes. They consist of two layers only: (1) endothelium, (2) corium.

(1) **Endothelium** is the name given to a variety of epithelium found lining (*i.e.* lying within) certain parts of the body. It consists of a single layer of flattened transparent cells joined edge to edge so as to form a smooth membrane.

(2) The **corium** consists of a thin layer of fibrous tissue, and contains blood-vessels, lymph-vessels, and lymphoid tissue.

Serous membranes are attached to the underlying parts by areolar tissue, called "subserous" tissue. They are found lining closed cavities and passages that do not communicate with the exterior. They may be divided into three classes: —

(1) Serous membranes proper.
(2) The lining membrane of the vascular system.
(3) The lining membrane of certain cavities.

(1) **Serous membranes proper.** — With one exception, these membranes form closed sacs, one part of which is attached to the walls of the cavity which it lines, — the **parietal** portion, — whilst the other is reflected over the surface of the organ or organs contained in the cavity, and is named the **visceral** portion of the membrane. In this way the viscera are not contained within the sac, but are really placed outside of it, and some of the organs may receive a complete, while others receive only a partial, or scanty, investment.

This class of serous membranes includes: —

(*a*) *The two pleuræ,* which cover the lungs and line the chest.

(*b*) *The pericardium,* which covers the heart, and lines the outer fibrous pericardium.

(*c*) *The peritoneum,*[1] which lines the abdominal cavity, clothes its contained viscera, and also the upper surface of some of the pelvic viscera.

(2) **The lining membrane of the vascular system.** — This applies to the internal coat of the heart, blood-vessels, and lymphatics. It bears a close resemblance to the proper serous membranes in structure and appearance.

(3) **The lining membrane of certain cavities**: —

(*a*) One illustration of this is the capsule of Tenon. This capsule is a shut sac placed back of the eyeball, with a visceral layer upon the globe of the eye, and the parietal layer next to the bed of fat on which the eyeball rests.

(*b*) The brain and spinal cord enclose cavities which are lined with a delicate serous membrane. One of the membranes that envelop the brain and spinal cord (arachnoid) is also a serous membrane.

Function of serous membranes. — The most important function of serous membrane is protection, which is accomplished in two ways: (1) by forming a smooth, slippery lining or covering for the viscera, blood-vessels, and cavities with which it is associated, and

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[1] The peritoneum in the female is the one exception to the rule that serous membranes are perfectly closed sacs, as it has two openings by which the *Fallopian* (uterine) tubes communicate with its cavity.

(2) by secreting serum which acts as a lubricating fluid and tends to lessen friction.

The inner surface of a serous membrane is free, smooth, and polished; and in the case of serous membranes proper, the inner surface of one part is applied to the corresponding inner surface of some other part, only a very small quantity of fluid being interposed between the surfaces. The organs situated in a cavity lined by a serous membrane, being themselves also covered by it, can thus glide easily against its walls or upon each other, their motions being rendered smoother by the lubricating fluid.

SYNOVIAL MEMBRANES

Synovial membranes are frequently classed as serous membranes, because their function is the same and they have no communication with the surface of the body. They differ, however, (1) in the nature of their secretion, (2) in their structure, and (3) they are associated with the bones and muscles, and not with the viscera. Synovial membrane is composed of fibrous tissue which has on its free surface an imperfect covering of cells that are irregularly shaped, and secrete a viscid glairy fluid that resembles the white of egg, and is named *synovia*.

They are divided into the following classes: —

1. Articular.
2. Vaginal.
3. Bursal.

1. **Articular.** — Articular synovial membranes are found surrounding and lubricating the cavities of the movable joints in which the opposed surfaces glide on each other.

2. **Vaginal.** — Vaginal synovial membranes are found forming sheaths for the tendons of some of the joints, and thus facilitating their motion as they glide in the fibrous sheaths which bind them down against the bones.

3. **Bursal.** — Bursal synovial membranes, or synovial bursæ, are found in the form of simple sacs, interposed, so as to prevent friction, between two surfaces which move upon each other. These bursæ may be either **deep-seated**, or **subcutaneous**. The deep-seated are for the most part placed between a muscle and a bone, or between a tendon and a bone. The subcutaneous

bursæ lie immediately under the skin, and occur in various parts of the body, interposed between the skin and some firm prominence beneath it. The large bursa, situated over the patella, is a well-known example of this class, but similar, though smaller, bursæ are found also over the olecranon, the malleoli, the knuckles, and other prominent parts.

Fig. 89. — The Anterior Annular Ligament of the Ankle and the Synovial Membranes of the Tendons beneath it. Artificially distended. (Gerrish.)

Function of synovial membranes. — As previously stated, the function of synovial membranes is similar to that of serous membranes, but synovial membranes are associated with the bones and muscles.

MUCOUS MEMBRANES

The mucous membranes, unlike the serous membranes, line passages and cavities which communicate with the exterior. Their surface is coated over and protected by mucus, from which it derives its name. The mucous membranes of different parts are continuous, and they may nearly all be reduced to two great divisions; namely, (1) gastro-pulmonary, and (2) the genito-urinary.

(1) **Gastro-pulmonary.** — The gastro-pulmonary mucous membrane covers the inside of the alimentary canal, the air-passages, and the cavities communicating with them. It commences at the edges of the lips and nostrils, proceeds through mouth and nose to the throat, and thence is continued throughout the entire length of the alimentary canal to the anus. At its origin and termination it is continuous with the external skin. It also extends throughout the trachea, bronchial tubes, and air-sacs. From the interior of the nose the membrane may be said to be prolonged into the frontal, ethmoidal, sphenoidal, and maxillary sinuses, also into the lacrimal passages, and under the name of conjunctival membrane, over the fore part of the eyeball and inside of the eyelids, on the edges of which it again meets with the skin.

From the upper and back part of the pharynx a prolongation extends on each side, along the passage to the ear, — Eustachian tube,[1] — and offsets in the alimentary canal go to line the salivary, pancreatic, and biliary ducts, and the gall-bladder.

(2) **Genito-urinary.** — The genito-urinary mucous membrane lines the inside of the bladder, and the whole urinary tract from the interior of the kidneys to the meatus urinarius, or orifice of the urethra; it also lines the vagina, uterus, and Fallopian (uterine) tubes in the females. A study of Figs. 91 and 92 will make this plain.

Structure. — A mucous membrane is composed of a layer of connective tissue called the corium, which is bounded toward the free surface by a basement membrane and covered by a layer of epithelium. Beneath the corium we usually find a thin layer of muscular tissue called the muscularis mucosæ. From the above, it will be seen

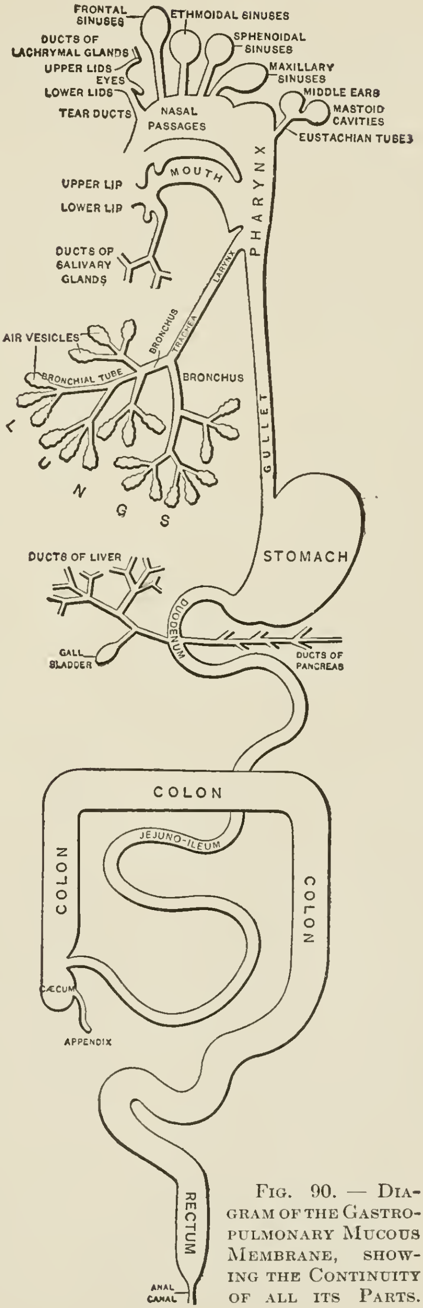

FIG. 90. — DIAGRAM OF THE GASTRO-PULMONARY MUCOUS MEMBRANE, SHOWING THE CONTINUITY OF ALL ITS PARTS. (Gerrish.)

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[1] Named after Eustachius, a famous anatomist.

that, starting at the free surface, the order of the tissues is as follows: —

(1) Epithelium.
(2) Basement membrane.
(3) Corium.
(4) Muscularis mucosæ.

(1) The **epithelium** is the most constant part of a mucous membrane, being continued over certain regions to which the other parts of the membrane cannot be traced. It may be scaly and stratified, as in the throat, columnar, as in the intestine, or ciliated, as in the respiratory tract.

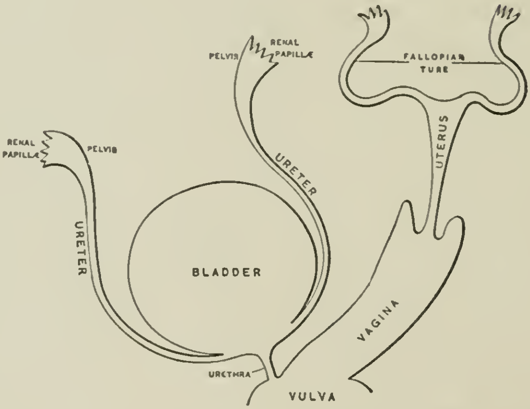

Fig. 91. — Diagram of the Female Genito-urinary Mucous Membrane, showing Continuity of all its Parts. (Gerrish.)

(2) The **basement membrane** consists of a layer of flattened cells, and is really part of the corium.

(3) The **corium** of a mucous membrane is composed of either areolar or lymphoid connective tissue. It is generally much thicker than in serous or synovial membranes, and varies much in structure in different parts.

(4) The **muscularis mucosæ** consists, as previously stated, of a thin layer of muscular tissue.

The mucous membranes are attached to the parts beneath them by areolar tissue, here named "submucous," and which differs greatly in quantity as well as in consistency in different parts. The connection is in some cases close and firm, as in the cavity of the nose. In other instances, especially in cavities subject to frequent variations in capacity, like the œsophagus and the stomach, it is lax; and when the cavity is narrowed by contraction of its outer coats, the mucous membrane is thrown into folds, or **rugæ**, which disappear again when the cavity is distended. But in certain parts the mucous membrane forms permanent folds that cannot be effaced, and which project conspicuously into the cavity which it lines. The best-marked example of these folds is seen in the small intestine, where they are called *valvulæ conniventes*[1] (circular folds), and which are doubtless provided for increasing the amount of absorbing surface for the products of digestion. In some locations the free surface of mucous membrane contains minute glands, or it is covered with papillæ, villi, or cilia.

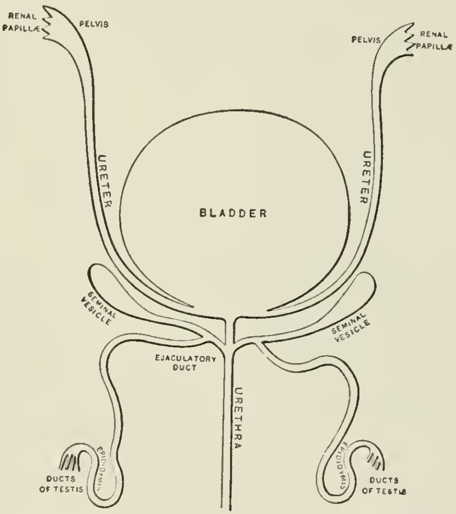

FIG. 92. — DIAGRAM OF THE MALE GENITO-URINARY MUCOUS MEMBRANE SHOWING CONTINUITY OF ALL ITS PARTS. (Gerrish.)

Papillæ.— The papillæ are best seen on the tongue; they are small processes of the corium, mostly of a conical shape, containing blood-vessels and nerves, and covered with epithelium.

Villi. — The villi are most fully developed on the mucous coat of the small intestine. They are little projections of the mucous membrane, covered with epithelium, containing blood-vessels and lacteals, and are favorably arranged for absorbing nutritive matters from the intestines.

Cilia. — For description of cilia see page 28.

Function of mucous membranes. — The function of mucous membranes is (1) protection, (2) support of blood-vessels and lymphatics, (3) to furnish a large amount of surface for absorption.

(1) It protects by forming a lining or inside skin for all

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[1] See page 266.

the passages that communicate with the exterior. These passages are subject to the contact of foreign substances, which are introduced into the body, and waste materials, which are expelled from the body. The mucus which it secretes is a thicker and more sticky fluid than either serum or synovia, and by coating the surface lessens the possibility of irritation from food, waste materials, or secreted substances. The cilia of the respiratory tract also assist in the function of protection. They keep up an incessant motion, and thus carry mucus toward the outlet of these passages. Dust and foreign materials usually become entangled in the mucus and are forced out with it.

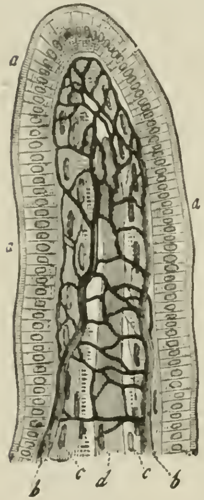

FIG. 93. — AN INTESTINAL VILLUS. *a, a, a,* columnar epithelium; *b, b,* capillary network; *d,* lacteal vessel.

(2) The redness of mucous membranes is due to their abundant supply of blood. The small blood-vessels which convey blood to the mucous membranes divide in the submucous tissue, and send smaller branches into the corium, where they form a network of capillaries just under the basement membrane. The lymphatics also form networks in the corium, and communicate with larger vessels in the submucous tissue below.

(3) The modifications of mucous membrane, such as the valvulæ conniventes, papillæ, and villi, are largely for the purpose of increasing the surface for absorption, and also to enable it to carry more blood-vessels and lymphatics.

CUTANEOUS MEMBRANE

By this term is indicated the membrane which covers the body and is commonly spoken of as skin. It is a complex structure, and has several functions in addition to serving as a protective covering for the deeper tissues lying beneath it. It will be more fully considered in Chapter XVIII.

GLANDS

A gland is a secreting organ, or an organ which abstracts from the blood certain materials and makes of them a new substance.

The simplest form of a gland may consist of just one cell, such as the goblet cells,[1] or may be a mere depression on the surface of a membrane, or a complex organ like the liver. No matter what the size or shape may be, all glands have three essential characteristics: (1) epithelial cells which are the active secreting agents, (2) a liberal blood supply from which the material for the secretion is drawn, (3) they are under the direct control of the nervous system and secretion is their response to stimulation, just as contraction is the response of a muscle. The usual arrangement is for the cells to cover the free surface of a basement membrane, a dense network of capillaries to be spread upon its under surface, and nerve fibrils to form a network in contact with the cells.

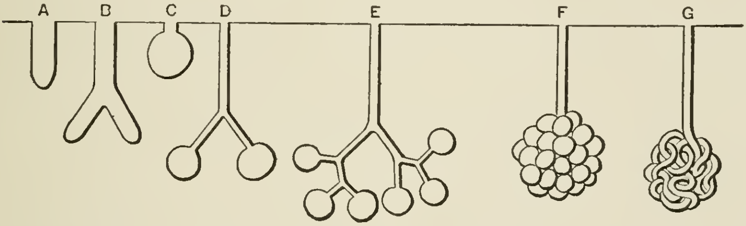

FIG. 94.—DIAGRAM SHOWING DEVELOPMENT OF GLANDS: *A*, a mere dimple in the surface; *B*, enlargement by division; *C*, enlargement by dilatation; *D*, a combination of *B* and *C*; *E*, a racemose gland; *F*, development of method of *E*; *G*, a single tube intricately coiled. (Gerrish.)

In order to economize space and to provide a more extensive secreting surface, the membrane is generally increased by dipping down and forming variously shaped recesses.

Classification. — The secreting glands are of three kinds: —

1. Simple.
2. Compound.
3. Ductless.

1. **Simple glands.** — The simple glands are generally tubular or saccular cavities, which open upon the surface by a single duct. They are named simple tubular, or saccular glands. Sometimes the tube is so long that it coils upon itself, as in the sweat glands of the skin. These are named simple convoluted tubular glands.

2. **Compound glands.** — In the compound glands the cavities are subdivided into smaller tubular or saccular cavities, opening

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[1] See page 257.

by small ducts into the main duct, which pours the secretion upon the surface. If composed of many tubes, either straight or convoluted, they are called compound tubular glands; if composed of groups of small sacs, they are called racemose glands.

3. **Ductless glands.** — This term is applied to a collection of glandular structures that possess no ducts. Whatever secretion or excretion they produce is discharged into the blood, either directly or indirectly by way of the lymphatics.

SECRETION

A new substance, the product of a gland, elaborated from the blood by cell action, and intended for use in the body is called a secretion.

For purposes of study we may divide the secretions into two groups: —

(1) External secretions.
(2) Internal secretions.

External secretions. — This term is used to designate those secretions of glandular tissues which are carried to their destination by a duct. All of the digestive juices — saliva, gastric juice, pancreatic juice, bile, and intestinal juice — are examples of external secretions, because they are carried off from the respective glands in which they are formed by means of ducts.

Function. — The function of the external secretions is dealt with in connection with the organs which produce them.

Internal secretions. — This term is used to designate those secretions of glandular tissues which are *not* carried off to the exterior by a duct, but instead are discharged into the blood or lymph. The conception is that probably all the ductless glands form secretions which have a profound influence on nutritive changes in the body. Such secretions are called internal secretions. It has also been shown that not only the ductless glands, but some at least of the typical glands provided with ducts, may give rise to internal secretions. For example, the pancreas forms the pancreatic juice and discharges it by means of a duct into the small intestine. In addition, it is believed that the pancreas forms an internal secretion which passes into the blood.

Function. — On account of the difficulty of separating internal secretions from the blood or lymph, the precise nature of their composition or function is not known, beyond the fact that most of them are essential to metabolism and they contain chemical substances called *hormones*. The term hormone is suggestive, because it means messenger and is applied to a substance which is produced in one organ and on being carried by the blood to another organ stimulates this latter to functional activity.

Excretion. — An excretion resembles a secretion, except that whereas the secretion is intended for use in the body, the excretion is generally formed to be thrown out of the body. It therefore follows that all excretions are first secretions, and some substances are made use of before they are eliminated. For instance, bile serves several purposes before it is eliminated, so that it is first a secretion and then an excretion. Urine, on the other hand, is a secretion, but is formed only to be eliminated.

SUMMARY

MEMBRANE
- **Definition** —
  - Any thin expansion of tissue.
  - An enveloping or lining tissue.
- **Varieties**
  - 1. Serous membranes.
  - 2. Synovial membranes.
  - 3. Mucous membranes.
  - 4. Cutaneous membranes.

SEROUS MEMBRANES
- **Consist of**
  - 1. Endothelium — a single layer of flat cells.
  - 2. Corium — a thin layer of fibrous tissue.
- **Found** — lining closed cavities or passages that do *not* communicate with the exterior. They are moistened by *serum*.
- **Three Classes**
  - Serous membranes proper
    - Pleuræ—cover the lungs and line the chest.
    - Pericardium — covers the heart and lines the outer fibrous pericardium.
    - Peritoneum—covers the abdominal and the top of some of the pelvic organs, lines the abdominal cavity.
  - Lining membrane of the vascular system
    - Heart.
    - Blood-vessels.
    - Lymphatics.

SEROUS MEMBRANES
- Lining membrane of certain cavities
  - Back of eye — capsule of Tenon.
  - Lining membrane of the cavity of the central nervous system.
- **Function** — Protection
  - 1. Furnishes a cover or lining.
    - Viscera.
    - Vascular system.
    - Certain cavities.
  - 2. Furnishes a secretion — serum — which acts as a lubricant.

SYNOVIAL MEMBRANES
- **Consist of**
  - 1. Imperfect layer of irregularly shaped cells.
  - 2. Layer of fibrous tissue.
- **Three Classes**
  - Articular synovial membranes
    - Surround cavities of movable joints.
  - Vaginal synovial membranes
    - Form sheaths for tendons.
  - Bursal synovial membranes
    - Sacs interposed between two surfaces which move upon each other.
- **Function** — Protection
  - Furnishes a cover or lining
    - Joints.
    - Tendons.
    - Sacs between muscles and bones.
  - Furnishes a secretion — synovia — which acts as a lubricant.

MUCOUS MEMBRANES
- **Found** — lining passages that communicate with the exterior and are protected by *mucus*.
- **Two Divisions**
  - Gastro-pulmonary
    - Alimentary canal.
    - Air-passages.
    - Cavities communicating with both alimentary canal and air-passages.
  - Genito-urinary
    - Urinary tract.
    - Generative organs.
- **Consist of**
  - 1. Epithelium
    - Stratified.
    - Columnar.
    - Ciliated.
  - 2. Basement membrane, a layer of flat cells.
  - 3. Corium
    - Areolar tissue, or
    - Lymphoid tissue.

- MUCOUS MEMBRANES
  - **Consist of**
    - 4. Muscularis mucosæ — thin layer of muscular tissue.
  - **Modifications**
    - Rugæ — temporary folds
      - Œsophagus.
      - Stomach.
    - Valvulæ conniventes — permanent folds of mucous membrane found in small intestine.
    - Papillæ — conical processes of mucous membrane best seen on tongue. Contain blood-vessels and nerves.
    - Villi — tiny thread-like projections of the mucous membrane of small intestine.
    - Cilia — hair-like processes.
  - **Function**
    - Protection
      - Inside skin.
      - Secretion of mucus.
      - Action of cilia.
    - Support — for network of blood-vessels.
    - Absorption — Various modifications increase the surface.

- GLANDS
  - **Definition** — Glands are organs that form secretions.
  - **Structure**
    - A single cell, or many cells arranged in various ways.
    - Essentials
      - Epithelial cells.
      - A liberal blood-supply.
      - Intimate connection with nervous system.
  - **Classification**
    - 1. **Simple** — *one* duct
      - Tubular — tube shape.
      - Saccular — sac shape.
      - Convoluted tubular — long tube coiled upon itself.
    - 2. **Compound** — *many* ducts
      - Compound tubular — many tubes.
      - Racemose — many sacs.
    - 3. **Ductless** — *no* duct

- SECRETIONS
  - **Definition** — Secretions are substances elaborated from the blood by the glands. They are intended to perform some office in the body.
  - **Classification**
    - *External* secretions — are substances formed by the simple and compound glands and discharged by means of a duct.
    - *Internal* secretions — are substances formed by any kind of gland and discharged into the blood or lymph.
  - **Function**
    - External secretions — studied later.
    - Internal secretions
      - Essential to metabolism.
      - Stimulate by means of hormones.
  - **Excretion** — a secretion which is eliminated.

TABLE OF SECRETIONS AND EXCRETIONS

SECRETION	SECRETING ORGANS	REACTION	MAIN PURPOSE
Mucus	Mucous cells of mucous membrane	Alkaline	Lubricant and diluent.
Serous secretion	Serous membranes	Alkaline	Lubricant and diluent.
Tears	Lacrimal glands	Alkaline	To moisten the conjunctiva.
Saliva	Salivary glands	Alkaline	To moisten food and digest carbohydrates.
Gastric juice	Stomach	Acid	To digest proteins.
Pancreatic juice	Pancreas	Alkaline	To digest proteins, fats, and carbohydrates.
Succus entericus	Intestines	Alkaline	To dilute the chyme.
Bile	Liver	Alkaline	Part of the bile is used in digestion and reabsorbed. Part is a true excretion (bile pigments).
Milk	Mammary glands	Alkaline	Food.
Sebum	Sebaceous glands of the skin	Alkaline	To oil the skin.
Sweat	Sweat-glands of skin	Acid	Elimination of water, carbon dioxide, and urea. Helps to regulate body-temperature.
Vaginal	Vagina	Acid	Lubricant, moistening and protection.
Urine	Kidneys	Acid	Elimination of water and urea.

CHAPTER IX

VASCULAR SYSTEM; THE BLOOD AND LYMPH

It is helpful to remember that the body consists of an enormous number of individual cells, and that each cell must be supplied with materials to enable it to carry on its activities, and at the same time it must have the waste materials that are the result of its activities removed. Many cells are far from the source of supplies and the organs of elimination; hence the need of a medium to distribute supplies and collect waste, and the need of a system so that the distribution will be orderly and systematic. These two needs are met by the *vascular system,* the divisions of which may be outlined as follows: —

- **Vascular System**
  - Circulating fluids
    - Blood
    - Lymph.
  - Systems
    - Blood vascular
    - Lymph vascular.

THE BLOOD

Characteristics. — The most striking external feature of the blood is its well-known color, which is bright red, approaching to scarlet in the arteries, but of a dark red or crimson tint in the veins.

It is a somewhat sticky liquid, a little heavier than water; its specific gravity is about 1.055. It has a peculiar odor, a saltish taste, a slightly alkaline reaction when tested with litmus, and a temperature of about 100° F. (37.8° C.).

Quantity of blood. — The quantity of blood contained in the body is estimated to be about $\frac{1}{20}$ of the body weight. This proportion was formerly said to be about $\frac{1}{13}$, but later experiments seem to place the figure at $\frac{1}{20}$. This, in an individual weighing 160 pounds, would weigh about 8 pounds, or measure 4 quarts.

Functions of the blood. — Blood is commonly spoken of as the nutritive fluid of the body. This is quite correct, but it is more than a nutritive fluid, as will be seen from the following list of its more important functions: —

(1) It carries to the tissues water and the nutritive substances resulting from digestion. These are required by each individual cell in order to enable it to carry on its metabolic processes.

(2) It carries to the tissues oxygen, absorbed from the air in the lungs. Every individual cell requires oxygen, in order to provide heat and energy.

(3) It carries from the tissues various waste products. These are not only useless, but poisonous, and must be eliminated by the lungs, kidneys, and skin.

(4) It serves as a medium for the transmission of certain secretions. The presence of these secretions promotes oxidation and metabolism.

(5) It aids in equalizing the temperature of the body. Blood passing through a tissue which is undergoing lively metabolism will have a higher temperature when it leaves than it had when it entered. This extra temperature will be lost in passing through a tissue that is not so active. In this way an average temperature is maintained.

(6) It aids in protecting the body from infections.

Composition of the blood. — Seen with the naked eye, the blood appears opaque and homogeneous; but when examined with a microscope it is seen to consist of minute, solid particles called *corpuscles,* floating in a transparent, slightly yellowish fluid called *plasma.*

- **Blood**
  - **Corpuscles**
    - Red or erythrocytes.
    - White or leucocytes.
    - Blood plates.
  - **Plasma**
    - Water, 90 %.
    - Proteins.
    - Extractives.
    - Inorganic salts.
    - Gases.
    - Enzymes.
    - Internal secretions.
    - Immune bodies.

Red corpuscles. — The red corpuscles are circular biconcave disks, with rounded edges. The average size is $\frac{1}{3200}$ of an inch (0.008 mm.) in diameter, and about $\frac{1}{12800}$ (0.002 mm.) of an inch in thickness. Because of their extremely small size, the red corpuscles do not appear red when viewed singly with a microscope, but merely of a reddish yellow tinge, or yellowish green in venous blood. It is only when great numbers of them are gathered together that a distinct red color is produced.

Authorities differ regarding the structure of the red corpuscles. Some describe them as consisting of a colorless filmy, elastic framework infiltrated in all parts by a red coloring matter termed hæmoglobin, which contains a small amount of iron. Others describe them as consisting of a colorless elastic envelope enclosing a solution of hæmoglobin. In either case it is correct to consider them as packets of hæmoglobin moving passively at the mercy of the blood current. They have no nuclei, are soft, flexible, and elastic, so that they readily squeeze through apertures and passages narrower than their own diameters, and immediately resume their proper shape.

Function of the red corpuscles. — The red corpuscles, or erythrocytes, by virtue of the hæmoglobin which they contain, are emphatically **oxygen carriers.** Exposed to the air in the lungs the hæmoglobin becomes fully charged with detachable oxygen and is known as oxyhæmoglobin. The red corpuscles carry this oxyhæmoglobin to the tissues, where it gives up the loosely engaged oxygen. It is then known as reduced hæmoglobin and is ready to be carried to the lungs for a fresh supply. The color of the blood is dependent upon this combination of the hæmoglobin with oxygen; when the hæmoglobin has its full complement of oxygen, the blood has a bright red hue; when the amount is decreased, it changes to a dark crimson hue. The scarlet blood is usually found in the arteries, and is called arterial; the dark crimson in the veins, and is called venous blood.

Life cycle of the red corpuscles. — There is every reason to believe that the red corpuscles, like all the cells of the body, have a definite term of existence, then disintegrate and are replaced by other corpuscles. They originate in the red marrow of the bones, but in case of special need, as after the loss of a large number by hemorrhage, they can be formed in other organs, especially the spleen. Before being forced into the blood stream they lose their nuclei, and this suggests that they do not live a great while in the circulation. Red corpuscles in various stages of disintegration have been found in the substance of the spleen and lymph nodes. Some authorities consider that their destruction takes place in these organs, but others consider that it takes place in the blood in any part of the system.

Number of red corpuscles. — The average number of red corpuscles in a cubic millimetre of healthy blood is given as 5,000,000 for men and 4,500,000 for women. Even in health this number varies and in disease it may be greatly reduced. An increase in temperature hastens the destruction of red corpuscles, and in this way causes a reduction in number. The condition known as *anemia* may be due to a diminished number of red corpuscles, which means a diminished supply of oxygen, and a consequent interference with the processes of metabolism.

White corpuscles. — The white corpuscles are masses of protoplasm containing a nucleus, sometimes even two or three nuclei, and they have no cell wall. Their form is very various, but when they are carried along in the blood current, or when the blood is first drawn, they are rounded or spheroidal. Measured in this condition, they are about $\frac{1}{2500}$ of an inch (0.010 mm.) in diameter. The white corpuscle may be taken as the type of a free animal cell.

Number of white corpuscles. — The average number of white corpuscles in a cubic millimetre of healthy blood is from 7000 to 9000, or in the proportion of 1 white to 500 or 600 red. A marked increase in number is designated as *leucocytosis*, a marked decrease as *leucopenia*. Under various normal conditions, such as digestion, exercise, or cold baths, leucocytosis occurs. It also occurs under abnormal conditions, and a knowledge of the variations under pathological conditions is an important aid in diagnosis.

Varieties of white corpuscles. — At least five varieties have been studied and described. They are classified under two main groups: —

(1) Leucocytes.
(2) Lymphocytes.

The most marked difference is in the nuclei and in the amount of amœboid movement exhibited. The difference is said to be due solely to the age of the corpuscle — the lymphocyte being the more recently formed, and in time will change into a leucocyte.

Each of these groups may be subdivided into two or more subgroups, and some authorities hold that each variety has some special function, but this has not been proven.

Amœboid movements. — One distinctive property of white blood corpuscles is their power of making amœboid movements, which enables them to change their form and escape through the walls of the blood capillaries into the surrounding tissues. This property has earned for them the title of *wandering cells,* and the process is spoken of as migration. It occurs under normal conditions, but is vastly accelerated under pathological conditions.

Function of the white corpuscles. — It is definitely known that they act (1) as protective agents, (2) aid in the absorption of fats and proteins from the intestines, and (3) assist in the coagulation of the blood.

Their function of protection is very important, and is accomplished in two ways: —

(*a*) By forming certain substances called **bacteriolysins**, which when imbibed by bacteria kills them; (*b*) by virtue of their amœboid movements they can creep around bacteria, envelop them with their own substance, and so put them inside themselves. This process is called **phagocytosis**, and has earned for them the name of phagocytes.

Opsonins. — This is a name given to chemical substances found in blood plasma. The function of an opsonin[1] is to prepare certain disease germs for destruction and absorption by the white corpuscles of the blood. The phagocytic properties of the leucocytes become especially developed as the result of the action of opsonins.

Inflammation. — When any of the tissues become inflamed either as the result of injury or infection, the first effect is irritation, followed by an increased supply of blood to the part. If the irritation continues or is severe, the flow of blood begins to slacken, and a condition of stasis or engorgement results. The white corpuscles become particularly active and migrate into the infected tissues in large numbers. Some of the blood plasma exudes, and a small number of red corpuscles are forced through the capillary walls.[2] This general condition is described as inflammation, and the symptoms of pain, heat, redness, and swelling are due, (1) to the increased supply of blood, (2) to the engorgement of the blood-vessels, and (3) to the collection of fluid in the tissues, which is

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[1] From *opso'no,* I prepare food for.

[2] This passive ability of red corpuscles to pass through the capillary walls is called *diapedesis.*

spoken of as inflammatory exudate. Under these conditions a death struggle between the leucocytes and bacteria takes place. If the leucocytes are victorious, they not only kill the bacteria but remove every vestige of the struggle, and find their way back to the blood. If the bacteria are victorious, and suppuration ensues, the leucocytes become pus corpuscles. Also, in the case of a wound, the leucocytes, by virtue of their amœboid movements, escape from the blood-vessels, accumulate in the region of the wound, and act as barriers against infection.

Life cycle of the white corpuscles. — It is presumed that the white corpuscles like all other cells have a definite term of existence. We do not know the length of this term, or where they are destroyed, except that large numbers are lost in the battle waged against bacteria, others by hemorrhage, and others may be converted into granulation tissue. These lost leucocytes are replaced by new leucocytes which result from the division of former leucocytes. This division usually takes place in the lymph nodes and the spleen.

Differences between white and red corpuscles. —

(1) White blood-cells are larger than red corpuscles, but normally are present in smaller numbers.

(2) They have no pigment or hæmoglobin, hence are colorless.

(3) On account of the property of amœboid movement their shape varies.

(4) They always have a nucleus, sometimes two or three nuclei.

(5) There are five varieties that differ in microscopical structure and possibly in function.

(6) During circulation they keep close to and even seem to adhere to the walls of the vessels, while the red corpuscles keep in the middle of the stream.

(7) By virtue of their amœboid movement they escape through the walls of the capillaries and are found in the tissue spaces. They are also found in lymph, chyle, and pus.

(8) The functions of the white blood-cells are quite different from the red corpuscles.

Blood-plates. — They are small, pale yellow, or colorless disks of which little is known. They vary in size and shape, but are always smaller than the red corpuscles. It is not decided whether they are to be considered as independent cells or as fragments of disintegrated cells. The number is usually about $\frac{1}{10}$ the number of red corpuscles.

Function. — When the blood leaves the blood-vessels and comes in contact with foreign matter, the blood-plates and some of the white corpuscles disintegrate and give rise to a substance called prothrombin. This is acted upon by substances in the blood plasma and converted into *thrombin*, which is one of the essentials for the formation of a clot.

Plasma. — The plasma of the blood is of a clear, slightly yellowish color. It consists for the most part of water charged with nutritive matter derived from our food, and waste matter derived from the tissues. In other words, it consists of water holding in solution or suspension : —

Proteins	Serum-albumin. Para-globulin or serum-globulin. Fibrinogen.		
Extractives . . .	Sugars. Fats.		
	Lecithin Cholesterin Urea Uric acid Hippuric acid Creatin	Represent waste products.	
Inorganic Salts .	Chlorides Sulphates Phosphates Carbonates	of	Sodium. Calcium. Magnesium.
Gases	Oxygen. Nitrogen. Carbon Dioxide.		
Enzymes			
Internal Secretions			
Immune Bodies	Opsonins. Antitoxins. Antibacterial substances.		

Proteins. — There are many indications which support the belief that the actual number of individual proteins is much greater than the usual three mentioned in our list. Our knowledge of these substances, and of the particular value of each one in the system is limited.

Serum-albumin belongs to the group of albumins of which white of egg is a member and holds the first place in regard to nutrition. It represents the protein portion of our food supply and the greater part of the material necessary for the daily nourishment and renovation of the tissues. In this process it undergoes a variety of transformations, by which it is converted into the structural characteristics of the tissues which it supplies.

Para-globulin[1] belongs to the class of globulins. The origin and function are undecided. It may be a source of nitrogenous food, and assists in coagulation of the blood.

The serum-albumin and para-globulin occur in about equal quantities.

Fibrinogen belongs to the class of globulins, and is the substance which produces the fibrin of coagulated blood. It is very difficult to obtain in the fluid condition, owing to the rapidity with which it solidifies when blood is withdrawn from the circulation. Though it is a most important element in the blood, it occurs in very small quantities.

Extractives. — Extractives are substances other than proteins that may be extracted from dried blood by special methods.

Sugar in the form of glucose is present under normal conditions in the amount of 0.1 to 0.2 per cent. A temporary increase in the amount of sugar may follow the ingestion of a large quantity.

Fat is found in the plasma in about the same proportion as sugar. It is much more subject to variation, rising notably after a meal in which there was much fat.

Waste products found in the plasma represent the end products resulting from the oxidation of our food. Due to the efficiency of the kidneys and supplementary organs of excretion they occur in very small quantities.

Salts.—The salts found in the blood amount to about one per cent of the total solids. They are derived from the food and from the chemical reactions going on in the body. The most abundant is sodium chloride.

Gases. — Oxygen, nitrogen, and carbon dioxide gas are found in the blood. Carbon dioxide is the result of oxidation in the

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[1] Albumins and globulins give the same general tests; they are both coagulated by heat, and the chief difference is in their solubilities.

tissues, and is found in both arterial and venous blood, but the quantity is greater in venous blood.

Enzymes.—An enzyme is a substance produced by living cells and is capable of effecting chemical change without itself undergoing alteration in the process. Each enzyme has a definite action at a suitable temperature, and will only work in a medium of definite reaction, either acid or alkaline. Further the products of the action must be removed. Five enzymes have been found in the blood.

Internal secretions. — The blood serves as a medium to carry internal secretions. (See page 136.)

Immune bodies. — In addition to the phagocytes and opsonins, the blood has been found to contain various other protective substances, which are described as antibodies. Just how they are formed, and whether they are a natural constituent of the blood, or whether they are developed only during an attack of disease, are undecided questions. The antibodies, like the enzymes, are specific in their action, that is, each variety will act against only one form of bacterium or toxin; for instance the antibody for typhoid is of no service against pneumonia.

THE CLOTTING OF BLOOD

Blood when drawn from the blood-vessels of a living body is perfectly fluid. In a short time it becomes viscid, and this viscidity increases rapidly until the whole mass of blood becomes a complete jelly. If the blood in this jelly stage be left untouched in a glass vessel, a few drops of an almost colorless fluid soon make their appearance on the surface of the jelly. Increasing in number

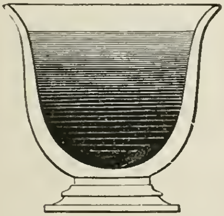

FIG. 95. — BOWL OF RECENTLY CLOTTED BLOOD, SHOWING THE WHOLE MASS UNIFORMLY SOLIDIFIED. (Dalton.)

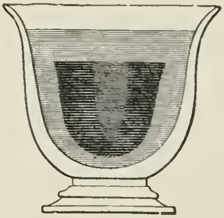

FIG. 96. — BOWL OF CLOTTED BLOOD AFTER TWELVE HOURS, SHOWING THE CLOT CONTRACTED AND FLOATING IN THE FLUID SERUM. (Dalton.)

and running together, the drops after a while form a superficial layer of pale straw-colored fluid. Later on, similar layers of the same fluid are seen at the sides, and finally at the bottom of the jelly, which, shrunk to a smaller size and of firmer consistency, now forms a **clot**, floating in a liquid. The upper surface of the clot is generally slightly concave. If a portion of the clot be examined under the microscope, it is seen to consist of a network of fine fibrils, in the meshes of which are entangled the red and some of the white corpuscles of the blood. The fibrils are composed of the fibrin; and the liquid in which the clot is suspended is blood minus corpuscles and fibrin, and is called serum. The relation between plasma and serum is shown in the following scheme: —

$$\textbf{Blood}\left\{\begin{array}{l}\text{Plasma}\left\{\begin{array}{l}\text{Serum}\\ \text{Fibrin}\end{array}\right.\\ \text{Corpuscles}\end{array}\right. \left.\begin{array}{l}\\ \\ \\ \end{array}\right\}\text{Clot}$$

The formation of insoluble fibrin from soluble fibrinogen is an instance of enzyme action and is comparable to the clotting of milk under the influence of rennin. When blood leaves the vessels, the blood-plates and some of the white corpuscles undergo prompt disintegration, and give rise to a substance called prothrombin, which is acted upon by the calcium salts of the plasma and converted into thrombin. It is this substance called thrombin which acts upon the fibrinogen and converts it into fibrin.

Value of clotting. — This property is of very great importance in the arrest of hemorrhage. The clot formed closes the openings of wounded vessels, and the procedures used to check hemorrhage are directed toward hastening the formation of a clot, and stimulating the blood-vessels to contract so that a smaller-sized clot will be sufficient.

The coagulability of the blood differs in different individuals, and in rare cases is so slight that the most trivial operation involving hemorrhage is attended with great danger. This condition is known as hemorrhagic diathesis or hemophilia, and is thought to be due to a lack of fibrinogen or of calcium salts.

Conditions affecting clotting. — Clotting is hastened by: —

(1) A temperature higher than that of the body, 110–120° F.

(2) Contact with any rough surface.

(3) Contact with any foreign substance, such as gauze.

(4) Injury to the walls of the blood-vessels.

(5) Rest.

It is generally conceded that the first four conditions hasten the disintegration of blood-plates and white corpuscles, and consequently the formation of thrombin and of a clot. Many standard text-books include *agitation* instead of *rest*. If blood is contained in a vessel, agitation of it does hasten the process of clotting in the same way that the first four conditions do. If, however, we consider the formation of a clot in the open end of an injured vessel, we keep the part at rest, because agitation might dislodge the clot after it had formed.

Clotting is hindered by: —

(1) A very low temperature. Cold hinders the formation of a clot but is often used to check hemorrhage, because it stimulates the blood-vessels to contract.

(2) Contact with living tissues, especially the walls of the blood-vessels.

(3) The addition of strong acids or alkalies, neutral salts, oil or other viscid substances, certain organic ferments, or a large quantity of water.

(4) Absence of calcium salts.

(5) Absence of fibrinogen.

(6) Removal of fibrin. If fresh blood, before it has time to clot, be whipped with a bundle of twigs, the fibrin will form on the twigs, and if the whipping of the blood be continued until after the fibrin has been deposited on the twigs, the blood left in the vessel will be found to have lost the power of clotting. Such blood is called **defibrinated.**

Why blood does not clot within the blood-vessels. — Fortunately blood rarely clots within the blood-vessels during life. Why it does not is not known, but two theories are advanced to account for it.

(1) Circulating blood does not contain thrombin because the blood-plates and white corpuscles do not disintegrate in sufficient numbers to allow for the formation of it.

(2) Circulating blood does contain some thrombin, but it also contains a substance called antithrombin which is secreted by the lining of the heart and blood-vessels. Antithrombin neutralizes or prevents the activity of thrombin.

Intravascular clotting. — It is well known that clots occasionally form within the blood-vessels. The most frequent causes are: —

(1) When the internal coat of a blood-vessel is injured, as for instance by a ligature, the endothelial cells are altered and may act as a foreign substance. If in addition there is a stasis of blood at this point, disintegration of the blood-plates and white corpuscles may result in the formation of thrombin and a clot.

(2) Any foreign material, even air, that is introduced into the blood and not absorbed may stimulate the formation of thrombin and a clot.

Thrombus and embolus. — A clot which forms inside a blood-vessel is called a thrombus. A thrombus may be broken up and disappear, but the danger is that it may be carried to some point in an important vessel where it acts as a wedge, blocks circulation, and may cause instant death. A thrombus that becomes dislodged from its place of formation is called an embolus.

Regeneration of the blood after hemorrhage. — A large portion of the total amount of blood in the body may be lost suddenly by hemorrhage without producing a fatal result. It is probable that a healthy individual may recover from the loss of as much as three per cent of the body weight, provided the lost blood is at once replaced by a solution having the same degree of concentration, and containing one or more of the important salts of the blood. Physiological saline solution, *i.e.*, sodium chloride 0.7 to 0.9 per cent, fulfills these conditions, and is usually introduced directly into a vein. This operation is called *intravenous infusion*, and the benefits derived from it are: —

(1) The heart-beat is increased, because it must make stronger contractions to propel the extra fluid.

(2) The volume of the circulating fluid is sufficiently increased to maintain normal conditions of pressure and velocity.

(3) The red corpuscles are kept in rapid circulation and thus loss of oxygen to the tissues is prevented.

(4) The tissue cells are provided with water and thus protected from the bad effects that would follow the withdrawal of water.

Plasma is regenerated with some rapidity but it may take days or even weeks before the number of red blood corpuscles and the hæmoglobin gets back to normal.

LYMPH

Lymph is a pale, straw-colored liquid that bathes all the tissue-spaces of the body. It is slightly alkaline, has a salty taste, and no odor. When examined with the microscope, it is seen to consist of a clear liquid with white corpuscles floating in it. In composition it resembles the blood, the essential differences being: —

BLOOD	LYMPH
Specific gravity about 1.055	Specific gravity about 1.015
Contains red corpuscles	Does not contain red corpuscles
Contains white corpuscles	Does contain white corpuscles
Contains blood-plates	Does not contain blood-plates
A high content of proteins	A low content of proteins
A low content of waste products	A higher content of waste products, particularly carbon dioxide and urea
Normally — clots quickly and firmly	Clots slowly and does not form a firm clot

Sources of lymph. — During the passage of the blood through the thin-walled capillaries, the plasma is forced to transude into such spaces as exist between the cells of the tissues. In addition to this transudation it is necessary to assume an active secretory process on the part of the endothelial cells composing the capillary walls. This plasma plus the leucocytes that have left the vessels by migration make up the lymph proper. Besides the lymph proper, the lymph that fills the lacteals of the intestinal villi absorbs some of the products of digestion, especially the fats.

This portion of the lymph that has absorbed the fats is milky in appearance, and is called **chyle**. The lymph, broadly speaking, is dilute blood minus its red corpuscles. The chyle is lymph plus a very large quantity of minutely divided fat.

Functions of the lymph. — The lymph bathes all portions of the body not reached by the blood. Hence the lymph conveys the nutrient ingredients of the blood to all cells not directly bathed by the blood. It delivers to the cells the material each cell needs to maintain its functional activity, and picks up and returns to the blood the products of this activity, which products may be simple waste, or matters capable of being made use of by some other tissue. There is thus a continual interchange going on between the blood and the lymph. This interchange is effected in two ways: —

(1) *By dialysis.* — The lymph becomes altered by the metabolic changes of the tissues which it bathes, and we have two different fluids, separated by the moist membrane which forms the walls of the blood-vessels, — the lymph in the tissues outside the walls of the capillaries and the blood inside the capillary walls. Some of the constituents of the lymph pass into the blood, while some of the constituents of the blood pass into the lymph, by the process of dialysis.[1]

These constituents, which, as we cannot too often emphasize, are products resulting from the activity of the tissues, are carried away by the blood to other tissues, which will either make use of them, or, as in the kidneys, take them up to make excretory fluids, and so remove them.

(2) *By osmosis.* — The blood, on account of the higher pressure, loses more liquid to the lymph than it receives back by the process of osmosis. This excess lymph gathers up the waste materials of the cells surrounding the lymph spaces and through the medium of the lymphatics pours this waste into the blood, to be eliminated by the skin, lungs, and kidneys.

In consequence of the different wants and wastes of different tissues at different times, both the lymph and blood must vary in composition in different parts of the body. But the loss and gain is so fairly balanced that the average composition is pretty constantly maintained.

The chyle, or lymph of digestion, absorbs nutrient materials (mostly fat) from the intestines and pours this food into the blood current, to be distributed to all parts of the body.

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[1] See page 12.

SUMMARY

- **Vascular System**
  - **Circulating Fluids**
    - Blood.
    - Lymph.
  - **Systems**
    - Blood vascular.
    - Lymph vascular.
- **Blood**
  - **Description**
    - Color
      - Bright red in arteries.
      - Dark red in veins.
    - Sticky fluid.
    - Specific gravity, about 1.055.
    - Alkaline reaction when tested with litmus.
    - Temperature, 100° F.
    - Peculiar odor. Salty taste.
    - $\frac{1}{20}$ of the body weight.
  - **Functions**
    - Carries water and nutritive substances to the tissues.
    - Carries oxygen to the tissues.
    - Carries waste products from the tissues to the organs of elimination.
    - Serves as a medium for the transmission of secretions.
    - Aids in protecting the body from infections.
    - Aids in equalizing temperature.
  - **Composition**
    - Corpuscles (minute, solid particles)
      - Red or erythrocytes.
      - White or leucocytes.
      - Blood-plates.
    - Plasma, transparent, slightly yellowish fluid
      - Water, 90 %.
      - Proteins.
      - Extractives.
      - Inorganic salts.
      - Gases.
      - Enzymes.
      - Immune bodies.
- **Red Corpuscles**
  - **Description**
    - Biconcave disks
      - $\frac{1}{3200}$ in. in diameter.
      - $\frac{1}{12800}$ in. in thickness.
    - Packets of hæmogloblin.
    - Have no nuclei.
    - Soft, flexible, and elastic.
  - **Function**
    - Oxygen carriers.
    - Color due to oxygen in combination with hæmoglobin.

- **Red Corpuscles**
  - **Life Cycle**
    - Originate in red marrow of bones.
    - Lose their nuclei before being forced into circulation.
    - Disintegrate probably in
      - Blood stream.
      - Spleen.
      - Lymph nodes.
  - **Number**
    - Cubic millimeter of blood
      - 5,000,000 for men.
      - 4,500,000 for women.
    - Pathological conditions may cause decrease.
- **White Corpuscles**
  - **Description**
    - Animal cell
      - Masses of protoplasm.
      - Nucleus (sometimes two or three nuclei).
      - No cell wall.
      - Round or spheroidal when circulating in blood.
      - $\frac{1}{2500}$ in. in diameter.
  - **Number**
    - Cubic millimeter of blood
      - 7000 to 9000.
      - 1 white to 500 or 600 red.
      - Marked increase = leucocytosis.
      - Marked decrease = leucopenia.
  - **Varieties**
    - Lymphocytes
      - (*a*) Small and mononuclear.
      - (*b*) Large and mononuclear.
    - Leucocytes
      - (*a*) Transition forms.
      - (*b*) Polynuclear — form 60 to 75 % of bulk of white corpuscles. Eosinophiles are a subgroup of this variety.
      - (*c*) Mast cells — exist in small numbers.
  - **Functions**
    - 1. Protective agents
      - (*a*) Form *Bacteriolysins.*
      - (*b*) Devour bacteria = *phagocytosis.*
    - 2. Aid in absorption of fats and proteins.
    - 3. Assist in coagulation of blood.
  - **Life Cycle**
    - New leucocytes formed in lymph nodes and spleen.
    - Numbers lost in
      - (1) Battles against bacteria.
      - (2) Hemorrhage.
      - (3) Formation of granulation tissue.

- **Inflammation**
  - Irritation resulting from injury or infection.
  - Engorgement of blood-vessels.
  - Migration of white blood-cells.
  - Diapedesis of red blood-cells.
  - Exudation of plasma.
  - **Symptoms**
    - Pain.
    - Heat.
    - Redness.
    - Swelling.
  - **Result**
    - (*a*) Resolution — White blood-cells eat up bacteria, clear up débris, and return to blood.
    - (*b*) Suppuration — Bacteria destroy white blood-cells and tissue cells, and form pus.
    - (*c*) Pus consists of
      - Plasma.
      - Red corpuscles.
      - White corpuscles.
      - Tissue cells.
      - Bacteria
        - dead.
        - living.
      - Toxins produced by bacteria.
- **Differences between white and red corpuscles**
  1. Size and number.
  2. Color.
  3. Property of amœboid movement and shape.
  4. Nucleus or nuclei.
  5. Varieties.
  6. Location during circulation.
  7. Migration. Found in other fluids.
  8. Functions.
- **Blood-plates**
  - **Description**
    - Pale yellow or colorless disks.
    - Size and shape various; always smaller than red corpuscles and about $\frac{1}{10}$ the number of red.
  - **Function** Stimulates formation of thrombin.

Plasma
- **Water, 90 %.**
- **Proteins**
  - Serum-albumin represents the protein portion of our food supply.
  - Para-globulin assists in coagulation of blood.
  - Fibrinogen produces the fibrin of coagulated blood.
- **Extractives**
  - Sugar
    - Normally present 0.1 % to 0.2 %.
    - May be increased after ingestion of large amount.
  - Fats
    - Derived from food.
    - Amount subject to wide variations.
  - Lecithin
  - Cholesterin
  - Urea
  - Uric acid
  - Hippuric acid
  - Creatin
    - (Lecithin to Creatin:) Represent waste products, result of oxidation of food. Normally present in small quantities.
- **Inorganic Salts**
  - Chlorides
  - Sulphates
  - Phosphates
  - Carbonates
    - of
      - Sodium
      - Calcium
      - Magnesium
        - Derived from our food, and also result from chemical reactions in our bodies.
        - About 1 % of solids.
- **Gases**
  - Oxygen obtained from air.
  - Nitrogen obtained from air.
  - Carbon dioxide result of oxidation. Found in both arterial and venous blood.
- **Enzymes**
  - Organic ferments that affect chemical changes, and remain unchanged themselves.
  - Five in blood
    - An amylolytic.
    - A glycolytic.
    - A lipolytic.
    - A proteolytic.
    - A coagulating.
- **Internal Secretions** — See Chapter VIII.
- **Immune Bodies**
  - Opsonins — Chemical substances that prepare disease germs for absorption and destruction by phagocytes.
  - Antitoxins — Chemical substances that act against toxins.
  - Antibodies — Chemical substances that act against bacteria or protozoa.

- **Clotting . . .**
  - **Description**
    - Serum
      - Water.
      - Mineral salts.
      - Albumin.
    - Clot
      - Fibrin formed from fibrinogen.
      - Corpuscles, red and white.
    - Process
      - White corpuscles and blood-plates disintegrate, and give rise to prothrombin. Prothrombin is acted upon by calcium salts and forms *thrombin.* Thrombin acts as ferment or enzyme.
  - **Value** . . . . . Checks hemorrhage.
  - **Hemophilia** . . Lack of coagulability of the blood.
  - **Hastened by**
    - A temperature higher than that of body, 110–120° F.
    - Contact with any rough surface.
    - Contact with foreign substances.
    - Injury to the walls of the vessels.
    - Rest.
  - **Hindered by**
    - A very low temperature.
    - Contact with living tissues, especially blood-vessels.
    - Addition of acids, alkalies, neutral salts, oils, ferments, water.
    - Absence of calcium salts.
    - Absence of fibrinogen.
    - Removal of fibrin. (Defibrinated blood.)
- **Intravascular Clotting**
  - **Theories to account for rare occurrence**
    - 1. Circulating blood does not contain thrombin.
    - 2. Circulating blood does contain thrombin, but it is counteracted by antithrombin.
  - **Causes . . .**
    - Injury to internal coat of blood-vessels.
    - Any foreign material that will stimulate clotting.
  - **Thrombus** . . . Name given to clot which forms inside vessel.
  - **Embolus** . . . . A thrombus that has become dislodged from place of formation.
- **Regeneration of blood after hemorrhage**
  - If immediate ill effects are counteracted by intravenous infusion, plasma is regenerated rapidly, red corpuscles in comparatively short time.

- **Intravenous Infusion**
  - **Definition** . . . . Injection of physiological saline solution directly into vein.
  - **Benefits** . . . .
    1. Heart stimulant.
    2. Increases volume of circulating blood.
    3. Red corpuscles kept circulating, and oxygen supply kept up as far as possible.
    4. Cells provided with water.
- **Lymph** . . .
  - **Description**. .
    - Pale straw-colored liquid.
    - Alkaline reaction when tested with litmus.
    - Salty taste. No odor.
    - Consists of blood plasma plus leucocytes.
    - Specific gravity about 1.015.
    - Contains a low content of proteins.
    - Contains a high content of waste products.
    - Clots slowly, does not form a firm clot.
  - **Sources**. . . .
    - Transudation through thin-walled capillaries.
    - Active secretory process on part of endothelial cells.
  - **Function** . . .
    - Lymph acts as middleman between the blood and the tissues.
    - Carries nourishment *from* blood to tissues.
    - Carries waste from tissues to blood.
    - Dependent upon
      1. Dialysis.
      2. Osmosis.
  - **Chyle** . . . . . . Lymph plus nutrient material, mostly fats.

CHAPTER X

THE BLOOD VASCULAR SYSTEM, AND THE LYMPH VASCULAR SYSTEM

BLOOD VASCULAR SYSTEM

The blood is the internal medium on which the tissues live. It is carried through the body by branched tubes named blood-vessels. It is driven along these tubes by the action of the **heart**, which is a hollow muscular organ placed in the centre of the vascular system. One set of vessels — the **arteries** — conducts the blood out from the heart and distributes it to the different parts of the body, whilst other vessels — the **veins** — bring it back to the heart again. The blood from the arteries gets into the veins by passing through a network of fine tubes which connect the two, and which are named, on account of their small size, the **capillary** (*i.e.* hair-like) vessels.

Blood Vascular System
Heart.
Arteries — small arteries are named arterioles.
Capillaries.
Veins — small veins are named venules.

We shall see that the structure of these several parts is adapted to their respective uses.

HEART

The heart is a hollow, muscular organ, situated in the thorax between the lungs, behind the sternum, and above the central depression of the diaphragm. It is about the size of the closed fist, shaped like a blunt cone, and so suspended by the great vessels that the broader end or base is directed upward, backward, and to the right. The pointed end or apex points downward, forward, and to the left. The impulse of the heart against the chest wall is felt in the space between the fifth and sixth ribs, a little below and to the inner side of the left nipple.

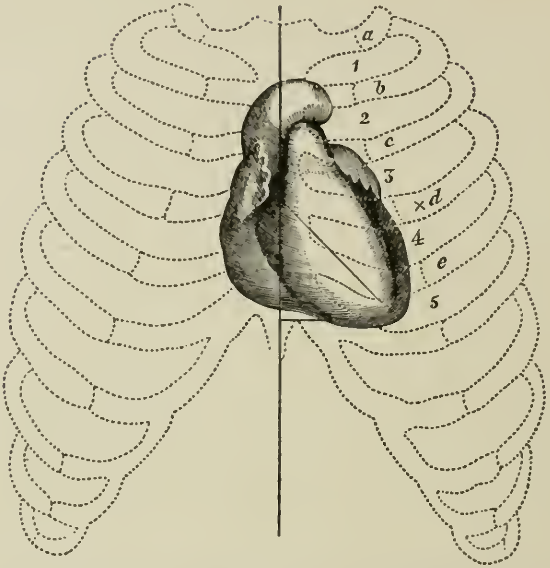

Fig. 97. — Heart *in situ* (Dalton, in Flint, "On the Heart"). *a, b, c, d, e,* ribs; 1, 2, 3, 4, 5, intercostal spaces; vertical line, median line; triangle, superficial cardiac region; × on the fourth rib, nipple.

As placed in the body, it has a very oblique position, and the right side is almost in front of the left.

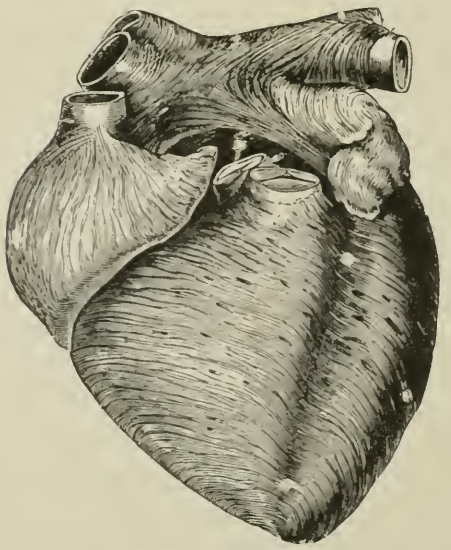

Fig. 98. — Anterior View of Heart, Dissected, after Long Boiling, to show the Superficial Muscular Fibres. (Quain.)

Myocardium. — The main substance of the heart is composed of muscular tissue and is called **myocardium.** (See page 91.)

The arrangement of the fibres is very intricate; they run transversely, longitudinally, obliquely, and in the apex take a spiral turn or twist. Between the muscle fibres is a certain amount of interstitial tissue, with numerous blood-vessels and lymphatics, and, in some parts, nerves and ganglia. There is also a considerable amount of fat, collected chiefly at the base of the heart, beneath the pericardium.

Pericardium. — The heart is covered by a membranous sac called the pericardium (around the heart.) It consists of two parts: (1) an external fibrous portion, and (2) an internal, serous portion.

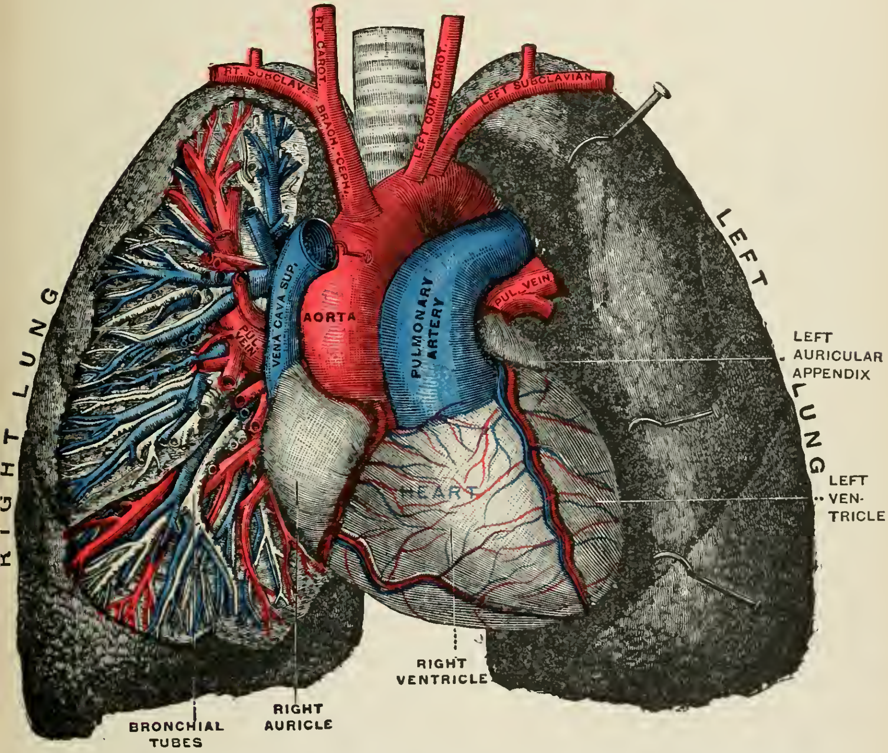

FIG. 99. — THE PULMONARY ARTERY AND AORTA. The front part of the right lung has been removed, and the pulmonary vessels and the bronchial tubes are thus exposed. (Gerrish.)

(1) The **external fibrous** pericardium is composed of white fibrous tissue, and is attached by its upper surface to the large blood-vessels which emerge from the heart. It covers these vessels for about an inch and a half (38 mm.) and blends with their sheaths. The lower border is firmly adherent to the diaphragm, and the front surface is attached to the sternum by means of fibrous bands.

(2) The **internal** or **serous portion** of the pericardium is a completely closed sac; it envelops the heart and lines the fibrous pericardium. The heart, however, is not within the cavity of the closed sac. (See Fig. 100.) That portion of the serous pericardium which lines and is closely adherent to the heart is called the visceral portion (*viscus* organ); the remaining part of the serous pericardium, namely, that which lines the fibrous pericardium, is known as the parietal portion (*paries*, a wall). The cavity of the serous pericardium contains a small quantity of serous liquid. Its contiguous or opposed surfaces are lined by endothelium and are very smooth and polished.

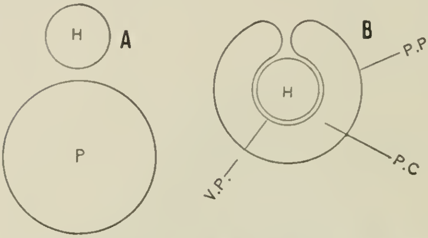

Fig. 100. — Diagram of Heart and Serous Pericardium. In *A*, heart and pericardium lying separately. In *B*, pericardium lying around heart. *H*, heart; *P. C.* pericardial cavity; *P. P.* parietal portion of pericardium; *V.P.* visceral portion.

As the opposing surfaces, owing to the constant contractions of the heart, are continually sliding one upon the other, they are admirably constructed to protect the heart from any loss of power by friction.

Endocardium. — The interior of the heart is lined by a delicate, smooth membrane, called the endocardium. This pavement membrane (endothelium) lines all the cavities of the heart, and is continued into the blood-vessels, forming their innermost coat.

The cavities of the heart. — The heart is divided from the base to the apex, by a fixed partition, into a right and left half, frequently called right and left heart. The two sides of the heart have no communication with each other after birth. The right always contains **venous**, and the left side **arterial**, blood. Each half is subdivided into two cavities, the upper, called **auricle** (atrium); the lower, **ventricle** (ventriculum). If we examine these cavities, we notice that the muscular walls of the auricles are much thinner than those of the ventricles, and the wall of the left ventricle is thicker than that of the right. This difference in bulk is to be accounted for, as we shall see later on, by the greater amount of work the ventricles, as compared with the auricles, have to do.

These cavities communicate with one another by means of constricted openings, the auriculo-ventricular orifices, which are strengthened by fibrous rings and protected by valves.

Important orifices of the heart. — Eight large blood-vessels are directly connected with the heart, hence there are eight orifices

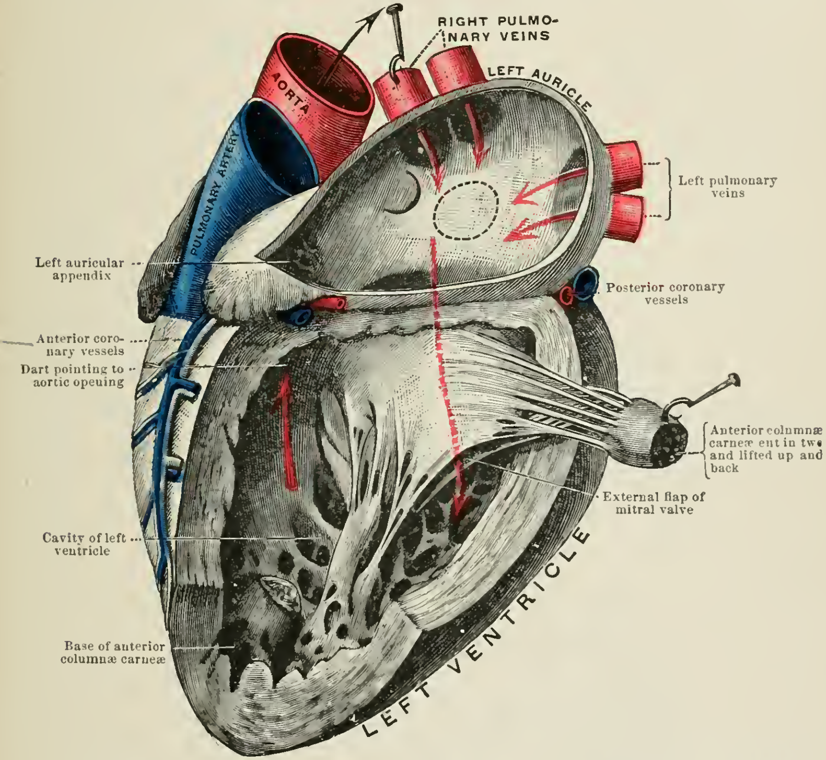

FIG. 101. — LEFT AURICLE AND VENTRICLE, THE HIND WALL OF EACH HAVING BEEN REMOVED. (Gerrish.)

plus the two between the auricles and ventricles, making a total of ten.

On the right side of the heart, the superior and inferior vena cava empty into the auricle, and the pulmonary artery leaves the ventricle.

On the left side of the heart, four pulmonary veins empty into the auricle, and the aorta leaves the ventricle. There are some smaller openings to receive blood directly from the heart substance, and before birth there is an opening between the right and left auricle called the *foramen ovale.* Normally this closes as soon as the infant breathes.

Valves of the heart. — The auriculo-ventricular orifices and the openings into the aorta and pulmonary artery are guarded by valves.

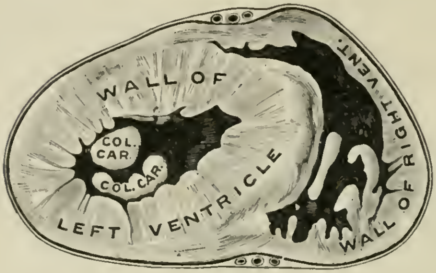

Fig. 102. — Cross-section through both Ventricles, showing the Shape of their Cavities and the Relative Thickness of their Walls. (Gerrish.)

The tricuspid valve. — The valve guarding the right auriculo-ventricular opening is composed of three irregular-shaped flaps, or cusps, and hence is named tricuspid. The flaps are mainly formed of fibrous tissue covered by endocardium. At their bases they are continuous with one another, and form a ring-shaped membrane around the margin of the auricular opening: their pointed ends are directed downward, and are attached by cords, the **chordæ tendineæ**, to little muscular pillars, the **papillary muscles**, provided in the interior of the ventricles for this purpose.

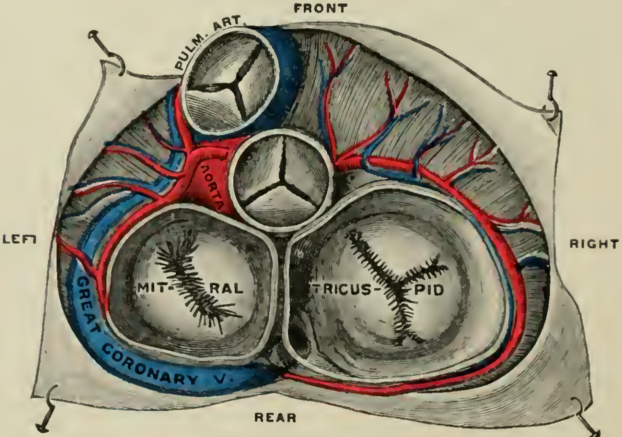

Fig. 103. — Valves of the Heart and Great Arteries, viewed from Above, the Auricles having been Removed. (Gerrish.)

The bicuspid valve. — The valve guarding the left auricular opening consists of only two flaps or cusps, and is named the bicuspid, or mitral valve. It is attached in the same manner as the triscuspid valve, which it closely resembles in structure, except that it is much stronger and thicker in all its parts.

Function. — These valves oppose no obstacle to the passage of the blood from the auricles into the ventricles because the free edges of the flaps are pointed in the direction of the blood current; but any flow forced backward gets behind the flaps of the valve (between the flap and the wall of the ventricle), and drives the flaps backward and upward, until, meeting at their edges, they unite and form a complete transverse partition between the ventricle and auricle. Being retained by the chordæ tendineæ, the expanded flaps of the valve resist any pressure of the blood which might otherwise force them back to open into the auricle; the papillary muscles, also, to which the chordæ tendineæ are attached, contract and shorten at the same time, and thus keep them taut.

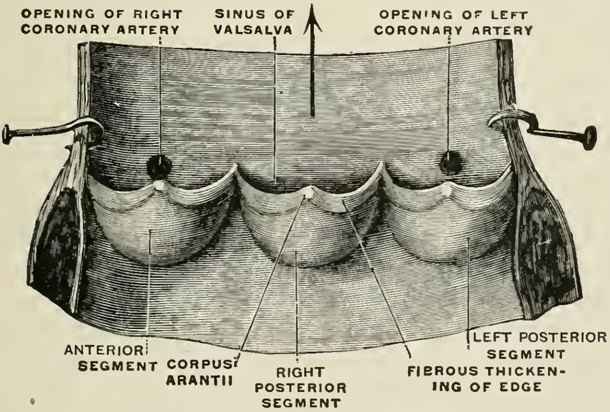

FIG. 104. — AORTIC VALVE. The artery has been cut open between the anterior and left posterior segments, and spread out. (Gerrish.)

Semilunar valves. — The valves between the ventricles and arteries are called the semilunar valves (aortic and pulmonary). These valves consist of three half-moon-shaped pockets, each pocket being attached by its convex border to the inside of the artery where it joins the ventricle, while its other border projects into the interior of the vessel. Small nodular bodies, called the **corpora Arantii**, are attached to the centre of the free edge of each pocket.

Function. — These valves offer no resistance to the passage of blood from the heart into the arteries, as the free borders project into the arteries, but they form a complete barrier to the passage of blood in the opposite direction. In this case each pocket becomes filled with blood, and the free borders are floated out and distended so that they meet in the centre of the vessel. The *corpora Arantii* assist in the closure of these valves and help to make the barrier perfect.

The orifices of the heart which serve for openings into veins are not protected by valves, with the possible exception of the opening into the inferior vena cava which is partly covered by a membrane known as the Eustachian valve.

Blood Supply. — Just after the aorta leaves the left ventricle it gives off two small branches, called the *right* and *left coronary* arteries. They encircle the heart like a crown, hence their name. They supply the substance of the heart with blood, as the blood contained within the cavities of the heart only nourishes the pericardium.

Nerve supply. — The heart is supplied (1) by the pneumo-gastric nerves from the central nervous system and (2) from the sympathetic system. Stimulation of the pneumo-gastric fibres slows the action of the heart. They are therefore known as cardiac inhibitors. Stimulation of the sympathetic fibres increases the force of the heart beat, therefore they are known as cardiac accelerators.

ARTERIES

These are hollow vessels that lead from the heart and are composed of three coats: —

1. A smooth **endothelial** lining.

2. A middle coat of **fibrous elastic tissue** with muscle fibres interlaced and circularly disposed around vessel.

3. An outer, dense, **fibrous** coat with fibres arranged longitudinally.

1. The inner lining or endothelium is continuous with the endocardium which lines the heart. It furnishes a smooth, slippery surface over which the blood can flow without any friction.

2. By virtue of the structure of the middle coat, the arteries are both contractile and elastic. It is thicker and contains a larger proportion of elastic tissue in the large arteries. In the smaller

arteries it is thinner and contains a larger proportion of muscular tissue. The proper functioning of the arteries depends upon their elasticity and contractility and may be demonstrated by the following example: —

If we tie a piece of a large artery at one end and inject fluid into the other end, the artery swells out to a very great extent, but will return at once to its former size when the fluid is let out. This great elasticity of the arteries adapts them for receiving the additional amount of blood thrown into them at each contraction of the heart.

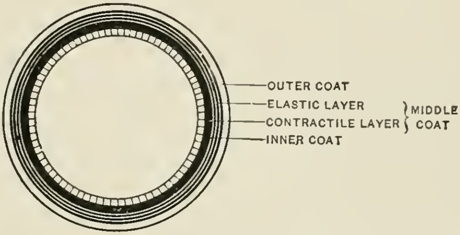

FIG. 105. — DIAGRAM OF A CROSS-SECTION OF AN ARTERY, SHOWING THE COMPOSITION OF ITS TUNICS. (Gerrish.)

3. The strength of an artery depends largely upon the outer fibrous coat; it is far less easily cut or torn than the other coats, and it serves to resist undue expansion of the vessel.

The arteries do not **collapse** when empty, and when an artery is severed the orifice remains open. The muscular coat, however, contracts somewhat in the neighborhood of the opening, and the elastic fibres cause the artery to retract a little within its sheath, so as to diminish its calibre and permit a blood-clot to plug the orifice. This property of the severed artery is an important factor in the arrest of hemorrhage.

Blood and nerve supply of the arteries. — The blood which flows through the arteries nourishes only the inner coat. The middle and outer coats are supplied with arteries, capillaries, and veins, called **vasa vasorum**, or blood-vessels of the blood-vessels.

The muscular tissue found in the walls of the arteries is supplied with nerves chiefly from the sympathetic system. These nerves are called **vasomotor**, and are divided into two sets, (1) vaso-constrictor, and (2) vaso-dilator.

Stimulation of one set of these nerves (vaso-constrictor) causes contraction of the muscle-fibres and constriction of the arteries; stimulation of a second set (vaso-dilator) causes a relaxation of the muscle-fibres, and dilatation of the arteries. The widening and narrowing of the arteries not only affects the local circulation in different parts of the body, but the amount of resistance they oppose to the arterial impulse also influences in some degree the character of the heart-beat. The term "**tone of the arteries**" is used to express the normal degree of contracture of the arterial walls.

Sheaths of the arteries. — The greater number of the arteries are accompanied by a nerve and one or two veins and surrounded by a sheath of connective tissue, which helps to support and hold these structures in position.

Size of the arteries. — The largest arteries in the body, the aorta and pulmonary artery, measure about one inch (28 mm.) in diameter, at their connection with the heart. These arteries give off branches, which divide and subdivide into smaller branches. A branch of an artery is always less than the trunk from which it springs, hence the arteries grow smaller as they subdivide, and gradually lose their characteristic structure. The smallest arteries are called *arterioles,* and at their distal ends, where only the internal coat remains, the capillaries begin.

CAPILLARIES

The capillaries are exceedingly minute vessels which average about $\frac{1}{2000}$ of an inch (0.0125 mm.) in diameter. They connect the arterioles with the venules (smallest veins), thus receiving the blood from the arterioles and carrying it to the venules.

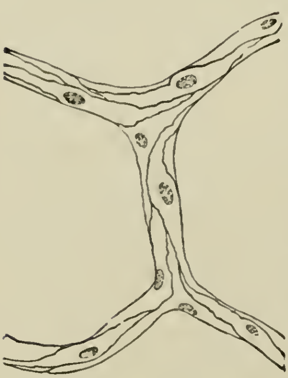

Fig. 106. — Fine Capillaries from the Mesentery. (Collins.)

Structure. — The walls of the capillaries are formed entirely of *one* layer of simple endothelium composed of flattened cells joined edge to edge by cement substance, and continuous with the layer which lines the arteries and veins.

Distribution. — The capillaries communicate freely with one another and form interlacing networks of variable form and size in the different tissues. All the tissues, with the exception of the cartilages, hair, nails, cuticle, and cornea of the eye,[1] are traversed by these networks of capillary vessels. Their diameter is so small that the blood-corpuscles must pass through them in single file and very frequently the corpuscle is bigger than the calibre of the vessel, and has to be squeezed to enable it to pass through. In many parts they lie so closely together that a pin's point cannot be inserted between them. They are most abundant, and form the finest networks, in those organs where the blood is needed for other purposes than local nutrition, such as, for example, secretion or absorption.

Function. In the glandular organs the capillaries supply the substances requisite for secretion; in the alimentary canal they take up some of the elements of digested food; in the lungs they absorb oxygen and give up carbon dioxide; in the kidneys they discharge the waste products collected from other parts; all the time, everywhere through their walls, that interchange is going on which is essential to the renovation and life of the whole body. It is in the capillaries, then, that the chief work of the blood is done; and the object of the vascular mechanism is to cause the blood to flow through these vessels in the manner best adapted for accomplishing this work.

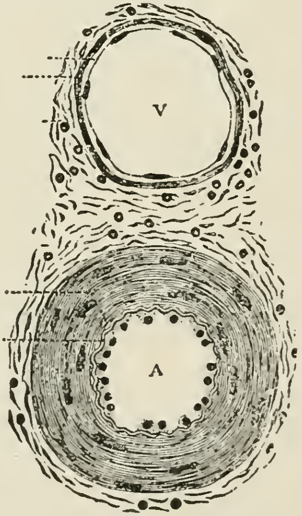

Fig. 107. Transverse Section through a Small Artery and Vein, showing the Relative Difference in the Thickness of their Walls. In the vein (*V*) the outer coat is thickest, in the artery (*A*) the contractile and elastic middle coat is thickest. (Klein and Noble Smith.)

VEINS

The veins have three coats and on the whole resemble the arteries in structure. They differ from them in having: (1) much thinner walls (see Fig. 107); (2) they contain less elastic tissue, more white fibrous tissue, and because of this are not so elastic or contractile as the arteries; (3) many of the veins are provided with valves.

Valves. — The valves are semilunar folds of the internal coat of the veins; and usually consist of two flaps, rarely one or three.

The convex border is attached to

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[1] These parts not penetrated by the blood-vessels imbibe nutritive matter from adjacent tissues, and are just as dependent on the blood as all the other tissues.

the side of the vein, and the free edge points toward the heart. Their function is to keep the blood flowing in the right direction, *i.e.* toward the heart, and prevent regurgitation.

Should the blood on its onward course toward the heart be for any reason driven backward, the refluent blood, getting behind the wall of the vein and the flaps of the valve, will press them inward until their edges meet in the middle of the channel and close it up.

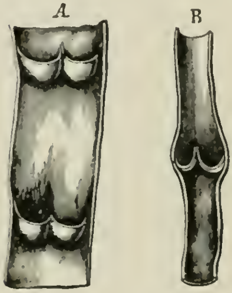

Fig. 108. — Diagram showing Valves of Veins. *A*, part of a vein, laid open, with two pairs of valves; *B*, longitudinal section of vein, showing valves closed. (Sharpey.)

The valves are most numerous in the veins where regurgitation is most likely to occur, *i.e.* the veins of the extremities. For the same reason a greater number are found in the lower than in the upper limbs. They are absent in many of the small veins, in the large veins of the trunk, and in veins not subjected to muscular pressure. The veins, like the arteries, are supplied with both blood-vessels and nerves; the supply, however, is far less abundant.

It must be remembered that although the arteries, capillaries, and veins have each the distinctive structure above described, it is at the same time difficult to draw the line between the smaller artery and larger capillary; and between the larger capillary and smaller vein. The veins on leaving the capillary networks only gradually assume their several coats, while the arteries dispense with their coats in the same imperceptible way as they approach the capillaries.

LYMPH VASCULAR SYSTEM

As the process of transudation described on page 153 is continual, it follows that œdema would result from the accumulation of lymph if some system of drainage were not provided. This drainage system is provided by the lymph vascular system.

Lymph Vascular System
- **Lymph spaces**
- **Lymph vessels**
  - Lymph capillaries.
  - Lymphatics.
  - Thoracic duct.
  - Right lymphatic duct.
  - Lacteals.
  - Serous sacs.
- **Lymph nodes**

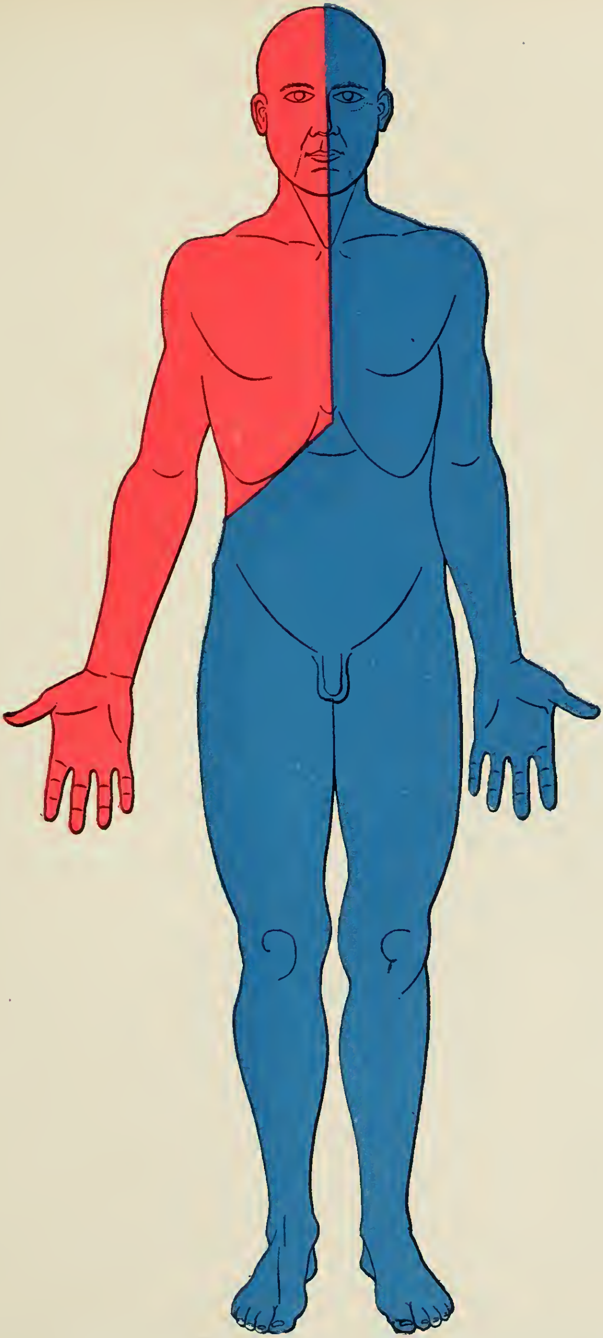

Fig. 109. — The Regions whose Lymph flows into the Right Lymphatic Duct are suggested by the Red Area; those which are tributary to the Thoracic Duct by the Blue Area. (Gerrish.)

Lymph Spaces. — The minute irregular spaces which exist between the cells of which the tissues are composed are called lymph spaces. They are filled with lymph, and in them the lymphatics begin.

Lymph vessels. — The plan upon which the lymphatic system is constructed is similar to that of the blood vascular system, if we omit the heart and the arteries. In the lymph spaces we find the closed ends of minute microscopic vessels, called *lymph capillaries,* which are comparable to, but somewhat larger than, the blood capillaries. These lymph capillaries unite to form larger vessels called *lymphatics,* which are comparable to the veins. The lymphatics continue to unite and form larger and larger vessels until finally they converge into two main channels, (1) the thoracic duct, and (2) the right lymphatic duct.

The thoracic duct. — The thoracic duct begins at the second lumbar vertebra and ascends upward to the seventh cervical. It lies in front of the bodies of the vertebræ, gradually inclining towards the left, until, when on a level with the seventh cervical vertebra, it turns outward and arches downward and forward to terminate in the innominate vein at the point of junction of the left internal jugular and left subclavian.

It is from fifteen to eighteen inches (375–450 mm.) long in the adult, and is about the size of a goose quill. It receives the lymph from the left side of the head, neck, and chest, all of the abdomen and both lower limbs, also the chyle from the lacteals. It is dilated below, where it receives the lymphatics from the lower limbs and the chyle from the lacteals, the dilatation being known as the chyle cistern (receptaculum chyli). (See Fig. 135.)


FIG. 110.—VALVES OF THE LYMPHATICS.

The right lymphatic duct. — The right lymphatic duct is a short vessel, usually from one to one and one-half inches (25 to 38 mm.) in length. It pours its contents into the innominate vein at the junction of the right internal jugular and subclavian veins.

The lymphatics from the right side of the head, neck, the right arm, and the upper part of the trunk enter the right lymphatic duct. The parts drained by each are suggested by Fig. 109.

Structure of the lymph vessels. — The lymphatics resemble the veins in their structure as well as in their arrangement. The smallest have but a single coat of endothelioid cells, having a peculiar dentated outline. The larger vessels have three coats, similar to veins, except that they are so thin as to be transparent, and they are more abundantly supplied with valves. The valves are constructed and arranged in the same fashion as those of the veins, but follow one another at such short intervals, that, when distended, they give the vessel a beaded or jointed appearance. They are usually wanting in the smaller networks. The valves allow the passage of material from the smaller to the larger lymphatics, and from these into the veins, and obstruct the flow of anything in the opposite direction.

Classification of lymphatics. — The lymph, like the blood in the veins, is returned from the limbs and viscera by a deep and by a superficial set of vessels. The deep lymphatics accompany the large blood-vessels, and the superficial are distributed through the subcutaneous areolar tissue. There is no communication between these two sets of vessels, but each set forms frequent anastomoses.

FIG. 111. — LACTEALS AND LYMPHATICS, DURING DIGESTION. (Dalton.)

Lacteals. — The lymphatics that have their origin in the villi of the small intestine are called lacteals. During the period of intestinal digestion they are filled with chyle which has a white aspect, dependent upon the fatty particles absorbed from the food, and suspended in it like oil globules in milk. After fasting, the lacteals contain lymph which differs very little from the lymph found in the ordinary lymphatics.

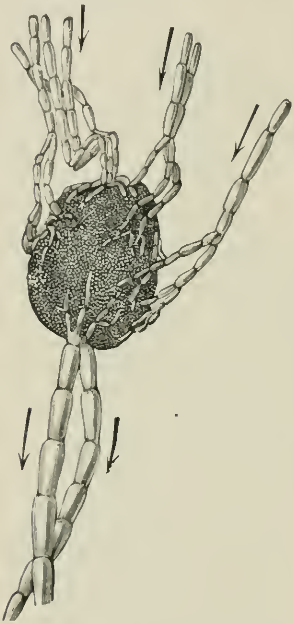

Fig. 112. — A Lymph Node with its Afferent and Efferent Vessels. (Gerrish.)

Serous sacs. — A close relationship exists between the lymphatics and the serous membranes proper. These closed sacs are to be regarded as prodigiously expanded lymph spaces. The true stomata of these serous membranes are connected with other lymph spaces.

Function of the lymphatics. — The function of the lymphatics is to carry from the tissues to the veins all the materials which the tissues do not need. Functionally they may be considered between the capillaries and the veins, as they gather up the lymph which exudes through the thin capillary walls, and return it to the innominate veins. Here it becomes mixed with the blood, enters the superior vena cava, and then the right auricle of the heart. The function of the lacteals is to help in the absorption of digested food, especially fats.

Lymph nodes. — The lymph nodes are numerous round or ovoid bodies placed in the course of the lymphatics. They vary in size from a pinhead to an almond. A lymph node is covered by an envelope, or capsule, of connective and muscular tissue. This capsule sends fibrous bands called trabeculæ (little beams) into the substance of the node, and divides it into irregular spaces, which communicate freely with each other. The irregular spaces are occupied by a mass of cellular pulp substance, which, however, does not quite fill them as it never touches the capsule or trabeculæ, but leaves a narrow interval between itself and them. It looks as if the pulp had originally filled the framework and then shrunk away slightly on all sides. The spaces thus left form channels for the passage of the lymph, which enters by afferent vessels, and, after circulating through the node, issues by efferent vessels. Lymph nodes are well supplied with blood. A lymph node is comparable

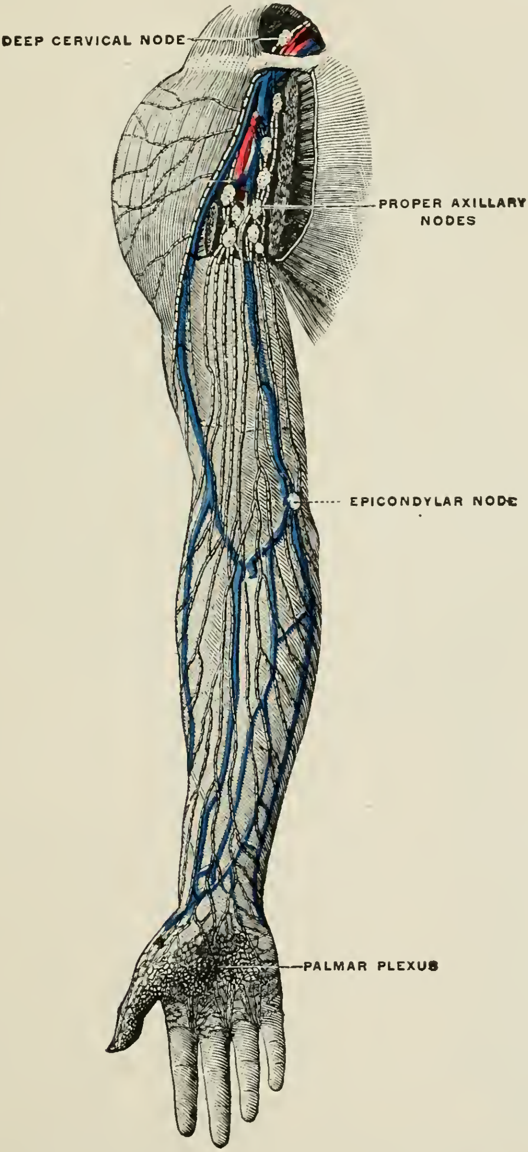

FIG. 113. — THE LYMPH NODES AND VESSELS OF THE UPPER LIMB. (Gerrish.)

to a sponge placed in a snugly fitting rubber bag. The rubber bag connects on one side with a rubber tube representing the afferent lymph vessel, and from the opposite side there leads away from the rubber bag another tube representing the efferent lymph vessel. The rubber bag is the representative of the capsule of the node, the meshwork of the sponge is comparable to the framework of the node, and the holes in the sponge to the open channels. The substance of a lymph node is reticular adenoid tissue.

Fig. 114. — The Lymph Nodes and Vessels of the Lower Limb. (Gerrish.)

Location of nodes. — Lymph nodes are found in great numbers in the neck, thorax, axilla, groin, mesentery and alongside of the aorta, vena cava inferior, and the iliac vessels. A few are found in the popliteal space and in the arm as far as the elbow, but none farther down the leg or forearm. They are usually named from the position in which they are found in the body, viz. cervical in the neck, thoracic in the thorax, axillary in the axilla, inguinal in the groin, mesenteric in the mesentery.

Function of the lymph nodes. — The lymph nodes serve two important purposes: —

(1) *As filters for the lymph.* — In this way they act as safety-valves and serve to retard the spread of infection through the body. If any portion of the body is infected, the poison may be carried by the lymphatics to their special nodes. There its course is stopped and the node may suffer enlargement or even break down

and be destroyed. If the infection is not arrested, the node next in line will suffer, then the next, and so on.

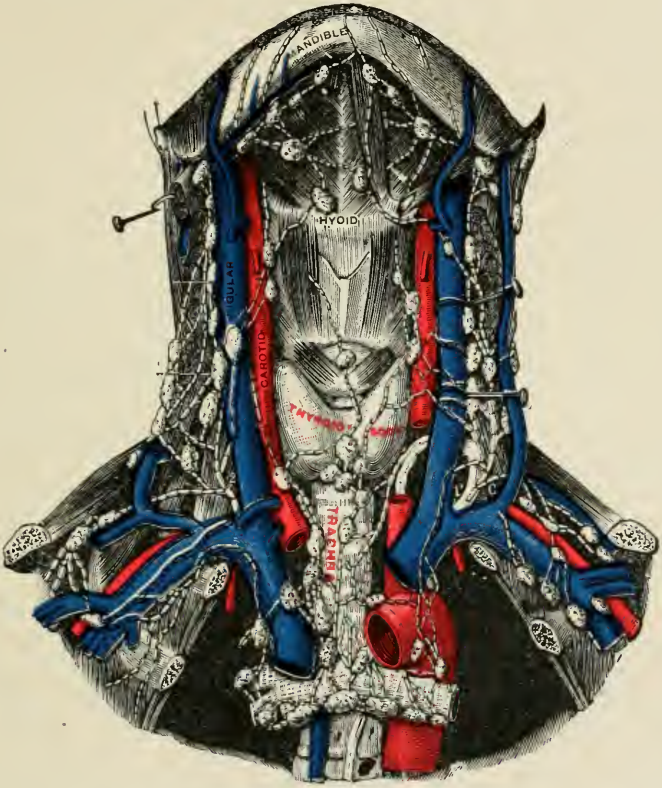

FIG. 115. — THE LYMPH NODES OF THE NECK AND UPPER PART OF THE THORAX. (Gerrish.)

(2) *Multiplication of leucocytes.* — In its passage through the node the lymph takes up fresh leucocytes, which are continually multiplying by cell division in the glandular substance.

SUMMARY

- **Blood Vascular System**
  - Heart.
  - Arteries — small arteries are named arterioles.
  - Capillaries.
  - Veins — small veins are named venules.

- **HEART**
  - **Location**
    - Between lungs.
    - Behind sternum.
    - Above diaphragm.
  - **Structure**
    - Smooth lining on inside — *Endocardium.*
    - Muscle substance — *Myocardium.*
    - Outside covering — *Pericardium*
      - Fibrous portion.
      - Serous
        - Visceral.
        - Parietal.
  - **Cavities**
    - **Right heart**
      - **Right auricle**
        - Receives blood.
        - Thin walls.
      - **Right ventricle**
        - Expels blood. Pulmonary artery.
        - Thick walls.
    - **Left heart**
      - **Left auricle**
        - Receives blood.
        - Thin walls.
      - **Left ventricle**
        - Expels blood. Aorta.
        - Very thick walls.
  - **Orifices**
    - **Right heart**
      - **Right auricle**
        - Superior vena cava — returns blood from upper portion of body.
        - Inferior vena cava — returns blood from lower portion of body.
      - Auriculo-ventricular orifice between auricle and ventricle.
      - **Right ventricle**
        - Pulmonary artery — carries blood from heart to lungs.
    - **Left heart**
      - **Left auricle**
        - Two right pulmonary veins
        - Two left pulmonary veins
        - Return blood from lungs.
      - Auriculo-ventricular orifice between auricle and ventricle.
      - **Left ventricle**
        - Aorta — distributes blood to all parts of body.

- HEART
  - **Valves**
    - **Tricuspid valve** — composed of three cusps situated in the right ventricle.
    - **Bicuspid or mitral valve** — composed of two strong, thick cusps situated in the left ventricle.
    - **Semilunar valves**
      - **Aortic** — composed of three half-moon-shaped pockets between aorta and left ventricle.
      - **Pulmonary** — composed of three half-moon-shaped pockets between pulmonary artery and right ventricle.
  - **Nerve Supply**
    - **Central nervous system** — Pneumogastric nerves, *inhibitory* fibres, slow the heart.
    - **Sympathetic system** — *Accelerator fibres* increase rapidity and force of heart.
  - **Blood Supply**
    - Right coronary artery / Left coronary artery — branches from aorta.

- **Arteries**
  - **Hollow tubes** — Carry blood *from* heart.
  - **Coats**
    1. Endothelial lining.
    2. Muscular and elastic tissue — contractile and elastic.
    3. Fibrous tissue.
  - **Sheaths** — outside covering of connective tissue which surrounds the arteries.
  - **Size** — Aorta about one inch in diameter. Arteries grow smaller as they subdivide. Smallest ones are microscopic and are called **arterioles**.

- **Capillaries**
  - **Tiny tubes** — about $\frac{1}{2000}$ of an inch in diameter. Connect arterioles and venules.
  - One coat of simple endothelium.
  - Communicate freely — form networks.

- **Veins**
  - **Collapsible tubes** — smallest ones, called venules, begin where capillaries end.
  - Carry blood to heart.
  - Three coats, same as arteries but thinner.
  - Less elastic and contractile.
  - Valves. 1–2–3 semilunar pockets.

Vaso vasorum — Term applied to blood-vessels that are supplied to coats of other blood-vessels.

Vasomotor — Term applied to *nerves* supplied to blood-vessels — 2 sets
- Vaso-constrictor.
- Vaso-dilator.

Lymph Vascular System
- **Lymph spaces**
- **Lymph vessels**
  - Lymph capillaries.
  - Lymphatics.
  - Thoracic duct.
  - Right lymphatic duct.
  - Lacteals.
  - Serous sacs.
- **Lymph nodes**

Lymph Spaces — Irregular spaces between cells of which tissues are composed.

Lymph Vessels
- **Lymph Capillaries**
  - Origin in lymph spaces.
  - One coat of endothelium — dentated.
  - Start as microscopic lymph capillaries, unite to form lymphatics. Comparable to formation of veins.
- **Lymphatics** — three coats — numerous valves.
- **Thoracic Duct**
  - 15 to 18 in. long. Size of goose-quill.
  - In front of vertebra from 2d lumbar to 7th cervical.
  - Has three coats — numerous valves.
  - Dilatation at lower portion called chyle cistern.
  - Receives lymph from left side of head, neck, and chest, left arm, all of abdomen, and both lower limbs. Receives chyle from lacteals.
  - Pours lymph and chyle into left innominate vein.
- **Right Lymphatic Duct**
  - 1 to 1½ in. long.
  - Receives lymph from right side of head, neck, and chest, also right arm.
  - Pours lymph into right innominate vein.
- **Classification**
  - **Deep** — accompany large blood-vessels.
  - **Superficial** — distributed through the subcutaneous areolar tissue.
- **Lacteals**
  - Lymphatics of the intestines.
  - Many originate in villi of small intestine.
  - Contain
    - During digestion — chyle.
    - During fasting — lymph.
  - Absorb fatty substances.
- **Serous Sacs**
  - Expanded lymph spaces.
  - Communicate by means of stomata with other lymph spaces.
- **Function** — Drain off lymph from all parts of the body and return it to the innominate veins.

Lymph Nodes

- **Description** .
  - Shape
    - Round.
    - Ovoid.
  - Size varies from pinhead to almond.
  - Consists of outer capsule
    - Connective and muscular tissue.
  - Interior divided into irregular spaces like sponge.
  - Spaces partially filled with reticular adenoid tissue. Communicating channels for lymph, which enters by afferent, leaves by efferent, vessels.
  - Are well supplied with blood.
- **Location** . .
  - Neck, thorax, axilla, groin, mesentery.
  - Alongside of great vessels of trunk.
  - In the arms as far as elbows.
  - In the legs as far as popliteal space.
  - Usually name indicates location.
- **Function** . .
  - 1. Filters — preventive and protective.
  - 2. Multiplication of leucocytes.

CHAPTER XI

THE VASCULAR SYSTEM CONTINUED: ARTERIES; PULMONARY SYSTEM; GENERAL SYSTEM; VEINS; SUPPLEMENTARY CHANNEL, AND PORTAL SYSTEM

ARTERIES

The arteries, which carry and regulate the supply of blood from the heart to the capillaries, are distributed throughout the body in a systematic manner, and before taking up the circulation, we must try to gain a general idea of this system of distribution, in order that we may be able to locate the position of these important vessels. The arteries usually occupy *protected* situations, that they may be exposed as little as possible to accidental injury, or to the effects of local pressure.

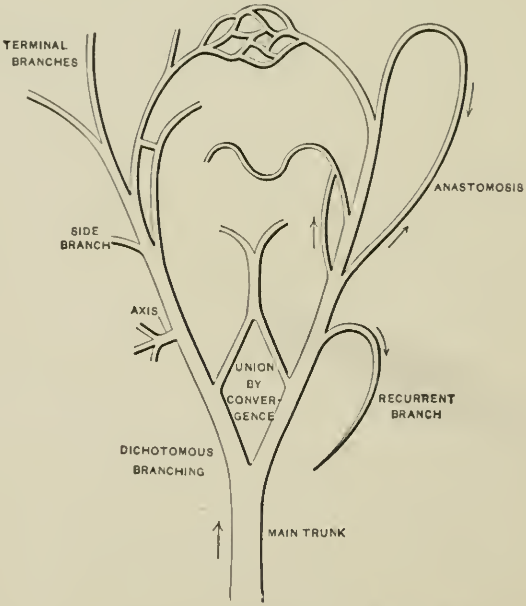

FIG. 116. — DIAGRAM SHOWING THE BRANCHINGS, ANASTOMOSES, AND CONFLUENCE OF ARTERIES. (Gerrish.)

Division. — As they proceed in their course they divide into branches, the division taking place in different ways.

(1) An artery may at once resolve itself into two branches of nearly equal size (dichotomous, division, or splitting in two).

(2) It may give off several branches in succession and still maintain its character as a trunk.

(3) It may give off one branch that divides into three equal branches. In this case the parent branch is called an axis. Example — cœliac axis.

Anastomosis or Inosculation. — The distal ends of arteries unite at frequent intervals, when they are said to anastomose, or inosculate. Such inosculations admit of free communication between the currents of the blood, tend to promote equality of distribution and of pressure, and to obviate the effects of local interruption. It is this arrangement which allows of the ligating of veins and arteries during operations, or after injuries, without serious interference with the circulation in the part.

Plexus. — When a number of arteries form many inosculations within a limited area, it is described as a plexus or network. Arteries commonly pursue a tolerably straight course, but in some parts of the body they are tortuous. The *facial* artery, in its course over the face, and the arteries of the lips are extremely tortuous, so that they may accommodate themselves to the movements of the parts.

Divisions of the vascular system. — The blood-vessels of the body are arranged in two main systems, namely, the pulmonary and the general or systemic.

The pulmonary system. — This is the lesser system and provides for the circulation of blood from the right ventricle to the lungs, and then back to the left auricle. This is called the pulmonary circulation.

Blood-vessels of the pulmonary system. — The blood-vessels of the pulmonary system are (1) the pulmonary artery and all its branches, (2) the capillaries which connect these branches with the veins, and (3) the pulmonary veins.

The pulmonary artery. — The pulmonary artery conveys the dark blood from the right side of the heart to the lungs. The main trunk is a short, wide vessel (diameter about one inch, or 30 mm.) which arises from the right ventricle and runs for a distance of two inches (50 mm.) upward, backward, and to the left. Between the fifth and sixth thoracic vertebræ it divides into two branches, the right and left pulmonary arteries which pass to the right and left lungs. (See Fig. 99.) From these main branches, arteries arise which divide and subdivide, grow smaller in size, and finally merge into capillaries. These capillaries unite, grow larger in size,

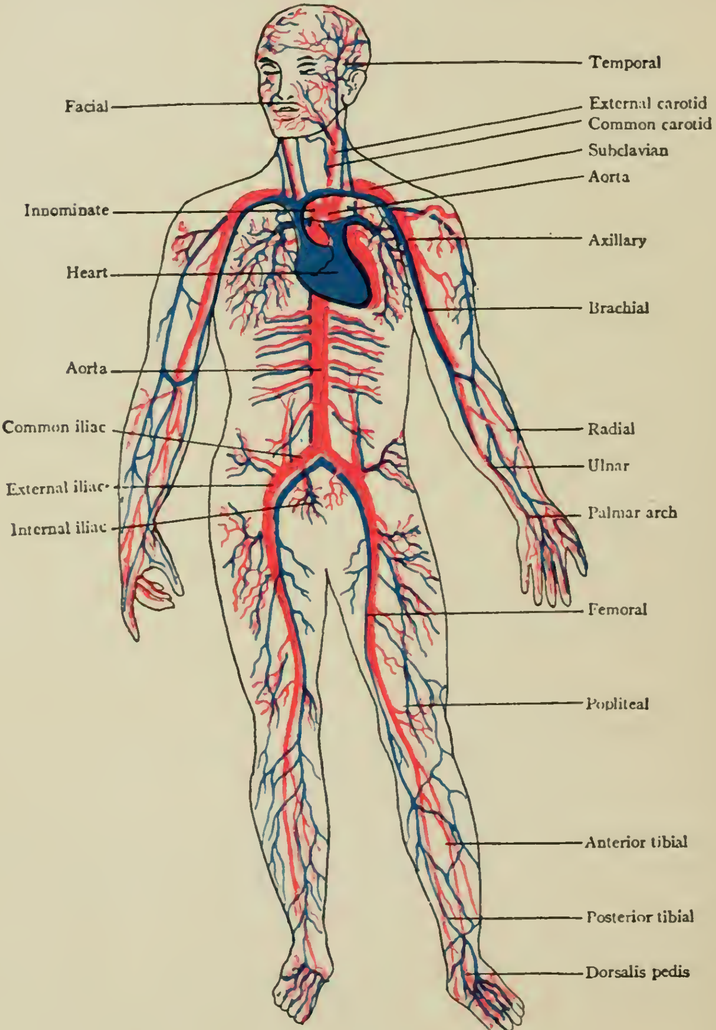

FIG. 117. — THE PRINCIPAL ARTERIES OF THE BODY. (Morrow.)

and gradually assume the characteristics of veins. The veins unite to form the pulmonary veins.

The pulmonary veins. — The pulmonary veins are four short trunks which convey the oxidized blood from the lungs to the left auricle, and which are found, two on each side, — in the root of the corresponding lung. The pulmonary veins have no valves.

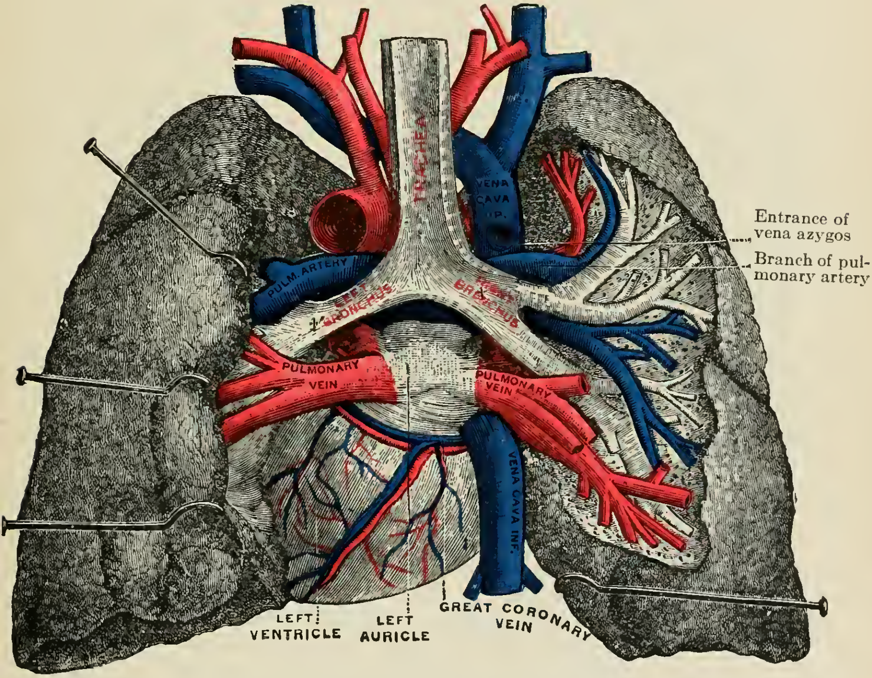

Fig. 118. — Pulmonary Veins, seen in a Dorsal View of the Heart and Lungs. The left lung is pulled to the left, and the right lung has been partly cut away to show the ramifications of the air-tubes and blood-vessels. (Gerrish.)

The general system. — This is the larger system and provides for the circulation of blood from the left ventricle to all parts of the body by means of the aorta and its branches, and the return to the right auricle by means of the venæ cavæ. This is called the systemic circulation.

The blood-vessels of the general system. — The blood-vessels of the general system consist of (1) the *aorta*, and all the arteries that originate from it, (2) the capillaries which connect the arteries and veins, and (3) all the veins of the body which empty either directly into the heart, or indirectly by means of the superior and inferior venæ cavæ.

The aorta.— The aorta is the main trunk of the arterial system. Springing from the left ventricle of the heart, it arches over the root of the left lung, descends along the vertebral column, and after passing through the diaphragm into the abdominal cavity, ends opposite the fourth lumbar vertebra by dividing into the right and left common iliac arteries. In this course the aorta forms a continuous single trunk, which gradually diminishes in size from its commencement to its termination (from 28 to 17 mm.) and gives off larger or smaller branches at various points.

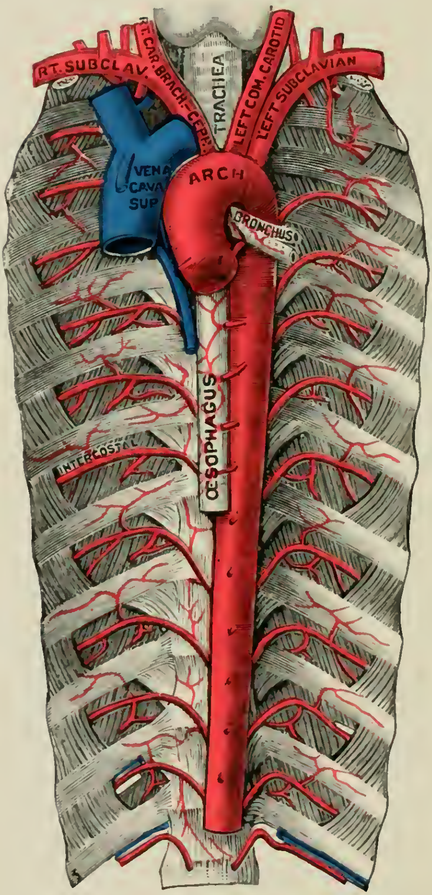

Fig. 119. — Thoracic Aorta. (Gerrish.)

It may be divided as follows: —

(1) The **ascending aorta** is the short part which is contained within the pericardium.

(2) The **arch** is the part extending from the ascending aorta and forming a well-marked curve in front of the trachea, and around the root of the left lung to the border of the fourth thoracic vertebra.

(3) The **descending thoracic aorta** is the comparatively straight part that extends from the lower border of the fourth thoracic vertebra on the left side, to the opening in the diaphragm below the last thoracic vertebra. It has a length of from seven to eight inches (175 to 200 mm.).

(4) The **abdominal aorta** commences about the lower border of the last thoracic vertebra, and terminates below by dividing into

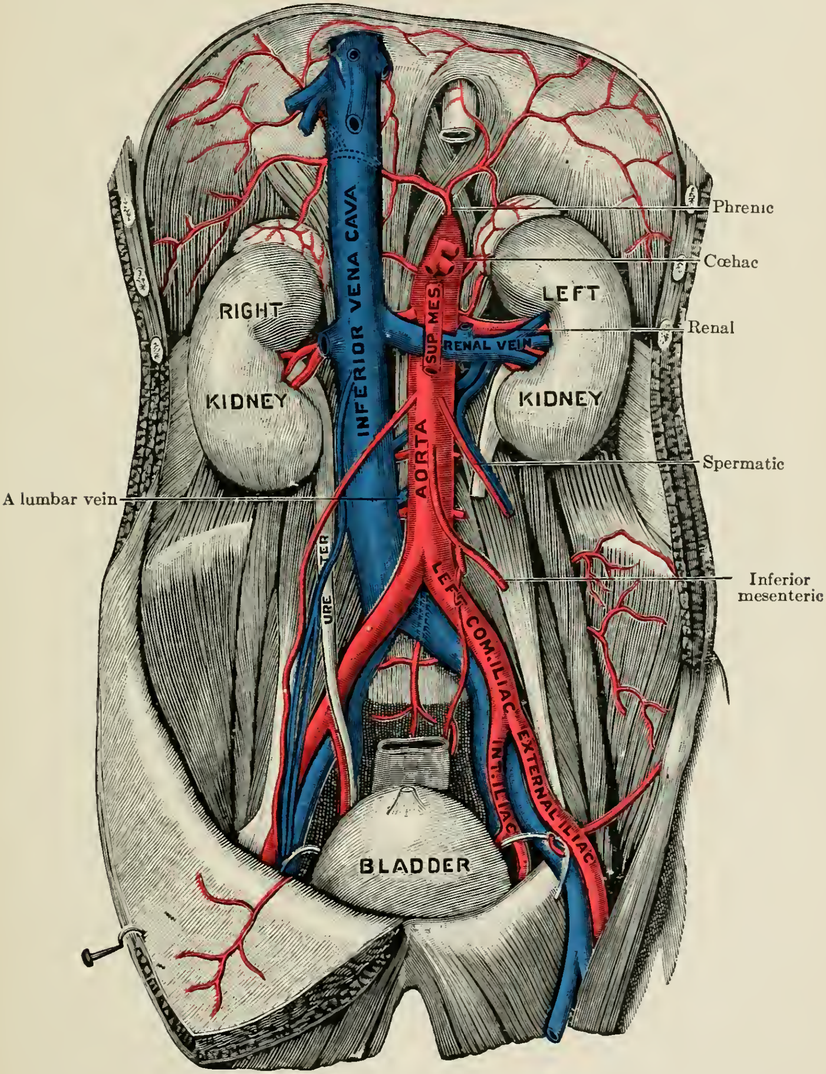

Fig. 120. — Abdominal Aorta. (Gerrish.)

the two common iliac arteries. The bifurcation usually takes place about halfway down the body of the fourth lumbar vertebra, which corresponds to a spot on the front of the abdomen, slightly below and to the left of the umbilicus. Its length is about five inches (125 mm.).

The important branches arising from the aorta may be outlined as follows: —

- **Aorta**
  - **Ascending Aorta** — Coronary arteries.
  - **Arch of Aorta**
    - Innominate.
    - Left common carotid.
    - Left subclavian.
  - **Thoracic Aorta**
    - Intercostal.
    - Pericardial.
    - Bronchial.
    - Œsophageal.
    - Posterior mediastinal.
  - **Abdominal Aorta**
    - Visceral group
      - Cœliac axis.
      - Superior mesenteric.
      - Inferior mesenteric.
      - Renal arteries.
      - Supra-renal.
      - Spermatic.
      - Ovarian.
    - Parietal group
      - Phrenic.
      - Lumbar.
      - Middle sacral.

The coronary arteries. — The right and left coronary arteries arise from the aorta immediately above the semilunar valves. (See Fig. 104.) They encircle the heart and give off numerous branches that supply the substance of the heart.

Innominate. — The innominate (brachio-cephalic) artery arises from the right upper surface of the arch, ascends obliquely toward the right, until, arriving on a level with the upper margin of the clavicle, it divides into the **right common carotid** and **right subclavian** arteries. Its usual length is from one to two inches (25 to 50 mm.).

The common carotid arteries. — The left common carotid arises from the middle of the upper surface of the arch of the aorta, and the right common carotid arises at the division of the innominate, consequently the left carotid is an inch or two longer than the right. They ascend obliquely on either side of the neck until, on a level with the upper border of the laryngeal prominence (Adam's apple), they divide into two great branches: (1) the

external carotid, (2) the **internal carotid**. At the root of the neck the common carotids are separated from each other by only a narrow interval, corresponding with the width of the trachea; but as they ascend they are separated by a much larger interval, corresponding with the breadth of the larynx and pharynx.

Each **external carotid** has eight branches, which are distributed to the throat, tongue, face, ears, and walls of the cranium.

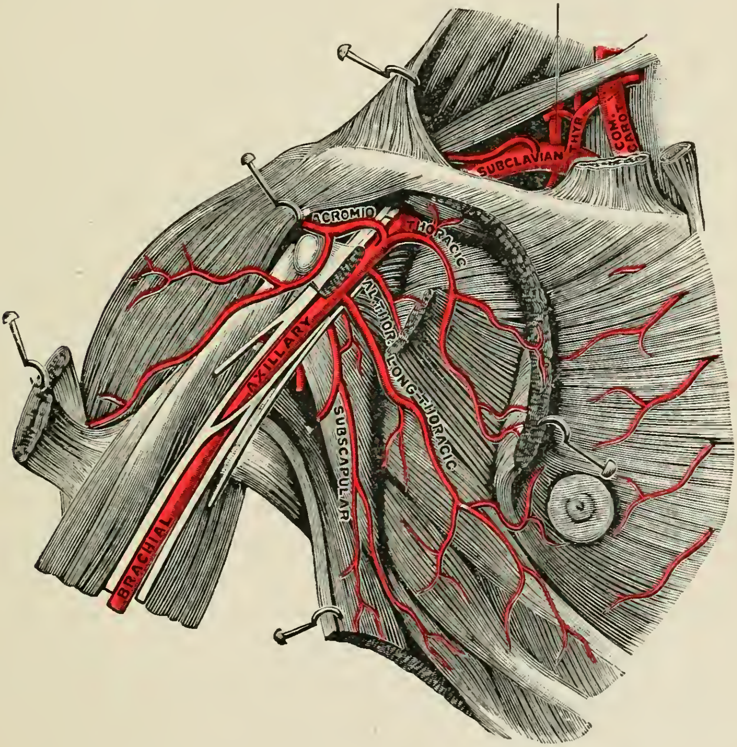

FIG. 121. — SUBCLAVIAN AND AXILLARY ARTERIES. (Gerrish.)

Each **internal carotid** has many branches which are distributed to the brain and eyes. The chief ones are the **cerebral** and **ophthalmic**.

Circle of Willis. — The circle of Willis is a remarkable anastomosis formed by the blood-vessels of the brain. It is situated at the base of the brain and is formed by the union of (1) the anterior and posterior cerebral arteries, which are branches of the internal carotid, and (2) branches of the basilar artery, which is formed by the union of the two vertebrals.[1] These arteries are joined in such a manner as to form a complete circle, and this arrangement serves (1) to equalize the circulation of the blood in the brain, and (2) in case of destruction of one of the arteries, it provides for the blood reaching the brain through other vessels.

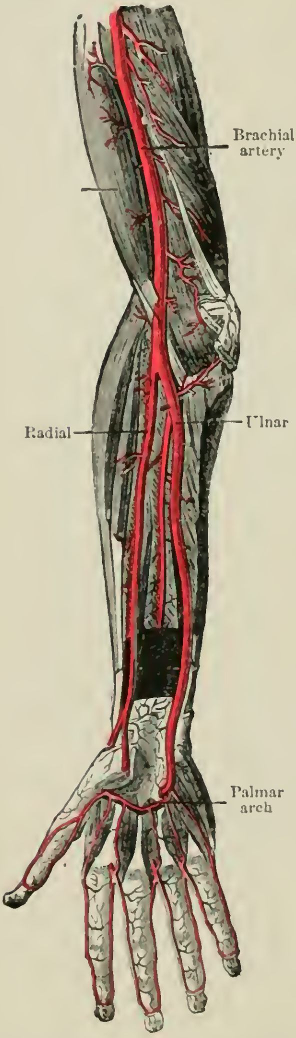

FIG. 122. — DEEP ANTERIOR VIEW OF THE ARTERIES OF THE ARM, FOREARM, AND HAND.

The subclavian arteries. — The right subclavian arises at the division of the innominate, and the left subclavian from the arch of the aorta. The subclavian arteries are the first portions of a long trunk which forms the main artery of the upper limb, and which is artificially divided for purposes of description into three parts; viz.: (1) **Subclavian**, (2) **Axillary**, and (3) **Brachial.**

The **subclavian** artery passes a short way up the thorax into the neck, and then turns downward to rest on the first rib. At the lower border of the first rib it ceases to be called subclavian, and is continued as the axillary. It gives off large branches to the brain, back, chest, and neck.

The **axillary** artery passes through the axilla, lying to the inner side of the shoulder joint and upper part of the arm. It gives off branches to chest, shoulder, and arm.

The **brachial** artery (continuation of the axillary) extends from the axillary space to just below the bend of the elbow, where it divides into

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[1] The vertebral arteries are branches given off from the subclavian. They ascend on either side of the vertebral column, pass through the foramen magnum, and at the base of the brain unite to form the *basilar* artery.

the **ulnar** and **radial** arteries. It may be readily located, lying in the depression along the inner border of the biceps muscle. Pressure made at this point from within outward against the humerus will control the blood supply to the arm.

The **ulnar**, the larger of the two vessels into which the brachial divides, extends along the inner side of the forearm into the palm of the hand, where it terminates in the **superficial palmar arch.**

The **radial** artery appears, by its direction, to be a continuation of the brachial, although it does not equal the ulnar in size. It extends along the outer side of the front of the forearm as far as the lower end of the radius, below which it turns around the outer border of the wrist, and passes forward into the palm of the hand. It terminates in the **deep palmar arch.** The superficial and deep palmar arches anastomose and supply the hand with blood.

Thoracic aorta. — The branches derived from it are numerous but small. The principal ones are: —

(1) The **intercostal** arteries are ten or eleven on each side. They arise from the aorta and extend outward to the intercostal spaces. They give off branches to supply the muscles of the back and chest, the pleuræ, the spinal cord and its membranes, and also the vertebral column. Branches from the third, fourth, fifth, and sixth supply the mammary glands. (See page 453.)

(2) The **pericardial** arteries pass to the pericardium and supply it with blood.

(3) The **bronchial** arteries are three in number and pass one to the right and two to the left lung. Branches from these arteries ramify through the lung tissue and supply it with nutritive material. Branches are also distributed to the bronchial tubes, œsophagus, and pericardium.

(4) The **œsophageal** arteries are four or five in number and supply the œsophagus.

(5) The **posterior mediastinal** arteries pass backward between the lungs to the thoracic vertebra and supply the lymph nodes found in the mediastinum. (See page 242.)

Abdominal aorta. — It gives off numerous branches, which may be divided into two sets: —

1. **Visceral**, or those which supply the viscera.
2. **Parietal**, or those which are distributed to the walls of the abdomen.

Visceral group: —

(*a*) The **cœliac axis** is a short, wide vessel, usually not more than half an inch (12.5 mm.) in length, which arises from the front of the aorta, just below the opening in the diaphragm. It divides into three branches; viz. (1) the **gastric**, which supplies the stomach; (2) the **hepatic**, which supplies the liver and the duodenum or portion of the intestine nearest to the stomach; and (3) the **splenic**, which supplies the spleen, and also takes part in the blood supply of the stomach and pancreas.

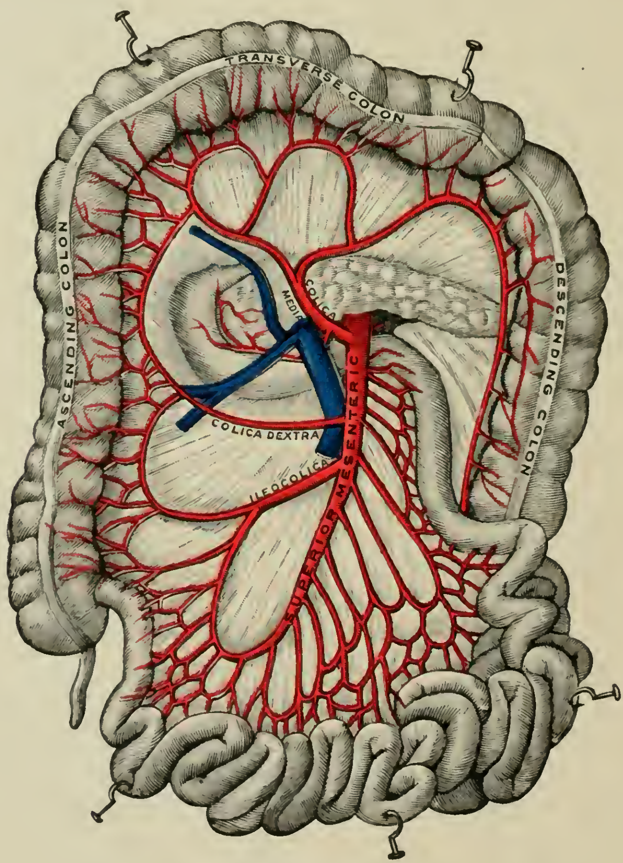

Fig. 123. — Superior Mesenteric Artery. (Gerrish.)

(*b*) The **superior mesenteric** artery arises from the fore part of the aorta, a little below the cœliac axis. It supplies the whole of the small intestine beyond the first portion, and half of the large intestine.

(*c*) The **inferior mesenteric** artery arises from the front of the aorta, about an inch and a half (38 mm.) above its bifurcation, and supplies the lower half of the large intestine. Continued under the name of the superior hemorrhoidal artery, it also takes part in the blood supply of the rectum.

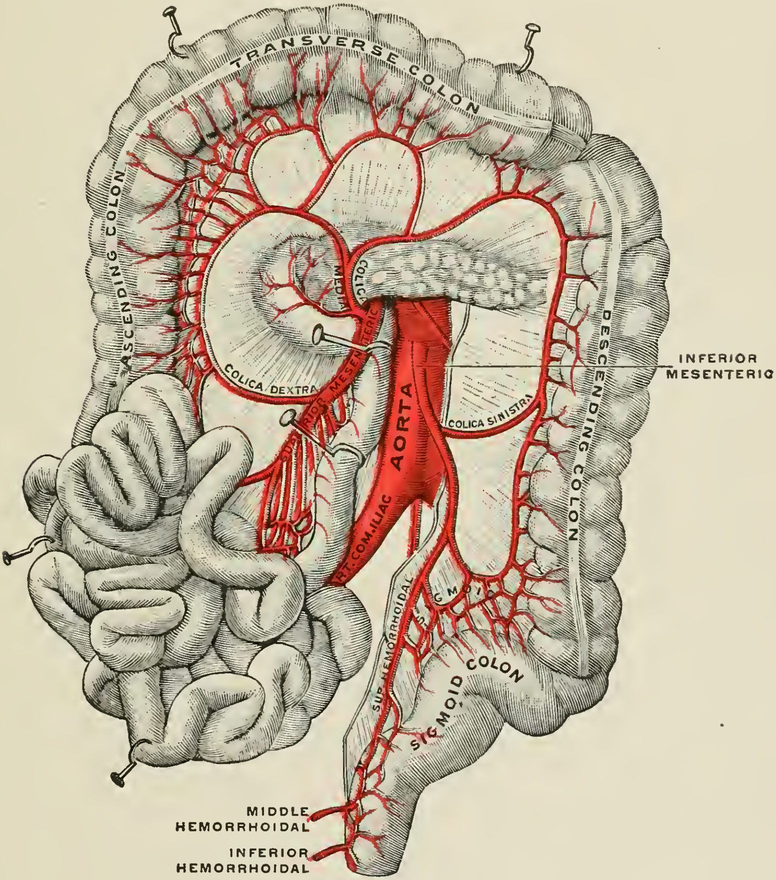

Fig. 124. — Inferior Mesenteric Artery. (Gerrish.)

(*d*) The **renal** arteries are of large size, in proportion to the bulk of the organs (kidneys) which they supply. They arise from the sides of the aorta, about half an inch (12.5 mm.) below the superior mesenteric artery, that of the right side being generally a little lower down than that of the left. Each is directed outward, so as to form nearly a right angle with the aorta.

(*e*) The **supra-renal** arteries are of small size. They arise from the side of the aorta, a little above the superior mesenteric. They supply the supra-renal or adrenal bodies. (See page 316.)

(*f*) The **spermatic** arteries in the male arise close together from the front of the aorta, a little below the renal arteries. They are distributed to the testes.

(*g*) The **ovarian** arteries in the female arise from the same portion of the aorta as the spermatic arteries in the male. They supply the ovaries, and, joined to the uterine artery, — a branch of the internal iliac, — also assist in supplying the uterus. During pregnancy the ovarian arteries become considerably enlarged.

Parietal group: —

(*a*) The **phrenic** arteries arise from the aorta above the cœliac axis and are distributed to the diaphragm.

(*b*) The **lumbar** arteries arise from the aorta, and the various branches, dorsal, spinal, and abdominal, supply the muscles and walls of the respective regions that their names suggest.

(*c*) The **middle sacral** artery arises from the lower end of the abdominal aorta and passes down to the sacrum and coccyx.

Common iliac. — The common iliac arteries, commencing at the bifurcation of the aorta, pass downward and outward about two inches (50 mm.), and then each divides into the **internal** (or hypogastric) and the **external iliac** arteries.

The **internal iliac** artery (or hypogastric) supplies branches to the pelvic walls, pelvic viscera, the external genitals and the buttocks. The **uterine** artery in the female which supplies the tissues of the uterus with blood is a very important branch of the internal iliac.

The **external iliac** is placed within the abdomen, and extends from the bifurcation of the common iliac to the lower border of the inguinal ligament, where it enters the thigh and is named femoral.

The external iliac artery forms a large, continuous trunk, which extends downward in the lower limb, and is named in successive parts of its course **femoral**, **popliteal**, and **posterior tibial**.

The **femoral** artery lies in the upper three-fourths of the thigh, its limits being marked above by the inguinal (Poupart's) ligament and below by the opening in the great adductor muscle, after passing through which the artery receives the name of **popliteal**. In the first part of its course the artery lies along the middle of the depression on the inner aspect of the thigh, known

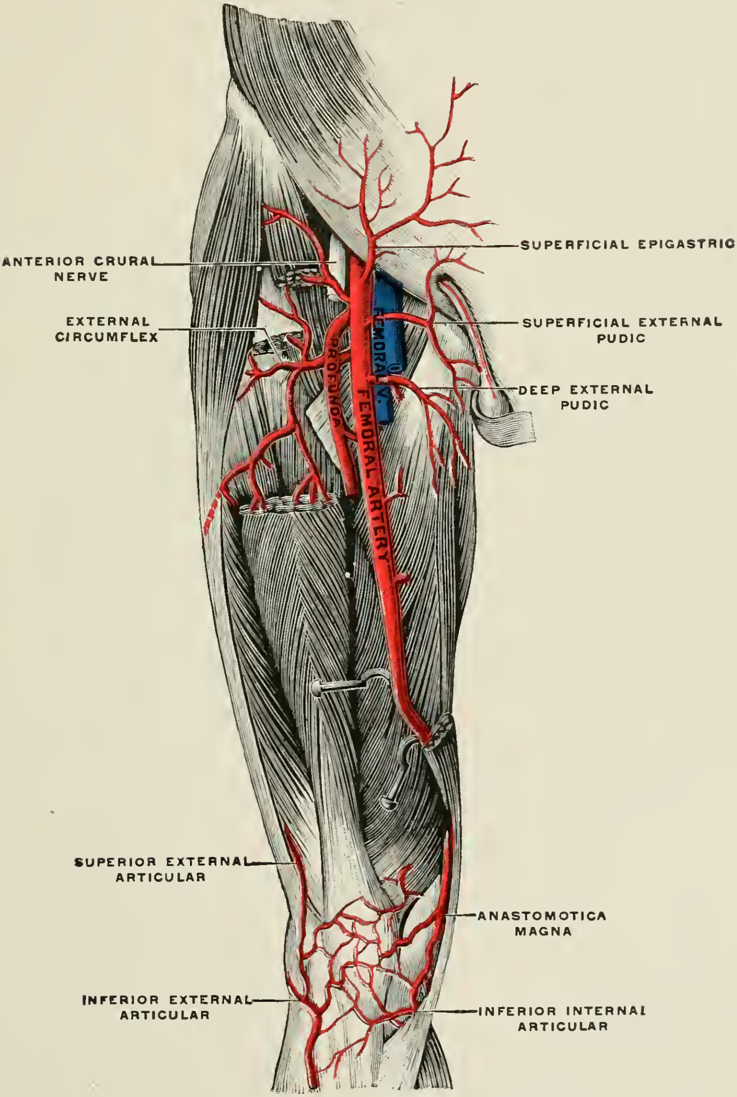

Fig. 125. — Femoral Artery. (Gerrish.)

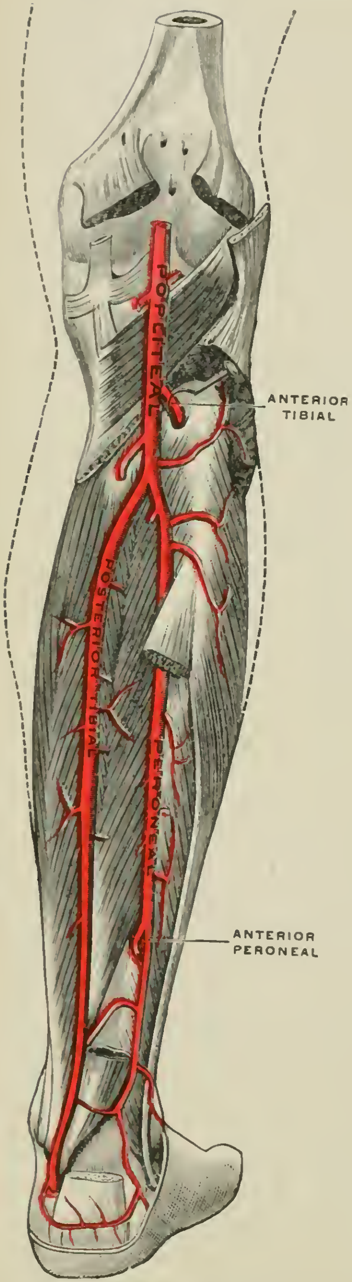

Fig. 126. — Arteries in the Dorsal Part of the Leg. (Gerrish.)

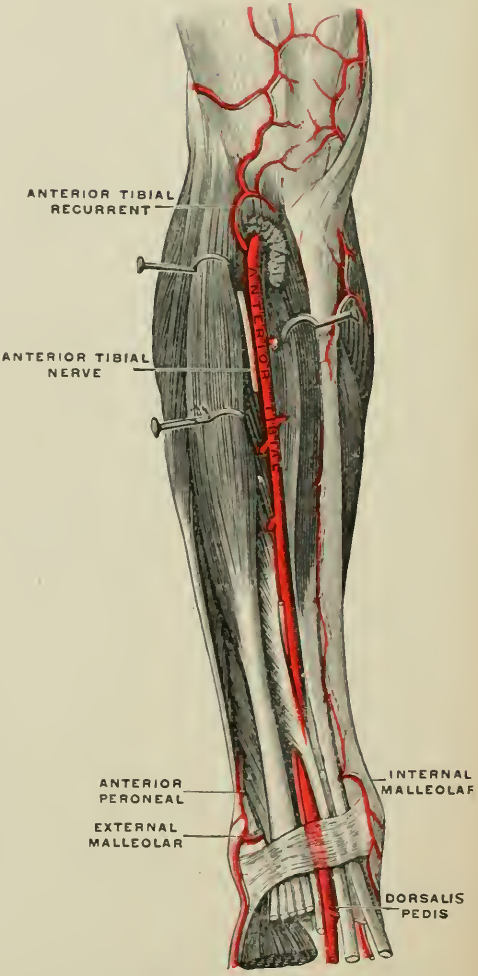

Fig. 127. — Anterior Tibial Artery. (Gerrish.)

as Scarpa's triangle.[1] In this situation the beating of the artery may be felt, and the circulation through the vessel may be most easily controlled by pressure.

The **popliteal** artery, continuous with the femoral, is placed at the back of the knee; just below the knee-joint it divides into the posterior tibial and anterior tibial arteries.

The **posterior tibial** artery lies along the back of the leg, and extends from the bifurcation of the popliteal to the ankle, where it divides into the **internal** and **external plantar** arteries.

The **peroneal** artery is a large branch given off by the posterior tibial just about an inch (25 mm.) below the bifurcation of the popliteal.

The **anterior tibial** artery, the smaller of the two divisions of the popliteal trunk, extends along the front of the leg to the bend of the ankle, whence it is prolonged into the foot under the name of the **dorsalis pedis** artery. This unites with the external and internal plantar arteries to form the **plantar arch** which supplies blood to the foot.[2]

VEINS

The arteries begin as large trunks, which gradually become smaller and smaller until they end in the small capillary tubes, while the veins begin as small branches which at first are scarcely distinguishable from the capillaries, and unite to form larger and larger vessels. They differ from the arteries in their larger capacity, greater number, thinner walls, and in the presence of valves which prevent backward circulation. The veins may be divided into two sets — a superficial and a deep set.

The **superficial set** — are found immediately beneath the skin.

The **deep set** — accompany the arteries and are usually called by the same names.

Sometimes two deep veins accompany an artery, and are then called **venæ comites**, or companion veins, or one single trunk may accompany an artery, and then be known as the **vena comes** of that artery. The superficial and the deep veins have very frequent

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[1] Scarpa's triangle is a name given to a triangular space situated on the upper, anterior, and inner surface of the thigh. It is bounded above by Poupart's ligament, on the outer side by the sartorius muscle, and on the inner side by the adductor.

[2] Drawing the outline of the aorta with its branches as an arterial tree will greatly aid the student in mastering the arterial distribution.

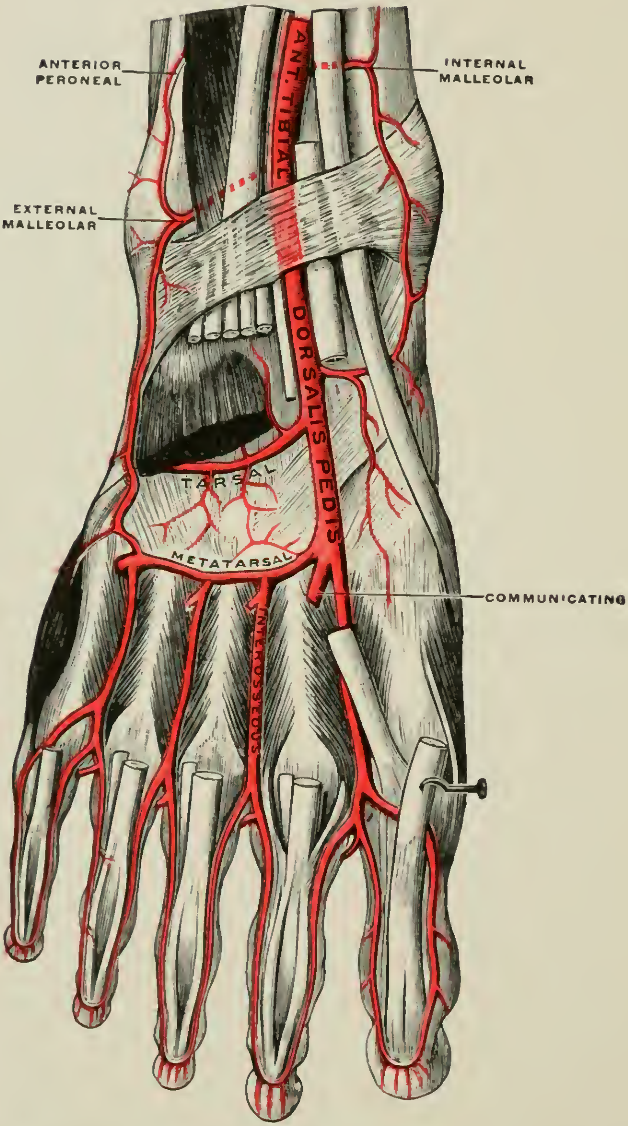

Fig. 128. — Arteries of the Dorsum of the Foot. Of the dorsal interosseous only the second is labelled. (Gerrish.)

communications with each other, and the anastomoses of veins are always more numerous than those of arteries.

The systemic veins. — The systemic veins are naturally divided into two groups: —

1. Those from which the blood is carried to the heart by the **superior vena cava**, viz. the veins of the head, neck, upper extremities, and the walls of the thorax.

2. Those from which the blood is carried to the heart by the **inferior vena cava**, viz. the veins of the lower limbs, the lower part of the trunk, and the abdominal viscera.

Coronary veins. — In this group we may include the veins of the heart, which, however, pass directly into the right auricle without entering the superior vena cava.

Veins of the head and neck. — The blood returning from the head and neck flows on each side into two principal veins, the **external** and **internal jugular.**

External jugular veins. — The right and left external jugular veins are formed in the substance of the parotid glands by the union of two of the veins of the face. This union takes place on a level with the angle of the lower jaw, and each vein descends almost vertically in the neck to its termination in the subclavian. These two veins receive the blood from the face and the exterior of the cranium.

Internal jugular veins. — These veins begin at the base of the skull and descend on either side of the neck, first with the external carotid, then with the common carotid, and join at a right angle with the subclavian to form the innominate (brachio-cephalic) vein. They receive the blood from the veins and sinuses of the cranial cavity. (See Fig. 131.)

Sinuses. — The blood from the interior of the skull is returned to the large veins by venous channels that are called sinuses. They are formed by a separation of the layers of the dura mater, the fibrous membrane which covers the brain. Their outer wall consists of the dura mater, and their inner lining of endothelium is continuous with the lining membrane of the vessels that communicate with them. (See Fig. 184.)

Veins of the upper extremities. — The blood from the upper limbs is returned by a deep and a superficial set of veins. The deep veins are the venæ comites of the forearm and arm and are called by the same names. They communicate with the superficial veins at the hand and elbow, and the vena comes of the brachial artery unites with a superficial vein, *i.e.* the basilic, to form the axillary vein.

The superficial veins. — The superficial veins are much larger than the deep, and take a greater share in returning the blood, especially from the distal portion of the limb. They commence in two plexuses, one on the back of the hand and one on the front of the wrist. They comprise the following: —

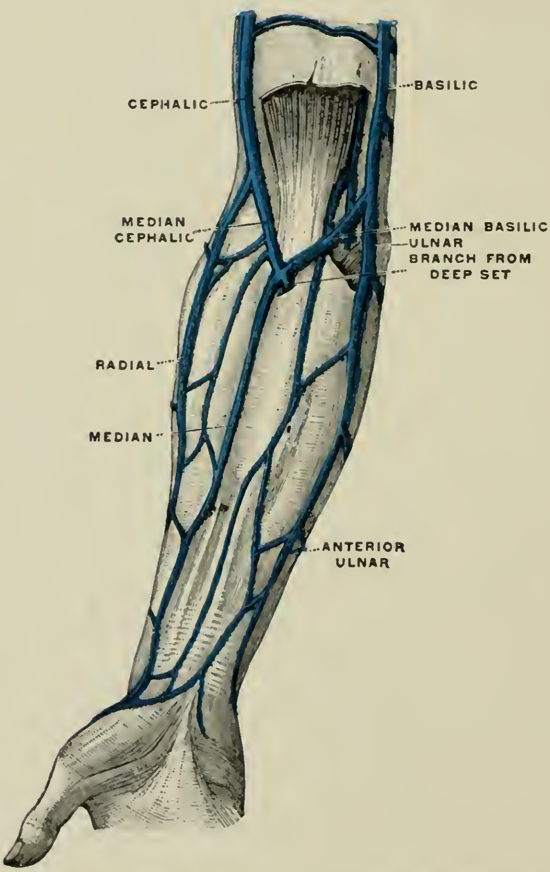

Fig. 129. — Superficial Veins of Front of Forearm and Lower Part of Arm. (Gerrish.)

(1) The **radial** vein begins in the dorsal plexus and runs up the radial side of the forearm to a little above the bend of the

elbow, where it joins the median cephalic vein to form the cephalic.

(2) The **posterior ulnar** begins in the dorsal plexus and extends upward along the back part of the ulnar side of the forearm. Near the bend of the elbow it usually receives the anterior ulnar vein.

(3) The **anterior ulnar** vein ascends from the wrist along the ulnar side of the front of the forearm.

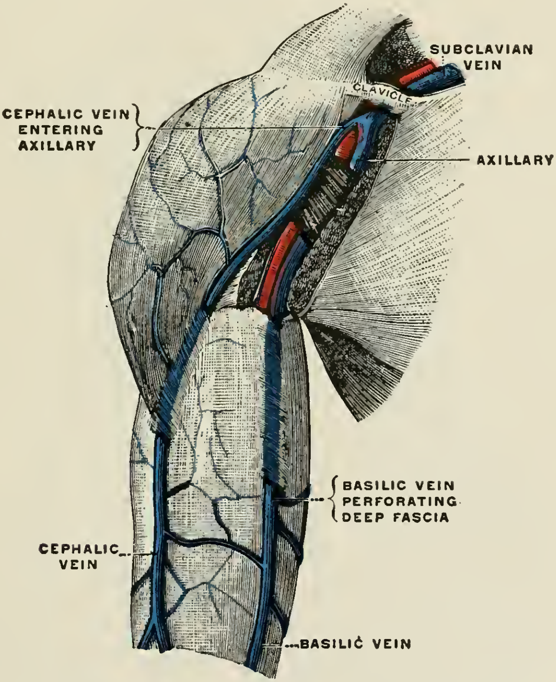

FIG. 130.—SUPERFICIAL VEINS OF FRONT OF ARM AND SHOULDER. (Gerrish.)

(4) The **common ulnar** is formed by the union of the anterior and posterior ulnar veins just below the elbow, and after a short course it joins the median basilic.

(5) The **median** vein begins in the plexus on the wrist and ascends along the front of the forearm to the bend of the elbow, where it bifurcates into the median basilic and median cephalic veins.

(6) The **median basilic** is directed upward and joins the common ulnar to form the basilic vein. The median basilic is the vein

usually chosen for the operation of phlebotomy or intravenous infusion.

(7) The **median cephalic** vein is directed upward and joins the radial vein to form the cephalic.

(8) The **basilic** vein ascends in the groove on the inner side of the biceps. It unites with the inner vena comes of the brachial artery to form the axillary vein.

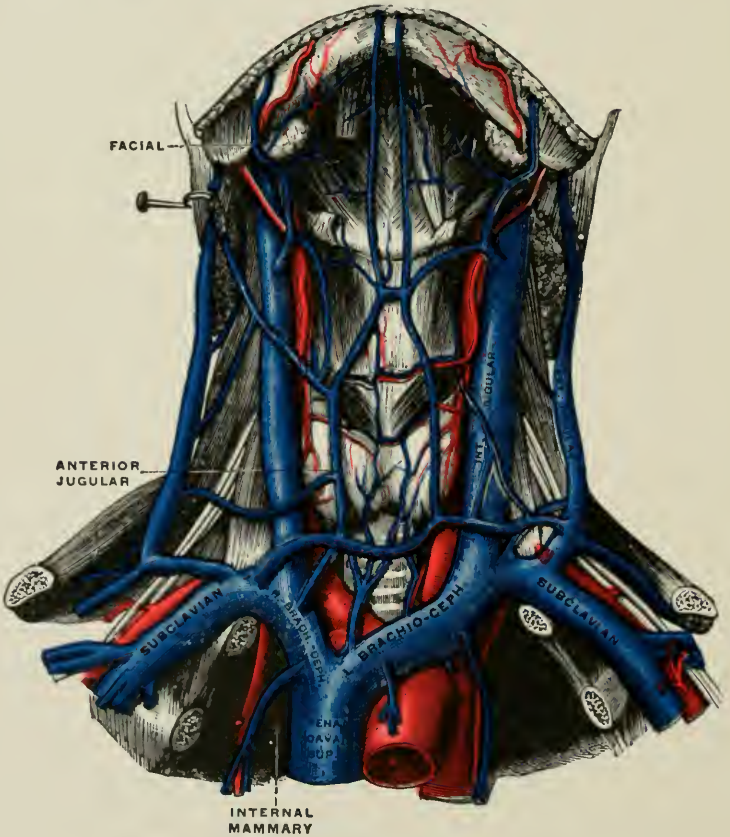

Fig. 131. — Veins of the Neck and Upper Part of Thorax. Front View. (Gerrish.)

(9) The **cephalic** vein ascends in the groove external to the biceps and ends in the axillary vein.

The axillary vein. — The axillary vein begins at the junction of the inner brachial and the basilic, and ends at the outer border of the first rib, in the subclavian. This vein accompanies the axillary artery and collects all the blood of the upper extremities.

The subclavian vein. — This vein continues the axillary from the first rib to the joint between the sternum and clavicle, where it unites with the internal jugular to form the innominate vein.

The innominate veins. — The innominate (brachio-cephalic) veins, commencing on each side by the union of the subclavian and internal jugular, transmit the blood returning from the head and neck, the upper limbs, and a part of the thoracic wall; they end below by uniting to form the **superior vena cava.** Both innominate veins are joined by many side tributaries: they also receive, at the junction of the subclavian and internal jugular, the lymph; on the left side from the thoracic duct, and on the right from the right lymphatic duct.

The superior vena cava. — The superior, or descending, vena cava, is formed by the union of the right and left innominate veins, just behind the junction of the first right costal cartilage with the sternum. It is about three inches (75 mm.) long, and opens into the right auricle, opposite the third rib.

Thoracic veins. — The great majority of the thoracic veins follow the same course as the arteries, and bear the same names. Two exceptions are the inferior vena cava and the azygos veins which will be described later.

Veins of the lower extremities. — The blood from the lower limbs is also returned by a deep and a superficial set of veins. They are more abundantly supplied with valves than the veins of the upper limbs.

The deep veins. — Below the knee the deep veins accompany the arteries in pairs, as venæ comites, and as in the upper limbs are called by the same names. The veins from the foot empty into **anterior tibial** and **posterior tibial** veins. They unite to form the single **popliteal** vein, which is continued as the **femoral** and becomes the **external iliac.**

The superficial veins. — The internal or long saphenous and the external or short saphenous are the two largest superficial veins.

The **internal saphenous** extends from the ankle to within an inch and a half (38 mm.) of the inguinal ligament. It lies along the inner side of the leg and thigh and terminates in the femoral vein.

The **external saphenous** arises from the sole of the foot, and, passing up the back of the leg, ends in the deep popliteal.

The femoral veins. — These vessels are a continuation of the

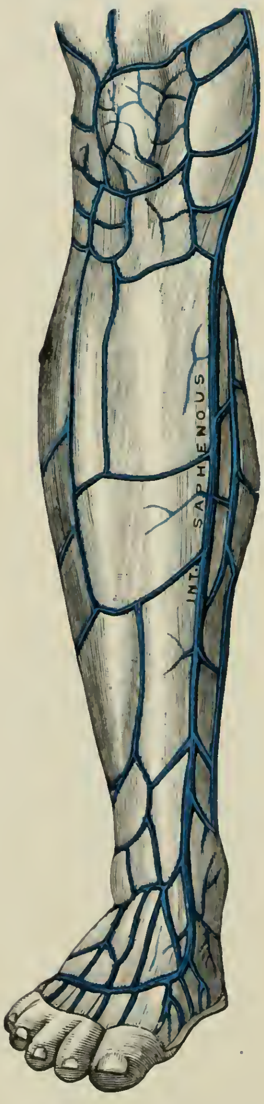

FIG. 132. — SUPERFICIAL VEINS OF THE FRONT OF THE LEG AND FOOT. (Gerrish.)

FIG. 133. — SUPERFICIAL VEINS OF THE FRONT OF THE RIGHT THIGH. (Gerrish.)

popliteal veins and extend from the opening in the adductor magnus to the level of the inguinal ligament.

The external iliacs. — These vessels are a continuation of the femoral veins, and extend from the level of the inguinal (Poupart's) ligament, on either side to the joint between the sacrum and the ilium. They receive the blood from the deep and superficial veins of the lower limbs.

The internal iliacs. — They are formed by the union of veins corresponding to the branches of the internal iliac arteries. They accompany the internal iliac arteries and unite with the external iliac veins to form the common iliacs.

The common iliacs. — The common iliacs extend from the base of the sacrum to the fourth lumbar vertebra, and then the two common iliacs unite to form the inferior vena cava.

The inferior vena cava. — The inferior, or ascending, vena cava, returns the blood from the lower limbs, pelvis, and abdomen. It begins at the junction of the two common iliacs, and thence ascends along the right side of the aorta, perforates the diaphragm, and terminates by entering the right auricle of the heart. The inferior vena cava receives many tributaries, the chief of which are the lumbar, ovarian, renal, and hepatic veins.

Supplementary channel. — A supplementary channel between the inferior and superior vena cava is formed by the azygos veins. They are three in number and lie on the sides of the front of the vertebral bodies.

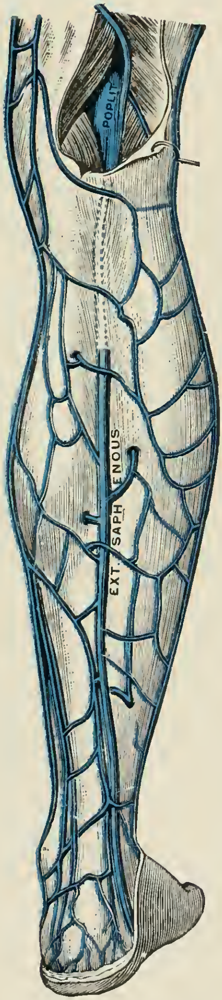

Fig. 134. — Superficial Veins of the Dorsum of the Leg. (Gerrish.)

The **right** or **great azygos** vein is an upward continuation of the lumbar vein which communicates with the common iliac vein, and often with the inferior vena cava and renal vein. It ascends on the right side of the vertebral column to the level of the fourth thoracic vertebra, where it empties into the superior vena cava.

The **left lower azygos** vein commences on the left side of the abdomen in a manner similar to the right. It ascends on the left side of the vertebral column, and at about the level of the eighth thoracic vertebra it connects with the right azygos vein.

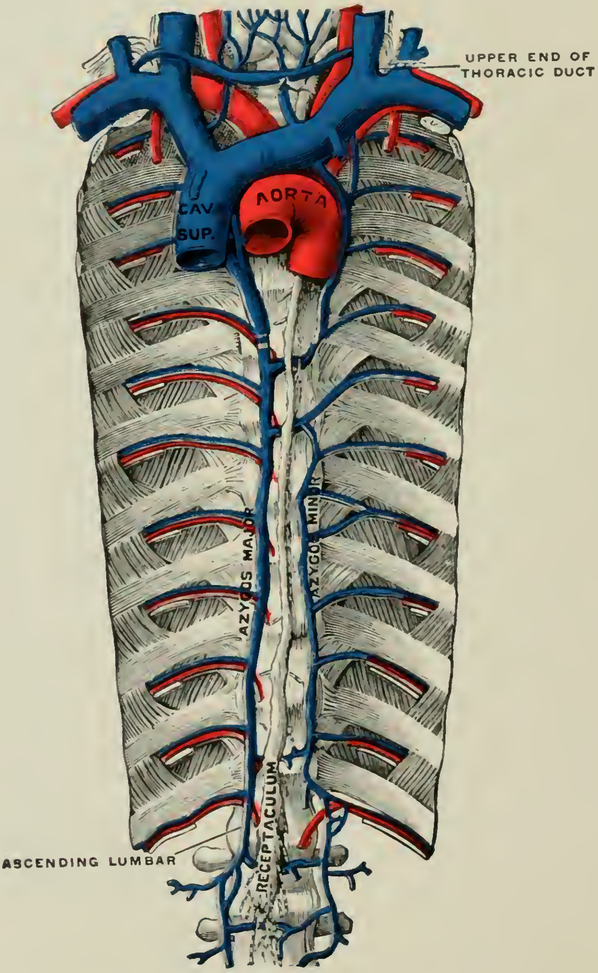

Fig. 135. — Azygos and Intercostal Veins. (Gerrish.)

The **left upper azygos** vein connects above with the superior intercostal vein, and opens below into either the left lower azygos,

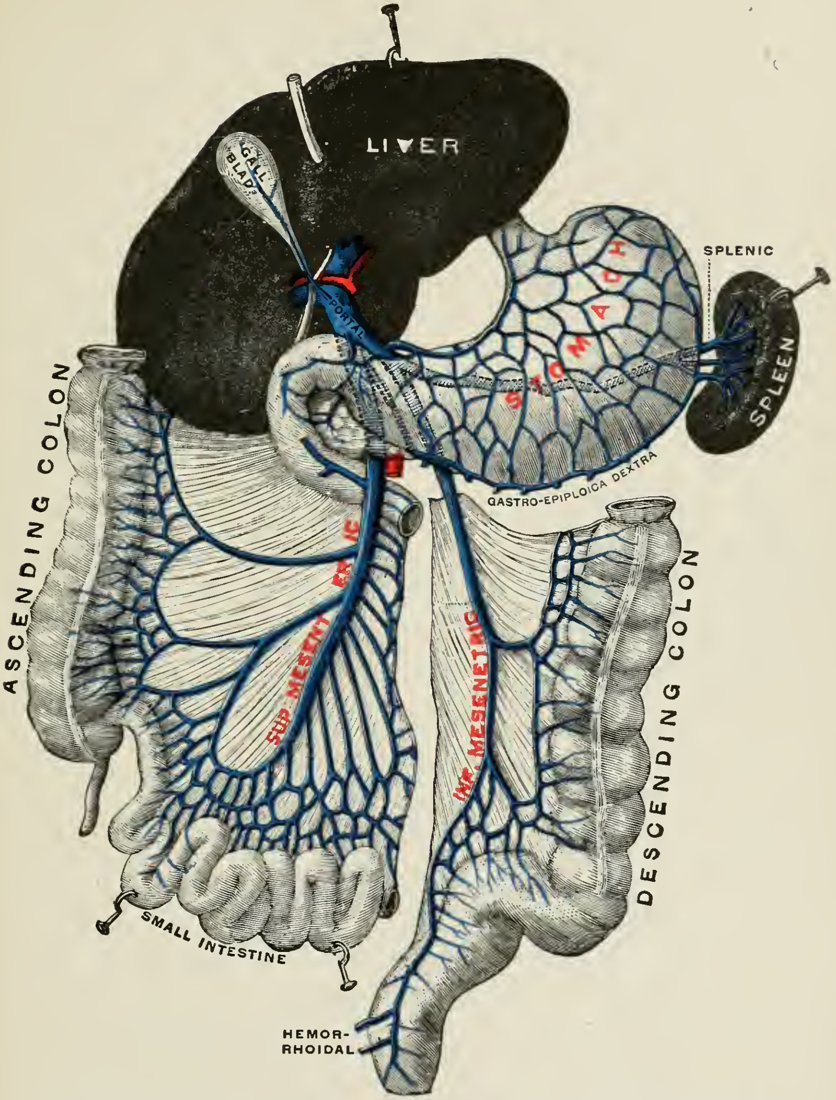

FIG. 136. — PORTAL SYSTEM OF VEINS. The liver is turned upward and backward, and the transverse colon and most of the small intestines are removed. (Gerrish.)

or the great azygos vein. These veins receive many tributaries from the thoracic walls and so are often grouped with the thoracic veins.

It is important to remember that they form a supplementary channel by which blood can be conveyed from the lower part of the body to the heart in case of obstruction in the inferior vena cava.

The portal system. — The gastric, splenic, inferior and superior mesenteric veins which bring back the blood from the intestinal tract do not take it directly to the inferior vena cava. Just back of the pancreas, the splenic and superior mesenteric unite to form the portal vein, and the gastric and inferior mesenteric empty into it. The portal vein runs upward and to the right for about three inches, then enters the liver, where it divides into many small veins, and these finally form plexuses of capillaries. These capillaries unite with another set of capillaries which arise from the hepatic artery, and form the hepatic vein, which carries the blood from the liver to the inferior vena cava. Thus it will be seen that the liver receives blood from two sources — (1) the portal vein which carries blood to the liver in order that certain chemical changes may take place, and (2) the hepatic artery which carries blood to the liver for nutritive purposes. The blood from both sources of supply is carried from the liver by the hepatic vein.

The portal vein and all its branches constitute the portal system, which is often described as a third or accessory system.

SUMMARY

- **Arteries**
  - Begin as large trunks, grow smaller.
  - Usually deep seated for protection.
  - Division
    - Two branches of nearly equal size.
    - Trunk gives off several branches.
    - One branch that serves as an axis.
  - Anastomosis or inosculation — distal ends unite.
  - Plexus — many inosculations within limited area.
  - Usually straight (facial and uterine are tortuous).
- **Divisions of the Vascular System**
  - **Pulmonary System**
    - Provides for pulmonary circulation.
    - 1. Pulmonary artery
      - Right pulmonary artery — right lung.
      - Left pulmonary artery — left lung.
    - 2. Capillaries.
    - 3. Four pulmonary veins — two from each lung.
  - **General System**
    - Provides for systemic circulation.
    - 1. Aorta and all its branches.
    - 2. Capillaries.
    - 3. Veins empty into heart either directly or by means of inferior and superior vena cava.

- **Aorta**
  - **Ascending Aorta**
    - Right and left coronary — supply the heart.
  - **I. Arch of Aorta**
    - Innominate 1 to 2 in.
      - Right common carotid
        - Int. carotid — brain and eye.
        - Ext. carotid—throat, tongue, face, ears, walls of cranium.
      - Right subclavian, — axillary — brachial
        - Ulnar
          - Superficial palmar arch.
        - Radial
          - Deep palmar arch.
    - Left common carotid — same branches as right common carotid.
    - Left subclavian — same branches as right subclavian.
  - **II. Thoracic Aorta 7 to 8 in.**
    - Intercostal — to the intercostal spaces.
    - Pericardial — to the pericardium.
    - Bronchial — to the lung tissue.
    - Œsophageal — to the œsophagus.
    - Posterior mediastinal — to the lymph nodes between the lungs.
  - Diaphragm muscle is dividing line between thoracic and abdominal aorta.
  - **III. Abdominal Aorta 5 in.**
    - **Visceral Group**
      - Cœliac axis
        - Gastric — stomach.
        - Hepatic — liver and duodenum.
        - Splenic — spleen, stomach, and pancreas.
      - Sup. mesenteric
        - Small intestine except duodenum.
        - Half of large intestine.
      - Inf. mesenteric
        - Lower half of large intestine and rectum.
      - Renal — kidneys.
      - Supra-renal — supra-renal bodies.
      - Spermatic — testes.
      - Ovarian — ovaries and uterus.
    - **Parietal Group**
      - Phrenic — diaphragm.
      - Lumbar — dorsal, spinal, and abdominal walls.
      - Middle sacral — sacrum and coccyx.

- **Common Iliac Arteries 2 in.**
  - Internal iliac — walls and viscera of pelvis.
  - External iliac — femoral — popliteal
    - Posterior tibial
      - Ext. plantar } Plantar arch.
      - Int. plantar } Plantar arch.
      - Peroneal.
    - Anterior tibial
      - Dorsalis pedis.

- **Veins**
  - Begin small, grow larger.
  - Differ from arteries
    - Larger capacity.
    - Greater number.
    - Thinner walls.
    - Valves.
    - More frequent anastomosis.
  - Sets
    - Superficial.
    - Deep
      - Venæ comites — companion veins.
      - Vena comes — companion vein.

- **External Jugular Veins**
  - Receive blood from the face and the exterior of the cranium.
  - Formed in parotid gland, terminate in the subclavian.

- **Internal Jugular Veins**
  - Receive blood from the veins and sinuses of the cranial cavity.
  - Begin at base of skull, unite with subclavian.

- **Axillary Veins**
  - (1) Receive blood from the deep veins of the forearm and arm.
    They accompany the arteries and are called by the same names.
  - (2) Receive blood from superficial veins
    - Radial.
    - Posterior ulnar.
    - Anterior ulnar.
    - Common ulnar.
    - Median.
    - Median basilic.
    - Median cephalic.
    - Basilic.
    - Cephalic.
  - Formed by union of the inner brachial and basilic, end in the subclavian.

- **Subclavian Veins**
  - Continuation of axillary from first rib to the joint between the sternum and clavicle.
  - Unite with internal jugular to form innominate.

- **Innominate Veins**
  - Transmit blood from head, neck, upper limbs, and part of thoracic wall. Receive lymph.
  - Formed by union of internal jugular and subclavian.
  - One on each side of body.

Superior Vena Cava
- Formed by union of right and left innominate veins. Three inches long.
- Opens into right auricle.

Thoracic Veins — Majority follow same course and bear same name as arteries.

Femoral Veins
- Continuation of the popliteal and extend from opening in adductor magnus muscle to the inguinal ligament.
- (1) Receive blood from deep veins of foot, leg, and thigh. They accompany the arteries and are called by the same names.
- (2) Receive blood from the superficial veins, two are important
  - Internal saphenous.
  - External saphenous.

External Iliacs
- Continuation of femoral veins. Extend from inguinal ligament to the joint between sacrum and ilium.

Internal Iliacs
- Formed by union of veins corresponding to branches of internal iliac artery.

Common Iliacs
- Formed by union of external and internal iliacs. Extend from base of sacrum to the fourth lumbar vertebra.

Inferior Vena Cava
- Formed by union of the common iliacs.
- Extends from fourth lumbar vertebra to the right auricle of the heart.
- Receives many tributaries corresponding to arteries given off from the aorta.

Supplementary Channel
- 1. Right azygos vein
- 2. Left lower azygos vein
- 3. Left upper azygos vein
  - Connect with superior vena cava above, and inferior vena cava below.

Portal Circulation
- **Portal Vein**
  - Splenic vein and superior mesenteric vein — Unite to form portal vein.
  - Gastric vein and inferior mesenteric vein — Empty into the portal vein before it enters the liver.
  - Carries blood to liver, breaks up into capillaries, then unites with capillaries from hepatic artery to form hepatic vein.
- **Hepatic Vein** — empties into inferior vena cava.

CHAPTER XII

THE VASCULAR SYSTEM CONTINUED: THE GENERAL CIRCULATION; BLOOD PRESSURE; THE PULSE; LYMPH; FŒTAL CIRCULATION

THE GENERAL CIRCULATION OF THE BLOOD

To trace the general circulation, we will begin with the venous blood, which is returned to the right auricle by the superior and inferior venæ cavæ. It enters and fills the right auricle, and beyond into the right ventricle, then the auricle contracts and forces the blood over the open tricuspid valve into the ventricle, which has already been passively filled, and now becomes well distended by the extra supply of blood. Almost instantly the ventricle contracts, the blood gets behind the cusps of the tricuspid valve and closes them, and thus is forced over the open semilunar valves into the pulmonary artery. The pulmonary artery divides into two branches and carries the blood to the lungs, where it passes through the innumerable capillaries that surround the alveoli or air sacs of the lungs. These capillaries unite to form veins, and these unite to form larger veins, until finally two pulmonary veins return the blood from each lung to the left auricle. The left auricle now contracts and forces the blood over the open bicuspid valve into the left ventricle, just as described for the right side of the heart. Upon contraction of the left ventricle the bicuspid valve is closed (in the same way as the tricuspid), and the blood is forced over the open semilunar valve into the aorta to be carried through the body. As soon as the ventricles relax the semilunar valves are closed by the excessive pressure within the pulmonary artery and the aorta. From the aorta and its branches the blood travels in the capillaries to every part of the body. The capillaries unite to form veins, and finally the blood is returned by means of the venæ cavæ to the right auricle, which brings it back to where we started from.

The pulmonary circulation. — The lesser circulation from the right ventricle to the left auricle is called the pulmonary circulation. The purpose of the pulmonary circulation is to carry the blood which has been through the system, giving up oxygen and collecting carbon dioxide, to the air sacs of the lungs, where the

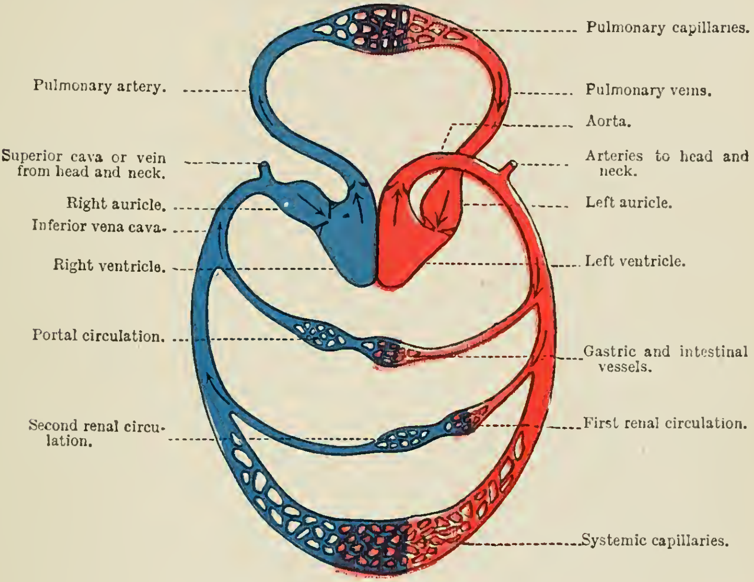

FIG. 137. — DIAGRAM OF THE CIRCULATION. (Halliburton.)

red corpuscles are recharged with oxygen, and the carbon dioxide is reduced to a standard amount.

The systemic circulation. — The more extensive circulation, from the left ventricle to all parts of the body, and the return to the right auricle, is known as the systemic circulation. The purpose of the systemic circulation is to carry oxygen and nutritive substances to all parts of the body, and gather up waste products.

This double circulation, pulmonary and systemic, is constantly and simultaneously going on, as each half of the heart is in a literal sense a force pump. The contraction of both ventricles drives a certain quantity of blood, probably amounting to six ounces, with great force into both the aorta and pulmonary artery.

Factors governing circulation. — The perfect circulation of the blood is dependent upon certain factors, the chief of which are: (1) the heart-beat, (2) the elasticity and extensibility of the arterial walls, (3) the position and direction of the valves, (4) the large number and small bore of the capillaries, and (5) the large size and non-contractile character of the walls of the veins.

(1) **Heart-beat.** — So long as life lasts, the muscular tissue of the heart contracts and relaxes unceasingly with a short interval of rest.

The contractions of the heart are rhythmical; that is to say, they occur in a certain order. First, there is a simultaneous contraction of the walls of both auricles; immediately following this, a simultaneous contraction of both ventricles; then comes a pause, or period of rest, when the cycle is repeated.

The state of contraction is called the **systole.**

The state of dilation, or rest, is called the **diastole.** During the diastole, or period of rest, the blood is flowing into the auricles and beyond into the ventricles (the auriculo-ventricular valves being open). Then the auricles and ventricles contract again in the same order as before, and their contractions are followed by the same pause as before.

The rhythmical succession of the systole and diastole constitutes a cardiac cycle and corresponds to one beat or pulsation of the heart. Reckoning on the number of heart-beats as 72 per minute, the time required for a cardiac cycle will be about 0.8 of a second, and half of this, or 0.4 of a second, represents the diastole or period of rest.

The sounds of the heart. — If the ear be applied over the heart, certain sounds are heard, which recur with great regularity. The first sound is a comparatively long, booming sound; the second, a short, sharp, sudden one. The sounds resemble the syllables **lubb-dup.** The causes which produce the first sound are supposed to be the closure of the auriculo-ventricular valves, the contraction of the ventricles, and the cardiac impulse against the chest wall. The second sound is caused by the closure of the semilunar valves. The first sound is heard best at the apex; the second sound is heard best at the base.

In certain diseases of the heart these sounds become changed and obscure, and are accompanied by various distinctive and characteristic sounds called **murmurs.**

Cause of the heart-beat. — The beat of the heart is caused by the rhythmical contractions of its muscular fibres. These contractions are automatic, and do not depend upon the central nervous system. That the contractions of the heart do not depend upon the nervous system is certain, for the heart will continue to beat for some time after its removal from the body. It probably depends upon a power inherent in the muscle tissue, and this power is most highly developed in the wall of the right auricle between the openings of the two venæ cavæ. Contractions seem to start in this area and pass first over the walls of the auricles, and thence over the walls of the ventricles. It is thought that the contractions are stimulated by the chlorides of sodium, potassium, and calcium contained in the blood.

Innervation of the heart. — As previously stated, the heart receives inhibitory nerve fibres from the pneumogastric nerve, and accelerator fibres from the sympathetic system. Both the inhibitory and accelerator fibres are in a state of constant, though slight, activity. This means that under normal conditions the heart-beat is controlled by two antagonistic influences, one tending to slow the heart action, and the other to quicken it. This arrangement is comparable to the antagonistic action of the flexor and extensor muscles and probably enables the heart to respond more promptly to stimulation. Stimulation of the pneumogastric may cause marked slowing of the heart-beat, and depression of the pneumogastric, or stimulation of the accelerator fibres, may quicken the heart-beat.

(2) **The elasticity and extensibility of the arterial walls.** — Each time the ventricles contract they force about six ounces of blood into arteries that are already full. This extra blood finds room for itself partly by distending the arteries and partly by driving forward the blood which is before it. The arteries are capable of distention because they contain a large amount of yellow elastic tissue in their coats. Following the distention the arteries recoil upon the contained blood and cause such a pressure to be exerted, that what would be an intermittent stream is converted into a continuous one. They thus serve not only as conducting tubes but exert a force that assists the heart in driving the blood into the capillaries.

The elasticity and extensibility of the arteries change with the health and age of the individual. Sometimes as the result of disease, and always as we grow older, the arterial walls grow stiffer and more rigid, and become less well adapted for the unceasing work they are called upon to perform. This condition is known as arteriosclerosis.

(3) **The position and direction of the valves.** — The position and direction of the tricuspid and bicuspid valves permit the ventricles to fill during their period of relaxation, and prevent the backward flow when they are emptying themselves. The aortic and pulmonary valves allow blood to pass out during each contraction of the ventricles, but not to return from either artery into the heart when the resting stage ensues. The valves also show signs of age as years advance, and even if not injured by disease, do not adjust themselves so perfectly as in early life.

(4) **The large number and small bore of the capillaries.** — The total number of capillaries is so immense that, even though each individual one is small, their total capacity is several hundred times greater than that of the aorta. This is due to the fact that each time an artery divides, the total capacity of its branches is greater than that of the parent artery, although each of the individual branches is of smaller calibre. In this way the bed of the blood stream is becoming greater until we reach the capillaries, and then it is increased enormously. The effect of this arrangement is to make the blood flow rapidly through the larger arteries, more slowly in the smaller and more numerous arteries, and slowest of all in the capillaries.

(5) **The large size and non-contractile character of the walls of the veins.** — In the case of the veins the conditions we have described are reversed. The size and capacity of a vein is always less than the size and capacity of its tributaries, hence the total bed of the blood stream is becoming continually smaller but never so small as in the corresponding arteries. A vein is always twice the size, often more than twice the size, of the corresponding artery. On leaving the capillaries the blood flows faster because the bed of the stream becomes narrower, but its speed in a vein is little more than half that in a corresponding artery, because the bed is twice as great. The veins contain very little elastic tissue in their walls, hence they are not capable of distention and contraction as the arteries are. As the blood flows in a steady stream, and the diameter of the veins is large, the non-contractile character of the walls offers no resistance to the flow of blood toward the

heart. The valves of the veins also render assistance in this respect.

Rate of blood flow. — The rate at which the blood flows is highest in the arteries, about twelve inches to a second. It is lower in the veins, about eight inches to a second. In the capillaries it is exceedingly slow, about an inch to a minute. When it is remembered that the actual service of the blood to the tissues is rendered in the capillaries (since the walls of the arteries and veins are too thick to permit of diffusion) the value of the slow passage is obvious.

Distribution of blood. — We have quoted the estimate of blood that the body contains as four quarts. During a period of rest about one-fourth of this may be assumed to be in the thorax, one-fourth in the skeletal muscles, one-fourth in the liver, and the remaining fourth elsewhere. Activity of any part of the body will increase the supply to that part, and lessen the supply in another part. When the digestive organs are active, other parts of the body are kept short of blood, but any condition that dilates the vessels of the skin will lessen the amount of blood sent to the digestive organs.

BLOOD PRESSURE

By blood pressure is meant the pressure the blood exerts against the walls of the vessels in which it is contained. The term includes arterial, capillary, and venous pressure.

Arterial pressure. — When an **artery** is severed, the flow of blood from the **proximal** end (that on the heart side) comes in jets corresponding to the heart-beats, provided the artery be near the heart. The larger the artery, and the nearer to the heart, the greater the force with which the blood issues, and the more marked the intermittence of the flow. This indicates that the blood in the arteries is under a high pressure, and the factors which produce and maintain this pressure are: —

1. The force of the contraction of the ventricles.

2. The extra supply of blood which the heart forces into arteries that are already full.

3. The semilunar valves which prevent regurgitation of the blood into the ventricles, when the ventricles relax.

4. The elasticity of the arteries, which enables them to dilate to receive the extra supply of blood, then to contract.

5. The resistance offered by the arterioles.

6. The increased surface over which the blood flows in the capillaries.

When the blood leaves the left ventricle the high pressure which it exerts against the wall of the aorta may be regarded as a measure of energy. This energy is transformed into heat in overcoming the friction encountered in the vessels. When the blood reaches the arterioles, the surface is multiplied and the friction increased. This offers an impediment to the flow, and the result is a decided drop in the pressure.

Arterial pressure is not uniform, but varies (1) with the systole and diastole of the heart, being greater during the systole; (2) it is less in youth, and increases as we grow older, because the arteries are less elastic; (3) conditions of health may affect the normal muscular tone of the arteries and heart. When the arteries lose their tone, or the heart-beat loses its force, the blood pressure is low. When the arteries are over-constricted, or the heart over-stimulated, the blood pressure is high.

Capillary pressure. — The pressure of blood in the capillaries is much lower than in the arteries, but is high considering the thickness of the capillary walls. It depends upon the condition of the arterioles: if they dilate, the capillary pressure rises; if they constrict, the capillary pressure falls. The phenomena produced by these local variations in the blood supply of certain parts are very familiar to us: the redness of the skin produced by an irritating application, the blushing or paling of the face from mental emotion, the increased flow of blood to the mucous membranes during digestion, being all instances of this kind.

Venous pressure. — When a **vein** is severed, the flow of blood, which is chiefly from the **distal** end (that away from the heart), is not intermittent, but continuous; the blood comes out with comparatively little force, and "wells up" rather than "spurts out." This indicates that the blood pressure in the veins is low. It is influenced by: —

1. The presence of valves which prevent a backward flow.

2. Respiration. The effect of inspiration is to suck venous blood into the thorax, empty the large veins, and cause a fall in the blood pressure. The effect of expiration is to offer a slight resistance to the flow of blood into the thorax and thus raise the blood pressure in the large veins.

Method of determining blood pressure. — We can gain some idea of the blood pressure by placing the fingers over a large artery where the pulsation can be felt. If the vessel is tense and hard to compress, it indicates high blood pressure. If, however, it is easy to obliterate the pulsation by pressure of the fingers, the blood pressure is low. Of late years several forms of apparatus have been devised by which a more accurate knowledge can be obtained. This apparatus is called a sphygmomanometer, and consists of an air pump which is connected by means of an inverted T (⊥) shaped rubber tubing with an elastic bag covered on the outside by a leather cuff, and a mercury manometer.

The elastic bag covered with the cuff is buckled snugly around the arm above the elbow. The bag is blown up by means of the air pump and exerts pressure upon the brachial artery until no pulsation can be felt in the radial artery at the wrist. The amount of pressure that is being exerted upon the arm is indicated by the mercury manometer, and should be read the moment the pulse disappears. This will give the maximum or systolic pressure. As the pressure on the arm is lowered, the pulse reappears, and the lowest position of the mercury gives the minimum or diastolic pressure.

Normal degree of blood pressure. — The average normal degree of blood pressure exerted on the walls of the brachial artery is about 110 to 116 mm. systolic; and 65 to 75 mm. diastolic. Pressure varies with age, and even in health is not constantly the same. Increase of the force or rate of the heart-beat increases the pressure. The effect of cold, also of certain drugs, *e.g.* adrenalin, is to constrict the arteries and raise the blood pressure. On the other hand the effect of heat, and of some drugs, *e.g.* amyl nitrite, is to dilate the arteries and lower the blood pressure.

THE PULSE

When the finger is placed on an artery, a sense of resistance is felt, and this resistance seems to be increased at intervals, corresponding to the heart-beat, the wall of the artery at each heart-beat being felt to rise up or expand under the finger. This alternate contraction and expansion of the artery constitutes the pulse; and in certain arteries which lie near the surface this pulse may be seen with the eye. When the finger is placed on a vein, very little resistance is felt; and, under ordinary circumstances, no pulse can be perceived by the touch or by the eye.

As each expansion of an artery is produced by a contraction of the heart, the pulse, as felt in any superficial artery, is a convenient guide for ascertaining the character of the heart's action.

Locations where the pulse may be felt. — The pulse may be counted wherever an artery approaches the surface of the body. These locations are: —

(1) The **facial** artery, where it passes over the lower jawbone.

(2) The **temporal** artery, above and to the outer side of the outer canthus of the eye.

(3) The **brachial** artery, along the inner side of the biceps muscle.

(4) The **radial** artery, on the thumb side of the wrist. On account of its accessible situation the radial artery is usually employed for this purpose.

(5) The **femoral** artery, where it passes over the pelvic bone.

(6) The **dorsalis pedis**, on the dorsum of the foot.

Points to note in feeling a pulse. — In feeling a pulse the following points should be noted.

(1) **Frequency**, or the number of pulse-beats per minute.

(2) **Strength**, or the force of the heart-beat.

(3) **Regularity**, or the same number of beats per minute.

(4) **Equality**. — Each beat should have the same force, not some strong and some weak. It sometimes happens that a beat is missed because the heart-beat is too weak to distend the artery. This is called an **intermittent** pulse.

Occasionally there is a lack of tone in the arterial walls and a **dicrotic** pulse is felt. This means that the pulsations are divided and the second part of the beat is weaker than the first.

(5) **Tension** or the strength of the blood pressure. This is indicated by the amount of force that is required to obliterate the pulse.

Average frequency of the pulse. — The average frequency of the pulse in man is seventy-two beats per minute. This rate may be increased after eating or by muscular action. Even the variation of the muscular effort entailed between the standing, sitting, and recumbent positions will make a difference in the frequency of the pulse of from eight to ten beats per minute. Mental excitement may also produce a temporary acceleration, varying in degree with the peculiarities of the individual. Age has a marked influence. At **birth** the pulse rate is about 130 per minute; at three years, 100; in adult life, 72; in old age, 65. It is somewhat more rapid in women than in men and is lowered during sleep. Idiosyncrasies are frequently met with. A person in perfect health may have a much higher or a much lower rate than 72. The relative frequency of the pulse and respirations is about four heart-beats to one respiration.

As a rule, the rapidity of the heart's action is in inverse ratio to its force. An infrequent pulse, within physiological limits, is usually a strong one, and a frequent pulse comparatively feeble. The same is true in disturbance of the heart's action in disease, the pulse in fever or debilitating affections becoming weaker as it grows more rapid.

LYMPH

Formation of lymph. — The lymph is derived from the blood in the capillaries, but the exact process is still an open question. It is considered probable that it is partly a process of transudation which depends on the permeable nature of the walls of the capillaries, and partly the result of a secretory process on the part of the endothelial cells lining the capillaries. The transudation theory is supported by the fact that the blood in the capillaries is under greater pressure than in the arteries or veins. The secretory process is supported by the chemical differences between the blood and the lymph.

Factors controlling the flow of lymph. — The onward progress of the lymph from the tissues to the veins is maintained chiefly by three things.

(1) **Differences in pressure.** — The lymph in the tissue spaces is under greater pressure than the lymph in the lymph capillaries, and the pressure in the large lymphatics near the ducts is much less than in the smaller vessels. Consequently we may consider that the lymphatics form a system of vessels leading from a region of higher pressure, viz. the lymph spaces of the tissues, to a region of lower pressure, viz. the interior of the large veins of the neck.

(2) **Muscular movements and valves.** — The muscular movements of the body compress the lymphatics and force the lymph

on in the proper direction. The numerous valves prevent a return flow in the wrong direction.

(3) **Respiration.** — During each inspiration the pressure on the thoracic duct is less than on the lymphatics outside the thorax, and the lymph is accordingly "sucked" into the duct. During the succeeding expiration the pressure on the thoracic duct is increased, and some of its contents, prevented by the valve from escaping below, are pressed out into the innominate veins.

Œdema. — The lymph in the various lymph spaces of the body varies in amount from time to time, but under normal circumstances never exceeds certain limits. Under abnormal conditions, these limits may be exceeded, and the result is known as œdema, or dropsy. Similar excessive accumulations may also occur in the larger lymph spaces, the serous cavities.

Among the possible causes of œdema are: —

(1) An obstruction to the flow of lymph from the lymph spaces.

(2) An excessive transudation, the lymph gathering in the lymph spaces faster than it can be carried away by a normal flow.

Œdema is almost always due to the latter cause, viz. excessive transudation.

FŒTAL CIRCULATION

Certain structures are necessary to the performance of fœtal circulation, but are of no use after birth. They are as follows: —

(1) **Foramen ovale.** — An opening between the two auricles. It furnishes direct communication between them.

(2) **Ductus arteriosus.** — A blood-vessel connecting the aorta and pulmonary artery.

(3) **Ductus venosus.** — A blood-vessel connecting the umbilical vein and the inferior vena cava.

(4) **The placenta and umbilical cord.** — By means of the placenta the child is nourished and obtains oxygen. The cord is made up of two arteries and one large vein protected by "Wharton's jelly." The vein carries the oxygenated blood from the placenta to the fœtus. The arteries carry the impure blood from the fœtus to the placenta. After birth these structures are of no further use. It is important that the "foramen ovale" should close as soon as the child breathes, else if the arterial and venous blood continue to mix, a "**blue baby**" will be seen.

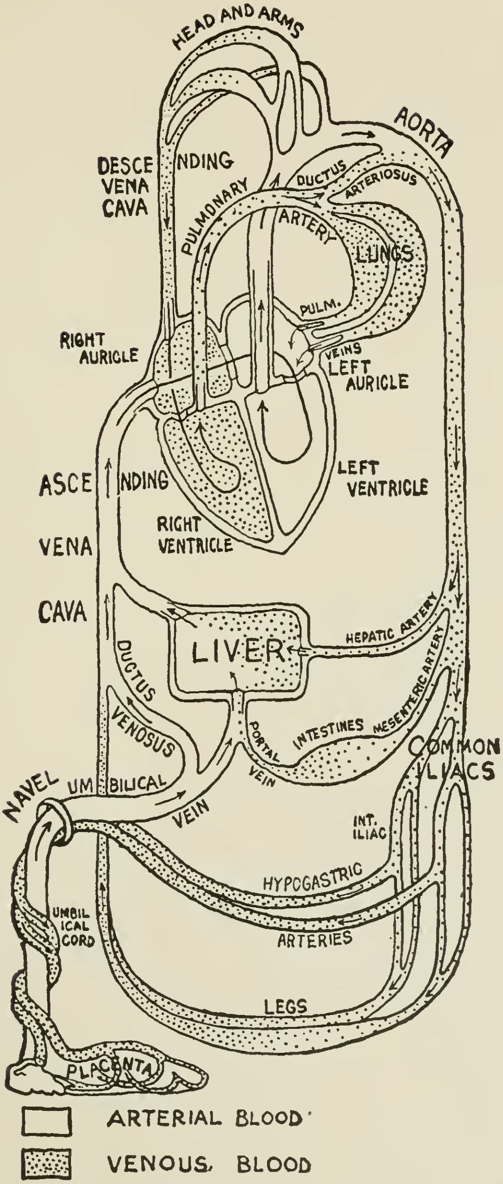

Fig. 138. — Diagram of Circulation before Birth. Fœtal type. (Cooke.)

Course of the blood. — The oxygenated blood for the nutrition of the fœtus is carried from the placenta along the umbilical cord by the umbilical vein. Entering the fœtus the blood is conveyed into the inferior vena cava partly through the liver but chiefly through the "**ductus venosus**," which connects these two vessels. From the inferior vena cava it enters the right auricle, passes through the foramen ovale into the left auricle, thence into the left ventricle, and out through the aorta, which distributes it principally to the upper extremities. The blood from the head and upper extremities returns by the superior vena cava to the right auricle, then passes into the right ventricle, and out through the pulmonary artery to the lungs. As the lungs in the fœtus are solid, they require very little blood (only for nutrition), and the greater part of the blood passes through the ductus arteriosus into the descending aorta, where, mixing with the blood delivered to the aorta by the left ventricle, it descends to supply the lower extremities of the fœtus. The chief portion of this blood is carried to the placenta by the two umbilical arteries, but a small amount passes back into the ascending vena cava and mixes with the blood from the placenta.

From this description of the fœtal circulation, it will be seen : —

1. That the placenta serves the double purpose of a respiratory and nutritive organ, receiving the venous blood from the fœtus, and returning it again charged with oxygen and additional nutritive material.

2. That the liver receives pure blood directly from the placenta ; hence the large size of this organ at birth.

3. That the blood from the placenta passes almost directly into the arch of the aorta, and is distributed by its branches to the head and upper extremities ; hence the large size and perfect development of these parts at birth.

4. That the blood in the descending aorta is chiefly derived from that which has already circulated in the upper extremities, and, mixed with only a small quantity from the left ventricle, is distributed to the lower extremities ; hence the small size and imperfect development of these parts at birth.

Changes in the vascular system at birth. — From the foregoing description it is obvious that at birth very important changes must take place: —

1. The blood clots in the umbilical vein, between the usual ligature and the liver, also in the ductus venosus. The blood clot becomes organized and these two vessels become obliterated.

2. As respiration commences, the blood traverses the pulmonary arteries, and then returns to the heart by the pulmonary veins; this raises the blood pressure in the left auricle, and causes the valve over the foramen ovale to close.

3. The blood in the ductus arteriosus clots, the clot organizes, and the ductus arteriosus becomes a fibrous cord.

4. The blood in the hypogastric arteries also clots, the clots organize and these vessels become obliterated.

SUMMARY

- **General Circulation**
  - **Pulmonary Circulation**
    - Right auricle to right ventricle, then pulmonary arteries to lungs. Capillary system. Return by pulmonary veins to left auricle.
    - **Purpose** — To increase oxygen and decrease carbon dioxide.
  - **Systemic Circulation**
    - Left auricle to left ventricle, then by means of aorta and its branches to all parts of the body. Capillary system. Return by veins which empty into superior and inferior venæ cavæ.
    - **Purpose**
      - Carry, and give up to tissues
        - Oxygen.
        - Nutritive materials.
      - Take from tissues
        - Carbon dioxide.
        - Waste products.
- **Factors Governing Circulation**
  1. The heart-beat.
  2. The elasticity and extensibility of the arterial walls.
  3. The position and direction of the valves.
  4. The large number and small bore of the capillaries.
  5. The large size and non-contractile character of the walls of the veins.
- **Heart-beat**
  - **Systole** — State of contraction
  - **Diastole** — State of dilatation or rest
    - Cardiac cycle, 72 per minute.
    - Occupies 0.8 of a second.
  - **Heart Sounds**
    - Lubb
      1. Closure of auriculo-ventricular valves.
      2. Contraction of ventricles.
      3. Cardiac impulse against chest wall.
    - Dup
      1. Closure of semilunar valves.
  - **Cause**
    - Power inherent in heart muscle.
    - Stimulated by chlorides
      - Sodium.
      - Potassium.
      - Calcium.
    - Innervation
      - Pneumogastric nerve — inhibitory.
      - Sympathetic nerve — accelerator.
- **Elasticity and Extensibility of Arterial Walls**
  - Enables them to stretch and receive extra amount of blood.
  - Enables them to recoil and convert intermittent into continuous stream.
  - Arteriosclerosis = loss of elasticity and extensibility.

Position and Direction of Valves
- Permit blood to flow from auricles into ventricles, *not* in reverse direction.
- Permit blood to flow from ventricles into arteries, *not* in reverse direction.
- Disease and advancing years may impair adjustment.

Large Number and Small Bore of the Capillaries
- Total number is immense.
- Each one is microscopic.
- Total capacity several hundred times greater than aorta.
- Rapidity of blood stream reduced by enormous increase in number of vessels, and in surface.

Large Size and Noncontractile Character of the Walls of the Veins
- Begin small — grow larger.
- Decrease in number of vessels and in total capacity.
- Vein twice as large as corresponding artery.
- Not capable of distention and recoil, hence offer no resistance to current of blood.

Distribution of Blood
- Estimated amount of blood in body, 4 qts.
- Estimated amount of blood in thorax, 1 qt.
- Estimated amount of blood in skeletal muscles, 1 qt.
- Estimated amount of blood in liver, 1 qt.
- Amount in any organ increased when there is need.
- Amount in any organ decreased when need is over.

Blood Pressure
- Pressure blood exerts against walls of vessels.
- **Arterial**
  - **High** — Hemorrhage from cut artery — "spurts" out.
  - Maintained by
    1. Contraction of ventricles.
    2. Extra blood forced into full arteries.
    3. Semilunar valves prevent regurgitation.
    4. Elasticity and recoil of arteries.
    5. Resistance offered by arterioles.
    6. Increased surface in capillaries.
  - Not uniform
    1. Higher during systole.
    2. Lower during diastole.
    3. Increases with age.
    4. Decreases if heart or arteries lose their tone.

- **Blood Pressure**
  - **Capillary**
    - Much lower than in arteries.
    - High considering thinness of walls.
    - Dependent on constriction or dilatation of arterioles.
  - **Venous**
    - Low — Hemorrhage from cut vein "wells up."
    - Influenced by
      - Presence of valves.
      - Respiration.
  - **Determined by**
    - Pressure of finger against large artery.
    - Use of sphygmomanometer
      - 1. Air pump.
      - 2. Elastic bag covered with leather cuff.
      - 3. Mercury manometer.
  - **Normal**
    - Systolic or maximum — 110 to 116 mm.
    - Diastolic or minimum — 65 to 75 mm.
- **Pulse**
  - Alternate contraction and expansion of artery.
  - **Locations where Pulse may be counted**
    - Facial artery.
    - Temporal artery.
    - Brachial artery.
    - Radial artery.
    - Femoral artery.
    - Dorsalis pedis.
  - **Points to note**
    - Frequency.
    - Strength.
    - Regularity.
    - Equality.
    - Tension.
  - **Pulse Rate**
    - Infant, 130
    - Three years, 100
    - Adult, 72
    - Old age, 65
    - Higher in women than in men.
  - **Changes in Pulse Rate may be due to**
    - Eating.
    - Muscular activity.
    - Mental excitement.
    - Age.
    - Sleep.
    - Condition of health.
    - Idiosyncrasies.
- **Lymph**
  - **Formation**
    - Process of transudation.
    - Process of secretion.
  - **Factors controlling flow**
    - Differences in pressure.
    - Muscular movements and valves.
    - Respiration.

Œdema	Accumulation of lymph in tissues. May be caused by 1. Obstruction to flow of lymph from tissue. 2. Excessive transudation.
Fœtal Circulation	1. Direct communication between right and left auricle by means of foramen ovale. 2. Direct communication between umbilical vein and inferior vena cava. Ductus venosus. 3. Direct communication between pulmonary artery and aorta. Ductus arteriosus. 4. Oxygen and nutritive substances obtained from placenta.
Changes in Vascular System at Birth	1. Umbilical vein and ductus venosus become obliterated. 2. Respiration stimulates pulmonary circulation; this raises the blood pressure in left auricle, and closes foramen ovale. 3. Ductus arteriosus becomes a fibrous cord. 4. Hypogastric arteries become obliterated.

CHAPTER XIII

RESPIRATORY SYSTEM: NOSE; LARYNX; TRACHEA; BRONCHI; LUNGS. — RESPIRATION; ABNORMAL TYPES OF RESPIRATION. MODIFIED RESPIRATORY MOVEMENTS

The process of respiration is dependent upon the proper functioning of certain organs, which we group together and call a respiratory system. A respiratory system consists essentially of a moist and permeable membrane, with blood-vessels containing a high percentage of carbon dioxide on one side, and air or fluid containing a high percentage of oxygen on the other. In most aquatic animals the respiratory organs are external in the form of gills; in terrestrial, or air-breathing animals, the respiratory organs are situated internally in the form of lungs, and are placed in communication with the nose and mouth by means of the bronchi, trachea, and larynx.

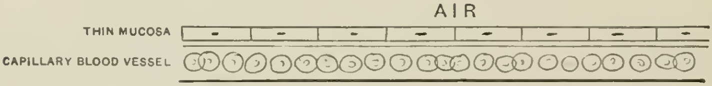

FIG. 139. — DIAGRAM OF THE ESSENTIALS OF A RESPIRATORY SYSTEM. (Gerrish.)

NOSE

The nose is the special organ of the sense of smell, but it also serves as a passageway for the entrance of air to the respiratory organs. It consists of two parts, — the external feature, the nose, and the internal cavities, the nasal fossæ.

The external nose is composed of a triangular framework of bone and cartilage, covered by skin and lined by mucous membrane. On its under surface are two oval-shaped openings — the nostrils, which are the external openings of the nasal fossæ. The margins of the nostrils are provided with a number of stiff hairs, which arrest the passage of dust and other foreign substances carried in with the inspired air.

The nasal fossæ are two irregularly wedge-shaped cavities, separated from one another by a partition, or septum, the upper part of which consists of the perpendicular plate of the ethmoid, and of the vomer, and the lower part of cartilage. The turbinated bones and turbinated processes of the ethmoid, which are exceedingly light and spongy, project into the nasal cavities, and divide them into three incomplete passages from before backwards, — the superior, middle, and inferior meatus. The palate and maxillæ separate the nasal and mouth cavities, and the cribriform plate of the ethmoid forms the partition between the cranial and nasal cavities.

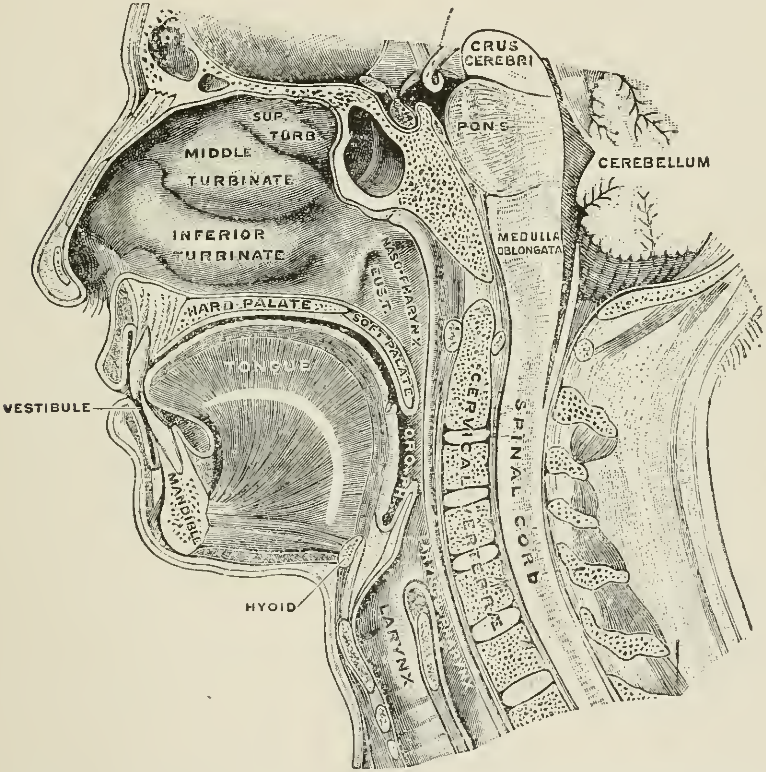

Fig. 140. — Sagittal Section of the Face and Neck, showing the First Portions of the Respiratory and Alimentary Tracts. (Gerrish.)

These cavities[1] communicate with the air in front by the anterior nares, or nostrils, while behind they open into the back of the pharynx by the two posterior nares.

The pituitary membrane (sometimes called the Schneiderian[2] membrane) is the mucous lining of the nose. It closely covers the nasal passages, and is thickest and most vascular over the turbinated bones.

Advantages of nasal breathing. — Under normal conditions breathing should take place through the nose only (1) because the arrangement of the turbinated bones makes the upper part of the nasal passages very narrow; (2) these passages are thickly lined, and freely supplied with blood-vessels, so that they can, even in the very coldest weather, moisten and warm the air before it reaches the lungs; and (3) the presence of hairs at the entrance to the nostrils serve as filters.

Sinuses which communicate with the nose. — Opening into the nasal cavities are minute channels which connect with (1) the frontal sinuses, (2) the ethmoidal sinuses, (3) the maxillary sinuses or antrums of Highmore, and (4) the sphenoidal sinuses. The pituitary membrane is prolonged into these sinuses, and inflammatory processes in the nose may extend into these cavities.

Mouth and pharynx. —As the mouth and pharynx are more closely associated with the process of digestion rather than respiration, they will be described with the digestive organs. The mouth serves as a passageway for the entrance of air, and the pharynx transmits the air from the nose or mouth to the larynx.

RESPIRATORY SYSTEM

Under this heading we group the organs which are concerned in the process of respiration. In man they are as follows: —

1. Larynx.
2. Trachea.
3. Bronchi.
4. Lungs.

---

[1] Eleven bones enter into the formation of the nasal cavities: the floor is formed by the palate (2) and part of the maxillæ bones (2); the roof is chiefly formed by the perforated plate of the ethmoid bone (1), the sphenoid (1), and by the (2) small nasal bones; in the outer walls we find, in addition to processes from other bones, the two scroll-like turbinated bones (2). The vomer (1) forms part of the septum.

[2] It was formerly supposed that the mucus secreted by the mucous membrane of the nose came from the brain. Schneider was the name of the anatomist who first disproved this.

THE LARYNX

The larynx is situated between the base of the tongue and the top of the trachea, in the upper and front part of the neck. Above and behind lies the pharynx, which opens into the œsophagus, or gullet, and on either side of it lie the great vessels of the neck. In form, the larynx is narrow and rounded below, where it blends with the trachea, but broad above and shaped somewhat like a triangular box, with flat sides and prominent ridge in front. It is made up of nine pieces of fibro-cartilage, united together by elastic ligaments, and moved by numerous muscles.

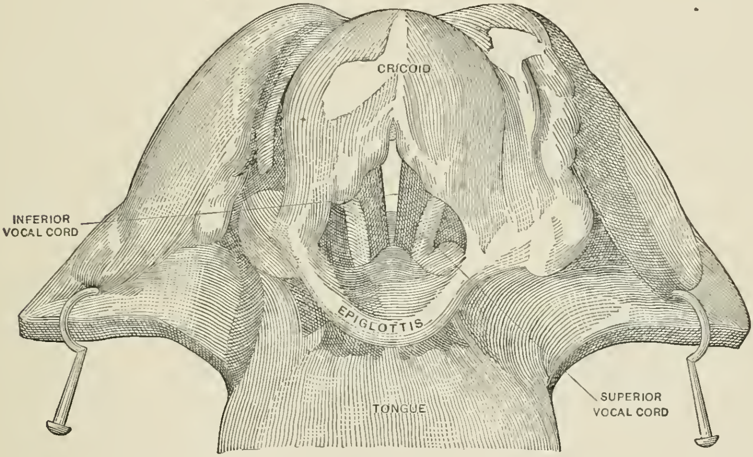

Fig. 141. — Larynx. Viewed from above. (Gerrish.)

The three principal cartilages are the **cricoid**, **thyroid**, and **epiglottis**. The cricoid resembles a seal ring with the hoop part in front and the signet part in the back. The thyroid resembles a shield and is the largest. It rests upon the cricoid and consists of two square plates, or alæ (right and left), which are joined together in front and form by their union the laryngeal prominence, called Adam's apple. The upper portion of the hind border of the thyroid is called the superior horn, and the lower portion the inferior horn (see Fig. 143). The epiglottis is shaped like a leaf. The stem is inserted in the notch between the two plates of the thyroid. The larynx is lined throughout by mucous membrane, which is continuous above with that lining the pharynx, and below with that lining the trachea.

The glottis. — Across the middle of the larynx is a transverse partition, formed by two folds of the lining mucous membrane, stretching from side to side, but not quite meeting in the middle line. They thus leave in the middle line a chink, or slit, running from front to back, called the **glottis**. The glottis is protected by the leaf-shaped lid of fibro-cartilage, called the epiglottis, which shuts down upon the opening during the passage of food or other matters into the œsophagus.

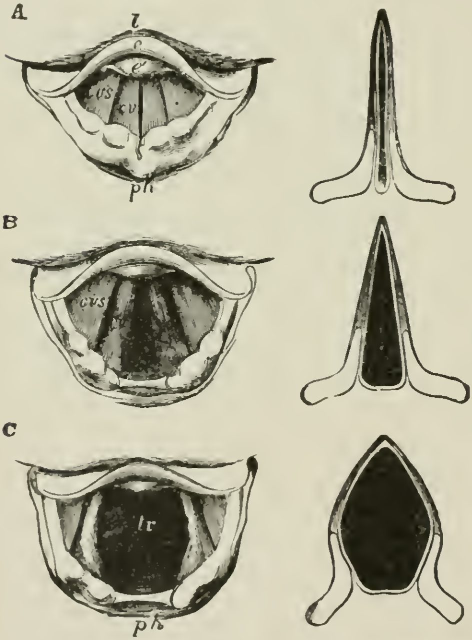

Fig. 142. — The Larynx as seen by Means of the Laryngoscope in Different Conditions of the Glottis. *A*, while singing a high note; *B*, in quiet breathing; *C*, during a deep inspiration. *l*, base of tongue; *e*, upper free edge of epiglottis; *e'*, cushion of the epiglottis; *ph*, part of anterior wall of pharynx; *cv*, the true vocal folds; *cvs*, the false vocal folds; *tr*, the trachea with its rings.

The vocal cords. — Embedded in the mucous membranes at the edges of the slit are fibrous and elastic ligaments, which strengthen the edges of the glottis and give them elasticity. These ligamentous bands, covered with mucous membrane, are firmly attached at either end to the cartilages of the larynx, and are called the **true vocal cords**, because they function in the production of the voice. Above the true vocal cords are two **false vocal cords**, so called because they do not function in the production of the voice.

Variations in size of glottis. — The glottis varies in shape and size, according to the action of the muscles upon the laryngeal walls. When the larynx is at rest during quiet breathing, the glottis is V-shaped; during a deep inspiration it becomes almost round, while during the production of a high note the edges of the folds approximate so closely as to leave scarcely any opening at all.

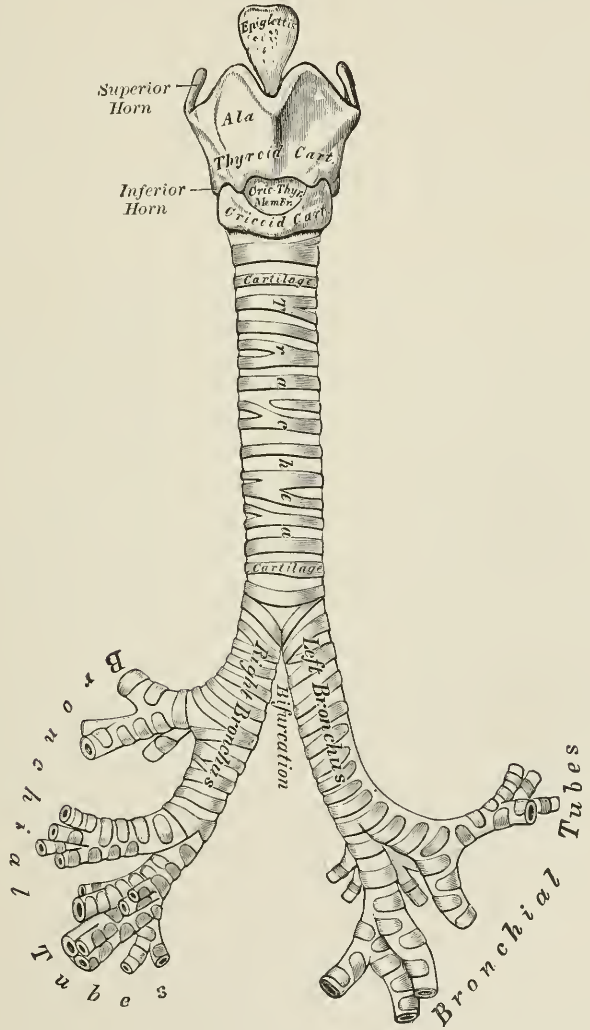

Fig. 143. — Front View of Cartilages of Larynx. Trachea and Bronchi.

Voice. — The vocal cords produce the voice. A blast of air, driven by an expiratory movement out of the lungs, throws the two elastic cords into vibrations. These impart their vibrations to the column of air above them, and so give rise to the sound which we call the voice. The pharynx, mouth, and nasal cavities above the glottis act as resonating cavities, and by alterations in their shape and size, they are able to pick out and emphasize certain parts of the tones produced in the larynx.

Differences between male and female voice. — At puberty in the male, the larynx enlarges, giving rise to what is commonly called Adam's apple. The increase in the size of the larynx causes an increase in the length of the vocal cords. To this is due the lower pitch of the voice in the male.

THE TRACHEA

The trachea, or windpipe, is a fibrous and muscular tube. It measures about four and a half inches (112 mm.) in length, and three-quarters of an inch (19 mm.) from side to side. It extends down into the thorax from the lower part of the larynx to opposite the third thoracic vertebra, where it divides into two tubes, — the two bronchi, — one for each lung.

The walls are strengthened and rendered more rigid by hoops of cartilage embedded in the fibrous tissue. These hoops are C-shaped and incomplete behind, the cartilaginous rings being completed by bands of plain muscular tissue where the trachea comes in contact with the œsophagus. Like the larynx, it is lined by mucous membrane, and has a ciliated epithelium upon its inner surface. The mucous membrane, which also extends into the bronchial tubes, keeps the internal surface of the air-passages free from impurities; the sticky mucus entangles particles of dust and other matters breathed in with the air, and the incessant movements of the cilia continually sweep this dirt-laden mucus upward and outward.

THE BRONCHI

The two bronchi, into which the trachea divides, differ slightly; the right bronchus is shorter, wider, and more nearly horizontal, the left bronchus is longer, narrower, and more nearly vertical. They enter the right and left lung, respectively, and then break up into a great number of smaller branches which are called the bronchial tubes, or bronchioles. The two bronchi resemble the trachea in structure; but as the bronchial tubes divide and subdivide their walls become thinner, the small plates of cartilage cease, the fibrous tissue disappears, and the finer tubes are composed of only a thin layer of muscular and elastic tissue lined by mucous membrane.

LUNGS

The lungs are cone-shaped organs which occupy almost all of the cavity of the thorax that is not taken up by the heart, the large blood-vessels, the lymphatics, and the œsophagus. Each lung presents an outer surface which is convex, a base which is concave to fit over the convex portion of the diaphragm, and a summit or apex which rises half an inch above the clavicle. On the inner surface is a vertical notch called the **hilum**, which gives passage to the bronchi, blood-vessels, lymph-vessels, and nerves.

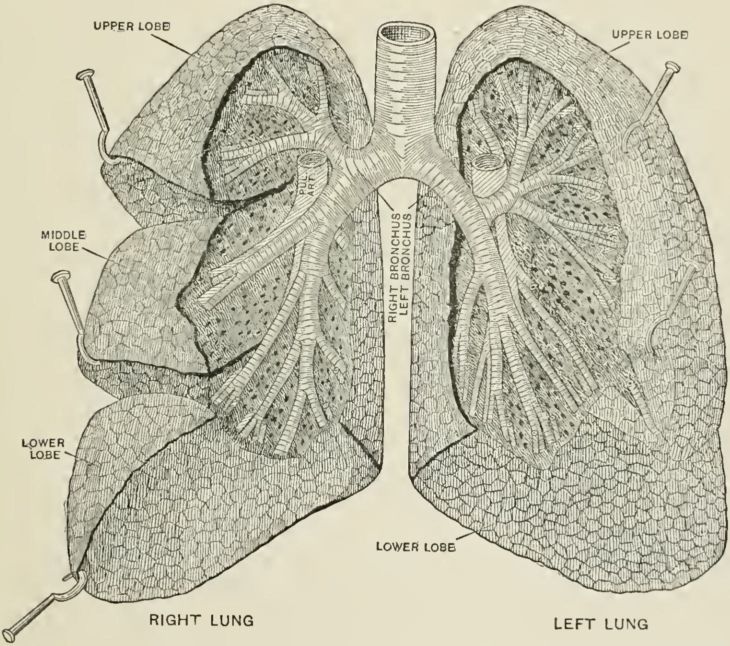

Fig. 144. — Bronchi and Bronchioles. The lungs have been widely separated and tissue cut away to expose the air-tubes. (Gerrish.)

The **right lung** is the larger and heavier; it is broader than the left, owing to the inclination of the heart to the left side; it is also shorter by one inch, in consequence of the diaphragm rising higher on the right side to accommodate the liver. The right lung is divided by fissures into three lobes, upper, middle, and lower.

The **left lung** is smaller, narrower, and longer than the right. It is only divided into two lobes, upper and lower. The front border is deeply notched to accommodate the heart.

Anatomy of the lungs. — The lungs are hollow, rather spongy organs, and consist of the bronchial tubes and their terminal dilatations, numerous blood-vessels, lymphatics, nerves, and an abundance of fine, elastic connective tissue, binding all together. (See Fig. 99.) Each lobe of the lung is composed of many lobules, and into each lobule a bronchiole enters and terminates in an enlargement having more or less the shape of a funnel, and called an **infundibulum.** From each infundibulum there is a series of small sac-like projections known as **alveoli,** the walls of which are honeycombed with cavities called the air-cells. In this way the amount of surface exposed to the air and covered by the capillaries is immensely increased.

Blood-vessels of the lungs. — Two sets of vessels are distributed to the lungs: (1) the branches of the pulmonary artery, and (2) the branches of the bronchial arteries.

(1) The branches of the pulmonary artery accompany the bronchial tubes and form a plexus of capillaries around the alveoli. The walls of the bronchioles consist of a single layer of flattened epithelioid cells, surrounded by a fine, elastic connective tissue, and are exceedingly thin and delicate. Immediately beneath the layer of flat cells, and lodged in the elastic connective tissue, is this very close plexus of capillary blood-vessels; and the air reaching the alveoli by the bronchial tubes is separated from the blood in the capillaries by only the thin membranes forming their respective walls. The pulmonary veins begin at the margin of the alveoli and return the blood distributed by the pulmonary artery.

(2) The branches of the bronchial arteries supply blood to the lung substance, — the bronchial tubes, coats of the blood-vessels, the lymph nodes, and the pleura. The bronchial veins return the blood distributed by the bronchial arteries.

Nerves. — The substance of the lungs is supplied with nerves which are derived from the sympathetic system, and from branches

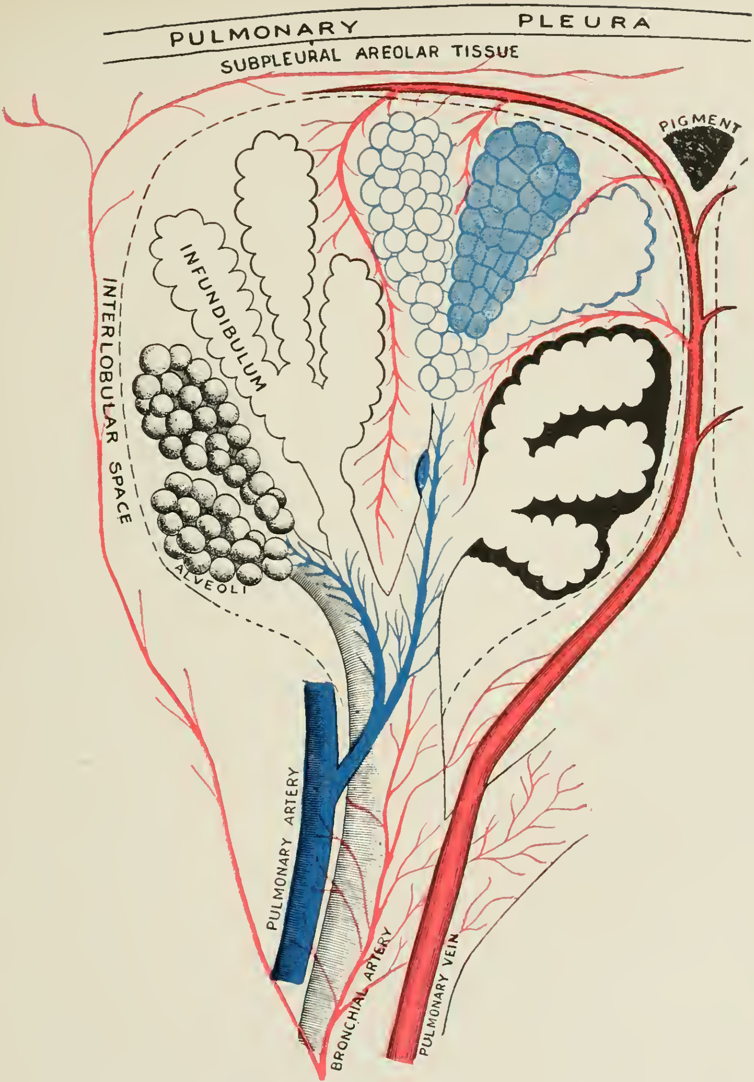

Fig. 145. — Diagram of a Lobule of the Lung. A bronchiole is seen dividing into two branches, one of which runs upward and ends in the lobule. In the lobule are four groups of infundibula. At the left are two infundibula, the alveoli of which present their outer surfaces. Next are three infundibula in vertical section, the alveoli of each opening into the common passageway. In the next group the first infundibulum shows a pulmonary arteriole surrounding the opening of each alveolus, and the second gives the same with the addition of the close capillary network in the wall of each alveolus. Around the fourth group is a deep deposit of pigment, such as occurs in old age, and in the lungs of those who inhale coal dust and the like. On the bronchiole lies a branch of the pulmonary artery (blue), bringing blood to the infundibula for aëration. Beginning between the infundibula are the radicles of the pulmonary vein (red), a root of which lies upon the bronchiole. The bronchial artery is shown as a small vessel bringing nutrient blood to the bronchiole. (Gerrish.)

of the pneumogastric. These nerves follow the course of the blood-vessels and bronchioles.

Pleura. — Each lung is enclosed in a serous sac, the pleura, one layer of which is closely adherent to the walls of the chest and diaphragm (parietal); the other closely covers the lung (visceral). The two layers of the pleural sacs, moistened by serum, are normally in close contact; they move easily upon one another, and prevent the friction that would otherwise occur between the lungs and the walls of the chest with every respiration. Inflammation of the pleura is called pleurisy.

Mediastinum. — The mediastinum is the space between the two pleural sacs. It extends from the sternum to the spinal column and holds a portion of many organs, *i.e.* the trachea, œsophagus, great vessels connected with the heart, nerves, and the thoracic duct.

RESPIRATION

Function. — The main purpose of respiration is to supply the body with oxygen and get rid of the excess carbon dioxide which results from oxidation. It also helps to equalize the temperature of the body and get rid of excess of water. To accomplish these purposes two processes are necessary, *i.e.* external and internal respiration.

External respiration. — This takes place in the lungs and consists of the absorption of oxygen from the air in the alveoli, and the elimination of some of the carbon dioxide and water from the blood in the capillaries. External respiration consists of *inspiration*, or the process of taking air into the lungs, and *expiration*, or the process of expelling air from the lungs.

Internal respiration. — This takes place in the cells and consists of the diffusion of oxygen from the blood in the capillaries into the tissues, and its union there with the protoplasm of the cells. As a result of this union or oxidation complex bodies are broken up into simpler ones, such as carbon dioxide and water, and there is thus liberated a great deal of energy, which is manifested in the increasing of muscular activity and in the production of heat. The carbon dioxide passes by diffusion into the venous blood, and is carried by it to the right side of the heart and thence to the lungs, a certain quantity, however, escaping from the blood through the kidneys and skin.

Mechanism of inspiration and expiration. — During inspiration the cavity of the chest is enlarged in all three diameters: (1) antero-posterior, (2) lateral, and (3) vertical. This is brought about by the action of the intercostal and other muscles, which elevate the ribs and thereby increase the antero-posterior and lateral diameters. The descent of the diaphragm increases the vertical diameter. The lungs are correspondingly distended to fill the enlarged cavity. To prevent a vacuum in the lungs, air rushes in by way of the trachea to the bronchi. Upon the relaxation of the inspiratory muscles, the elasticity of the lungs and the weight and elasticity of the chest walls cause the chest to return to its original size, in consequence of which the air is expelled from the lungs. As in the heart, the auricular systole, the ventricular systole, and then a pause follow in regular order, so in the lungs the inspiration, the expiration, and then a pause succeed one another.

Control of respiration. — Respiration is both a voluntary and an involuntary act. It is possible for a short time to increase or retard the rate of respiration within certain limits by voluntary effort, but this cannot be done continuously. If we intentionally arrest the breathing or diminish its frequency, after a short time the nervous impulse becomes too strong to be controlled, and the movements will recommence, as usual. If, on the other hand, we purposely accelerate respiration to any great degree, the exertion soon becomes too fatiguing for continuance, and the movements return to their normal standard.

Cause of respiration. — The nervous impulses which cause the contractions of the respiratory muscles are entirely dependent on the nervous system, especially that part known as the *respiratory centre,* which is located in the medulla oblongata. Efferent nerves from the respiratory centre travel down the spinal cord and end at different levels, where they connect with the fibres of the pneumogastric and sympathetic nerves that are distributed in the lung tissue. Afferent nerves lead from these different levels to the respiratory centre.

The consensus of opinion at the present time seems to be that the action of the respiratory centre is automatic, but that the rate and rhythm of the respiratory movements is controlled (1) by the pneumogastric nerve, and (2) by the chemical condition of the blood.

(1) The fibres from the pneumogastric nerve are of two kinds: (*a*) inspiratory fibres which tend to increase the rate of respiration, and (*b*) expiratory fibres which check the action of the inspiratory set. The inspiratory fibres are stimulated to action when the lung collapses; the expiratory when the lung expands.

(2) The respiratory centre shows a specific irritability for carbon dioxide, and an increased amount of carbon dioxide in the blood acts as a stimulus, increasing the rate and depth of the respirations, so that the lungs are more thoroughly ventilated. Increased activity, or any abnormal condition that increases the oxidation of the tissues, naturally results in an increased production of carbon dioxide, and an increase in the rate and depth of the respirations. On the other hand, an excess of oxygen in the blood may cause a condition known as *physiological apnœa*, *i.e.* where the blood is so rich in oxygen and poor in carbon dioxide that a respiratory act is unnecessary.

Reflex stimulation of the respiratory centre. — Every one must have noticed that the respiratory movements are affected by stimulation of the sensory nerves. Strong emotion, sudden pain, or a dash of cold water on the skin produce changes in the rate of the respirations. It is assumed, therefore, that the respiratory centre is in connection with the sensory fibres of all the cranial and spinal nerves.

Cause of the first respiration. — The immediate cause of the first respiratory effort is closely connected with the cause of the activity of the respiratory centre during life. The stimulus is supposed to come from (1) the increased amount of carbon dioxide in the blood, due to the cutting of the cord; and (2) the sensory nerves of the skin, due to cooler air, handling, etc. During intrauterine life the fœtus receives its supply of oxygen from the blood-vessels of the umbilical cord, which connect with the placenta. The lungs are in a collapsed condition and contain no air. The walls of the air-sacs are in close contact, and the walls of the smaller bronchial tubes, or bronchioles, touch one another When the chest expands with the first breath taken, the inspired air has to overcome the adhesions existing between the walls of the bronchioles and air-sacs. The force of this first inspiratory effort, spent in opening out and unfolding, as it were, the inner recesses of the lungs, is considerable. In the succeeding expiration, most of the air introduced by the first inspiration remains in the lungs, succeeding breaths unfold the lungs more and more, until finally the air-sacs and bronchioles are all opened up and filled with air. The lungs thus once filled with air are never completely emptied again until after death.

Frequency of respiration. — Each respiratory act in the adult is ordinarily repeated about eighteen times per minute. This rate may be increased by muscular exercise, emotion, etc. Anything that affects the heart-beat will have a similar effect on the respirations. The ratio to the pulse is about 1 to 4 in health. Age has a marked influence. The average rate in the newly born infant has been found to be forty-four per minute, and at the age of five years, twenty-six per minute. It is reduced between the ages of fifteen and twenty to the normal standard.

Respiratory sounds. — The entry and exit of the air are accompanied by respiratory sounds or murmurs. These murmurs differ as the air passes through the trachea, the larger bronchial tubes, and the bronchioles. They are variously modified in lung disease, and are then often spoken of under the name of " râles." In labored breathing the contraction of the respiratory muscles not usually brought into play, such as the muscles of the throat and nostrils, becomes very marked.

Effects of respiration upon the blood. — While the blood is passing through the pulmonary capillaries, the following changes take place: (1) it loses carbon dioxide; (2) it gains oxygen, which combines with the reduced hæmoglobin of the red corpuscles and turns it into oxyhæmoglobin, and as a result of this the crimson color shifts to scarlet; (3) the temperature is slightly reduced.

Capacity of the lungs. — As the lungs are not emptied at each expiration, neither are they filled. If filled to their utmost, they can hold a little more than one gallon (4500 c.c.) of air. This total is divided as follows: —

(1) Tidal.
(2) Complementary.
(3) Reserve.
(4) Residual.

Tidal air is the air introduced with every ordinary inspiration.

Complementary air is the excess over the tidal air which may be introduced during a forced inspiration.

Reserve air is the amount of air in addition to the tidal air one can expel from the lungs in a forced expiration.

Residual air is the air remaining in the lungs after the most powerful expiration.

The vital capacity is the sum of the tidal, complementary, and reserve airs added together. It equals about 225 cubic inches (3700 c.c.).

It is not correct to think of the residual air in the lungs as stationary, for the air is being constantly moved and renewed. This movement is maintained by: (1) the alternate expansion and collapse of the lungs in respiration, (2) the convection currents due to the differences in temperature between the inspired air and the residual air, (3) the pulsation of the arteries, and (4) the difference in the proportion of carbon dioxide and oxygen in the inspired air and residual air. This fourth factor is also responsible for the interchange of gases between the air in the air-sacs and the blood in the capillaries. The reason is that the blood contains more carbon dioxide and less oxygen than the air in the alveoli, and the tendency of gases is always to mix in uniform proportions.

The effects of respiration upon the air outside the body. — With every inspiration a well-grown man takes into his lungs about 30 cubic inches (500 c.c.) of air. The air he takes in differs from the air he gives out mainly in three particulars: —

1. Whatever the temperature of the external air, the expired air is nearly as hot as the blood; namely, of a temperature between 98° and 100° F. (36.7 and 37.8° C.).

2. However dry the external air may be, the expired air is quite, or nearly, saturated with moisture.

3. The air when breathed loses about one-fourth of its oxygen and increases the carbon dioxide an hundred fold; the quantity of nitrogen is changed little, if any. To be exact, the air loses 4.94 volumes of oxygen and gains 4.38 volumes of carbon dioxide. Thus: —

	Oxygen	Carbon Dioxide	Nitrogen
Inspired air	20.96	0.04	79
Expired air	16.02	4.38	79
	4.94 loss	4.34 gain	0

In addition the expired air contains a certain amount of organic matter which comes principally from the mouth and particles of food left in the mouth.

Ventilation.—Since at every breath the external air loses oxygen, gains carbon dioxide, and a certain amount of organic matter, it was formerly taught that the general discomfort, headache, and languor that result from staying in a badly ventilated room were due to the increase in carbon dioxide, and the poisonous effects of the organic matter. The results of many experiments seem to prove that people can become so accustomed to a low percentage of oxygen and a high percentage of carbon dioxide that they suffer little discomfort, and the organic matter is not poisonous, though when present in any amount it causes disagreeable odors and makes the air stuffy. It is now thought that the injurious effects of remaining in a badly ventilated room are due to interference with the heat-regulating mechanism of the body. The air is heated to a high temperature and becomes saturated with watery vapor. Both of these conditions prevent loss of heat from the body and produce a fever temperature. Even when these conditions exist it has been found that moving the air, *i.e.* keeping it in circulation even without renewing it, has a stimulating effect and lessens discomfort. Because of these facts we are now taught that the maintenance of proper air conditions must be based (1) on the normal composition of the air as regards oxygen and carbon dioxide, (2) on the temperature, and (3) on the degree of humidity. Any system of ventilation that is based solely on the first condition, and neglects to take into account the second and third is sure to prove unsatisfactory.

ABNORMAL TYPES OF RESPIRATION

Dyspnœa. — The word dyspnœa means difficult breathing. It is caused by (1) an increase in the percentage of carbon dioxide in the blood, (2) a decrease in the oxygen, and (3) any condition that stimulates the sensory nerves and causes pain in the lungs.

Hyperpnœa. — The word hyperpnœa means excessive breathing and is applied to the initial stages of dyspnœa, when the respirations are simply increased.

Apnœa. — The word apnœa means a lack of breathing.

Cheyne-Stokes Respirations. — This is a type of respirations which was first described by the two physicians whose names it bears. It appears in two forms: (1) the respirations increase in force and frequency up to a certain point, and then gradually decrease until they cease altogether, and there is a short period of apnœa, then the respirations recommence and the cycle is repeated. (2) The respirations increase in force and frequency up to a certain point, then cease, and the period of apnœa intervenes, without the gradual cessation of the respirations. This condition is associated with disease of the kidney, brain, or heart. The cause is not settled, but it is of bad prognosis and generally indicates a fatal termination.

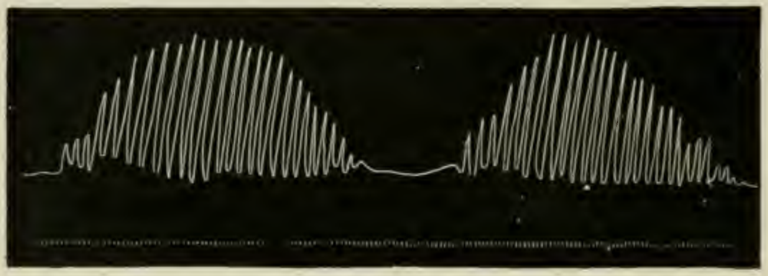

FIG. 146. — STETHOGRAPH TRACING OF CHEYNE-STOKES RESPIRATIONS IN A MAN. The time is marked in seconds. (Halliburton.)

Œdematous Respiration. — When the air cells become infiltrated with fluid from the blood, the breathing becomes œdematous and is recognized by the moist, rattling sounds, called râles, that accompany each inspiration. It is a serious condition because it interferes with aeration of the blood and often results in asphyxia.

Asphyxia. — This condition is usually the sequel to severe dyspnœa and œdematous respiration. It is produced by any condition that causes prolonged interference with the aeration of the blood. After death from asphyxia it will be found that the right side of the heart, the pulmonary arteries and the systemic veins are overloaded, and the left side of the heart, the pulmonary veins, and the systemic arteries are empty.

MODIFIED RESPIRATORY MOVEMENTS

Various emotions may be expressed by means of the respiratory apparatus.

Sighing is a deep and long-drawn inspiration, followed by a sudden expiration.

Yawning is an inspiration, deeper and longer continued than a sigh, drawn through the widely open mouth, and accompanied by a peculiar depression of the lower jaw.

Hiccough is caused by a sudden inspiratory contraction of the diaphragm; the glottis suddenly closes and cuts off the column of air just entering, which, striking upon the closed glottis, gives rise to the characteristic sound.

Sobbing is a series of convulsive inspirations during which the glottis is closed, so that little or no air enters the chest.

Coughing consists, in the first place, of a deep and long-drawn inspiration by which the lungs are well filled with air. This is followed by a complete closure of the glottis, and then comes a forcible and sudden expiration, in the midst of which the glottis suddenly opens, and thus a blast of air is driven through the upper respiratory passages.

Sneezing consists of a deep inspiration, followed by a sudden and forced expiration, which directs the air through the nasal passages.

Laughing consists essentially in an inspiration, followed by a whole series of short, spasmodic expirations, the glottis being freely open during the whole time, and the vocal cords being thrown into characteristic vibrations.

Crying consists of the same respiratory movements as laughing; the rhythm and the accompanying facial expressions are, however, different, though laughing and crying often become indistinguishable.

Speaking consists of a voluntary expiration and the vibration of the vocal cords as the air passes over them.

SUMMARY

Respiration is dependent upon the proper functioning of organs that comprise the respiratory system. Air passes through the nose or mouth to these organs.

- **Nose**
  - **Function**
    - Special organ of the sense of smell.
    - Passageway for entrance of air to the respiratory organs.
  - **External nose**
    - Framework of bone (nasal) and cartilage.
    - Covered with skin, lined with mucous membrane known as pituitary, or Schneiderian.
    - Nostrils are oval-shaped openings on under surface, separated by a partition.
  - **Internal cavities, or nasal fossæ**
    - Extend from nostrils to the pharynx.
    - Two wedge-shaped cavities.
    - Formed by
      - 2 palate.
      - 2 maxillæ.
      - 1 ethmoid.
      - 1 sphenoid.
      - 2 nasal.
      - 2 turbinated, and processes of the ethmoid
        - Superior meatus.
        - Middle meatus.
        - Inferior meatus.
      - 1 vomer.
      - 11 bones.
  - **Advantages of nasal breathing**
    - **Air**
      - Warmed.
      - Moistened.
      - Filtered.
  - **Communicating sinuses**
    1. Frontal.
    2. Ethmoidal.
    3. Maxillary or Antrums of Highmore.
    4. Sphenoidal.
- **Respiratory System**
  1. Larynx.
  2. Trachea.
  3. Bronchi.
  4. Lungs.
- **Larynx**
  - Triangular box made up of nine pieces of cartilage.
  - Situated between the tongue and trachea.
  - Contains vocal cords.
  - Slit or opening between cords called *glottis*, which is protected by leaf-shaped lid called epiglottis.
  - Connected with external air by
    - Mouth.
    - Nose.

- **Voice**
  - Produced by vibrations of vocal cords.
  - Resonating cavities
    - Pharynx.
    - Mouth.
    - Nasal cavities.
  - Lower pitch of male voice is due to greater length of vocal cords.
- **Trachea**
  - Fibrous and muscular tube, $4\frac{1}{2}$ in. long.
  - Strengthened by C-shaped hoops of cartilage
    - Complete in front.
    - Incomplete behind.
  - In front of œsophagus.
  - Extends from larynx to third thoracic vertebra, where it divides into two bronchi.
- **Bronchi**
  - Right and left — structure similar to trachea.
  - Right
    - 1 in. long.
    - $\frac{3}{5}$ in. wide.
    - Almost horizontal.
  - Left
    - 2 in. long.
    - $\frac{2}{5}$ in. wide.
    - Almost vertical.
  - Divide into innumerable bronchial tubes or bronchioles.
- **Lungs**
  - **Location** — Occupy all of the cavity of the thorax that is not taken up by the heart, blood-vessels, lymphatics, and œsophagus.
  - **Cone-shaped organs**
    - Outer surface convex to fit in concave cavity.
    - Base concave to fit over convex diaphragm.
    - Apex rises half an inch above the clavicle.
    - Hilum or depression on inner surface gives passage to bronchi, blood-vessels, lymphatics, and nerves.
  - **Right**
    - Three lobes — larger, heavier, broader, shorter.
  - **Left**
    - Two lobes — smaller, narrower, longer, front border deeply indented.
  - **Anatomy**
    - Hollow, spongy organs. Consist of bronchial tubes — infundibula — alveoli, also blood-vessels, lymphatics, and nerves held together by connective tissues.
  - **Blood-vessels**
    - **Pulmonary artery**
      - Blood for aëration.
      - Accompany bronchial tubes.
      - Plexus of capillaries around alveoli.
      - Returned by pulmonary veins.
    - **Bronchial arteries**—supply lung substance.
  - **Nerves**
    1. Branches from the sympathetic system.
    2. Branches from the pneumogastric.

- **Pleura**
  - Closed sac. Envelops lungs, but they are not in it.
  - Two layers
    - Visceral — next to lung
    - Parietal — outside of visceral
      - Moistened by serum.
  - **Function** — To lessen friction.
- **Mediastinum** — Space between pleural sacs. Extends from sternum to spinal column.
- **Respiration**
  - **Function**
    - Increase the amount of oxygen.
    - Decrease the amount of carbon dioxide.
    - Help to maintain temperature.
    - Help to eliminate waste.
  - **External**
    - Absorption of oxygen from air by circulating blood in the lungs.
    - Absorption of carbon dioxide from circulating blood by the air in the air sacs.
    - **Inspiration** — Process of taking air into lungs.
    - **Expiration** — Process of expelling air from lungs.
  - **Internal**
    - Absorption of oxygen from the blood by all the cells of the body.
    - Absorption of carbon dioxide from all the cells by the blood.
- **Mechanism of Inspiration and Expiration**
  - **Inspiration**
    - Chest cavity enlarged
      - Elevation of ribs.
      - Descent of diaphragm.
    - Lungs expand.
    - Air rushes in through trachea and bronchi.
  - **Expiration**
    - Chest cavity made smaller
      - Inspiratory muscles relax.
      - Recoil of elastic thorax.
      - Recoil of elastic lungs.
    - Air forced out through trachea.
- **Cause of Respiration**
  1. **Respiratory centre** — Action is automatic. Assumed to be in connection with all the cranial and spinal nerves.
  2. **Pneumogastric nerves.**
  3. **Sympathetic nerves.**
  - Rate and rhythm controlled by
    - Pneumogastric nerves
      - Inspiratory — tend to increase rate.
      - Expiratory — check the action of the inspiratory set.
    - Carbon dioxide content of blood.

Cause of First Respiration
1. Increased amount of carbon dioxide due to cutting of the cord.
2. Reflex, due to stimulation of the sensory nerves of the skin.

Respiratory Rate
- 18 times per minute.
- Ratio to pulse 1 to 4.
- Influenced by
  - Muscular exercise.
  - Emotion.
  - Heart-beat.
  - Age.

Effect of Respiration upon the Blood
1. Loses carbon dioxide.
2. Gains oxygen
   - Oxyhæmoglobin.
   - Scarlet color.
3. Temperature is slightly reduced.

Capacity of Lungs
- A little more than 1 gallon of air (4500 c.c.)
  - Tidal
  - Complementary
  - Reserve
  - Residual
- Tidal, Complementary, Reserve: Vital capacity 3700 c.c.

Movement of Residual Air maintained by
1. Alternate expansion and collapse of lungs.
2. Convection currents.
3. Pulsation of the arteries.
4. Diffusion of gases.

Effect of Respiration upon the Air outside the Body
1. Temperature increased. Expired air is as hot as blood.
2. Moisture increased. Expired air is saturated with moisture.
3. Oxygen decreased by 4.94 parts in a hundred.
4. Carbon dioxide increased by 4.38 parts in a hundred.
5. Organic matter gained.

Proper Ventilation
1. Composition of air as regards oxygen and carbon dioxide.
2. Proper temperature.
3. Degree of humidity.

Abnormal Types
- Dyspnœa — difficult breathing.
- Hyperpnœa — excessive breathing.
- Apnœa — lack of breathing.
- Cheyne-Stokes
  1. Respirations increase in force and frequency, then gradually decrease and stop. Cycle repeated.
  2. Respirations increase in force and frequency up to a certain point, then stop. Cycle repeated.
- Œdematous — air cells filled with fluid, hence moist, rattling sounds.
- Asphyxia — oxygen starvation.

CHAPTER XIV

THE DIGESTIVE SYSTEM: ALIMENTARY CANAL AND ACCESSORY ORGANS

DIGESTION is the process by means of which the food we take into our mouths is transformed into a condition of solution or emulsion suitable for absorption into the blood. The organs in which the food is contained while undergoing digestion as well as the organs which assist in the process are grouped together and called the digestive system.

THE DIGESTIVE SYSTEM

The digestive system consists of the alimentary canal and the accessory organs: (1) the salivary glands, (2) the tongue, (3) the teeth, (4) the pancreas, and (5) the liver.

ALIMENTARY CANAL

The alimentary canal is a musculo-membranous tube extending from the mouth to the anus. It is about twenty-eight feet long and the greater part of it is coiled up in the cavity of the abdomen. The diameter of the tube is by no means uniform, being considerably dilated in certain parts of its course. It is composed of three coats, the serous coat being absent from the mouth, to where it passes through the diaphragm, and of four coats in the abdominal cavity. These coats are: —

(1) **The mucous**	Both described in Chapter VIII.
(2) **The areolar**, or sub-mucous	

(3) **The muscular coat** is composed for the most part of unstriped muscular fibres, the layers of which are disposed in various ways, the most general arrangement being in a longitudinal and circular direction. By the alternate contraction and relaxation of fibres arranged in this fashion (the contractions starting from above), the contents of the tube are propelled from above downward.

(4) **The serous coat** is derived from the peritoneum.

The peritoneum. — This is a double membrane, the outer or parietal layer of which lines the inner surface of the abdominal and pelvic cavities, and the inner or visceral layer is reflected back over the contained organs. The arrangement of the peritoneum is very complex, for several elongated sacs and double folds extend from it, to pass in between and either wholly or partially surround the viscera of the abdomen and pelvis. One important fold is the *omentum,* which hangs like a curtain in front of the stomach and the intestines; another is the *mesentery,* which surrounds the greater part of the small intestine. The posterior portion of the mesentery is gathered into folds which are attached to the spine and serve to hold the intestines in place.

Functions of the peritoneum. — Like all serous membranes the peritoneum serves to prevent friction between contiguous organs by secreting serum which acts as a lubricant. It also serves to hold the abdominal and pelvic organs in position, to unite and separate these organs, and supports numerous nerves and blood-vessels. The omentum usually contains fat, and, in addition to the usual functions, serves to keep the organs it covers warm.

Divisions of the alimentary canal. — For convenience of description, the alimentary canal may be divided into: —

Mouth, containing tonsils, tongue, salivary glands, and teeth.

Pharynx.
Œsophagus.
Stomach.
Small or thin intestine
  Duodenum.
  Jejunum.
  Ileum.
Large or thick intestine
  Cæcum.
  Colon
    Ascending.
    Transverse.
    Descending.
  Rectum.

MOUTH, OR BUCCAL CAVITY

The mouth is a nearly oval-shaped cavity with a fixed roof anteriorly, a flexible roof posteriorly, and a movable floor. It is bounded in front by the lips, on the sides by the cheeks, below by the tongue, and above by the palate.

The palate. — The palate consists of a hard portion in front formed by bone, covered by mucous membrane, and of a soft portion behind containing no bone. The hard palate forms the partition between the mouth and nose; the soft palate arches backward and hangs like a curtain between the mouth and the pharynx. Hanging from the middle of its lower border is a pointed portion of the soft palate called the **uvula** (little grape).

Palatine arches. — From the base of the uvula on either side there passes a curved fold of muscular tissue covered by mucous membrane, which shortly after leaving the uvula is, as it were, split into two pillars, the one going outward, downward, and forward, passing to the side of the tongue, the other outward, downward, and backward to the side of the pharynx. These pillars are known respectively as the anterior and the posterior pillars of the fauces.

Tonsils. — In the lower part of the triangular space between the anterior and posterior pillars on either side lie the small masses of lymphoid tissue called tonsils. They consist of a collection of lymph nodules held together by a distinct capsule and covered on their exposed surface by mucous membrane.

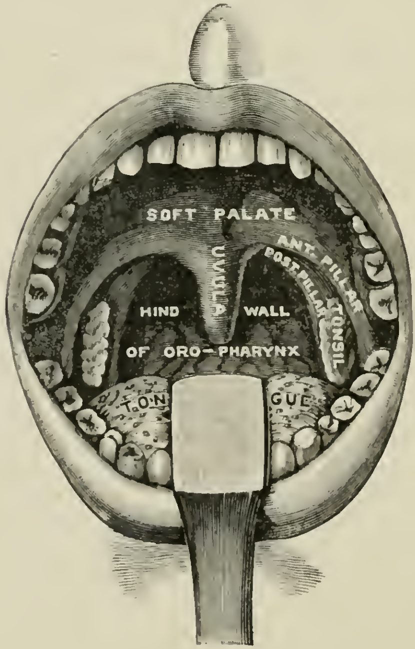

Fig. 147. — The Soft Palate and Tonsillar Regions. (Gerrish.)

Function. — The function of the tonsils is imperfectly understood. They may be a source of lymphocytes and leucocytes, or they may act as filters and prevent the entrance of microörganisms. Inflammation of the tonsils is called tonsillitis.

The palate, uvula, palatine arches, and tonsils are plainly seen if the mouth is widely opened and the tongue depressed.

The **fauces** is the name given to the aperture leading from the mouth into the pharynx, or throat cavity.

The tongue. — The tongue[1] is the special organ of the sense of taste and assists in speech. It has also to be considered with reference to digestion, (1) because stimulation of the nerves of the sense of taste start the secretion of digestive juices, (2) it assists in swallowing, and (3) the follicles at the back of the tongue secrete mucus, which lubricates the food and makes swallowing easier.

The salivary glands. — The mucous membrane lining the mouth contains many minute glands consisting of just one cell. These are called goblet cells and pour their secretion upon its surface, but the chief secretion of the mouth is supplied by the salivary glands, which are three pairs of compound saccular glands called the parotid, submaxillary, and sublingual, respectively. Each **parotid** gland is placed just under and in front of the ear; its duct passes forward along the cheek, until it opens into the interior of the mouth opposite the second molar tooth of the upper jaw. The **submaxillary** and **sublingual** glands are situated below the jaw and under the tongue, the submaxillary being placed further back than the sublingual. Their ducts open in the floor of the mouth beneath the tongue. The secretion of these salivary glands, mixed with that of the small glands of the mouth, is called saliva.

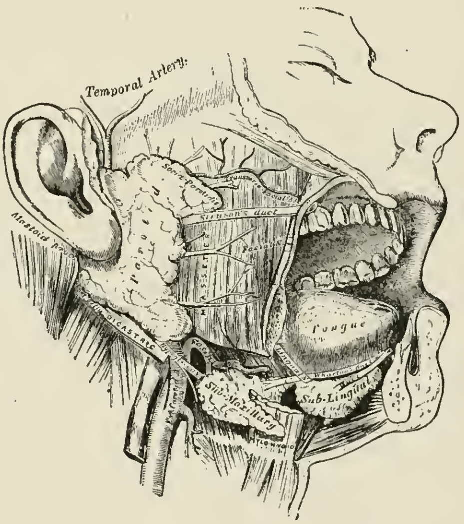

FIG. 148. — THE SALIVARY GLANDS.

The teeth. — The semicircular borders of the upper and lower

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[1] A detailed description of the tongue will be found in Chapter XX.

jaw-bones (the alveolar processes) contain sockets for the reception of the teeth. A dense insensitive fibrous membrane covered by smooth mucous membrane — the gums — covers these processes and extends a little way into each socket. These sockets are lined by periosteum, which connects with the gums and serves (1) to attach the teeth to their sockets, and (2) as a source of nourishment.

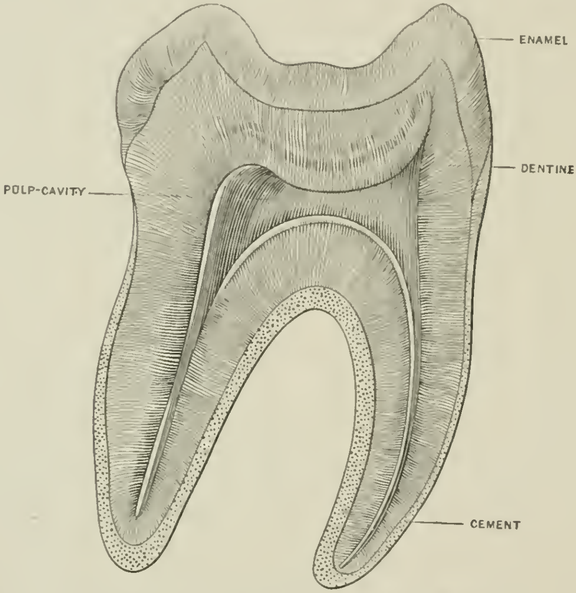

Fig. 149. — Section of Human Molar Tooth. Magnified. (Dalton.)

Each tooth consists of three portions: (1) the *root*, consisting of one or more fangs contained in the socket; (2) the *crown*, which projects beyond the level of the gums; and (3) the *neck* or constricted portion between the root and the crown, which is enveloped by the gum.

Each tooth is composed principally of dentine, which gives it shape and encloses a cavity, the pulp cavity. The dentine of the crown is capped with a dense layer of enamel. The dentine of the root is covered by cement. These three substances, enamel, dentine, and cement, are all harder than bone, enamel being the hardest substance found in the body. They are developed from epithelial tissue. The pulp cavity is just under the crown and is continuous with a canal that traverses the centre of each root, and opens by a small aperture at its extremity. It is filled with dental pulp, which consists of loose connective tissue holding a number of blood-vessels and nerves which enter by means of the canal from the root.

There are two sets of teeth developed during life: the first, temporary or deciduous; and the second, permanent.

Temporary teeth. — In the first set are twenty teeth, ten in each jaw. The cutting of the temporary teeth begins usually at seven months and ends at about the age of two and one-half years.[1]

Permanent teeth. — In the second set are thirty-two permanent teeth, sixteen in each jaw. During childhood the temporary teeth are replaced by the permanent. The first molar usually appears at six years of age.

According to their shape and use the teeth are divided into incisors, canines, premolars, and molars.

	Right			Middle	Left		
	Molar	Premolar	Canine	Incisor	Canine	Premolar	Molar
Upper . . .	3	2	1	4	1	2	3
Lower . . .	3	2	1	4	1	2	3

(Collins.)

Incisors are eight in number and form the four front teeth of each jaw. They have wide, sharp edges, and are specially adapted for cutting food.

Canines are four in number, two in each jaw. The upper canines are commonly called eye-teeth, the lower, stomach teeth. They have a sharp, pointed edge and are longer than the incisors. In the human animal they serve the same purpose as the incisors.

Premolars (or bicuspids) are eight in number in the permanent set, but there are none in the temporary set. There are four in each jaw, two being placed just behind each of the canine teeth.

They are broad, with two points or cusps on each crown; these teeth have only one root, the root, however, being more or less completely divided into two. Their function is to cut and grind food.

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[1] The temporary teeth are usually cut in the following order, the teeth of each group appearing first in the lower jaw: central incisors, 7th month; lateral incisors, 7th to 10th month; front molars, 12th to 14th month; canine, 14th to 20th month; back molars, 18th to 30th month.

Molars are twelve in number in the permanent set, but there are only eight in the temporary set.

The molars, or true grinders, have broad crowns with small, pointed projections, which make them well fitted for crushing and bruising the food: they each have two or three roots. The twelve molars do not replace the temporary teeth, but are gradually added with the growth of the jaws; the last or hindermost molars may not appear until twenty-one years of age; hence called " late teeth " or " wisdom teeth."

Function. — The teeth assist in the process of mastication by cutting and grinding the food.

THE PHARYNX

The pharynx, or throat cavity, is a musculo-membranous bag shaped somewhat like a funnel, with its broad end turned upward, and its constricted end downward to end in the œsophagus. It is about four and a half inches (113 mm.) long, and lies behind the nose and mouth. Above, it is attached to the base of the skull, and behind, to the cervical vertebræ; in front and on each side are apertures which communicate with the nose, ears, mouth, and larynx.

Of these apertures there are **seven**: —

Two in front above, leading into the back of the nose, the posterior nares.

Two, one on either side above, leading into the Eustachian tubes, which communicate with the ears.

One midway in front, the fauces.

Two below, one opening into the larynx and the other into the œsophagus.

The mucous membrane lining the pharynx is well supplied with glands, and at the back of the cavity there is a considerable mass of lymphoid tissue. During infancy and childhood this may increase to such an extent that it interferes with nasal breathing. The child is then said to have *adenoids* and is obliged to breathe through the mouth; hence the term " mouth breathers."

Function. — The muscular tissue in the walls of the pharynx is of the striped variety, and when the act of swallowing is about to be performed, the muscles draw the pharyngeal bag upward and dilate it to receive the food; they then relax, the bag sinks, and the other muscles contracting upon the food, it is pressed downward and onward into the œsophagus.

THE ŒSOPHAGUS, OR GULLET

The œsophagus is a comparatively straight tube, about nine inches (225 mm.) long, which commences at the lower end of the pharynx, behind the trachea. It descends in front of the spine, passes through the diaphragm, and terminates in the upper or cardiac end of the stomach.

Structure. — The walls of the œsophagus are composed of three coats: (1) an external or muscular, (2) a middle or areolar, and (3) an internal or mucous, coat. The fibres of the muscular coat are arranged in an external longitudinal and in an internal circular layer. Contraction of the outer layer produces dilatation of the tube; contraction of the inner, constriction. Consequently this arrangement is of importance in the movements which carry the food from the pharynx to the stomach. These movements are called peristaltic and consist of contraction of the longitudinal fibres, followed by contraction of the circular fibres. The areolar coat serves to connect the muscular and mucous coats. The mucous membrane is disposed in longitudinal folds which disappear upon distention of the tube.

Function. —The œsophagus serves (1) to connect the pharynx with the stomach, and (2) to receive the food from the pharynx and by a series of peristaltic contractions pass it on to the stomach.

Regions of the abdomen. —That portion of the alimentary canal which is below the thorax is contained in the abdomen. For convenience of description, the abdomen may be artificially divided into nine regions by drawing the following arbitrary lines: —

1. Draw a circular line around the body at the level of the tenth costal cartilages.
2. Draw another circular line at the level of the anterior superior spines of the ilia.
3. Draw a vertical line on each side from the centre of Poupart's ligament upward.

These lines are to be considered as edges of planes which divide the abdomen into the following regions as per illustration.

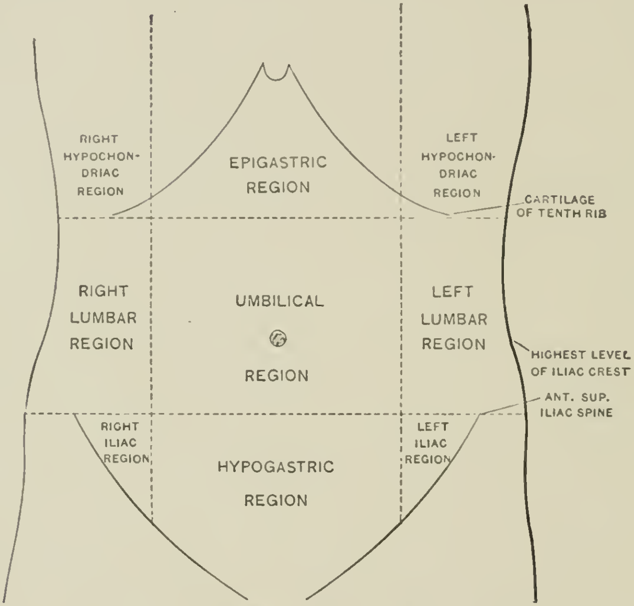

Fig. 150. — Regions of the Abdomen. (Gerrish.)

Right Hypochondriac. — The right lobe of the liver and the gall-bladder, hepatic flexure (right colic flexure) of the colon, and part of the right kidney.

Epigastric Region. — The pyloric end of the stomach, left lobe of the liver, the pancreas, the duodenum, parts of the kidneys, and the suprarenal capsules.

Left Hypochondriac. — The cardiac end of the stomach, the spleen and extremity of the pancreas, the splenic flexure (left colic flexure) of the colon, and part of the left kidney.

Right Lumbar. — Ascending colon, part of the right kidney, and some convolutions of the small intestines.

Umbilical Region. — The transverse colon, part of the great omentum and mesentery, transverse part of the duodenum, and some convolutions of the jejunum and ileum, and part of both kidneys.

Left Lumbar. — Descending colon, part of the omentum, part of the left kidney, and some convolutions of the small intestines.

Right Inguinal (Iliac). — The cæcum, vermiform appendix; the right ureter.

Hypogastric Region. — Convolutions of the small intestines, the bladder in children, and in adults if distended, and the uterus during pregnancy.

Left Inguinal (Iliac). — Sigmoid flexure of the colon; the left ureter.

THE STOMACH

After the œsophagus perforates the diaphragm it ends in the stomach (gaster), which is the most dilated portion of the alimentary canal. It is a hollow pouch placed obliquely in the left side of the upper portion of the abdominal cavity.[1] It is curved upon itself, so that below it presents a long, rounded outline, called the **greater curvature**, and above, a constricted, concave outline, called the **lesser curvature.**

The greater curvature is directed to the left, and the lesser curvature faces mostly to the right.

The **fundus**, or cardiac, end is the greater extremity, which projects several inches to the left of the œsophagus and is in contact with the spleen. The opposite or smaller end is called the pyloric extremity and lies under the liver.

The central portion between the fundus and pyloric extremity is called the intermediate region.

The stomach has necessarily two openings: the one leading into the œsophagus is usually termed the **cardiac aperture**; the other, leading into the small intestine, the **pyloric.** Both the cardiac and pyloric apertures are guarded by strong circular bands of muscle which are normally in a state of contraction. By this arrangement, the food is kept in the stomach until it is ready for intestinal digestion, when the circular fibres guarding the pyloric aperture relax and allow it to pass.

When distended, the stomach measures about fifteen inches (38 cm.) from end to end and about five inches (13 cm.) anteroposteriorly, and has a capacity of about one quart. The above description applies to the position and form of the stomach when normally filled with food, but the student must bear in mind that, when empty, the stomach contracts down so as more nearly to approach a true cylinder, the contraction and dilatation affecting more the greater curvature than the lesser. When contracted, the stomach is shorter as well as of lesser diameter.

Coats of the stomach. — It has four coats: from the outside, (1) serous, (2) muscular, (3) submucous or areolar, and (4) mucous.

(1) The **serous** coat is formed by a fold of the peritoneum. The

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[1] Epigastric and left hypochondriac region.

fold is slung over the stomach, in much the same way as we sling a towel over a clothesline, and covers it before and behind. The anterior and posterior folds unite at the lower border of the stomach and form an apron-like appendage, the **omentum**, which covers the whole of the intestines.

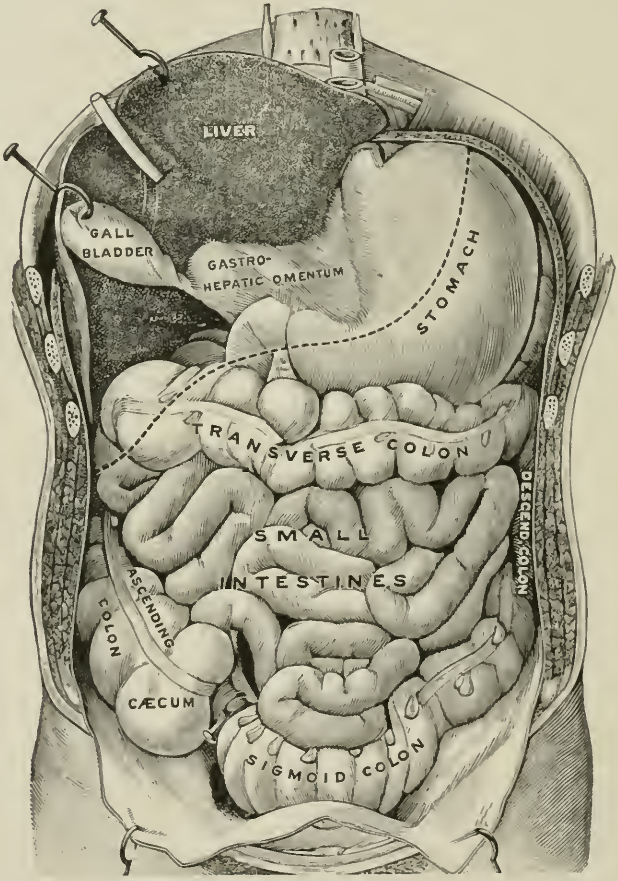

Fig. 151. — The Stomach and Intestines, Front View, the Great Omentum having been removed, and the Liver turned up and to the Right. The dotted line shows the normal position of the anterior border of the liver. (Gerrish.)

(2) The **muscular** coat of the stomach consists of three layers of unstriped muscular tissue: an outer, formed of longitudinal fibres; a middle, of circular; and an inner, of less well-developed, obliquely disposed fibres.

(3) The **submucous**, also called the areolar coat, is loose and vascular. It carries the nerves and vessels which go to and from the muscular and mucous coats.

(4) The **mucous** coat is very soft and thick, the thickness being mainly due to the fact that it is densely packed with small tubular glands. It is covered with columnar epithelium, and in its undistended condition is thrown into folds or rugæ. The surface is honeycombed by tiny, shallow pits, into which the ducts or mouths of the tubular glands open. The glands are of two kinds: (1) peptic, (2) pyloric. During digestion they secrete the gastric juice.

Nerves and blood-vessels. — The stomach is supplied with nerves from the sympathetic system, and also with branches from the pneumogastric nerve, which comes from the cerebrospinal system. The blood-vessels are derived from the three divisions of the cœliac axis.

Function. — The functions of the stomach are (1) to connect the œsophagus with the intestine, (2) to hold the food while it undergoes gastric digestion, and (3) to secrete mucus and gastric juice.

THE SMALL OR THIN INTESTINE

The small intestine extends from the stomach (pyloric valve) above to the large intestine (valve of the colon) below. It is a convoluted tube about twenty feet (6.0 m.) in length, and fills the greater part of the front abdominal cavity. Its diameter at the beginning is about two inches (5 cm.), but it gradually diminishes in size and is hardly an inch (2.5 cm.) in diameter at its lower end. The small intestine is divided by anatomists into three portions: —

The duodenum.
The jejunum.
The ileum.

The duodenum. — The duodenum is twelve fingers' breadth in length (eight inches or 20 cm.), and is the widest part of the small intestine. It extends from the pyloric end of the stomach to the jejunum.

Beginning at the pylorus, the duodenum at first passes in a direction upward and backward to the under surface of the liver; it then makes a complete bend and passes in a direction downward in front of the kidney; it again turns in a right angle direction to the left and passes horizontally across the front of the vertebral column. This third portion of the duodenum lies retroperitoneally, so that only its anterior aspect is covered by peritoneum. The small intestine now passes forward so as to leave the posterior abdominal wall, and becomes completely invested by peritoneum and has a true mesentery. The point at which it becomes completely invested by peritoneum marks the termination of the duodenum and the beginning of the jejunum.

The jejunum. — The jejunum, or empty intestine, so called because it is always found empty after death, constitutes about two-fifths of the remainder, or seven and a half feet (2.2 m.), of the small intestine, and extends from the duodenum to the ileum.

The ileum. — The ileum, or twisted intestine, so called from its numerous coils, constitutes the remainder of the small intestine, and extends from the jejunum to the large intestine, which it joins at a right angle.

There is no definite landmark to determine the point at which the jejunum ceases and the ileum begins, although the mucous membrane of the one differs somewhat from the mucous membrane of the other; the change is a gradual transition, and one structure shades off into the other. The lengths in feet as given are arbitrary, but those usually accepted.

Coats of the small intestine. — The small intestine has four coats, which correspond in character and arrangement with those of the stomach.

(1) The **serous** coat furnished by the peritoneum forms an almost complete covering for the whole tube except for part of the duodenum.

(2) The **muscular** coat of the small intestine has only two layers: an outer, thinner and longitudinal; and an inner, thicker and circular. This arrangement is necessary for the peristaltic action of the intestine.

(3) The **submucous**, or areolar coat, carries blood-vessels, lymphatics, and nerves.

(4) The **mucous** coat is thick and very vascular.

Valvulæ conniventes. — About two inches beyond the pylorus the mucous and submucous coats of the small intestine are arranged in circular folds called valvulæ conniventes. Each of these folds extends part of the way around the circumference of the intestine. Unlike the rugæ of the stomach, the valvulæ conniventes do not disappear when the intestine is distended. About the middle of the jejunum they begin to decrease in size, and in the lower part of the ileum they almost entirely disappear. The purpose of the circular folds is: (1) to prevent the food from passing through the intestines too quickly, and (2) to present a greater surface for the absorption of digested food.

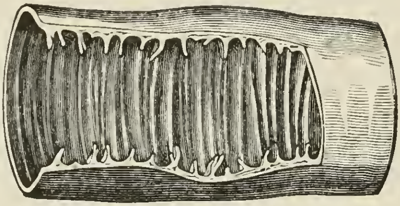

FIG. 152. — PORTION OF SMALL INTESTINE LAID OPEN TO SHOW VALVULÆ CONNIVENTES. (Collins.)

Villi. — Throughout the whole length of the small intestine the mucous membrane presents a velvety appearance due to minute finger-like projections called villi. Each villus consists of a central lymph channel called a lacteal, surrounded by a network of blood capillaries, held together by lymphoid tissue. This in turn is surrounded by a layer of columnar cells and covered by the mucous coat of the intestine. After the food has been digested it passes into the lacteals and capillaries of the villi, so that this arrangement increases the surface for absorption.

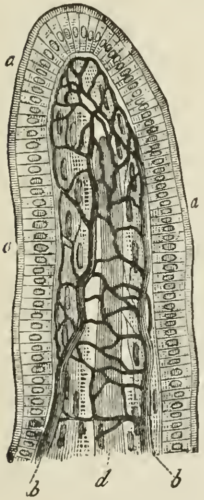

FIG. 153.—AN INTESTINAL VILLUS. *a, a, a,* columnar epithelium; *b, b,* capillary network; *d,* lacteal vessel.

Glands and nodes of the small intestine. — Besides these projections formed for absorption the mucous membrane is thickly studded with secretory glands and nodes. These are known as —

1. Simple follicles or crypts of Lieberkuhn.
2. Duodenal or Brunner's glands.
3. Lymph nodules $\begin{cases} (a) \text{ Solitary lymph nodules.} \\ (b) \text{ Aggregated lymph nodules.} \end{cases}$

(1) **Simple follicles.** — These glands are found all over the surface of the small and large intestine. They are simply tubular

depressions in the mucous membrane, lined with columnar epithelium.

(2) **Duodenal glands.** — These glands are better known as Brunner's glands. They are compound glands found in the submucous tissue of the duodenum. The simple follicles and the duodenal glands secrete the intestinal digestive juice which is named the succus entericus.

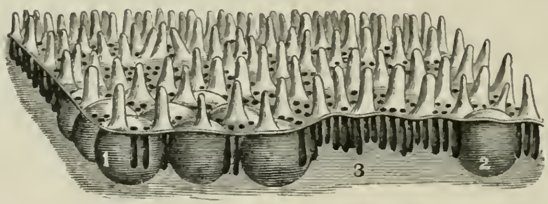

Fig. 154. — Portion of the Mucous Membrane, from the Ileum. Moderately magnified, exhibiting the villi on its free surface, and between them the orifices of the tubular glands. 1, portion of an aggregated lymph nodule; 2, a solitary lymph nodule; 3, fibrous tissue. (Dalton.)

(3) **Lymph nodules.** — These are of two varieties, (*a*) solitary lymph nodules, (*b*) aggregated lymph nodules of Peyer.

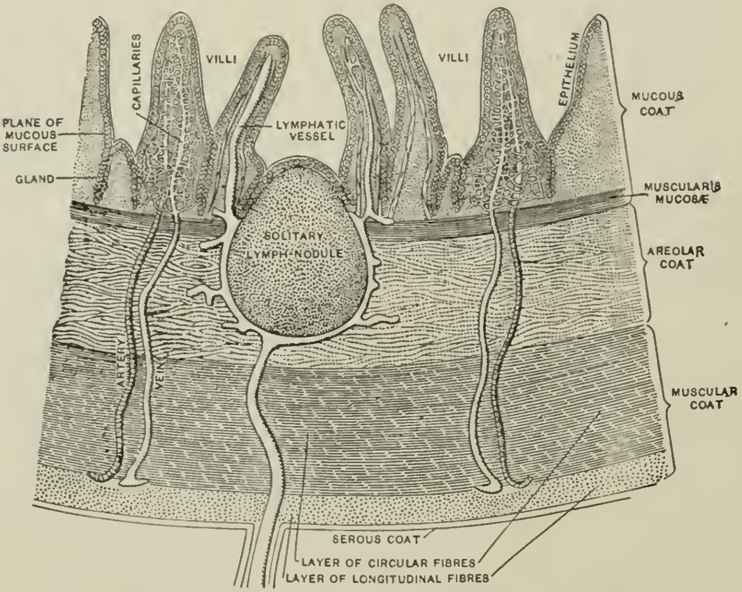

Fig. 155. — Mucosa of Small Intestine in Ideal Vertical Cross-section. (Gerrish.)

(*a*) *Solitary lymph nodules.* — Closely connected with the lymphatic vessels in the walls of the intestines are small, rounded bodies of the size of a small pin's head, called solitary lymph nodules. These bodies consist of a rounded mass of fine lymphoid tissue, the meshes of which are crowded with leucocytes. Into this mass of tissue one or more small arteries enter and form a capillary network, from which the blood is carried away by one or more small veins. Surrounding the mass are lymph channels which are continuous with the lymphatic vessels in the tissue below.

Aggregated lymph nodules. — They are simply collections of lymph nodules, commonly called Peyer's patches. A well-formed Peyer's patch consists of fifty or more of these solitary lymph nodules, arranged in a single layer, close under the epithelium of the intestinal mucous membrane, and stretching well down into the tissue beneath. These patches are circular or oval in shape, from one-half to three inches (12.5–75 mm.) long, and one-half inch (12.5 mm.) wide, and from twenty to thirty in number. They are largest and most numerous in the ileum. They increase in size during digestion. These Peyer's patches are the seat of local inflammation and ulceration in typhoid fever. It is interesting to note that in this condition, the long axis of the ulcer runs in the same direction as the long axis of the intestine; whereas in tuberculosis of the intestine, the long axis of the ulcer is at right angles to the long axis of the intestines.

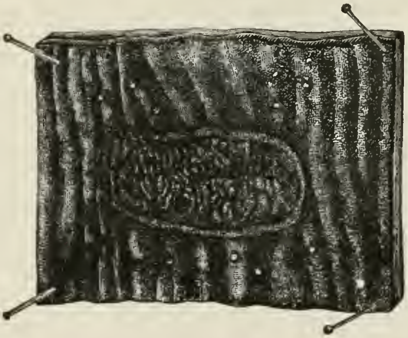

Fig. 156. — Aggregated Lymph Nodule (Peyer's Patch). (Gerrish.)

Function. — It is in the small intestine that the greatest amount of digestion and absorption takes place. The valvulæ conniventes delay the food so that it is more thoroughly subjected to the action of the digestive juices; and being covered with villi they increase the surface for absorption. The glands of the small intestine secrete the succus entericus which aids in the digestion of food.

THE LARGE OR THICK INTESTINE

The largeness of the next division of the alimentary canal is in its transverse, not in its longitudinal, diameter; for it is only about five feet (1.5 m.) long, but is much wider, being two and one-half inches (63 mm.) in its broadest part. It extends from the ileum to the anus. Like the small intestine, it is divided into three parts: the cæcum with the vermiform appendix, colon, and rectum.

The cæcum. — The cæcum (*cæcus*, blind) is a large blind pouch at the commencement of the large intestine. The small intestine opens into the side wall of the large intestine about two and a half inches (63 mm.) above its — the large intestine's — commencement, the cæcum forming a cul-de-sac below the opening. The opening from the ileum into the large intestine is provided with two large projecting lips of mucous membrane which allow the passage of material into the large intestine, but effectually prevent the passage of material in the opposite direction. These mucous folds form what is known as the valve of the colon, or the ileo-cæcal valve.

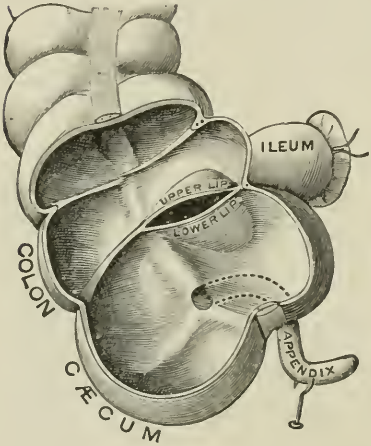

Fig. 157. — Cavity of the Cæcum, its Front Wall having been cut away. The valve of the colon and the opening of the appendix are shown. (Gerrish.)

The **vermiform appendix** is a narrow, wormlike tube about the diameter of an ordinary lead pencil, and from three to seven inches (7.5 to 17.5 cm.) long. It is attached to the lower end of the cæcum, but its directions and relations are very variable. In a general way it may be said to be located in the right iliac fossa.

The colon. — The colon, though one continuous tube, is subdivided into the **ascending**, **transverse**, and **descending** colon, with the sigmoid flexure. The ascending portion ascends on the right side of the abdomen until it reaches the under surface of the liver, where it bends abruptly to the left (right colic or hepatic flexure), and is continued across the abdomen as the transverse colon until, reaching the left side, it curves beneath the lower end of the spleen (left colic or splenic flexure) and passes downward as the descending colon. Reaching the left iliac region on a level with the margin of the crest of the ileum, it makes a curve like the letter S, — hence its name of sigmoid flexure, — and finally ends in the rectum.

The rectum. — The rectum is from six to eight inches (15 to 20 cm.) long; it passes obliquely from the left until it reaches the middle of the sacrum, then it follows the curve of the sacrum and the coccyx, and finally arches slightly backward to its termination at the anus.

The *anus* is the aperture leading from the rectum to the exterior of the body. It is guarded, and except during defecation is kept closed by the contraction of two involuntary circular muscles called, respectively, the internal and external sphincters.

Coats of the large intestine. — The large intestine has the usual four coats except in some parts where the serous coat only partially covers it, and the rectum, where the serous coat is lacking. The muscular coat consists of two layers of fibres, one arranged longitudinally and the other circularly. Beginning at the appendix, the longitudinal fibres are arranged in three ribbon-like bands, which extend the whole length of the colon to the rectum, and these bands being shorter than the rest of the tube, the walls are puckered between them. The third coat consists of submucous areolar tissue, and the fourth or inner coat consists of mucous membrane. The mucous coat possesses no villi and no circular folds. It contains numerous tubular glands and solitary lymph nodules which closely resemble those of the small intestine.

Functions. — The functions of the large intestine are three. (1) The process of digestion is continued. This is due to the presence of bacteria, and to the digestive juices with which the food became mixed in the small intestine. (2) The process of absorption is continued, and (3) the waste products are removed from the body.

ACCESSORY ORGANS OF DIGESTION

The accessory organs of digestion are: (1) the salivary glands, (2) the tongue, (3) the teeth, (4) the pancreas, and (5) the liver. The first three have been described.

PANCREAS

The pancreas is an elongated organ, of a pinkish color, which lies in front of the first and second lumbar vertebræ and behind the stomach. It weighs between two and three ounces (60 to 90 grams), is about six inches (150 mm.) long, two inches (50 mm.) wide, and one-half inch (12.5 mm.) thick. In shape it somewhat resembles a hammer, and is divided into head, body, and tail. The right end or head is thicker and fills the curve of the duodenum, to which it is firmly attached. The left, free end is the tail, and reaches to the spleen. The intervening portion is the body.

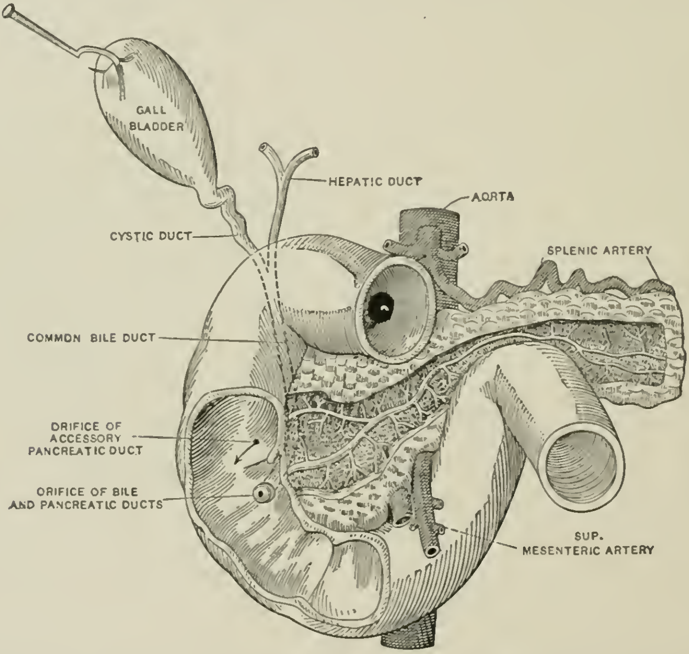

Fig. 158. — Ducts of the Pancreas. Part of the front wall of the duodenum is cut away. (Gerrish.)

Structure of the pancreas. — It is a compound secreting gland and consists of minute tubes coiled up into little masses called lobules, each lobule having its own duct. The lobules are joined together by connective tissue to form lobes, and the lobes, united in the same manner, form the gland. The small ducts open into one main duct about the size of a goose-quill, which runs lengthwise through the gland, from the tail to the head. The pancreatic and common bile duct enter by means of a common opening into the duodenum about three inches (75 mm.) beyond the pylorus.

Islands of Langerhans. — Scattered throughout the pancreas are round or ovoid bodies known as the islands of Langerhans. Each island is about one twenty-fifth inch (1 mm.) in diameter and consists of a group of many-sided cells. They are surrounded by a rich capillary network. Considerable evidence supports the theory that the internal secretion of the pancreas is formed by these islands.

Function. — Two secretions are formed in the pancreas. (1) The pancreatic juice, which is one of the most important of the digestive juices, is an external secretion and is poured into the duodenum during intestinal digestion. (2) The secretion formed by the islands of Langerhans is an internal secretion that is absorbed by the blood and carried to the tissues. This internal secretion aids in the oxidation of glucose.

Diabetes mellitus. — This is a disease characterized by a lack of oxidation of glucose and its consequent loss to the body as it is excreted in the urine. The cause is not settled, but it is believed that disease of the pancreas involving the islands of Langerhans may produce this condition.

THE LIVER

The liver (hepar) is the largest gland in the body, weighing ordinarily from fifty to sixty ounces (1500 to 1800 grams). It measures ten to twelve inches (25 to 30 cm.) from side to side, six to seven inches (15 to 17.5 cm.) from front to back, and three to four inches (7.5 to 10 cm.) from above downward in its thickest part. It is a dark reddish brown organ, placed in the upper right and middle portion of the abdomen,[1] and extending somewhat into the left hypochondriac region. The upper convex surface fits closely into the under surface of the diaphragm. The under concave surface of the organ fits over the right kidney, the upper portion of the ascending colon, and the pyloric end of the stomach. The number *five* prevails in the parts and appendages of the liver.

Ligaments. — The liver is held in place by five ligaments, four of which are formed by folds of peritoneum, and the fifth, or round

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[1] Right hypochondriac and epigastric regions.

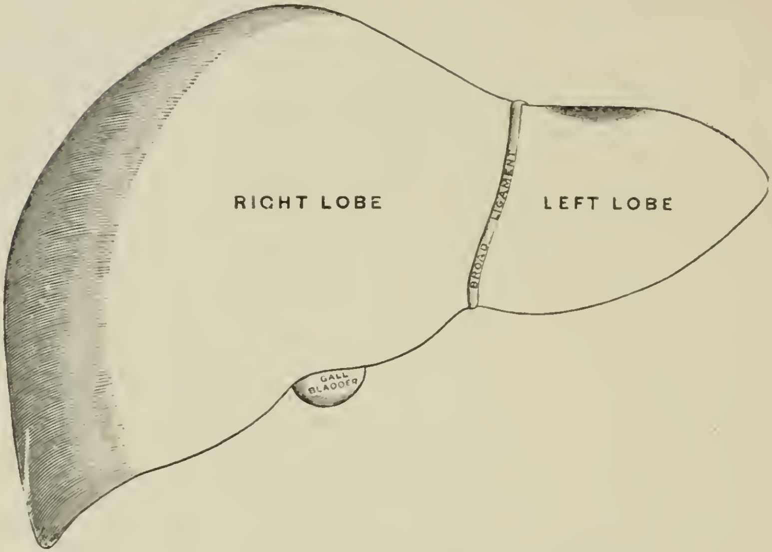

Fig. 159. — The Liver. Front View. (Gerrish.)

ligament, results from the atrophy of the umbilical vein of intrauterine life.

Fissures. — The liver is divided by five fissures into five lobes. The important fissures are (1) the **portal**, or transverse, which is the gateway for vessels, ducts, and nerves to enter and leave

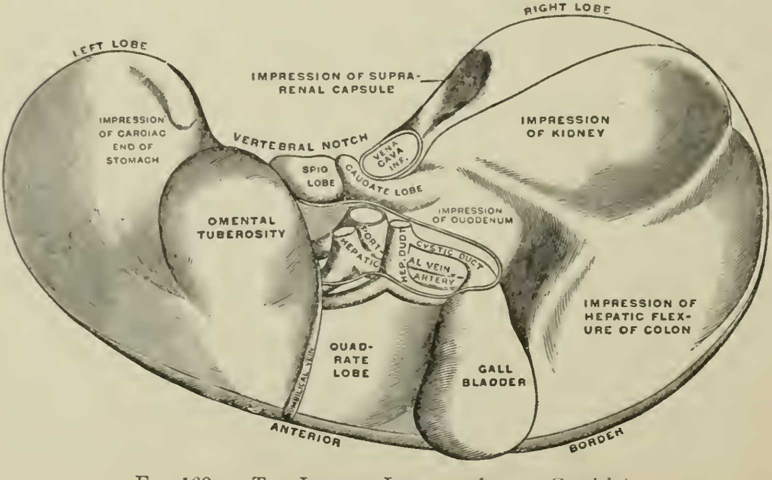

Fig. 160. — The Liver. Lower surface. (Gerrish.)

the liver, and (2) the gall bladder fissure, which supports the gall bladder. Both these fissures are in the under surface of the liver.

Lobes. — The liver is divided into five lobes: —

1. Right (largest lobe).
2. Left (smaller and wedge-shaped).
3. Quadrate (square).
4. Caudate (tail-like).
5. Spigelian.

Vessels. — The liver has five sets of vessels: —

1. Branches of portal vein.
2. Hepatic veins.
3. Bile ducts.
4. Branches of hepatic artery.
5. Lymphatics.

Minute anatomy of liver. — The liver may be regarded as made up of many minute livers called lobules. Each **lobule** is an irregular body about one-twelfth inch (2 mm.) in diameter, composed of a multitude of hepatic cells packed so closely together that only enough room is left between them for the passage of vessels and nerves. Thus each lobule is a mass of hepatic cells, pierced everywhere with a network of blood capillaries.

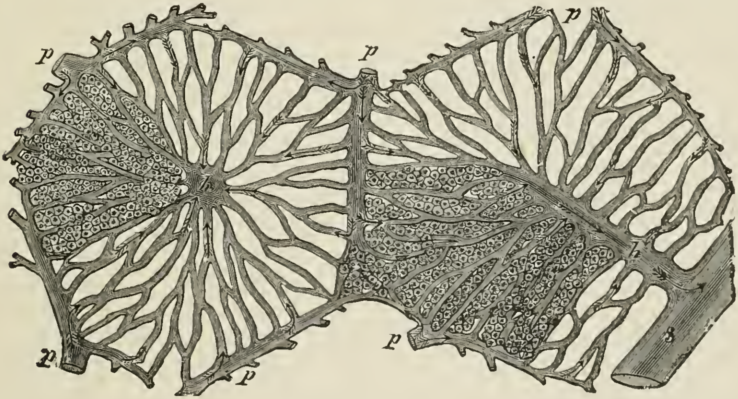

Fig. 161. — Diagrammatic Representation of two Hepatic Lobules. The left-hand lobule is represented with the intralobular vein cut across; in the right-hand one the section takes the course of the intralobular vein. *p*, interlobular branches of the portal vein; *h*, intralobular branches of the hepatic veins; *s*, sublobular vein. The arrows indicate the direction of the course of the blood. The liver-cells are only represented in one part of each lobule.

Hepatic cells. — They are about $\frac{1}{1000}$ of an inch in diameter, but because of compression are very irregular in shape. They are epithelial cells composed of protoplasm, with a single clear nucleus, but no cell-wall.

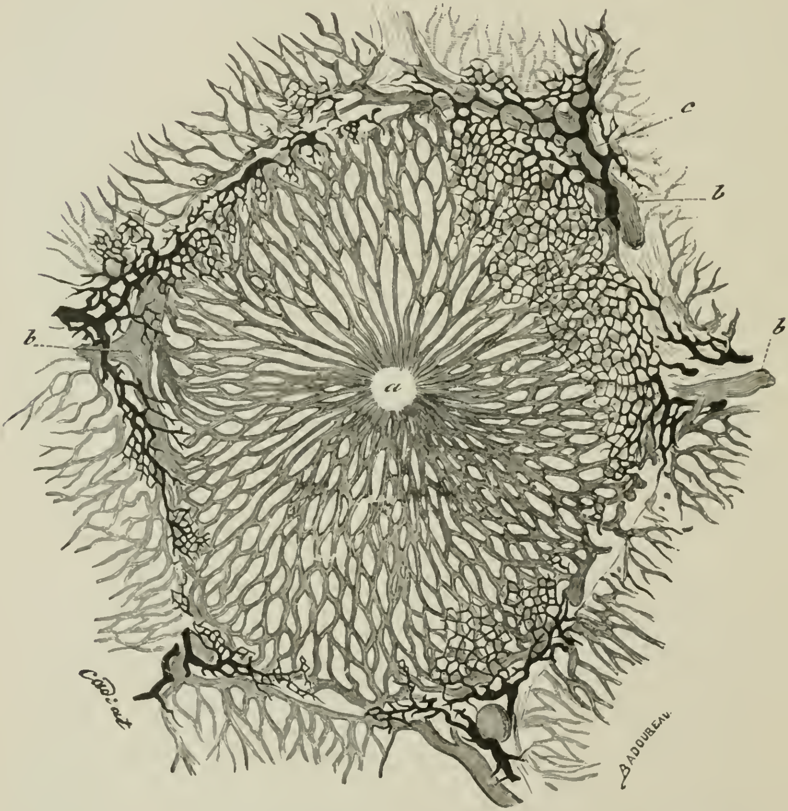

Fig. 162. — Lobule of Rabbit's Liver, Vessels and Bile Ducts Injected. *a*, central or intralobular vein; *b*, *b*, interlobular veins; *c*, interlobular bile duct.

The portal vein. — The portal vein, after entering the liver, divides into a vast number of branches which form a network surrounding each lobule, and hence are known as **interlobular** (between the lobules). From this network minute capillaries enter the lobule, penetrate between each cell and thus surround them, so that each cell is generously supplied with blood containing the raw material for the manufacture of bile. These capillary branches which enter the lobule and surround the cells are called **intralobular** (within the lobule). These vessels converge toward the centre of the lobule like the spokes of a wheel and empty into a vein (**intralobular**) which carries the blood away from the lobule. The intralobular veins from a number of lobules empty into a much larger vein upon whose surface a vast number of lobules rest, and therefore the name **sublobular** (under the lobule) is given to this kind of veins. They empty into still larger veins, the **hepatic**, which converge to a few large trunks and terminate in the **inferior vena cava**, which is embedded in the posterior surface of the gland.

The bile ducts. — The surfaces of the hepatic cells are grooved, and the grooves on two adjacent cells fit together and form a channel into which the bile is poured as soon as it is formed by the cells. These channels form a network between and around the cells as intricate as the network of blood-vessels. They are called intralobular ducts, and empty into larger ducts called interlobular. These unite and form larger and larger ducts until two main ducts, one from the right and one from the left side of the liver, unite in the portal fissure and form the **hepatic** duct.

The **hepatic duct** runs downward and to the right for about two inches (50 mm.) and then joins at an acute angle the duct from the gall-bladder, termed the **cystic duct**. The hepatic and cystic ducts together form the **common bile duct** (*ductus communis choledochus*), which runs downward for about three inches (75 mm.) and enters the duodenum about three inches (75 mm.) below the pylorus. This orifice serves as a common opening for both the common bile and the pancreatic duct. It is very small and is guarded by a sphincter muscle which keeps it closed except during digestion. (See Fig. 158.)

Hepatic artery. — We must remember that the blood brought to the liver by the portal vein is venous blood from the stomach, spleen, pancreas, and intestines. It is rich with the products of digestion and intended for the manufacture of bile, etc. It is not intended for purposes of nourishment of the liver itself, hence arterial blood is furnished by the **hepatic artery**. It enters the liver with the portal vein, divides and subdivides in the same way, thus forming another network between the lobules, and in the lobules between the cells. The capillaries from the portal vein and the hepatic artery are separate and distinct until, near the centre of each lobule, they unite, and all the blood supplied to the liver is carried away from it by the one set of veins described under head of portal vein.

Lymphatics. — There is a deep and a superficial set. They begin in irregular spaces in the lobules, form networks around the lobules, and run always from the centre outward. They drain off waste products and unconsumed nutritious substances.

Glisson's capsule. — The whole liver is invested in an outer capsule of areolar connective tissue, which is reflected inward at the portal fissure and encloses the vessels and ducts passing through this opening.

Serous membrane. — With the exception of a few small areas, the liver is enclosed in a serous tunic derived from the peritoneum.

Nerves. — Nerves are derived from the left pneumogastric and the solar plexus.[1]

Functions. — The liver may be compared to a wonderful laboratory, the most wonderful in the body. It has three important functions: —

1. *Bile secreting.* — The cells of the liver manufacture bile from the blood brought to them by the portal vein. The function of bile is considered in the next chapter.

2. *Glycogenic.* — The cells of the liver take from the blood brought to them by the portal vein a substance called glucose, which is derived from the carbohydrates eaten. This is stored in the liver in the form of glycogen until such time as the body needs more glucose than the food eaten furnishes. When such demand is made, the liver cells reconvert the glycogen into glucose and pour it into the circulation.

3. *Higher chemical activities.* — Many of the end products of protein digestion are toxic substances. Some of these substances are acted upon by the liver and rendered less harmful. Others are changed into urea, and in the form of urea it is possible for the kidneys to eliminate them from the blood.

The gall-bladder. — The gall-bladder is a pear-shaped sac, lodged in the gall-bladder fissure on the under surface of the liver, where it is held in place by a fold of the peritoneum. It is about four inches (10 cm.) long, one inch (25 mm.) wide, and holds about ten drachms (25 gms.). It is composed of three coats: (1) the inner one is

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[1] See page 376.

mucous membrane, (2) the middle one is muscular and fibrous tissue, and (3) the outer one is serous membrane derived from the peritoneum.

Function. — The gall-bladder serves as a reservoir for the bile. During digestion the bile is poured steadily into the intestine; in the intervals it is stored in the gall-bladder.

SUMMARY

Digestion. — This is the process of changing food into products capable of absorption. It is dependent on the proper functioning of certain organs that are grouped together and called the digestive system.

- **Digestive System**
  - **Alimentary canal**
    - Mouth.
    - Pharynx.
    - Œsophagus, or gullet.
    - Stomach.
    - Small or thin intestine
      - Duodenum.
      - Jejunum.
      - Ileum.
    - Large or thick intestine
      - Cæcum.
      - Colon
        - Ascending.
        - Transverse.
        - Descending.
      - Rectum.
  - **Accessory organs**
    - Salivary glands.
    - Tongue.
    - Teeth.
    - Pancreas.
    - Liver.
- **Alimentary Canal**
  - About 28 ft. long.
  - From mouth to diaphragm — 3 coats
    - Mucous.
    - Areolar.
    - Muscular.
  - From diaphragm to rectum — 4 coats
    - Mucous.
    - Areolar.
    - Muscular.
    - Serous derived from peritoneum.
- **Mouth or Buccal Cavity**
  - Above — palate
    - 1. Hard palate.
    - 2. Soft palate — uvula, palatine arches, and tonsils.
  - Below — tongue.
  - Front — lips.
  - Sides — cheeks.
  - Contains
    - Tonsils.
    - Tongue.
    - Salivary glands.
    - Teeth.

Tonsils
- Collections of lymph nodules occupy triangular space between palatine arches on either side of throat.
- **Function**
  1. May be a source of lymphocytes and leucocytes.
  2. May act as a filter and prevent entrance of microörganisms.

Tongue
- Special organ of sense of taste.
- Assists in digestion
  1. Stimulates secretion of digestive juices.
  2. Assists in swallowing.
  3. Secretes mucus.

Salivary Glands
- Parotid — just under and in front of ear.
- Submaxillary, Sublingual — Below the jaw and under the tongue.
- **Function** — Form a secretion, that mixed with that of the mouth is called saliva.

Teeth
- Contained in sockets of alveolar processes of maxillæ and mandible.
- **Gums** — cover processes and extend into sockets.
- **Sockets** — lined with periosteum
  - Attaches teeth to sockets.
  - Source of nourishment.
- 3 portions
  - Root — one or more fangs contained in socket.
  - Crown — projects beyond level of gums.
  - Neck — portion between root and crown.
- Composed of three substances developed from epithelium
  - Dentine
    - Gives shape.
    - Encloses pulp cavity which contains nerves and blood-vessels, that enter by canal from root.
  - Enamel — Caps the crown.
  - Cement — Covers the root.
- 2 sets
  1. Temporary — 7 months to 2½ yrs.
     - Incisors 8
     - Canines 4
     - Molars 8
     - 20.
  2. Permanent — 6 yrs. to 21 yrs. of age
     - Incisors 8
     - Canines 4
     - Premolars 8
     - Molars 12
     - 32.
- **Function** — To assist in the process of mastication.

Pharynx
- Funnel-shaped bag, 4½ inches long, between mouth and œsophagus.
- Muscular and lined with mucous membrane.
- 7 apertures
  - 1 fauces.
  - 2 posterior nares.
  - 2 Eustachian tubes.
  - 1 larynx.
  - 1 œsophagus.

- **Œsophagus, or Gullet**
  - Tube — 9 in. long. Extends from pharynx to stomach.
  - 3 coats
    - Inner — mucous — disposed in folds.
    - Middle — submucous.
    - Outer — muscular
      - Internal circular fibres.
      - External longitudinal fibres.
  - **Function**—
    1. Connects the pharynx with the stomach.
    2. Receives the food and passes it on to stomach.
- **Stomach, or Gaster**
  - Hollow pouch. Capacity, 1 qt.
  - Oblique position in epigastric and left hypochondriac regions.
  - Curved upon itself
    - Greater curvature, below, directed toward the left.
    - Lesser curvature, above, directed toward the right.
  - Fundus or cardiac end is in contact with spleen.
  - Pyloric extremity under the liver.
  - Intermediate region, between fundus and pyloric extremity.
  - 4 coats
    - Outer — serous — peritoneum.
    - Muscular
      1. Longitudinal fibres.
      2. Circular.
      3. Oblique.
    - Submucous — vascular.
    - Mucous
      - Rugæ.
      - Glands
        - Peptic
        - Pyloric

        Gastric juice.
  - Nerves
    - Sympathetic system.
    - Pneumogastric nerve.
  - Blood-vessels from cœliac axis.
  - **Function**
    1. Connect the œsophagus with the intestine.
    2. To hold the food while it undergoes gastric digestion.
    3. To secrete mucus and gastric juice.
- **Small or Thin Intestine**
  - Convoluted tube extends from stomach to valve of colon. Twenty feet coiled up in abdominal cavity.
  - 3 divisions
    - Duodenum.
    - Jejunum.
    - Ileum.
  - 4 coats
    1. Serous from peritoneum, called mesentery.
    2. Muscular
       - Longitudinal layer.
       - Circular layer.
    3. Submucous
       - Blood-vessels.
       - Lymphatics.
       - Nerves.
    4. Mucous
       - Circular folds.
       - Villi — contain lacteals.

- **Small or Thin Intestine**
  - **Glands and nodes**
    - Simple follicles; Duodenal or Brunner's — Secrete intestinal juice.
    - Lymph nodules
      - Solitary.
      - Aggregated lymph nodules of Peyer — fifty or more solitary lymph nodules form so-called patches in small intestine.
  - **Function**
    - Digestion.
    - Absorption.
    - Secretion of succus entericus.
- **Large or Thick Intestine**
  - Largeness in its transverse, not in its longitudinal, diameter.
  - Length, 5 ft.; width, 2½ in. to 1½ in.
  - Extends from ileum to anus.
  - 3 divisions
    - Cæcum, with vermiform appendix.
    - Colon
      - Ascending.
      - Transverse.
      - Descending with sigmoid flexure.
    - Rectum — anus
      - Internal sphincter.
      - External sphincter.
  - 4 coats
    - 1. Serous, except in some parts it is only a partial covering, and at rectum it is wanting.
    - 2. Muscular
      - Longitudinal layer — Arranged in three ribbon-like bands that begin at appendix, and extend to rectum.
      - Circular layer
    - 3. Submucous.
    - 4. Mucous
      - No villi.
      - No circular folds.
      - Numerous
        - Tubular glands.
        - Solitary lymph nodules.
  - **Function**
    - Continuance of digestion and absorption
    - Elimination of waste.

- **Pancreas**
  - In front of first and second lumbar vertebræ, behind stomach.
  - Hammer shape
    - Head attached to duodenum.
    - Body in front of vertebra.
    - Tail reaches to spleen.
  - Size
    - Six inches long.
    - Two inches wide.
    - One-half inch thick.
  - Weight — two to three ounces.
  - Structure
    - Compound gland — coiled tubes form lobules.
    - Lobules held together by connective tissue form lobes.
    - Lobes form gland.
    - Duct from each lobule empties into pancreatic duct.
  - **Function**
    - 1\. Secretes pancreatic juice.
    - 2\. Forms an internal secretion.
- **Liver**
  - Largest gland in body.
  - Location
    - Right hypochondriac.
    - Epigastric.
    - Left hypochondriac.
  - Convex above — fits under diaphragm.
  - Concave below — fits over right kidney, ascending colon, and pyloric end of stomach.
  - **Five ligaments**
    - Formed by folds of peritoneum.
      - 1\. Suspensory, broad, or falciform
      - 2\. Coronary
      - 3\. Right lateral
      - 4\. Left lateral
    - Results from atrophy of umbilical vein.
      - 5\. Round ligament
  - **Five fissures**
    - Under surface.
      - 1\. Umbilical fissure
      - 2\. Gall-bladder fissure
      - 3\. Portal or transverse fissure
    - Dorsal surface.
      - 4\. Ductus venous fissure
      - 5\. Vena cava
  - **Five lobes**
    - 1\. Right (largest lobe).
    - 2\. Left (smaller and wedge-shaped).
    - 3\. Quadrate (square).
    - 4\. Caudate (tail-like).
    - 5\. Spigelian.

- **Liver**
  - **Five sets of vessels**
    1. Branches of portal vein.
    2. Bile ducts.
    3. Hepatic veins.
    4. Branches of hepatic artery.
    5. Lymphatics.
  - **Anatomy of liver**
    - Hepatic cells $\frac{1}{1000}$ in. in diameter grouped in lobules.
    - Lobules $\frac{1}{12}$ in. in diameter.
    - Branches of portal vein
      - Interlobular veins (between lobules).
      - Intralobular capillaries (within lobules).
      - Intralobular veins (within lobules).
      - Sublobular veins (under lobules).
      - Hepatic veins — exit at portal fissure, empty into superior vena cava.
    - Bile ducts
      - Channels between cells (within lobules).
      - Intralobular ducts.
      - Interlobular ducts.
      - Hepatic duct — exit at portal fissure.
    - Branches of hepatic artery
      - Interlobular arteries (between lobules).
      - Intralobular capillaries (within lobules).
      - Course beyond the intralobular capillaries same as that pursued by blood from portal vein.
    - Lymphatics
      - Start in lobules, form network, and run from centre to periphery.
      - Act as drain-pipes.
    - Glisson's capsule encloses the whole of the liver.
    - Serous membrane from the peritoneum almost completely covers it.
  - **Functions**
    1. Bile secreting.
    2. Glycogenic.
    3. Higher chemical activities
       - Renders waste products less toxic.
       - Forms urea.

Gall-bladder
- Pear-shaped sac lodged in gall-bladder fissure on under surface of liver.
- **Size**
  - Two inches long.
  - One inch wide.
  - Capacity about ten drachms.
- **3 coats**
  1. Mucous membrane.
  2. Fibrous and muscular tissue.
  3. Serous membrane from peritoneum.
- **Function** — Serves as a reservoir for bile.

CHAPTER XV

CLASSIFICATION OF FOOD. — DIGESTIVE PROCESSES; CHANGES THE FOOD UNDERGOES IN THE MOUTH, STOMACH, SMALL AND LARGE INTESTINE; ABSORPTION

Digestion. — The process of digestion takes place in the alimentary canal, and the purpose of it, as stated in a previous chapter, is to change the food that we eat into a soluble form, so that it can pass through the intestinal membranes and be absorbed by the blood.

Definition of food. — A food may be defined as a substance that contains one or more of the constituents found in the body, or a substance which the tissues of the body can act upon and convert into material for the production or repair of living tissue, or to yield energy.

CLASSIFICATION OF FOOD

As commonly used the term food includes everything that we eat and drink and comprises a great variety of substances. Chemical analysis enables us to divide all these substances into two great classes, and these are further subdivided as follows: —

1. Inorganic
   - Water.
   - Mineral matter or salts.
2. Organic
   - Proteins.
   - Carbohydrates.
   - Fats.

Water. — Water (H_2O) is a very stable compound of hydrogen and oxygen. It does not yield energy, but it does enter into the composition of all the tissues, supplies fluid for the body, acts as a solvent for food, and aids in the elimination of waste. Next to air it is the most necessary principle of life and constitutes about two-thirds of the body weight (66 per cent).

Salts. — The principal inorganic salts are: —

$$\left.\begin{array}{l}\text{Chloride}\\ \text{Phosphate}\\ \text{Sulphate}\\ \text{Carbonate}\end{array}\right\}\text{ of sodium and potassium.}$$

$$\left.\begin{array}{l}\text{Phosphate}\\ \text{Carbonate}\end{array}\right\}\text{ of calcium and magnesium.}$$

The inorganic salts are not oxidized in the body and therefore do not yield energy, but they are an essential part of all the tissues, and take part in the functions of the body in six ways: (1) they maintain the alkaline or neutral reaction of the fluids of the body; (2) they furnish the material for the acidity or alkalinity of the digestive fluids and other secretions; (3) they help in regulating the flow of fluids to and from the tissues, because they maintain the normal osmotic pressure; (4) they enter largely into the composition of the bones, teeth, and cartilage; (5) they are necessary for the clotting of blood; and (6) they give the fluids of the body their influence upon the elasticity and irritability of nerve and muscle.

Proteins. — Proteins are complex compounds and consist of carbon, hydrogen, nitrogen, oxygen; sulphur, phosphorus, and other elements may be present. They differ from carbohydrates and fats in having nitrogen and therefore are described as nitrogenous compounds. They occur in the form of: —

Albumins. — Simple proteins that are soluble in water and coagulable by heat. The white of egg when cooked, the scum that forms on milk when it is heated, and the coating that forms on meat when it has been subjected to high temperature are all forms of albumin that have been coagulated by heat.

Caseinogen. — If milk is allowed to stand until it sours, or if the process is hastened by the addition of acid or rennet, the caseinogen is formed into a curd.

Gluten. — This is the starchy nitrogenous substance found in wheat flour.

Legumin. — This is a protein substance found in vegetables that are classed as legumes, *i.e.* peas, beans, lentils, etc.

Extractives. — These are protein substances found in plant and animal bodies as a result of their metabolism.

Carbohydrates. — All sugars and starches are grouped together under the name of carbohydrates. They contain but three elements, carbon, hydrogen, and oxygen, the two latter in the proportion to form water. The varieties of carbohydrates are as follows: —

Simple or Monosaccharids	Glucose or dextrose, found in fruits, especially the grape, and in the blood. $C_6H_{12}O_6$.	Invert sugar.
	Fructose or levulose, found with glucose in fruits. $C_6H_{12}O_6$.	
Complex or Disaccharids	Sucrose or cane sugar. $C_{12}H_{22}O_{11}$.	
	Lactose or milk sugar. $C_{12}H_{22}O_{11}$.	
	Maltose or malt sugar. $C_{12}H_{22}O_{11}$.	

Sugars. — A study of the formulæ of the complex sugars will show that the composition is the same, but they are differently named because they give different reactions. Before any of the complex sugars can be utilized in the body they must first be changed either into glucose, or into invert sugar, which consists of a molecule each of glucose and fructose. One molecule of a complex sugar plus one molecule of water will form one molecule of glucose and fructose.

$$\overset{\text{Complex Sugar}}{C_{12}H_{22}O_{11}} + \overset{\text{Water}}{H_2O} = \underbrace{\overset{\text{Glucose}}{C_6H_{12}O_6} \,.\, \overset{\text{Fructose}}{C_6H_{12}O_6}}_{\text{Invert Sugar.}}$$

Polysaccharids	Starch — found in grain, tubers, roots, etc.	$(C_6H_{10}O_5)n$
	Cellulose — outside covering of starch grains, and basis of all woody fibres.	$(C_6H_{10}O_5)n$
	Glycogen — form in which sugar is stored in liver.	$(C_6H_{10}O_5)n$
	Dextrin — formed from starch by partial hydrolysis.	$(C_6H_{10}O_5)n$

Polysaccharids. — In all of these compounds the composition of the molecule is supposed to be rather complex, although the elements are present in each in the same relative proportion, as shown in the formulæ. The value of *n*, however, may be very small or very large and is probably different for each polysaccharid, which makes the actual composition of each member of the group different. For instance, n for the starch molecule is large, while for the dextrin molecule it is smaller, so that a single starch molecule in digestion may split into several molecules of dextrin of the same relative composition.

Fats. — Fats are composed of carbon, hydrogen, and oxygen, but the two latter elements, hydrogen and oxygen, are not in the proportion to form water. They are not simple substances, but are mixtures of palmitin, stearin, and olein, which are derived from the fatty acids named respectively palmitic, stearic, and oleic. Each molecule of a simple fat is made from one molecule of glycerine and three molecules of a fatty acid.

$$\overset{\text{GLYCERINE}}{C_3H_5(OH)_3} + \overset{\text{STEARIC ACID}}{3\ H \,.\, C_{18}H_{35}O_2} \rightarrow \overset{\text{STEARIN}}{C_3H_5(C_{18}H_{35}O_2)_3} + \overset{\text{WATER}}{3\ H_2O}.$$

In general, fats and oils are practically the same, and the mixture of fats found in the body is liquid at the body temperature. They are soluble in ether, chloroform, and hot alcohol, but are insoluble in water.

Decomposition of fats. — Under the influence of steam, mineral acids, and certain ferments found in the body, fats split up into the substances out of which they are built, *i.e.* glycerine and fatty acid.

$$\overset{\text{STEARIN}}{C_3H_5(C_{18}H_{35}O_2)_3} + \overset{\text{WATER}}{3\ H_2O} \rightarrow \overset{\text{GLYCERINE}}{C_3H_5(OH)_3} + \overset{\text{STEARIC ACID}}{3\ H \,.\, C_{18}H_{35}O_2}.$$

The process of *saponification* is similar to the above, only that instead of water a base is used and the final products are glycerine and soap.

$$\overset{\text{STEARIN}}{C_3H_5(C_{18}H_{35}O_2)_3} + \overset{\text{POTASSIUM HYDROXIDE}}{3\ KOH} \longrightarrow \overset{\text{GLYCERINE}}{C_3H_5(OH)_3} + \overset{\text{SOAP}}{3\ K(C_{18}H_{35}O_2)}.$$

Necessity for digestion. — Digestion is necessary because organic foods, with the exception of simple sugars, are not soluble in water, hence they cannot be absorbed. Inorganic foods are absorbed directly, because salts dissolve in water.

DIGESTIVE PROCESSES

Digestion consists of two processes, *i.e.* mechanical and chemical.

Mechanical processes. — Mechanical processes consist of various movements that result from the action of the muscles in the alimentary canal. They serve two important purposes: (1) in taking food in and moving it along through the digestive canal, and (2) in separating the food into small particles upon which the digestive fluids can act rapidly. These processes consist of: —

1. Mastication.
2. Deglutition.
3. Peristaltic action of œsophagus.
4. Peristaltic action of stomach.
5. Movements of the intestines.
6. Defecation.

Chemical digestion. — Chemical digestion is a process of hydrolysis which is dependent upon the presence of enzymes. By the term hydrolysis is meant the breaking down of complex molecules into simpler ones with the absorption of water. An example of hydrolysis is the conversion of any of the complex sugars into simpler sugars. (See page 8.) In the disaccharids only one splitting is necessary, as each molecule of a complex sugar plus one molecule of water will give two molecules of a simple sugar which is soluble and ready for absorption. The starches are more complex in their composition, hence they must pass through several stages of decomposition before they are changed by hydrolysis to a simple sugar. Each splitting of the molecule gives substances with simpler composition, though with the same relative proportion of the constituents, and to each such substance produced is given a special name. The **proteins** are even more complex than the starches, and pass through a greater number of stages in the process of digestion. The substances formed in each stage are of lighter molecular weight and are named (1) meta-proteins, (2) proteoses, (3) peptones, (4) polypeptids, and (5) amino-acids. Many physiologists are of the opinion that protein digestion does not pass beyond the peptone stage, as peptones are soluble and can be absorbed.

Fats are hydrolyzed and split up into fatty acids and glycerine; the fatty acids are then acted upon by the bile and pancreatic juice, and form soap. (See page 298.)

Cause of chemical digestion. — It is possible to make carbohydrates, proteins, and fats undergo the same changes outside the body as occur during digestion. Carbohydrates, proteins, and fats, if boiled with a mineral acid or subjected to the action of enzymes, will hydrolyze and split up into simpler substances.

Within the body the change takes place at body temperature, and is due to the presence of organic ferments or enzymes present in all of the digestive juices.

Enzymes.—An enzyme is an organic ferment produced by living cells, and is capable of effecting chemical change without itself undergoing alterations in the process. Each enzyme has a definite action at a suitable temperature, and will only work in a medium of definite reaction, either acid or alkaline. Further, the products of the action must be removed, and in the body this is accomplished by absorption.

CHANGES THE FOOD UNDERGOES IN THE MOUTH

Mastication. — When solid food is taken into the mouth it is cut and ground by the teeth, being pushed between them again and again by the muscular contractions of the cheeks and the movements of the tongue until the whole is thoroughly crushed and ground down.

Insalivation. — During the process of mastication saliva is poured in large quantities into the mouth, and mixing with the food moistens it and reduces it to a soft, pulpy condition. A certain amount of air caught in the bubbles of the saliva also becomes entangled in the food, and this facilitates the penetration of the gastric juice.

Secretion of saliva. — The secretion of saliva is the result of reflex stimulation of the nerves connected with the salivary glands. The movements of mastication, the taste and odor of food, act as stimulants to the sensory or afferent nerves which carry these impulses to a nerve centre in the brain (probably in the medulla oblongata), and from thence motor impulses are transmitted through efferent nerves to the gland. Psychical acts may also influence the secretion of saliva, as for example the thought or smell of food, or a feeling of nausea may stimulate the secretion, and anger, fear, or worry may inhibit it.

Saliva. — Saliva is a mixture of the secretions of all three pairs of salivary glands, as well as of the small glands of the mucous membrane of the mouth. It consists of water, some mucus, and an enzyme called ptyalin. It has a specific gravity of 1.004 to 1.008 and an alkaline reaction. The amount secreted in twenty-four hours is estimated to be from one to two quarts.

The functions of saliva. — Saliva has four distinct functions. (1) It assists in speech by moistening the mucous membrane of the mouth and tongue. (2) It assists in mastication and deglutition by softening and moistening the food. Saliva causes the masticated portions to stick together and thus helps to form a bolus which is coated with mucus and easily swallowed.

(3) It renders soluble substances capable of being tasted. Salts, sugar, acids, and bitters are dissolved in the saliva.

(4) It acts upon starch.

Ptyalin. — By the ptyalin-ferment present in saliva, starch, which is an insoluble substance, is partially changed to dextrin and sugar (maltose). This process is a complicated one and it is probable that a number of intermediate compounds exist between the huge starch molecule and the dextrin and maltose. This change is best effected at the temperature of the body,[1] in a slightly alkaline solution, saliva that is distinctly acid hindering or arresting the process. Boiled starch is changed more rapidly and completely than raw, but the food is never retained in the mouth long enough for the saliva to more than begin the transformation of starchy matters.[2]

Deglutition, or swallowing. — The food thus softened and moistened is collected from every part of the mouth by the movements of the tongue, brought together upon its upper surface, and then pressed backward through the fauces into the pharynx. The elevation of the soft palate prevents the entrance of food into the nasal chambers, while the epiglottis bars its entrance into the air-passages, and it is guided safely and rapidly through the pharynx into the œsophagus. Here it passes beyond the control of the will; it is grasped by the œsophageal muscles and by a continuous *peristaltic* action is carried downward. The cardiac orifice of the stomach is guarded by a sphincter muscle which is normally in a state of contraction. The peristaltic wave which passes slowly down the œsophagus inhibits this contraction and forces the food into the stomach.

During the process of mastication, insalivation, and deglutition the food is first reduced to a soft, pulpy condition; second,

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[1] A temperature of 100° F. in the alimentary canal is necessary for digestion, hence iced drinks or iced foods that lower this temperature delay digestion,

[2] The salivary glands do not become active until the subject is from four to six months old; hence the reason for avoiding starchy food for young infants.

any starch it may contain begins to be changed into sugar; third, it acquires a more or less alkaline reaction.

Vomiting. — Under ordinary circumstances the contractions of the cardiac sphincter muscle prevent the regurgitation of food, but strong contractions of the stomach or spasmodic contractions of the abdominal muscles may, if the diaphragm is fixed, force the contents of the stomach through the œsophagus and mouth to the exterior. This is called vomiting.

CHANGES THE FOOD UNDERGOES IN THE STOMACH, OR STOMACH DIGESTION

Peristaltic action of the stomach. — The food which enters the stomach is delayed there by the contraction of the sphincter muscles at the cardiac and pyloric openings. The cavity of the stomach is always the size of its contents, which means that when it is empty it is contracted, but when food enters it expands just enough to hold it. Within a few minutes after the entrance of food small contractions start in the middle region of the stomach and run toward the pylorus. These contractions are regular and become more and more forcible as digestion progresses. As a result of these movements the food is macerated, mixed with the acid gastric juice, and reduced to a liquid mass called **chyme**. At intervals the pyloric sphincter relaxes and the wave of contraction forces some of the chyme into the duodenum. The fundal end of the stomach does not take part in these movements, but serves as a reservoir for food which is under slight pressure, as the muscles are in a state of continual contraction or tone. Due to the lack of movement and the muscular tone, the gastric juice cannot penetrate the bolus of food, and the ptyalin with which it became mixed in the mouth continues its action, and the digestion of starch continues for about twenty minutes. As the chyme is gradually forced into the duodenum, the pressure of the fundus forces the food into the pyloric end.

Time required for stomach digestion. — It is obvious that the time required for gastric digestion depends upon the nature of the food eaten. An average meal of mixed food requires about five hours for gastric digestion. The ejection of chyme through the pylorus occurs at regular intervals, and is supposed to depend upon the consistency and acidity of the chyme. Solid particles forced against the pylorus tend to keep it closed, but hydrochloric acid in the stomach seems to favor or produce relaxation of the pyloric sphincter. In the intestines hydrochloric acid has a contrary effect, as it causes a contraction of the sphincter, which remains closed after each ejection until the acidity has been neutralized.

Secretion of gastric juice. — During the intervals of digestion the stomach is bathed in an alkaline mucus. The entrance of food acts as a stimulant to the whole organ. The blood-vessels dilate, and the glands pour out an abundant secretion upon the mucous lining. This secretion continues as long as food remains in the stomach, and is caused and maintained by two factors: (1) *psychical*, the sensations of eating, the taste and odor of food stimulate the sensory nerves situated in the mouth and nose. These afferent impulses are transferred through nerve centres to efferent fibres of the pneumogastric nerve, and thus are carried to the stomach. (2) *Chemical*, (*a*) by secretogogues contained in certain foods and (*b*) by secretogogues contained in the products of digestion. Certain foods, such as meat juices and extracts, contain substances called secretogogues or hormones which are supposed to act directly upon the nerves of the pyloric mucous membrane and form a substance called *gastrin* or *gastric secretin*, which is absorbed into the blood and carried to the gastric glands. This substance stimulates the glands to secretion. Other foods, such as milk, bread, white of egg, etc., do not appear to contain secretogogues. When such foods are eaten, a psychical secretion is started and when this has acted, some products of their digestion in turn become capable of stimulating a further secretion of gastric juice.

Gastric juice. — Gastric juice, secreted by the peptic and pyloric glands in the mucous lining of the stomach, is a thin, colorless, or pale yellow fluid, of an acid reaction. The amount secreted in twenty-four hours has never been accurately measured, but has been estimated to be about fifteen pints (7.1 litres). It contains few solids, and is dependent for its specific action upon two enzymes called (1) pepsin and (2) rennin. Pepsin is only properly active in an acid solution, and we therefore find that free hydrochloric acid in the proportion of 0.2 to 0.4 per cent is always present in normal gastric juice.

The action of gastric juice upon food. — The action of gastric juice upon food is dependent on (1) hydrochloric acid, (2) pepsin, and (3) rennin.

(1) *Hydrochloric acid.* — The hydrochloric acid found in the gastric juice is supposed to be secreted by special cells in the intermediate portion of the stomach, from chlorides found in the blood. The chief chloride is sodium chloride (NaCl), and by some means this is decomposed; the chlorine (Cl) combines with hydrogen (H), and is then secreted upon the free surface of the stomach as hydrochloric acid (HCl). Besides giving an acid medium, which is necessary for the pepsin to carry on its work, it serves: (1) to swell the protein fibres and thus give easier access to pepsin, (2) it helps in the inversion of sugar, *i.e.* changing complex sugars to simple ones, (3) it acts as a disinfectant and kills many bacteria that enter the stomach, and (4) it helps to regulate the opening and closing of the pyloric valve.

(2) *Pepsin.* — The property of converting proteins into peptones is dependent upon the enzyme pepsin. Whatever the protein may be, whether the albumin of eggs, the gluten of flour in bread, the myosin in flesh, the result is the same; pepsin, in conjunction with an acid at the temperature of the body, transforms them into peptones. This process of converting an insoluble protein to a soluble peptone is complicated, as the protein under digestion passes through a number of intermediate stages. Peptones readily dissolve in water, and pass with ease through animal membranes.

(3) *Rennin.* — So far as is known, this ferment acts *only* upon the soluble protein of milk, which is called **caseinogen**. It converts this substance into a clotted mass called curd, which is later prepared for absorption by the action of the enzyme pepsin.

The gastric juice has no action upon starch, and upon fats it has at most a limited action. The fats are set free from their mixture with other food-stuffs by the dissolving action of the gastric juice, they are liquefied by the heat of the body, and are scattered through the chyme in a coarse emulsion by the movements of the stomach. In addition to pepsin and rennin, various authorities describe other enzymes in the gastric juice, but there is a good deal of uncertainty regarding them. It is probable that a third enzyme, called *gastric lipase,* acts upon fats that are ingested in an emulsified form, and this action may be important in the digestion of milk fat by infants, as the pancreas is inactive.

CHANGES THE FOOD UNDERGOES IN THE SMALL INTESTINE

The chyme, on entering the duodenum, after an ordinary meal, is a mixture of various matters. It contains some undigested proteins; some undigested starch; oils from fats eaten; peptones formed in the stomach; salines and sugars; all mixed with a good deal of water and the secretions of the alimentary canal. It is in the intestines that this mixture undergoes the most profound digestive changes. These changes which constitute intestinal digestion are effected by: (1) the movements of the intestines, (2) the pancreatic juice, (3) the succus entericus or secretion of the intestinal glands, and (4) the bile.

Movements of the small intestine. — The movements of the small intestine are of two kinds: (1) peristaltic and (2) rhythmic segmentation.

(1) A peristaltic movement may be defined as a quick succession of waves of contraction and inhibition passing slowly along the intestine and affecting the longitudinal fibres. The wave of contraction begins at a certain point, passes downward away from the stomach, and is always preceded by an area of inhibition or relaxation. The purpose of it is to pass the food slowly forward, and it is obvious that the wave of contraction is more effective in forcing the contents forward because just in front of it the intestine is relaxed.

(2) The movements of rhythmic segmentation consist of contractions of the circular fibres of the intestine, which occur at the same time as the contractions of the longitudinal fibres. The purpose of these contractions is to split the column of food into a number of equal segments. Within a few seconds each of these segments is halved and the corresponding halves of adjoining segments unite. Again contractions recur and these newly formed segments are divided, and the halves re-form in the same position as they had at first. In this way every particle of food is brought into intimate contact with the valvulæ conniventes and is thoroughly mixed with the digestive juices.

Secretion of pancreatic juice. — Just as chewing and swallowing of food starts the gastric secretion, so the presence of acid chyme in the intestine starts the pancreatic secretion. This effect is due to a special substance called *secretin* which is formed by the action of the acid upon some substance present in the mucous membrane of the intestine. This secretin is absorbed by the blood and carried to the pancreas, which it stimulates to activity. Like the secretin of the gastric juice, this is not an enzyme but a hormone.

Pancreatic juice. — Healthy pancreatic juice is a clear, somewhat viscid fluid, with a very decided alkaline reaction. The amount secreted in twenty-four hours is about 15 to 25 ounces (7.1 to 11 litres). It contains few solids and is dependent for its remarkable power on three enzymes: (1) trypsin, (2) diastase (amylopsin), and (3) lipase (steapsin).

Action of pancreatic juice upon food. — Pancreatic juice has the power of acting on all the food-stuffs, proteins, carbohydrates, and fats. This action is due to its enzymes.

(1) *Trypsin.* — Trypsin, like pepsin, has the power to decompose proteins, but the action is more rapid and more powerful, and the protein molecule is broken up into simpler substances than peptones, depending on the amount of trypsin and the time that it acts. If complete hydrolysis takes place, the end products consist chiefly of amino-acids. Unlike pepsin, trypsin requires a neutral or alkaline medium. The preliminary action of pepsin, on a protein molecule, hastens the action of trypsin, and renders it more complete than if the trypsin acted alone.

Diastase (*Amylopsin*). — The action of diastase is similar to that of ptyalin. It causes hydrolysis of starch with the production of maltose. The starchy food that escapes digestion in the mouth and stomach becomes mixed with this enzyme and continues under its action until the ileo-cæcal valve is reached.

Lipase (*Steapsin*). — Lipase is an enzyme capable of decomposing fats. This action is twofold:

(*a*) It emulsifies them.

(*b*) It splits them up into fatty acids and glycerine.

(*a*) If we shake up olive oil with water, the two cannot be got to mix: as soon as the shaking ceases, the oil floats to the top; but if we shake up olive oil with pancreatic juice, the oil remains evenly suspended in it. The reason of this is that the oil has been minutely divided into tiny droplets, and each droplet surrounded by a delicate envelope supplied from the albumin in the pancreatic juice, so that they cannot fuse together to form the large drops, which would soon float to the top.[1]

(*b*) The fats that are not emulsified are broken up into glycerine and fatty acids. The glycerine is absorbed, and the fatty acids in the presence of an alkali form soaps which are soluble in water and capable of absorption. It is probable that the greater part of the fat is absorbed by the latter method.

Succus entericus, or intestinal juice. — Succus entericus is the secretion of the intestinal glands. It is a clear, yellowish fluid, having a marked alkaline reaction and containing a certain quantity of mucus.

The number of enzymes[2] described as present in succus entericus differs with different authorities and it is probable that the entire physiology is not known. Its chief function seems to be a continuation of the work of pepsin and trypsin and the inversion of complex sugars to simple ones. It also acts as a diluent and supplies a loss of fluid.

Bile. — Bile, secreted in the lobules of the liver and stored in the gall-bladder until needed, is a fluid of a golden brown or greenish color[3] with an alkaline reaction. The quantity secreted in twenty-four hours varies with the amount of food taken, but is estimated at about one quart.

Bile contains no enzyme, but the fact that it is poured into the intestine through an orifice common to it and the pancreatic juice suggests that these two fluids coöperate in their action on food.

Action of bile. — Its most important function as a digestive is noted in its action on fats.

(1) It splits up neutral fats and, assisted by the pancreatic juice, emulsifies and saponifies them.

(2) It aids in the absorption of fats. The passage of digested food through membranes is assisted by wetting the membranes with bile or with a solution of bile salts. It is known that oil

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[1] This fine subdivision of fats gives the white color to the chyle, which is its most striking external characteristic, the innumerable tiny oil drops reflecting all the light that falls on its surface.

[2] See Summary at end of this chapter.

[3] The color of bile is determined by the respective amounts of the bile pigments: (1) biliverdin, and (2) bilirubin, that are present.

will pass to a certain extent through a filter paper, kept wet with a solution of bile salts, whereas it will not pass, or passes with extreme difficulty, through one kept wet with distilled water.

(3) It has a feeble and questioned antiseptic action upon the intestinal contents, and its presence limits putrefaction to some extent.

(4) In addition to being a secretion, about one-sixteenth of the bile is an excretion, as it furnishes the channel by which the products of the disintegration of hæmoglobin are carried from the body.

(5) It acts as a mild laxative by stimulating peristalsis.[1]

Action of bacteria in small intestine. — Bacteria are constantly present in the small intestine, but only those capable of fermenting carbohydrate food show any activity. If the products of protein digestion are promptly absorbed, there is no fermentation of protein material. Various theories are offered to explain this protection of protein, but opinions differ, even among investigators.

CHANGES THE FOOD UNDERGOES IN THE LARGE INTESTINE

Movements of the large intestine. — After the food passes from the small intestine into the large intestine, its regurgitation is prevented by the closure of the ileo-cæcal valve. When the cæcum becomes filled, strong contractions of the walls exert pressure upon the contained food and force it into the ascending colon. The waves of contraction which pass over the walls of the ascending colon are described as antiperistaltic because they pass in two directions, (1) from the small intestine, and (2) toward the small intestine. This delays the food, keeps it moving backward and forward, and helps absorption. It has been estimated that it requires about two hours for the food to pass from the ileo-cæcal valve to the hepatic flexure, and about four and one-half hours to reach the splenic flexure.

Secretion of the large intestine. — The secretion of the large intestine is alkaline, contains much mucus, and does not contain any enzymes. When the contents of the small intestine pass the ileo-cæcal valve, they still contain a certain amount of unabsorbed food material. This remains a long time in the

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[1] Slow peristalsis will cause constipation, and is often associated with a torpid liver. As bile is a natural stimulant to the muscles of the bowel, an insufficient quantity may result in slow peristalsis.

intestine, and since it contains the digestive enzymes received in the duodenum, the process of digestion and absorption continues.

By the abstraction of all the soluble constituents, and especially by the withdrawal of water, the liquid contents become, as they approach the rectum, changed into a firm and solid mass of waste matters, ready for ejection from the body, and called **feces.**

Action of bacteria in large intestine. — Protein putrefaction due to the action of bacteria is a constant and normal occurrence in the large intestine. A long list of end products result from this putrefaction. Some are given off in the feces, others are absorbed and later excreted in the urine. The action of bacteria is considered of doubtful value. It is possible that they may act upon the cellulose of vegetable foods and render it useful in nutrition. A conservative view is that bacteria confer no positive benefit, but under normal conditions the body is able to neutralize their action.

The feces. — The feces consist of: (1) the undigested and indigestible parts of the food, (2) the products of bacterial decomposition, (3) great quantities of bacteria of different kinds, (4) bile and other secretions, (5) enzymes, and (6) inorganic salts. The color of feces is due to the presence of pigments derived from the bile.

Defecation. — The anal canal is guarded by an internal sphincter muscle of the involuntary type, and an external sphincter that is voluntary, but both are supplied with nerves from the central nervous system and consequently defecation is a voluntary act. Normally the rectum is empty until just before defecation. Various stimuli (depending on one's habits) will produce peristaltic action of the colon, so that a small quantity of feces enters the rectum. This irritates the sensory nerve endings and causes a desire to defecate. The voluntary contraction of the abdominal muscles, the descent of the diaphragm, and powerful peristalsis of the colon all combine to empty the colon and rectum.

One of the commonest causes of constipation is the retention of feces in the rectum because of failure to act on the desire for defecation. After feces once enter the rectum there is no retroperistalsis to carry it back to the colon, and the sense of irritation becomes blunted. The desire may not recur for twenty-four hours, and during this time the feces continue to lose water, become harder, and more difficult to expel.

ABSORPTION

This is the process by means of which the digested food is taken from the intestines and carried into the blood. We have now to consider this process, for, properly speaking, though the food may be digested and ready for nutritive purposes, it is, until it passes through the walls of the alimentary canal, still practically outside the body.

Absorption. — Absorption is a very complex process and may be subdivided into a physical and physiological process. The **physical** process consists of the passage of the digested food from the intestines into the blood-vessels, and is governed by the laws of diffusion and osmosis. The **physiological** process consists in the building up of the end products of protein and fat digestion into the substances found in the blood. This process of reconstruction is not understood, but is dependent on the living epithelial cells that make up the intestinal walls.

Paths of absorption. — There are two paths by means of which the products of digestion find their way into the blood : —

(1) By the capillaries in the walls of the stomach and intestines.

(2) By the lymphatics in the walls of the small intestine (the lacteals).

It is now thought that absorption through the stomach is limited to small quantities of such substances as water, glucose, and salts. This means that the greater part of absorption is a function of the small and large intestines. The products that result from the digestion of proteins and carbohydrates pass into the capillaries. The products resulting from the digestion of fats pass into the villi of the small intestine.

SUMMARY

Digestion — Is the process of changing food into products capable of absorption.

Food — Substances that contain elements found in the body, or furnish material for production and repair of tissue, or yield energy.

- **Classification**
  - **Inorganic**
    - Water.
    - Mineral matter or salts.
  - **Organic**
    - Proteins.
    - Carbohydrates.
    - Fats.

- **Water**
  - H_2O. About 66 per cent of body weight.
  - Found in all tissues.
  - Supplies fluid.
  - Acts as solvent.
  - Aids in elimination of waste.

- **Mineral Matter**
  - Chloride, Phosphate, Sulphate, Carbonate } of sodium and potassium.
  - Phosphate, Carbonate } of calcium and magnesium.
  - **Function**
    1. To maintain alkalinity of body fluids.
    2. To furnish material for acidity or alkalinity of digestive fluids.
    3. To maintain osmotic pressure.
    4. To enter into bones, teeth, and cartilage.
    5. To influence elasticity and irritability of muscles and nerves.

- **Proteins**
  - Consist of C, H, N, O; S, P, and other elements may be present.
  - Differ from carbohydrates and fats in having nitrogen.
  - Examples
    - Albumins.
    - Caseinogen.
    - Gluten.
    - Legumin.
    - Extractives.

- **Carbohydrates**
  - Consist of C, H, and O, the two latter in the proportion to form water. Include sugars and starches.
  - **Simple or Monosaccharids**
    - Glucose or dextrose $C_6H_{12}O_6$
    - Fructose or levulose $C_6H_{12}O_6$
    - Invert sugar.
  - **Complex or Disaccharids**
    - Sucrose or cane sugar $C_{12}H_{22}O_{11}$.
    - Lactose or milk sugar $C_{12}H_{22}O_{11}$.
    - Maltose or malt sugar $C_{12}H_{22}O_{11}$.
  - **Polysaccharids**
    - Starch $(C_6H_{10}O_5)n$.
    - Cellulose $(C_6H_{10}O_5)n$.
    - Glycogen $(C_6H_{10}O_5)n$.
    - Dextrin $(C_6H_{10}O_5)n$.

- **Fats**
  - Consist of C, H, and O.
  - Made from one molecule of glycerine and three molecules of fatty acid.
  - Fats are liquid at body temperature.
  - Soluble in ether, chloroform, and hot alcohol.
  - Decompose to give glycerine and fatty acids.

- **Digestion**
  - Organic foods are not soluble, hence necessity for digestion.
  - Inorganic foods are soluble, and are absorbed directly.
  - **Processes**
    - Mechanical
      - Mastication.
      - Deglutition.
      - Peristaltic action of œsophagus.
      - Peristaltic action of stomach.
      - Movements of intestines.
      - Defecation.
    - Chemical
      - Splitting of complex molecules into simple ones, with absorption of water.
      - Process of hydrolysis that is dependent on **enzymes**.

- **Enzymes**
  - An enzyme is produced by living cells and acts by catalysis. Its action is specific, it requires a medium of definite reaction, and the products must be removed.

LIST OF DIGESTIVE FLUIDS AND CHIEF ENZYMES

Digestive Fluids	Enzymes	Functions
Saliva	Ptyalin	Changes starch to dextrin and sugar (maltose).
Gastric Juice	Pepsin	Changes proteins into proteoses and peptones in an acid medium.
Gastric Juice	Rennin	Curdles the caseinogen of milk.
Pancreatic Juice	Trypsin	Continues action of pepsin, splits proteoses into peptones and amino-acids. Requires alkaline or neutral medium.
Pancreatic Juice	Diastase	Changes starch to dextrin and sugar (maltose).
Pancreatic Juice	Lipase	Splits fats to fatty acids and glycerine.
Succus Entericus	Erepsin	Splits peptones into simpler products.
Succus Entericus	Inverting: Sucrase Maltase Lactase	Changes sucrose to invert sugar. Changes maltose to dextrose. Changes lactose to dextrose.
Bile	No enzyme	Splits fats into fatty acids and glycerine. Assist in saponification and aids in absorption.

Changes Food undergoes in Mouth

- Mastication (chewing).
- Insalivation (mixing with saliva).
- **Saliva**
  - Secreted by salivary glands
    - Parotid
    - Submaxillary
    - Sublingual
    - and mucous glands of mouth.
  - Result of
    - 1. Reflex stimulation.
    - 2. Psychical.
  - Consists of water, mucus, and enzyme — **ptyalin.**
  - Specific gravity 1.004–1.008. Alkaline reaction.
  - One or two quarts in 24 hours.
  - **Functions**
    - 1. Assists in speech.
    - 2. Assists in mastication and deglutition.
    - 3. Assists in taste.
    - 4. Acts upon starch.
- Deglutition (swallowing).

- **Stomach Digestion**
  - Peristaltic action of stomach.
  - Time required for stomach digestion about 5 hours.
  - Secretion of gastric juice
    - Psychical.
    - Chemical — Secretin.
  - **Gastric juice**
    - Secreted by glands of stomach
      - Peptic.
      - Pyloric.
    - About 15 pints in 24 hours. Pale yellow liquid
    - Acid reaction due to free hydrochloric acid.
    - Enzymes
      - Pepsin.
      - Rennin.
      - Gastric lipase.

- **INTESTINAL DIGESTION**
  - **Small Intestine**
    - Movements of small intestine
      - Peristaltic.
      - Rhythmic segmentation.
    - Secretion of pancreatic juice
      - Psychical.
      - Chemical — secretin.
    - **Pancreatic juice**
      - Secreted by pancreas, discharged into small intestine during digestion.
      - Viscid fluid, alkaline reaction.
      - **Enzymes**
        - Trypsin.
        - Diastase.
        - Lipase.
    - **Succus entericus**
      - Secreted by glands found in intestines
        - 1. Intestinal or Lieberkuhn's.
        - 2. Duodenal or Brunner's.
      - Yellowish fluid, alkaline reaction.
      - **Enzymes**
        - Erepsin.
        - Inverting.
    - **Bile**
      - Secreted by liver, stored in gall-bladder, discharged into small intestine during digestion.
      - Golden brown or greenish liquid with alkaline reaction.
      - About 1 quart in 24 hours.
      - **Action**
        - 1. Splits up neutral fats.
        - 2. Aids in absorption of fats.
        - 3. Antiseptic action on intestinal contents.
        - 4. Excretes products of disintegration of hæmoglobin.
        - 5. Mild laxative.
    - **Bacteria**
      - Decompose carbohydrates.
      - Little or no effect on proteins.

INTESTINAL DIGESTION

- **Large Intestine**
  - Movements of large intestine — antiperistaltic.
  - Time required for food to pass from cæcum to splenic flexure about 6½ hours.
  - **Secretion**
    - Alkaline reaction.
    - Contains a great deal of mucus.
    - No enzymes.
  - **Bacteria**
    - Decomposition of proteins constant.
    - Possible action on cellulose.
    - Benefit doubtful.
  - **Feces**
    - Undigested and indigestible portions of food.
    - Products of bacterial decomposition.
    - Great quantities of bacteria.
    - Bile and other secretions.
    - Enzymes and inorganic salts.
  - **Defecation** — This term is applied to the act of expelling the feces from the rectum.

- **Absorption**
  - Process of taking up digested food-stuffs and carrying them to the blood.
  - **Two parts**
    - **Physical** — Diffusion and osmosis.
    - **Physiological** — Reconstruction of end products of digestion into substances found in the blood.
  - **Paths of absorption**
    1. Capillaries in the walls of the stomach and intestines. This blood is carried by means of portal vein to liver, from liver by hepatic veins to inferior vena cava, thence to right auricle.
    2. Lymphatics in the walls of small intestine (lacteals) absorb digested fats and empty into chyle cistern of thoracic duct, superior vena cava, and right auricle of heart.

CHAPTER XVI

METABOLISM — DUCTLESS GLANDS

THE nutritive processes in the human body include: (1) the reception and digestion of food, followed by absorption of the different food products, and the distribution of these products to all the cells by the circulating liquids of the body; (2) the absorption of oxygen by the circulating liquids in the lungs, its distribution to all the cells of the body, and its union with the constituents of the cells. We have studied digestion and absorption, and our special problem in this chapter is metabolism.

Metabolism. — This term includes all the changes that occur in digested food-stuffs from the time of their absorption until their elimination in the excretions.

Metabolic changes. — The most important chemical changes that occur in metabolism are as follows: —

(1) The cells take from the blood the substances which they require for repair and growth, and build it up into protoplasm. This involves the conversion of non-living material into the living protoplasm of the cells.

(2) Oxidation, or the union of oxygen with the constituents of the cells, resulting in the release of energy and the breaking down of complex substances into simpler products.

(3) Some of the simpler products that result from oxidation are acids. These acids must be eliminated or decomposed, as all the digestive fluids of the body, with the exception of gastric juice, are alkaline or neutral, and this condition is essential to nutrition and even to the immediate continuance of life. (*a*) Some of the weaker acids are eliminated in the urine; one, carbonic acid (H_2CO_3), is a very unstable compound and breaks down to form water (H_2O) and carbon dioxide (CO_2). (*b*) When proteins are oxidized, sulphur is set free. This sulphur (S) unites with water (H_2O) and oxygen (O_2) to form sulphuric acid (H_2SO_4). Sulphuric acid is promptly neutralized by the alkalies present in the tissues, so that the body never contains sulphuric acid, but does contain sul-

phates and water, which result from the process of neutralization. (See page 8.)

(4) The conversion of glucose into glycogen, and the reconversion of glycogen into glucose.

(5) The conversion of glucose into fat. This is a chemical change that is not well understood, but various experiments have satisfied physiologists that the tissues can produce fat from sugar.

These changes can be classified under two heads: (1) **anabolism**, or the building-up processes, and (2) **katabolism**, or the splitting of complex substances into simpler ones.

Functions of metabolism. — Metabolic changes serve two important purposes: (1) the repair and growth of tissue, and (2) the release of chemical energy in the form of heat, nervous activity, and muscular activity.

Factors which promote metabolic changes. — The factors which produce metabolic changes are: (1) enzymes, (2) oxygen, and (3) internal secretions. It was formerly taught that the oxygen absorbed from the lungs was responsible for all the processes of oxidation that occur in the body. More accurate study has demonstrated that while oxygen is an important factor, it is only one, and the enzymes that are present in nearly all the body tissues are capable of decomposing complex materials into simpler substances. Moreover, it is generally considered that the action of the tissue enzymes comes first and causes decomposition by hydrolysis, then other enzymes termed **oxidases** activate the process of oxidation.

METABOLISM OF FATS

We have traced the digested fat or chyle into the lacteals. From the small lacteals it must find its way through the larger lymphatics in the mesentery to the thoracic duct, and then through the thoracic duct to the blood. This fat is carried by the blood to all the different parts of the body, and the tissues slowly take it out as they need it in their metabolic processes. Within the tissues it serves as a fuel and is oxidized to supply the energy needs of the cells. If fat is burned outside the body, heat is liberated, and the waste products are carbon dioxide and water. This process is similar to the one that takes place in the body. Fat that is not required for the production of energy is stored up in certain parts of the body, but not all the adipose tissue found in the body is derived from fats, as excess carbohydrates are also stored as fat.

Function of fats. — The main function of fat is to serve as fuel and yield heat and energy. The fat that is stored in the form of adipose tissue constitutes an important reserve fund to be drawn upon in time of need. In diseased conditions or when the supply of food is insufficient, the body oxidizes first the glycogen stored in the liver and then the fats stored in adipose tissue, and the proteins of the tissues themselves. If the supply of fat is large, it follows that the protein tissues will be protected. (For other functions, see page 39.)

The cause of obesity. — This condition is usually caused by eating more carbohydrate and fat than the body needs. The excess is stored as glycogen and adipose tissue. The needs of different individuals vary, depending on their mode of life, and on their capacity to oxidize food materials, so that a diet which will give an excess to one individual may in the body of another be entirely consumed. A sedentary life and absence of worry lessen the oxidation of food products and increase the tendency to take on flesh, while a very active muscular life has the opposite effect.

METABOLISM OF CARBOHYDRATES

During the process of digestion all the carbohydrates are changed to glucose, absorbed into the blood, and carried to the liver. The liver cells take this glucose from the blood, and by putting together a number of molecules and withdrawing water, the soluble glucose is changed to insoluble glycogen, which is stored in the liver cells and the muscles. In thus storing up glycogen and doling it out as needed, the liver helps to maintain the normal quantity of glucose — 0.1 to 0.15 per cent — in the blood. An increased amount of glucose in the blood, resulting from the ingestion of a large amount of sugar, may provide more glucose than the liver can take care of, and the excess is eliminated in the urine. A permanent increase in the amount of sugar in the blood is irritating to the tissues and acts as a poison, so that the liver by maintaining the normal quantity protects the tissues from such irritation.

Factors controlling the metabolism of carbohydrates. — The metabolism of carbohydrates is under the control of the nervous system, but the enzymes contained in the liver and the internal secretion of the pancreas, and some of the ductless glands play a very important part.

Function of carbohydrates. — The oxidation of glucose serves the following purposes: (1) It furnishes the main if not the only source of energy for muscular work, and for all the nutritive processes of the body. (2) It furnishes an important part of the heat needed to maintain the body temperature. (3) It prevents oxidation of the body tissues, because it constitutes a reserve fund that is the first to be drawn upon in time of need. (4) An excess of carbohydrates over and above what can be stored as glycogen in the liver and tissues is converted into adipose tissue.

Waste products of carbohydrate metabolism. — The waste products resulting from the oxidation of glucose are carbon dioxide (CO_2) and water (H_2O). This process is thought to be comparable to the fermentation of sugar outside the body, and the same substances are formed, viz. alcohol, acids, carbon dioxide, and water.

METABOLISM OF PROTEINS

The substances resulting from the digestion of proteins, *i.e.* peptones, polypeptids, and amino-acids are not found in the blood to any extent, because during the passage of these substances through the intestinal walls they are changed to serum-albumin and serum-globulin. The tissues take these substances from the blood and, by a process that is not well understood, convert them into protein material of the kind found in any particular tissue. In this way broken-down tissue is replaced and new tissue is formed. The protein substances absorbed are usually in excess of what is needed for repair and tissue building. This excess is acted upon by the liver, and the protein molecule is split up into two parts. One part is known as the ammonia molecule, and contains hydrogen and nitrogen. This is subsequently converted into urea and similar substances, which are carried by the blood to the kidneys and excreted in the urine. The second part may be either oxidized directly, or built up into carbohydrates and fats which eventually become oxidized, and in either case heat and energy are liberated.

Classification of proteins. — Proteins vary in their constituents and vary in their nutritive value. Because of this they are classed as adequate and inadequate proteins. *Adequate* proteins contain all the constituents for the maintenance and growth of the body. *Inadequate* proteins furnish material for energy needs, but not for the repair of tissue waste. Gelatine is an example of an inadequate protein. It is easily digested and absorbed, undergoes oxidation, which results in the liberation of energy and the production of urea, carbon dioxide, and water, but it does not supply the material needed for the repair of tissue waste.

Function of proteins. — The main function of proteins is to build up tissue, and they are the *one* class of foods capable of doing this. In addition they serve the same purpose as carbohydrates and fats and may even be converted into adipose tissue.

Nitrogen equilibrium. — The protein molecules are characterized by containing nitrogen (some say as much as 16 per cent). After the metabolism of protein, nitrogen is eliminated chiefly in the urine, and to a limited extent in the feces and sweat. The body is said to be in nitrogen equilibrium when the amount of protein nitrogen taken into the body is equal to the amount eliminated in the excreta. If there is a plus balance in favor of the food, it means that protein is being stored in the body, and this is an ideal condition during the period of growth, or convalescence from wasting illness. If the balance is minus, the body must be losing protein, but under normal conditions this does not occur.

Heat value of food. — The supply of heat needed to maintain the body temperature comes from the processes of oxidation. The heat produced is estimated in terms of calories [1] and is measured with the calorimeter. There are two kinds of calories, *i.e.* small and large. A small calorie is the quantity of heat necessary to raise one gram of water, one degree centigrade in temperature. A large calorie is the quantity of heat necessary to raise one thousand grams of water one degree centigrade. The large calorie is the one referred to in physiology. It has been estimated that each gram of fat yields about 9.3 calories, each gram of carbohydrate yields about 4.1 calories, and each gram of protein yields about 4.1 calories.

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[1] See page 12.

The amount of food necessary for normal nutrition. — In a normal condition the main object of food is: (1) to furnish the material for the repair of tissue, and (2) to furnish material for the heat produced and the muscular and other work done. The most important factors influencing the amount of food required are activity, age, size, sex, and climate. The greater the amount of muscular work, the greater the amount of food required. Children need more food in proportion to their weight than adults, because they are more active, and in addition must provide for the growth of new tissue. Increased age usually means less active life and thus less food is required. A large person requires more food because the greater amount of tissue requires the expenditure of more energy in all the nutritive processes. Women as a rule require less food than men, because they are smaller, and possibly less energetic in their movements. In an extremely cold climate more food is required for heat production in order to make up for the loss of heat from the body. It is ordinarily estimated that the daily diet should yield 2400 calories for an individual weighing about 60 kilograms (130 lbs.), that is, 40 calories for each kilogram of body weight.

In computing the proportion of different foods to be used the total number of calories is divided into fifths; sufficient protein is allowed to give one-fifth; sufficient fat to give one- to two-fifths, and sufficient carbohydrates to give two- to three-fifths.

Ranke's diet is as follows:

Protein	100 gm. = 410 calories.
Fats	100 gm. = 930 calories.
Carbohydrates	240 gm. = 984 calories.
Total	2324 calories.

There is no approach to unanimity in the amounts required; thus Moleschott would give 130 grams of protein, while Chittenden thinks 60 grams of protein sufficient.

Ranke's diet is given because it is the simplest, other diets by other authors may be just as good or even better. For further details some standard book on dietetics should be consulted.

For a healthy person leading a normal life appetite and experience seem safe guides by which to control the diet. They will at least prevent undernutrition, and the consequent lessening of the body's natural powers of resistance to disease. The opposite danger of overeating is a real one, because an excess of food puts unnecessary strain upon the organs of nutrition and excretion, and favors the formation of excessive adipose tissue. Excess of proteins overloads the system with the products of intestinal putrefaction. Excess of carbohydrates causes flatulence, due to fermentation of these foods. It is thought that an excess of fat interferes with digestion by retarding the secretion of gastric juice.

DUCTLESS GLANDS

The ductless glands form a group of organs that produce secretions, called internal secretions, which leave the gland by the blood or lymph, and not by means of a duct. Many of the glands that possess ducts and form an external secretion form an internal secretion as well, but these are not classed as ductless, because the external secretion is carried out of the gland by means of a duct, though the internal secretion passes into the blood or lymph just as in the ductless glands. The function of the ductless glands is intimately connected with the purpose of the internal secretions, and this is very imperfectly understood, because of the impossibility of securing the internal secretions in a state of purity, *i.e.* free from blood or lymph. As the result of many experiments it is considered probable that the internal secretions contain hormones which act as chemical stimuli and to a limited extent assist in the correlation of the activities of different organs.

The most important ductless glands are: —

(1) The Thyroid.
(2) The Parathyroids.
(3) The Thymus.
(4) The Adrenals (supra-renal capsules).
(5) The Hypophysis.
(6) The Epiphysis.
(7) The Carotid glands.
(8) The Coccygeal glands.

(1) **The thyroid.** — The thyroid is a small, flat gland lying against the fore part of the trachea, below the thyroid cartilage. It is of a deep red color, weighs about an ounce (30 grams) or more, and consists of two lateral lobes connected at their lower

parts by an isthmus. The lobes are broadest below and taper to a point above. Small masses of thyroid tissue are sometimes found along the trachea as far down as the heart. They are called **accessory thyroids**. Comparatively little is known about the action of the thyroid secretion, but much clinical evidence supports the belief that it is necessary for the normal growth and functions of almost all the tissues of the body.

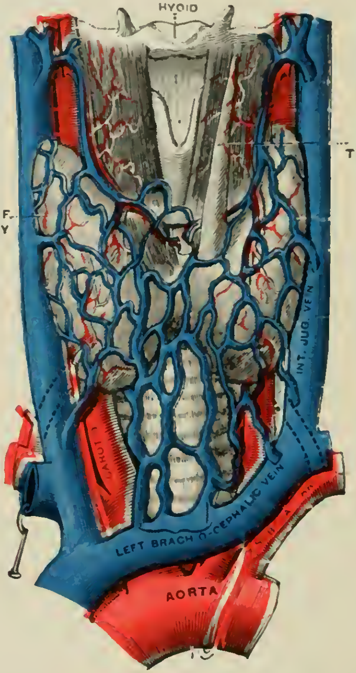

Fig. 163. — The Thyroid Body and the Related Blood-vessels. (Gerrish.)

Cretinism is a condition caused by congenital defects of the thyroid or atrophy occurring in early life. The growth of the skeleton ceases and there is complete arrest of mental development. Children so afflicted may live for many years, but at twenty-five or thirty, they have the intelligence of a child of four or five, and present a childish appearance.

Myxœdema is a disturbed condition of metabolism that follows the removal or atrophy of the gland. The individual so afflicted presents a peculiar appearance, as the subcutaneous connective tissue becomes thickened, so that the face and hands are swollen and puffy. The mental faculties become blunted and idiocy results unless proper treatment is instituted.

Cretinism and myxœdema are both supposed to be due to a lack of the internal secretion of the thyroid, and much success has followed the administration of thyroid extract in various ways.

Goitre is a condition in which the gland is enlarged, but the secretion may not be interfered with.

Exophthalmic goitre is a disease characterized by extreme nervousness, quickened heart action, protruding eyeballs, and goitre. It is caused by an overabundant production of thyroid secretion, due to enlargement and over activity of the gland.

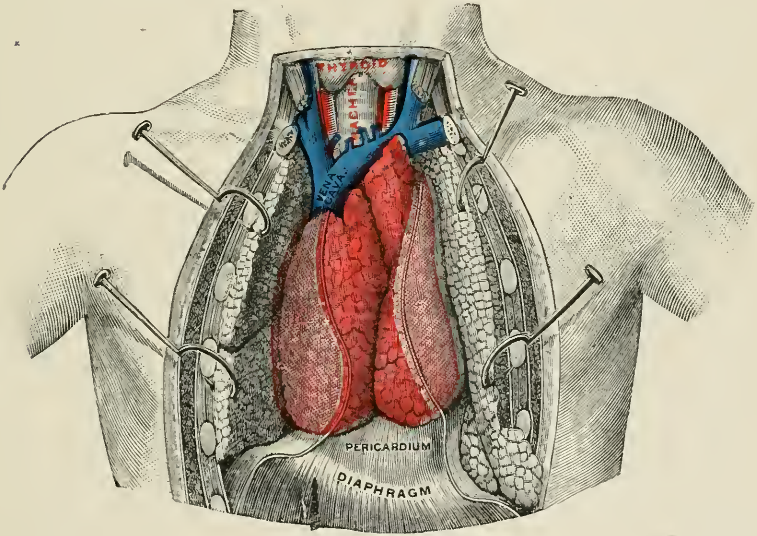

FIG. 164. — THE THYMUS, THE STERNAL AND COSTAL CARTILAGES HAVING BEEN REMOVED. (Gerrish.)

(2) **The Parathyroids.** — Embedded in the surface of each lateral lobe of the thyroid are two little masses, each about one-fourth inch (6.25 mm.) in diameter. They are solid accumulations of epithelioid cells, invested with a tunic of areolar tissue and well supplied with blood-vessels. The function of the parathyroids is supposed to consist in neutralizing toxic substances found elsewhere in the body.

(3) **The Thymus.** — The thymus consists of two large masses of glandular tissue situated below the thyroid and in front of the

trachea. It is described as a temporary organ of fœtal and infantile life. It appears at the end of the second month of intra-uterine life and continues to grow until a child is two or three years old. At that time it weighs about six drachms. Thereafter it atrophies and disappears, except for some shreds of tissue still present at the age of puberty. The function of this gland is not known, but it is thought to have a definite connection with growth and with the development of the reproductive organs.

(4) **The adrenals or supra-renal capsules.** — The adrenals are small flattened bodies of a yellowish color which are placed one above each kidney. They are usually classified with the ductless glands, as they have no excretory duct, but are sometimes classed with the organs of the central nervous system, as they contain a great deal of nerve-tissue. Each organ weighs about one drachm, and is invested by a fibrous capsule which sends fibres into the glandular substance; these fibres form a framework for the soft, pulpy substance of the gland, and within the spaces of the framework are groups of cells. (See Fig. 166.)

The adrenals are plentifully supplied with blood-vessels and lymphatics, and they contain some striking coloring matters. In diseases of these organs, the skin frequently becomes "bronzed" from an increase of pigment or coloring matter.

Function. — The adrenals produce an internal secretion which is called adrenalin. The function of this secretion seems to be connected with maintaining the tone of the heart and blood-vessels. It is still a question whether this maintenance of tone is the result of the secretion acting directly on the tissues of the heart and blood-vessels, or indirectly on the nerve centres. Removal of these glands results in such a loss of tone that death follows.

Adrenalin extract is made from the supra-renal capsules of animals, and is used as a heart stimulant to improve the tone of the heart and blood-vessels, also in hemorrhage to constrict the vessels.

(5) **The hypophysis.** — The hypophysis, also called the pituitary body, is of an ovoid form, a reddish gray color, and consists of two lobes. The anterior lobe is larger and distinctly glandular, the posterior lobe is smaller and composed of nerve cells and fibres.

The pituitary is lodged in a depression of the middle portion of the sphenoid bone, and is firmly held in place by the dura mater.

Little is known of the function of this gland, but the results of various experiments justify the belief that the secretion of both the anterior and posterior lobes has an important influence upon metabolism. The secretion of the anterior lobe is connected with growth, particularly of the skeleton. The secretion of the posterior lobe has a specific effect upon the organs of circulation, increases the secretion of urine and milk, and is connected in some way with the metabolism of carbohydrates. There seems to be an inter-relation between the hypophysis, and the pancreas, adrenals, and thyroid.

Gigantism, or excessive growth, and dwarfism, or underdevelopment, are thought to be due to abnormal conditions of this gland in early life. In later life abnormal conditions are attended with enlargement of the bones of the extremities and the features of the face, a condition known as **acromegaly**.

(6) **The epiphysis.** — The epiphysis or pineal body is a small reddish gray body located in the third ventricle of the brain. In early life it is glandular and attains its maximum growth about the seventh year. After this period, and particularly after puberty, it decreases in size, and the glandular tissue is replaced by fibrous tissue. It is thought that in early life the gland furnishes a secretion that inhibits growth, and restrains the development of the reproductive glands.

(7) **The carotid glands.** — They are so named because each is situated in the bifurcation of a common carotid artery. They are composed of nodules, each of which is a mass of epithelial cells, among which are large capillaries. They are covered by a fibrous capsule.

(8) **Coccygeal gland.** — The coccygeal gland is situated in front of the tip of the coccyx. It is covered by fibrous tissue and composed of epithelial cells.

SPLEEN

Some authorities class the spleen with the ductless glands; other authorities question this, as it has not been possible to demonstrate that it furnishes an internal secretion. It is directly beneath the diaphragm, behind and to the left of the stomach. It is covered by a portion of the peritoneum, the serous membrane covering the viscera of the abdomen. It is bean-shaped, convex on the outer surface, concave on the inner, and weighs usually from five to eight ounces (150 to 240 grams). Beneath the serous coat it is covered by a fibrous and muscular capsule which sends fibrous bands (trabecules) to form a network in the interior of the organ. The meshes of this fibrous framework are filled with a substance called spleen pulp, which is dark red in color, and consists of blood containing splenic cells, leucocytes, red corpuscles of normal appearance, and others variously changed. This soft red pulp is dotted with whitish specks, which are small masses of lymphoid tissue, and are called the **Malpighian corpuscles of the spleen.**

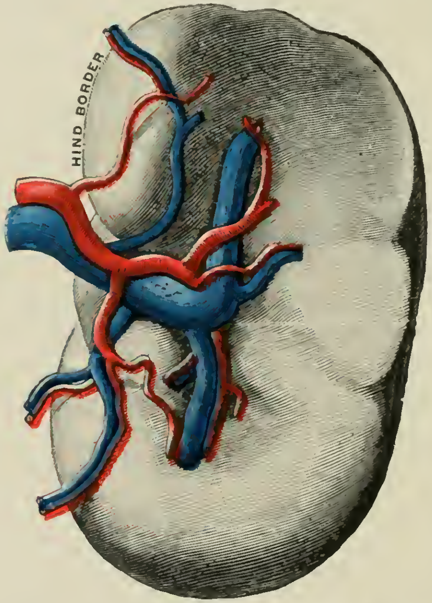

Fig. 165. — The Spleen, showing the Gastric and Renal Surfaces and the Blood-vessels. (Gerrish.)

Blood supply. — Blood is supplied to the spleen by the splenic artery, which enters the concave side of the spleen at a depression called the hilus. The arrangement of the blood-vessels is peculiar to this organ. The splenic artery divides into several branches before entering the organ, and after entering, rapidly divides into smaller vessels. When the minute arteriole stage is reached, the vessels terminate, and the blood escapes into the spleen pulp. The blood is collected from the pulp by thin-walled veins, which unite to form the splenic vein. The splenic vein unites with the superior mesenteric to form the portal vein, and carries the blood to the liver.

Function. — The functions of the spleen are imperfectly understood, but it is usually credited with the following: —

(1) The formation of leucocytes. The reason for this is that the blood which leaves the spleen by the splenic vein contains a larger number of leucocytes than the blood that enters by the splenic artery.

(2) The formation of red corpuscles during fœtal life and for a short period after birth.

(3) The presence of a large amount of iron suggests that it may help in the preparation of new hæmoglobin, or in the preservation of the iron set free by the death of the red corpuscles. The presence of iron was formerly considered an evidence that the red corpuscles were destroyed in the spleen, but this is not accepted at the present time.

(4) The spleen increases in size during digestion, and after digestion is over it returns to its usual size. It is always large in well-fed, and small in starved animals. This supports the belief that it may be concerned in digestion or metabolism.

(5) It is probable that the spleen is concerned in the production of uric acid. Various waste products that result from the metabolism of protein are found in the spleen, and it is thought that by the action of special enzymes these substances are changed to uric acid.

(6) In certain diseases, more especially typhoid and malaria, a temporary enlargement takes place. Some physiologists interpret this as an evidence that the spleen has an important protective function. Phagocytosis is a normal occurrence, and in addition it serves as a filter and may modify abnormal material found in the blood.

SUMMARY

- **Metabolism**
  - Refers to changes that occur in food-stuffs from time of absorption to elimination.
  - **Consists of**
    - 1. Conversion of non-living material into protoplasm.
    - 2. Oxidation.
    - 3. Neutralization or elimination of acids.
    - 4. Conversion of glucose into glycogen and glycogen into glucose.
  - **Equals the sum of the**
    - Anabolic or constructive changes.
    - Katabolic or destructive changes.
  - **Functions**
    - 1. Release of chemical energy in the form of heat, nervous and muscular activity.
    - 2. Repair and growth of tissue.
  - **Dependent upon**
    - Enzymes.
    - Oxygen.
    - Internal secretions.

- **Metabolism of Fats**
  - Fats are oxidized and serve as fuel
    - Liberation of energy.
    - Waste products
      - Carbon dioxide.
      - Water.
  - **Function**
    - Yield heat and energy.
    - Form reserve fund for time of need (adipose tissue).
    - Protect protein tissue.
  - **Obesity**
    - Due to excessive amounts of carbohydrates and fats.
    - Sedentary life and absence of worry are contributing factors.

- **Metabolism of Carbohydrates**
  - Conversion of simple sugars into glycogen.
  - **Dependent upon**
    - Control of nervous system.
    - Action of enzymes.
  - **Functions**
    - Furnish main source of energy for muscular work and all the nutritive processes.
    - Help to maintain the body temperature.
    - Form reserve fund for time of need (glycogen).
    - Protect the body tissues.
    - Excess carbohydrates are converted into adipose tissue.
  - **Waste Products**
    - Carbon dioxide.
    - Water.

- **Metabolism of Proteins**
  - 1. Conversion of peptones, polypeptids, and amino-acids into serum-albumin and serum-globulin, and the conversion of these blood proteins into living tissues.
  - 2. Excess protein molecules are split into two parts. One part is converted into urea and excreted, the other part may be oxidized directly, or built into carbohydrates and fats and oxidized later.
  - **Classification**
    - **Adequate** proteins contain all the materials for maintenance and growth of tissue.
    - **Inadequate** proteins serve same purpose as carbohydrates and fats.
  - **Function**
    - 1. **Build up tissue.**
    - 2. Serve same purpose as carbohydrates and fats.
  - **Nitrogen equilibrium.** — Condition when the amount of protein nitrogen taken into the body in food is equal to the amount eliminated in the excreta.

Heat Value of Food
- Heat results from processes of oxidation.
- **Calorie**
  - Unit of measurement for heat production.
  - Small calorie = quantity of heat necessary to raise one gram of water one degree centigrade.
  - Large calorie = quantity of heat necessary to raise one gram of water 1000 degrees centigrade.
- **Fat** — 1 gram yields about 9.3 large calories.
- **Carbohydrates** — 1 gram yields about 4.1 large calories.
- **Protein** — 1 gram yields about 4.1 large calories.

Average Amount of Food required
- Dependent upon
  - 1. Activity.
  - 2. Age.
  - 3. Size.
  - 4. Sex.
  - 5. Climate.
- Average number of calories
  - Fats $\frac{1}{5}$ to $\frac{2}{3}$ or about 930 calories.
  - Carbohydrates $\frac{2}{5}$ to $\frac{3}{5}$ or about 984 calories.
  - Proteins $\frac{1}{5}$ or about 410 calories.
- **Undernutrition** — lessens natural powers of resistance to disease.
- **Overeating**
  - 1. Puts unnecessary strain on the organs of nutrition and excretion.
  - 2. Favors obesity.
  - 3. Increases amount of waste products, toxic material, and flatulence.
  - 4. Retards secretion of gastric juice.

Ductless Glands
- Glandular structures that possess no ducts.
- Produce internal secretions that are carried from the gland by the blood or lymph.
- Function is imperfectly understood, because it is dependent upon the internal secretions and these cannot be obtained in a pure state.
- **Most important**
  - The Thyroid.
  - The Parathyroids.
  - The Thymus.
  - The Adrenals.
  - The Hypophysis.
  - The Epiphysis.
  - The Carotid glands.
  - The Coccygeal gland.

Thyroid
- Small gland. Weighs about one ounce.
- Consists of two lobes connected by an isthmus.
- Placed in front of trachea, below thyroid cartilage.
- Function not definitely known, but the internal secretion is thought to be necessary for normal growth, and the functioning of all the tissues.

Parathyroids	Four small masses, each about $\frac{1}{4}$ in. diameter. Two are embedded in each lobe of thyroid. Consist of epithelioid cells, invested with areolar tissue. Function is supposed to consist in neutralizing toxic substances.
Thymus . .	Consists of two large masses of glandular tissue situated below the thyroid and in front of the trachea. Temporary organ. Appears at second month of intra-uterine life, grows until child is two or three years of age, and it weighs about six drachms. Then atrophies steadily until age of puberty, when only some shreds of tissue are left. Function not definitely known, but it is thought to have a definite connection with growth and with the development of the reproductive organs.
Adrenals . .	Small glands lying above each kidney. Weigh one drachm. Consist of a fibrous framework, the spaces of which are filled with groups of cells. They are enclosed in a fibrous capsule and are well supplied with blood-vessels, lymphatics, and nerves. Internal secretion — adrenalin. Function seems to be connected with maintaining the normal tone of the heart and blood-vessels.
Hypophysis	Small reddish gray gland, weighs 5–10 grains. Consists of two lobes . { Anterior lobe, large and glandular. Posterior lobe, small and composed of nerve tissue. Lodged in depression of the sphenoid bone. Function not positively known, but it is thought to have a definite connection with growth, with the organs of circulation, with the secretion of urine and milk; and with the metabolism of the carbohydrates.
Epiphysis . .	Small reddish gray body located in the third ventricle of the brain. Glandular organ and attains maximum growth about seventh year. From this period and particularly after puberty it decreases in size and becomes fibrous. Function not definitely known, but it is thought to inhibit growth and restrain the development of the reproductive organs.
Carotid Glands	Small glands, one situated in bifurcation of each carotid artery.
Coccygeal Gland	Small gland $\frac{1}{10}$ in. in diameter, situated in front of tip of coccyx.

- **Spleen**
  - **Description**
    - Beneath diaphragm, behind and to the left of the stomach.
    - Consists of a fibrous network filled with a vascular pulp, enclosed in a fibrous and muscular capsule which is covered by serous membrane.
    - Blood supply peculiar — arteries — veins, no connecting capillaries.
  - **Functions**
    - Not definitely known. Credited with the following: —
    - 1. Formation of leucocytes.
    - 2. Formation of red corpuscles during fœtal life and for short period after birth.
    - 3. Helps in preparation of new hæmoglobin or preservation of iron set free by death of red corpuscles.
    - 4. May assist in digestion and metabolism.
    - 5. May assist in production of uric acid.
    - 6. May protect body from infections.

CHAPTER XVII

WASTE PRODUCTS. EXCRETORY ORGANS; DESCRIPTION OF THE ORGANS CONSTITUTING THE URINARY SYSTEM; GENERAL CHARACTERS OF URINE; COMPOSITION OF URINE

In the previous chapters we have seen that the blood is constantly supplied by means of the respiratory and digestive mechanisms, with all the chemical substances it requires to maintain the life, growth, and activity of the body. These substances, entering the current of the blood, are carried to all the tissues, and are incessantly combining with the chemical substances of which these tissues are composed. One of the results of these chemical combinations is the formation of waste products, which must be removed from the body, as many of them are toxic.

WASTE PRODUCTS

The principal waste products formed in the body are urea, uric acid, creatinin, hippuric acid, carbon dioxide, and other organic substances; inorganic salts and water. Waste products are classed as excreta and the process by which they are removed from the body as excretion or elimination.

EXCRETORY ORGANS

The organs whose sole function is the elimination of waste products are the organs of the urinary system. These are called the excretory organs and consist of the following:—

2 *Kidneys,* which form the urine from materials taken from the blood.
2 *Ureters,* ducts which convey the urine away from the kidneys.
1 *Bladder,* a reservoir for the reception of urine. (See Fig. 120.)
1 *Urethra,* a tube through which the urine passes from the bladder and is finally voided.

Other organs that assist in the process of elimination are: (1) the lungs, (2) the skin, (3) the liver, and (4) the intestines.

The waste matters discharged relatively by the urinary organs, lungs, skin, liver, and intestines may be stated as follows: —

(1) **By the urinary organs:**	All, or nearly all, the urea and allied bodies.[1] These waste products result from the metabolism of food proteins and body tissues. The greater portion of the salts. These salts represent those taken into the body and not utilized, also those that result from the neutralization of acids and the metabolism of foods and tissues. A large amount of water. This consists of water taken as such with food, and that formed in the body as the result of chemical reactions. A very small quantity of carbon dioxide.
(2) **By the lungs:**	The greater part of the carbon dioxide, formed by oxidation. A considerable quantity of water. A small quantity of urea is eliminated in diseased conditions of the kidneys.
(3) **By the skin:**	A variable but, on the whole, large quantity of water. This is influenced by temperature, and the amount excreted by the kidneys. A small quantity of salts. A small quantity of urea. Under normal conditions the quantity of urea is negligible, but in diseased conditions of the kidneys or when free perspiration is induced, the quantity is increased. A small quantity of carbon dioxide.
(4) **By the liver:**	A small quantity of bile. This contains waste products that result from chemical reactions that occur in the liver.
(5) **By the intestines:**	Undigested and indigestible food material. A small quantity of salts. In diseased conditions of the kidneys, some urea and allied bodies.

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[1] Uric acid, hippuric acid, creatin, creatinin, xanthin, etc.

In this chapter we shall devote ourselves to the consideration of the urinary system.

KIDNEYS

The kidneys are two compound tubular glands, placed at the back of the abdominal cavity, one on each side of the spinal column and behind the peritoneal cavity. They correspond in position to the space included between the upper border of the twelfth thoracic and the third lumbar vertebra. The right is a little lower than the left in consequence of the large space occupied by the liver.

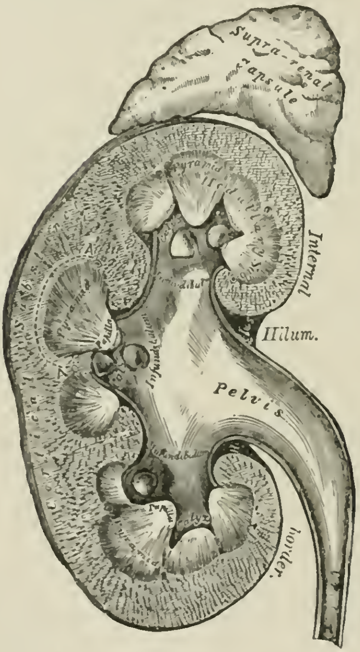

Fig. 166. — Vertical Section of the Kidney. (Collins.)

Capsule and supports. — The kidneys are covered by a thin but rather tough envelope of fibrous tissue called the capsule of the kidney, and are usually embedded in a considerable quantity of fat, which, with the assistance of their vessels and the peritoneum, helps to hold them in place.

Size and shape. — Each kidney is about four inches (100 mm.) long, two inches (50 mm.) broad, one inch (25 mm.) thick, and weighs about four and one half ounces (135 gm.) They are bean-shaped, with the concave side turned toward the spine, and the convex side directed outward. Near the centre of the concave side is a depression called the hilum, which serves as a passageway for the ureter, and for the blood-vessels, lymph-vessels, and nerves going to and from the kidney.

Anatomy of the kidney. — If we cut a kidney in two lengthwise, it is seen that the upper end of the ureter expands into a basin-like cavity, called the **pelvis** of the kidney. This pelvis is irregularly subdivided into smaller, cup-like cavities, called **calyces**, which receive the pointed projections of the kidney substance.

The substance of the kidney is readily seen by the naked eye to consist of two distinct parts: (1) An outer, lighter, and more solid portion, called the cortex (bark). (2) An inner, darker, striated portion, called the medulla (marrow), which is not a solid mass, but more or less distinctly divided into pyramidal-shaped sections. The pointed projections, or **papillæ**, of the pyramids are received by the cup-like cavities or calyces of the pelvis. The bulk of the kidney substance, both in the cortex and medulla, is composed of little tubes or tubules, closely packed together, having only just so much connective tissue as is sufficient to carry a large supply of blood-vessels and a certain number of lymphatics and nerves.

Uriniferous tubules. — Examined under the microscope, it is seen that the uriniferous tubules begin as little hollow globes, called **capsules**, in the cortex of the kidney. These capsules are joined to the tubules by a constricted neck, and the tubules, after running a very irregular course, open into straight collecting tubes, which pour their contents through their openings in the pointed ends or papillæ of the pyramids, into the calyces of the kidney.

The tubules are composed of basement membrane, lined throughout by epithelial cells. The cells vary in the different parts of a tubule, those of the capsule and convoluted or irregular parts being more especially adapted to secretory purposes than the straight parts of the tubule.

Pyramid. — These collecting tubules *en masse*, together with interstitial tissue, blood-vessels, and lymphatics, make a pyramid. The number of pyramids varies from eight to twelve.

Renal or Malpighian corpuscles. — In the cortical portion of the kidney are found renal corpuscles which consist of two parts: (1) a minute tuft of capillaries called a *glomerulus*, surrounded by (2) a closed *capsule* which is the beginning of a uriniferous tubule. The investment of the glomerulus by the capsule is double and quite complete except at one point where an afferent vessel enters, and an efferent vessel leaves.

The blood supply of the kidney. — For its size, the kidney is abundantly supplied with blood. The renal artery, coming directly from the aorta, divides, before it enters the hilus of the kidney, into several branches, which pass into the tissue of the organ. Branches from these arteries have two destinations: (1) into the cortex, and (2) into the pyramids.

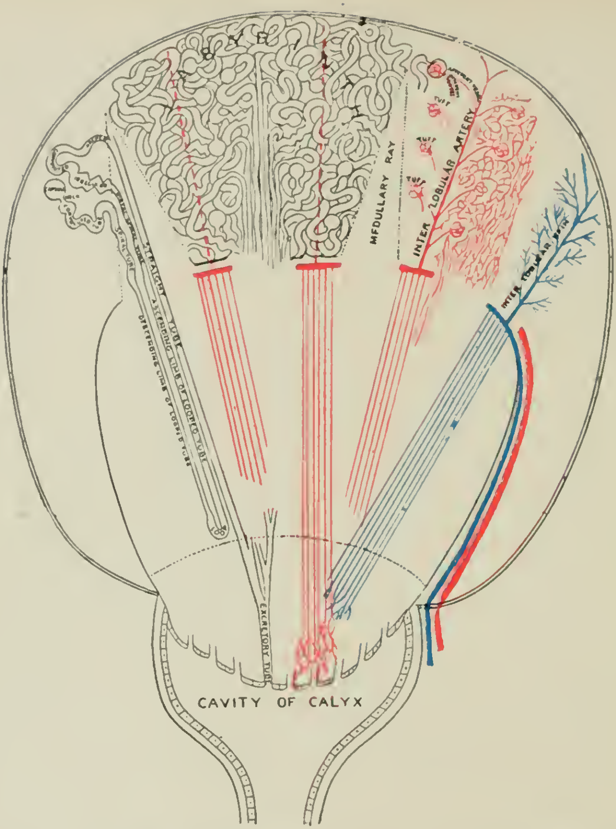

Fig. 167. — Diagram of the Structure of a Lobe of the Kidney. The lobe is seen in vertical section, the cortex being marked off from the medulla. Four medullary rays encroach upon the cortex. At the left is shown the course of a single, continuous series of tubes — the straight and spiral tubes appearing in the medullary ray, the straight, looped, and excretory in the medulla proper, the capsule, neck, convoluted, irregular, and arched in the cortex proper. Next is seen the labyrinth, composed of a mass of tubes in the cortex, with a medullary ray for a centre. Equidistant from the ray on each side is a broken red line, marking the position of an interlobular artery. The parts between these lines constitute a lobule. Farther to the right is an interlobular artery, giving off lateral branches (afferent vessels), each of which ends in a tuft of capillaries, from which the blood is collected by an efferent vessel. The uppermost of the tufts is shown enclosed in a capsule. On the right of the interlobular artery the efferent vessels break up into a capillary network which surrounds the (unrepresented) tubes in the cortex and ray. The lowest efferent sends vertical vessels also into the medulla. On the right the interlobular vein is seen gathering the blood from all the parts supplied by the interlobular artery. A branch of the renal artery courses upward between cortex and medulla, and forms an arch (here broken) over the base of the medulla. From it the interlobular arteries pass upward into the cortex, and straight branches go downward into the medulla, supplying its structure, and ending at the apex in the capillaries. From the last the radicles of the renal vein arise, and accompany the straight arteries to the base of the medulla, where a venous arch is formed, continuous with which is the vena comes of the entering artery. The calyx embraces the apex of the medullary pyramid. It is lined with epithelium, which continues from it over the apex, the latter being perforated with the many apertures of excretory tubes. (Gerrish.)

(1) When the arteries reach the level of the base of the pyramid, the branches divide laterally to form more or less complete arches between the cortex and medulla. From the arterial arches, vessels pass upward through the cortex (interlobular), giving off at intervals tiny arteries, each of which enters the dilated commencement or capsule of a uriniferous tubule. These tiny arteries, entering the capsule, are spoken of as afferent vessels. They push the thin walls of the capsule before them, break up into a knot of capillary vessels, called a *glomerulus,* and finally issue from the capsule as efferent vessels, near the point at which the afferent vessel entered. These efferent vessels are much smaller than the afferent vessels. They do not immediately join to form veins, but break up into a close meshwork or plexus of capillaries around the tubules, before they unite to form the larger vessels and pour their contents into the veins. These veins terminate in venous arches between the cortex and medulla. It is in this way that the cortex is supplied with blood.

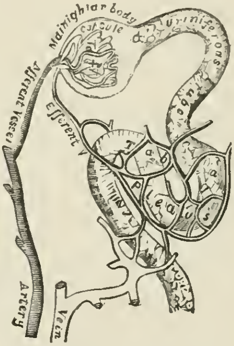

Fig. 168. — Plan of the Blood-vessels connected with the Tubules. (Note that in the text the term "renal or Malpighian corpuscles" is used instead of the term "Malpighian body" which is found on the illustration.)

(2) The pyramids also receive their blood supply from the arterial arches. The blood passes downward in straight vessels between the uriniferous tubules, to be returned by more or less straight veins to the venous arches, whence it is conveyed by large branches into the renal vein, which leaves the kidney at the hilus and pours its contents into the inferior vena cava.

It is worthy of note that, unlike the lungs and the liver, the kidney receives blood from just one artery, and this blood distributed in different sets of vessels serves the purposes of nourishment for the kidney substance, and the purposes of excretion. It is from the capillaries of the glomeruli and the plexus of capillaries around the convoluted portion of the tubules, that the passage of waste material from the blood into the tubule takes place. Other capillaries serve to hold the blood that is used for nourishment.

Nerves and lymphatics. — The kidneys are well supplied with nerves derived from both the sympathetic and central nervous system. Many of these nerves are vasomotor nerves, and by regulating the contraction and relaxation of the blood-vessels, they influence the blood pressure in the kidney. They are also well supplied with lymphatics.

Function of the kidneys. — The function of the kidneys is to separate waste matters (urine) from the blood, and thus help to maintain the normal composition of the blood. The waste matters are those resulting from metabolism, particularly of proteins, water, salts, and foreign matters such as toxins, whether formed in the body, or taken into the body from outside.

The secretion of urine. — The exact way in which the kidneys separate the urine from the blood is not known, but it is thought to be a double process, being partially accomplished by transudation, and partially by the selective action of the secreting cells lining the tubules.

(1) Into each hollow capsule which forms the beginning of a uriniferous tubule an afferent artery enters. This artery breaks up into capillaries which form a bunch of looped and twisted blood-vessels called a *glomerulus*. The walls of the capsule being double, the glomerulus pushes back the inner wall or visceral layer, until the capsule is entirely filled, leaving only a small space between it and the outer wall or parietal layer. The blood in the glomerulus is only separated from the interior of the tubule by the thin walls of the capillaries and the inverted wall of the capsule. The artery (afferent) which enters the capsule is larger than the issuing (efferent) vessel, and during its passage through the glomerulus, the blood is subjected to considerable pressure. As a result of this, a transudation of the watery constituents of the blood, with some dissolved salts, takes place through the walls of the blood-vessels and the walls of the capsule into the capsular space, then into the tubule.

(2) After leaving the capsule, the efferent vessel communicates with other similar vessels, which together form a meshwork or plexus of capillaries closely surrounding the tubules, so that the blood is again brought into close communication with the interior of the tubules. The tubules are lined with secreting cells, and these cells appear to have the power of selecting from the blood the more solid waste matters (especially the urea), which fail to filter through the flat cells forming the wall of the capsule.

THE URETERS

The ureters are the excretory ducts of the kidneys. They consist of a distended portion called the *pelvis*, which is contained within the kidney, and a *duct*. Each duct is about the diameter of a goose-quill, and from twelve to eighteen inches (300 to 450 mm.) long. They consist of three coats: —

(1) An inner or **mucous** coat continuous above with that of the pelvis of the kidney, and below with that of the bladder.

(2) A middle or **muscular** coat which is arranged in two layers, an inner longitudinal, and an outer circular.

(3) An outer or **fibrous** coat which carries the blood-vessels and nerves with which the tube is supplied.

Fig. 169. — Diagram showing Method of Entrance of the Ureter into the Bladder. (Gerrish.)

Function. — The ureters connect the kidneys with the bladder and serve as a passageway to convey urine from the kidneys to the bladder.

BLADDER

The bladder is a hollow muscular organ situated in the pelvic cavity behind the pubes, in front of the rectum in the male, and in front of the anterior wall of the vagina, and the neck of the uterus, in the female. It is a freely movable organ, but is held in position by ligaments. During infancy it is conical in shape and projects above the upper border of the pubes into the hypogastric region. In the adult, when quite empty, it is placed deeply in the pelvis; when slightly distended, it has a round form; but when greatly distended, it is ovoid in shape and rises to a considerable height in the abdominal cavity. It is customary to speak of the widest part as the **fundus**, and the part where the bladder becomes continuous with the urethra as the neck, or **cervix**. It has four coats: —

1. The **mucous** membrane lining the bladder is continuous with that of the ureters and the urethra. When the bladder is empty, the mucous membrane is thrown into irregular rugæ.

2. The **areolar** coat connects the mucous and muscular. It permits freedom of movement such as is essential in an organ subject to change in size and shape.

3. The **muscular** coat has three layers, an inner longitudinal, middle circular, and outer longitudinal. The circular fibres are collected into a layer of some thickness around the cervix or neck, where the bladder becomes continuous with the urethra. These circular fibres around the neck form a sphincter muscle which is normally in a state of contraction, only relaxing at intervals, when the accumulation of urine within the bladder renders its expulsion necessary.

4. The **serous** coat is a reflection of the peritoneum, and only covers the upper portion of the fundus.

Function. — The bladder serves as a reservoir for the reception of urine. When moderately distended, it holds about one pint (about one-half litre).

THE URETHRA

The urethra is a narrow, membranous canal, about an inch and a half (38 mm.) in length in the female. Its normal diameter is about one-quarter of an inch (6.3 mm.), but it admits of considerable dilatation. It extends from the neck of the bladder to the external orifice, which is named the meatus urinarius. It is placed behind the symphysis pubis, and is embedded in the anterior wall of the vagina. Its direction is obliquely downward and forward, its course being slightly curved, with the concavity directed forward and upward. Its external orifice is the narrowest part and is located between the clitoris and the opening of the vagina. (See Fig. 207.)

The wall of the urethra consists of three coats: —

(1) An inner or **mucous** coat which is continuous with that of the bladder.

(2) A **submucous** coat which contains a network of veins.

(3) An outer **muscular** coat which is continuous with that of the bladder.

MICTURITION

.Urine is secreted continuously by the kidneys. It is carried to the bladder by the ureters, and at intervals is expelled from the bladder through the urethra. The act by which the urine is expelled is called micturition. It occurs normally as the result of irritation due to the accumulation of urine within the bladder. The accumulation stimulates the muscular walls to contract, and the resistance of the sphincter at the neck of the bladder is overcome. The action is involuntary, but it may be controlled by voluntary effort.

Involuntary micturition. — Involuntary micturition may occur as the result of lack of consciousness; and as the result of spinal injury involving the nerve centres, which send nerves of control to the bladder. It may be due to a want of " tone " in the muscular walls, or it may result from some abnormal irritation.

Retention of urine. — When the kidneys secrete urine, but it is retained within the bladder, we speak of it as retention. Retention or failure to void urine may be due to: (1) dulling of the senses so that there is no desire to void, (2) nervous contraction of the urethra, and (3) some obstruction in the urethra or in the neck of the bladder.

In some cases the bladder may become so fully distended that the retention of urine may be accompanied by more or less constant voiding of small amounts of urine.

Suppression of urine. — When the kidneys fail to secrete urine, it is spoken of as suppression, and is a far more serious condition than retention, as it is usually due to disease of the kidneys.

GENERAL CHARACTERS OF THE URINE

Normal urine may be described as a transparent, amber-colored liquid, with a characteristic odor, an acid reaction, and a specific gravity of about 1.020.

Transparency. — The transparency of urine may be diminished in health by the presence of mucus, derived from the genito-urinary tract, or by the deposit of salts. In disease the urine may become clouded by the presence of pus.

Color. — The color of urine depends upon the quantity voided and the relative amounts of water and coloring matters. If the quantity is abnormally increased, it is usually more dilute and of a paler color; as, for instance, the copious light-colored urine of hysteria or diabetes insipidus. One exception to this is diabetes mellitus, where the quantity is increased, but the color is dark because of the presence of sugar. When the quantity is diminished, as in fevers, it is generally highly colored, because the amount of solids present is large. Other causes of change of color are the presence of abnormal substances, and large doses of certain drugs.

Reaction. — The reaction of human urine is largely dependent on the kind of food we eat. Many of the waste products that result from a mixed diet are acid, hence the reaction of human urine is usually acid. On a diet of carbohydrates the urine will be alkaline, as it is with herbivorous animals. If human urine is allowed to stand for any length of time, it will become alkaline, because bacteria will decompose the protein constituents into ammonia and other alkalies. In certain diseased conditions of the urinary organs this same process takes place within the body.

Specific gravity. — The specific gravity depends upon the amount of solid waste matters present in the urine. In health, it may vary from 1.010 to 1.030. When the solids are dissolved in a large amount of water, the specific gravity will naturally be lower than when, from a deficiency of water, the urine is more concentrated. A high specific gravity denotes the presence of abnormal constituents; as, for instance, the specific gravity is notably heightened by the presence of sugar in diabetes mellitus. A low specific gravity generally denotes the presence of albumin, or hysteria or mere polyuria.

Quantity. — The average quantity of urine secreted in twenty-four hours by a healthy adult is from forty to fifty ounces (1.19 to 1.48 litres). A child voids relatively more urine than an adult, but absolutely it voids less.

From 2–5 years, 16–24 ounces.
From 5–8 years, 24–32 ounces.
From 9–16 years, 32–40 ounces.

The quantity of urine may be increased by (1) the ingestion of a large amount of liquids, (2) the action of diuretics, (3) nervousness, (4) certain diseases such as diabetes insipidus, diabetes mellitus, and hysteria.

The quantity of urine may be decreased by (1) the ingestion of a small amount of liquids, (2) vomiting, (3) diarrhœa, (4) high fever, (5) disease of the kidneys, and (6) the action of diaphoretics, muscular activity, or any treatment that induces free perspiration.

COMPOSITION OF URINE

The composition of urine is very complex; even in health it varies, depending on the quantity and kind of food eaten, etc.

The chief constituents are as follows: —

Urine
- **Water,** 95 per cent
- **Solids,** 5 per cent
  - Organic, about 3.7
    - **Urea** (2 per cent of total solids).
    - Uric acid.
    - Creatinin.
    - Hippuric acid.
    - Other substances.
  - Inorganic, about 1.3
    - Sodium chloride.
    - Sulphates.
    - Phosphates.
    - Salts of
      - Potassium.
      - Ammonium.
      - Magnesium.
      - Calcium.
    - Other substances.

Urea. — Urea constitutes about one-half of the solid constituents of the urine, and represents the chief end product resulting from the metabolism of the proteins of the food and tissues. The result of the oxidation of protein material exists in the blood until the blood reaches the liver. Under the action of the liver cells this material (ammonium carbamate) is converted into urea and remains in the circulation until the blood reaches the kidneys. To **eliminate** urea is the special work of the kidneys, and if for any reason they fail to execute their work, the accumulation of urea in the system leads to a condition of poisoning.

Normally an adult voids about one ounce (30 gm.) in twenty-four hours, but the quantity is increased by a diet rich in proteins, strenuous exercise, fever, and some diseases. A small amount of protein food, excessive vomiting, free perspiration, and diseases that interfere with elimination will decrease the amount of urea voided.

Uric acid. — Uric acid is thought to represent the end products resulting from the oxidation of the tissues, and next to urea is the medium by which nitrogen is eliminated from the body. Uric acid combines with potassium and sodium to form urates, and is found in the form of urates in the urine. In gout the excretion of urates is decreased, and it accumulates in the blood and is deposited in the tissues.

Creatinin. — Creatinin represents a meat extractive and may be taken into the body in food, or formed in the body by the oxidation of certain proteins.

Hippuric acid. — This is increased in amount by a vegetable diet, so that it is thought to represent a waste product that results from the metabolism of vegetables. However, some hippuric acid is excreted even on a meat diet, so that it may result from the metabolism of proteins, or it may be derived from the process of protein putrefaction that occurs in the intestines.

Salts. — The salts found in the blood are derived partly from the food eaten, and partly from the metabolism of proteins, particularly the neutralization of acids. Sodium chloride is the most abundant, and, next to urea, is the chief solid found in urine. In certain inflammatory conditions, coupled with serous exudate, the amount of sodium chloride excreted is very much diminished.

Abnormal constituents. — The chief abnormal constituents that are liable to appear in the urine are albumin, glucose, indican, acetone, casts, calculi, pus, and blood.

Albumin. — Normally the kidney cells do not allow albumin to pass into the tubules, but a condition of temporary albuminuria may follow overeating or severe muscular exercise. In abnormal conditions of the kidneys associated with nephritis and acute fevers, albumin is usually found in the urine. In cases of heart disease, where the blood vessels of the kidney are subjected to abnormal pressure changes, albumin is usually present in the urine.

Glucose. — In health the amount of glucose present in the blood varies from 0.1 to 0.15 per cent. A higher per cent is irritating to the tissues, so when the quantity of sugar eaten is greater than the system can promptly change to glycogen and fat, the kidneys secrete and excrete it. When glucose is found in the urine from this cause, it is called *temporary glycosuria.* Temporary glycosuria frequently follows an injury to the head, or occurs during convalescence from fevers. In these cases it is thought to be due to temporary inability of the system to oxidize sugar. In the disease called diabetes mellitus glucose persists in the urine. In mild cases this condition can be controlled by lessening the amount of carbohydrate food, but in severe cases glucose will appear in the urine even when no carbohydrates are eaten. This condition is serious because it means that the body tissues are being oxidized to form glucose. The cause of diabetes mellitus is not definitely known. It frequently follows injuries to the head, and is associated with disease of the pancreas, which interferes with the internal secretion.

Indican. — Indican is a substance that is formed from indol. Indol results from the putrefaction of protein food in the large intestine. It is absorbed and carried to the liver, which it is thought changes the indol to indican, a less poisonous substance. Traces of indican are found in normal urine, but the presence of it in any amount is abnormal and denotes: (1) excessive putrefaction of protein food in the intestines, or (2) disease of the stomach. (1) Excessive putrefaction may be due to a diseased condition of the intestine that interferes with absorption, to a diet containing too much protein food, or to constipation. (2) In certain diseases of the stomach, food is held until it undergoes fermentative changes.

Acetone. — Acetone is a volatile substance that is thought to be the result of incomplete oxidation of fats and possibly of proteins. It is found in the urine of individuals suffering from defective metabolism, and in the urine of normal individuals during periods of fasting.

Casts. — In some abnormal conditions the kidney tubules become lined with substances which harden and form a mould or cast inside the tube. Later these casts are washed out by the urine, and their presence in urine can be detected by the aid of a microscope. They are named either from the substances composing them or from their appearance. Thus there are (1) pus casts, (2) blood casts, (3) epithelial casts from the walls of the tubes, (4) granular casts from cells which have decomposed and form masses of granules, (5) fatty casts from cells which have become fatty, and (6) hyaline casts which are formed from coagulable elements of the blood.

Calculi. — A deposit of solid matter that has been precipitated from the urine is called a urinary calculus or stone. They vary in size, shape, and composition, the size and shape being determined largely by their composition and location. They may be formed in any part of the urinary tract from the tubules to the external orifice of the urethra. The causes which lead to their formation are (1) an increase in the slightly soluble constituents of the urine, (2) a decrease in the amount of water secreted, and (3) abnormally acid or abnormally alkaline urine.

Pus. — In suppurative conditions of any of the urinary organs pus cells are present in the urine.

Blood. — In cases of acute inflammation of any of the urinary organs, of tuberculosis, of cancer, and of renal stone, red blood corpuscles may be found in the urine. If present in large numbers, they make the urine look like blood, and this condition is known as hematuria.

Toxicity of urine. — As urine is the medium by which the body gets rid of toxic material, it follows that urine itself is toxic, and must be eliminated, else a condition of toxemia will result. This condition is called uremia, because it was thought that the symptoms of poisoning were due to the retention of urea in the body. It is now believed that while urea is poisonous, it is only one of several substances that renders urine toxic. During illness the kidneys always try to eliminate any poisonous substances that find their way into the blood, whether these substances are derived from defective metabolism or from bacterial activity. This accounts for the fact that after a severe illness the kidneys are often left in a damaged condition.

SUMMARY

- **Waste Products or Excreta**
  - Urea.
  - Uric acid.
  - Creatinin.
  - Hippuric acid.
  - Carbon dioxide.
  - Other organic substances.
  - Inorganic salts.
  - Water.
- **Excretory Organs**
  - **Urinary system**
    - **Kidneys** (2) — secrete urine.
    - **Ureters** (2) — ducts which convey urine from kidneys to bladder.
    - **Bladder** (1) — reservoir for urine.
    - **Urethra** (1) — tube through which urine is voided.
  - **Assist in excretion**
    - Lungs.
    - Skin.
    - Liver.
    - Intestines.

KIDNEY

- **Location**
  - Posterior part of lumbar region, behind peritoneum.
  - Placed on either side of spinal column and extend from upper border of twelfth thoracic to third lumbar vertebra.
- **Capsule and supports**
  - Covered by tough envelope of fibrous tissue.
  - Supported by quantity of fat, vessels, and peritoneum.
- **Size and shape**
  - Four inches long, two inches broad, one inch thick.
  - Weight, four and one half ounces (140 gm.).
  - Bean-shaped, tubular glands.
  - Concave side toward spine, convex side outward.
  - Hilum — depression near centre of concave side serves for vessels to enter and leave.
- **Anatomy of the kidney**
  - **Pelvis** — Upper expanded end of ureter.
  - **Calyces** — Cup-like cavities of the pelvis that receive papillæ of pyramids.
  - **Cortex** — outer, lighter, more solid portion.
  - **Medulla** — inner, darker, striated portion.
  - **Uriniferous tubules**
    - Begin as hollow globes or capsules in the cortex of kidney, and after a very irregular course open into straight collecting tubes which pour their contents into calyces of pelvis.
  - **Pyramids**
    - Cone-shaped masses in the medullary portion of the kidney. Vary in number from 8–12.
    - **Bases** directed toward cortex.
    - **Papillæ** — Apices of the pyramids, directed toward pelvis.
    - Consist of uriniferous tubules, blood-vessels, and lymphatics, held together by connective tissue.
  - **Renal corpuscles**
    - Minute tufts of capillaries — glomeruli — in the cortical portion of kidneys which are surrounded by inverted capsule of uriniferous tubule.
  - **Blood supply**
    - **Renal artery** — direct from aorta.
    - Enters hilus of kidney, divides into many branches.
    - **Arterial arches**
      - Lateral branches at the level of the base of the pyramids.
      - 1. Send branches to cortex (cortical).
      - 2. Send branches to pyramids.

- KIDNEY
  - **Anatomy of the kidney**
    - **Blood supply**
      - **Venous arches**
        - Lateral branches at level of base of pyramids.
        - Receive blood from cortex.
        - Receive blood from pyramids.
      - Veins empty into renal vein, leave kidney at hilus, and empty into inferior vena cava.
      - **Note** — Blood from renal artery serves for purposes of nourishment of kidney and purposes of excretion.
    - **Nerves and lymphatics**
      - Nerves from sympathetic and central nervous system.
      - Many are vasomotor, and by regulating size of blood-vessels, influence blood pressure.
      - Well supplied with lymphatics.
  - **Function**
    - **Secretion of urine**
      1. Process of transudation or filtration. Water and saline elements are filtered from the blood during the circulation through the glomeruli.
      2. Secretory action of the cells lining the uriniferous tubules. Urea and other foreign substances are separated from the blood during the circulation through the plexus of capillaries which surrounds the tubules.

- **Ureters**
  - Excretory ducts. Extend from kidney to bladder.
  - Consist of expanded portion called pelvis and duct.
  - Size of goose-quill. 12–18 in. long.
  - **Three coats**
    1. Mucous — lining.
    2. Muscular
       - Inner, longitudinal layer.
       - Outer, circular layer.
    3. Fibrous — carries blood-vessels and nerves.
  - **Function**
    - Connect kidneys with bladder.
    - Passageway for urine.

- **Bladder**
  - Hollow muscular organ.
  - Situated in pelvic cavity behind the pubes
    - in front of rectum in male.
    - in front of anterior wall of vagina and neck of uterus in female.

- **Bladder**
  - Freely movable. Held in position by ligaments.
  - Size, shape, and position depend upon age, sex, and whether bladder is full or empty.
  - Fundus — widest part.
  - Cervix — where the bladder becomes continuous with the urethra.
  - **Four coats**
    - 1. Mucous — lining.
    - 2. Areolar — connects mucous and muscular.
    - 3. Muscular
      - Inner layer — longitudinal.
      - Middle layer — circular.
      - Outer layer — longitudinal.
    - 4. Serous — partial covering derived from peritoneum.
  - **Function**
    - Serves as a reservoir for the reception of urine.
    - When moderately distended, holds about one pint.
- **Urethra**
  - Membranous canal, extends from the bladder to the meatus urinarius. 1½ in. long and ¼ in. in diameter in female.
  - Behind symphysis pubis, and embedded in the anterior wall of vagina.
  - **Three coats**
    - 1. Mucous — lining.
    - 2. Submucous — supports network of veins.
    - 3. Muscular
      - Inner — longitudinal.
      - External — circular.
  - Meatus urinarius — external orifice located between clitoris and vagina.
- **Micturition**
  - Act of expelling urine from bladder.
  - Occurs as result of irritation due to accumulation of urine in bladder.
  - Involuntary act — can be controlled by voluntary effort.
- **Retention**
  - Failure to void urine.
  - Due to
    - 1. Dulling of the senses.
    - 2. Nervous contraction of urethra.
    - 3. Some obstruction in urethra or neck of bladder.
  - May be accompanied by overflow or constant voiding of small amounts.
- **Suppression** — Failure of the kidneys to secrete urine.
- **Characters of Urine**
  - **Transparency** — depends on absence or presence of mucus and pus.
  - **Color** — depends on concentration. Relative amounts of water and solids.
  - **Reaction** — usually acid.
  - **Specific gravity** — average 1.020. Depends on concentration.

- **Characters of Urine**
  - **Quantity**
    - Average 40 to 50 ounces.
    - Increased by
      - Action of diuretics.
      - Nervousness.
      - Certain disease
        - Diabetes insipidus.
        - Diabetes mellitus.
        - Hysteria.
    - Decreased by
      - Ingestion of small amounts of water.
      - Vomiting, diarrhœa.
      - High fever.
      - Disease of kidneys.
      - Increased action of skin.
- **Urine**
  - Water, 95 per cent
  - Solids, 5 per cent
    - **Organic,** about 3.7
      - **Urea** (2 per cent of total solids).
      - Uric acid.
      - Creatinin.
      - Hippuric acid.
      - Other substances.
    - **Inorganic,** about 1.3
      - Sodium chloride.
      - Sulphates.
      - Phosphates.
      - Salts of
        - Potassium.
        - Ammonium.
        - Magnesium.
        - Calcium.
      - Other substances.
- **Urea**
  - End product resulting from metabolism of proteins.
  - Average excreted in twenty-four hours — 1 ounce.
  - Increased by
    - Diet rich in proteins.
    - Strenuous exercise.
    - Fever, and some diseases.
  - Decreased by
    - Small amount of protein food.
    - Excessive vomiting, free perspiration.
    - Diseases that interfere with elimination.
- **Uric acid**
  - End product resulting from oxidation of tissues.
  - Combines with potassium and sodium to form urates.
  - Failure to excrete results in gout.
- **Creatinin**
  - May be taken into body in food.
  - Formed in body by oxidation of certain proteins.
- **Hippuric Acid**
  - May be derived from oxidation of proteins.
  - May result from putrefactive processes in the intestines.
  - Increased by a vegetable diet.

Salts
- Derived from food eaten.
- Derived from neutralization of acids.
- Sodium chloride is most abundant.

Abnormal Constituents
- Albumin.
- Glucose.
- Indican.
- Acetone.
- Casts.
- Calculi.
- Pus.
- Blood.

CHAPTER XVIII

THE SKIN; APPENDAGES OF THE SKIN. PRODUCTION OF HEAT; REGULATION OF HEAT. VARIATIONS IN TEMPERATURE

THE SKIN

Functions. — The skin is not, like the kidneys, set apart to perform one special function. It serves: (1) as a protective covering for the deeper tissues lying beneath it, (2) as a sense organ, (3) as an excretory organ, (4) as an absorbing organ, (5) as an important organ in heat regulation, and (6) as a respiratory organ.

Structure. — It consists of two distinct layers: —

(1) Epidermis, scarf skin, or cuticle.
(2) Derma, cutis vera, or corium.

Epidermis. — The epidermis is a stratified epithelium, composed of a number of layers of cells. The thickness varies in different parts of the body, measuring in some places not more than $\frac{1}{240}$ inch (0.104 mm.), and in others as much as $\frac{1}{24}$ inch (1.04 mm.). It is thickest in the palms of the hands and on the soles of the feet, where the skin is most exposed to friction, and thinnest on the ventral surface of the trunk, and the inner surfaces of the limbs. It forms a protective covering over every part of the true skin, upon which it is closely moulded.

It is roughly divisible into two layers: —

(1) Upper, or Horny.
(2) Germinative, or Malpighian.

(1) The **horny** layer consists of three strata of cells, which are practically dead, and are constantly being shed and renewed from the cells of the germinative layer.

(2) The **germinative** layer consists of soft protoplasmic cells.

The growth of the epidermis takes place by the multiplication of these cells. As they multiply they push upward toward the surface those previously formed. In their upward progress they undergo a chemical transformation, and the soft protoplasmic cells become converted into the flat, horny scales which are constantly being rubbed off the surface of the skin. The pigment in the skin of the negro, as well as that of the nipple in white races, is found in the deepest cells of the germinative layer.

No blood-vessels pass into the epidermis; it, however, receives fine nerve-fibrils between the cells of the germinative layer.

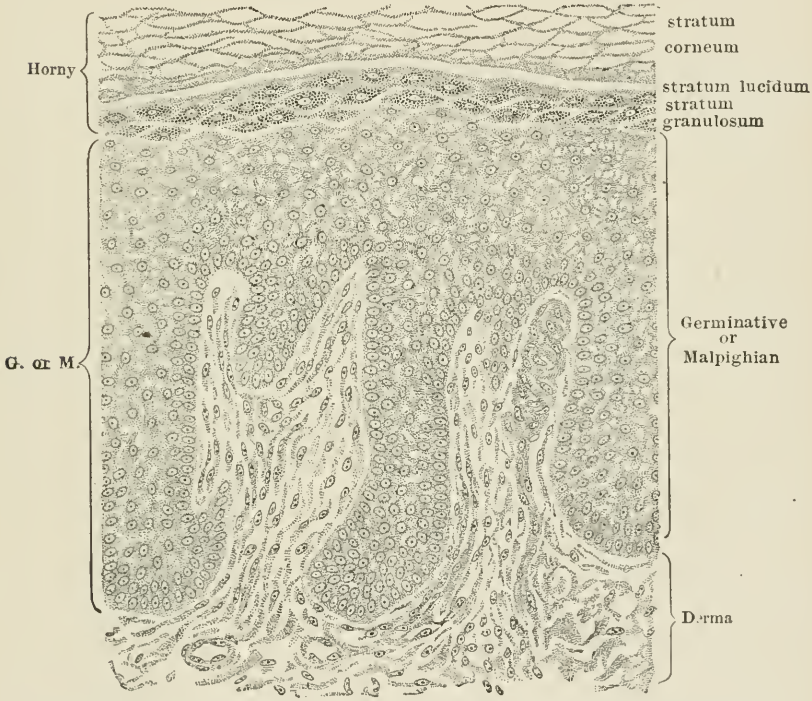

FIG. 170. — VERTICAL SECTION THROUGH THE SKIN OF THE PALMAR SIDE OF THE FINGER, SHOWING TWO PAPILLÆ (ONE OF WHICH CONTAINS A TACTILE CORPUSCLE) AND THE DEEPER LAYER OF THE EPIDERMIS. (Schäfer.)

Derma. — The derma is a highly sensitive and vascular layer of connective tissue. It is described as consisting of two layers: —

(1) Superficial, or papillary layer.
(2) Deeper, or reticular layer.

(1) The surface of the **papillary** layer is increased by protrusions in the form of small conical elevations, called papillæ, whence this layer derives its name. They project up into the epidermis, which is moulded over them, and contain for the most part looped blood-vessels, but they also contain the terminations of nerve-fibres in the shape of little bodies called **tactile corpuscles.**

The papillæ seem to exist chiefly for the purpose of giving the skin its sense of touch, being always well developed where the sense of touch is exquisite. They are specially large and numerous on the palm of the hand and the tips of the fingers, and on the corresponding parts of the foot.

(2) The **reticular** layer of the corium is a continuation of the papillary layer, there being no real division between them. It is made up of bundles of white fibrous and elastic tissue.

The derma is attached to the parts beneath it by a layer of areolar tissue, here named *subcutaneous,* which layer, with very few exceptions, contains fat. The connection in some parts is loose and movable, as on the front of the neck; in others, close and firm, as on the palmar surface of the hand and the sole of the foot.

Blood-vessels. — The blood-vessels of the skin are found in the derma only. They form a network of capillaries in which the vessels are very close to each other, and send branches to the papillæ and glands of the skin. The capillaries of the skin are capable of holding from one-half to two-thirds of the blood contained in the body. The amount of blood they contain is dependent on their calibre, and this is regulated largely by the vasomotor nerves.

Nerves. — The skin is provided with a great variety of nerves. They are classified as follows: —

(1) Vasomotor nerves, which are distributed in the walls of the blood-vessels.

(2) Two sets of nerves concerned in the temperature sense, which terminate in the hot and cold spots of the skin.

(3) The nerves concerned in the sense of touch or pressure.

(4) Nerves which are stimulated by pain.

(5) Motor nerves, which are derived from the sympathetic system and distributed to the glands and the arrector muscles.

Nearly every nerve centre in the body may be affected by sensations arising in the skin, because of the number of afferent nerves which lead from the skin to centres in the brain and spinal cord. It is for this reason that hydrotherapeutic applications, heat, cold, and counter irritants excite so many and such varied reflexes.

THE APPENDAGES OF THE SKIN

The appendages of the skin are the nails, the hair, the sebaceous glands, the ceruminous glands, and the sudoriferous or sweat-glands.

The nails. — The nails are composed of clear, horny cells of the epidermis, joined together so as to form a solid, continuous plate. Each nail is convex on its outer surface, concave on its inner side, and closely adherent to the underlying derma, which is modified to form what is called the bed, or **matrix**, of the nail. At the hinder part of the bed of the nail the skin forms a deep fold, in which is lodged the root of the nail.

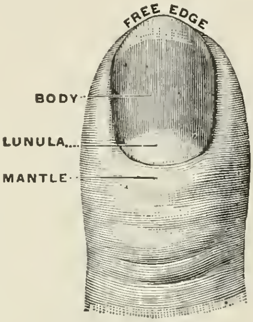

FIG. 171. — THUMB-NAIL. (Gerrish.)

The growth of the nail is accomplished by constant multiplication of the soft cells in the germinative layer at the root. These cells are transformed into dry, hard scales, which unite into a solid plate, and the nail, constantly receiving additions from below, slides forward over its bed and projects beyond the end of the finger. When a nail is thrown off by suppuration or torn off by violence, a new one will grow in its place provided any of the cells of the germinative layer are left.

FIG. 172. — PIECE OF HUMAN HAIR. (Highly magnified.) *a*, cuticle; *b*, fibrous substance; *c*, medulla.

The hair. — The hair is a growth of the epidermis, developed in little pits, the hair-follicles, which extend downward into the deeper part of the true skin, or even into the subcutaneous tissue. The hair grows from the bottom of the little pit or follicle. The part which lies within the follicle is known as the root, and that portion which projects beyond the surface of the skin is called the shaft or stem. The substance of the hair is composed of coalesced, horny cells, arranged in different layers, and we usually distinguish three parts in the stem or shaft of a hair: —

(1) *Cuticle* — an outer layer of delicate, scale-like cells.

(2) *Fibrous substance* — a middle, horny, thick portion, formed

of elongated cells. These cells and the intercellular spaces contain a varying amount of pigment, and the color of the hair depends upon the quantity. The gray hair of old age is produced by loss of pigment.

(3) *Medulla* — a central pith formed of round cells. Minute air bubbles may be present in both the medulla and fibrous layer, and cause the hair to look white by reflected light.

The root of the hair is enlarged at the bottom of the follicle into a bulb or knob. This bulb is composed of soft-growing cells, and fits over a vascular papilla which projects into the bottom of the follicle. Hair has no blood-vessels but receives nourishment from the blood vessels of the papilla.

Growth of hair. — Hair grows from the bottom of the follicle by multiplication of the soft cells which cover the papilla. These cells become elongated to form the fibres of the fibrous portion, and as they are pushed to the surface, they become flattened and form the cuticle. If the scalp is thick, pliable, and moves freely over the skull it is favorable to the growth of hair. A thin scalp that is drawn tightly over the skull tends to constrict the blood-vessels, lessen the supply of blood, and cause atrophy of the roots of the hair by pressure. In such cases massage of the head loosens the scalp, improves the circulation of the blood, and usually stimulates the growth of hair.

With the exceptions of the palms of the hands, the soles of the feet, and the last phalanges of the fingers and toes, the whole skin is studded with hair. The hair of the scalp is long and coarse, but most of the hair is very fine and extends only a little beyond the hair follicle.

Arrector muscles. — The follicles containing the hairs are narrow pits which slant obliquely upward, so that the hairs they contain lie down on the surface of the body. Connected with each follicle is a small muscle called the arrector muscle. It is composed of bundles of plain muscular tissue which pass from the surface of the true skin, **on the side to which the hair slopes**, obliquely downward, to be attached to the bottom of the follicle. When these muscles contract, as they will under the influence of cold or terror, the little hairs are pulled up straight, and stand " on end "; the follicle also is dragged upward, and in this way the roughened condition of the skin known as " gooseflesh," is produced.

Sebaceous glands. — The sebaceous glands are small, saccular glands, which lie between the hairs and their arrector muscles. They occur everywhere over the skin surface, with the exception of the palms of the hands and the soles of the feet.

Each gland consists of a collection of small tubes overspread with a network of capillaries. From the gland a small duct ascends, and opens either upon the surface of the skin or, as is more common, into a hair follicle. Their size is not regulated by the length of the hair. Thus, some of the largest are found on the nostrils and other parts of the face, where they often become enlarged with pent-up secretion.

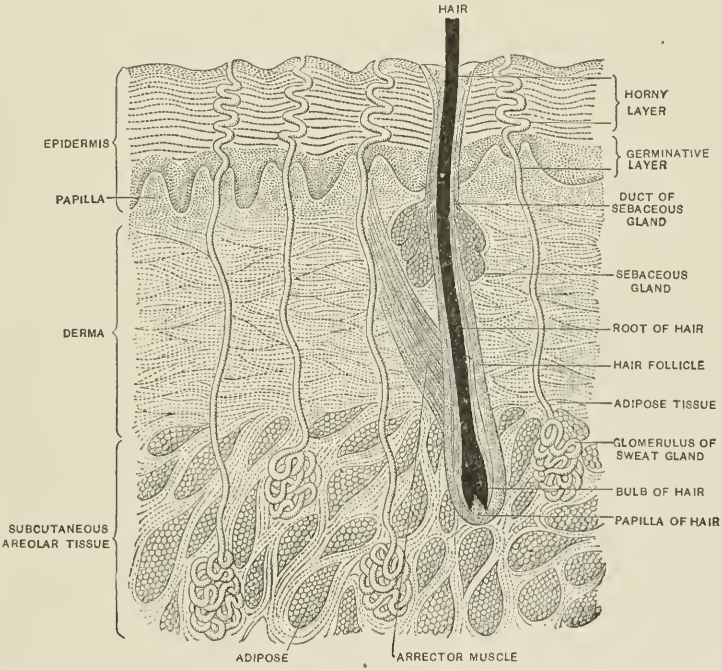

Fig. 173. — Vertical Section of the Skin, showing Sebaceous Glands, Sweat-glands, Hair, and Follicle, also Arrector Muscle. (Gerrish.)

Sebum. — The secretion of the sebaceous glands is called sebum. It contains fats, soaps, epithelial cells, albuminous matter and inorganic salts. It serves to remove waste matters and is classed as an excretion, but its more important purposes are to keep the skin and hair soft and pliable, and to form a protective layer on the surface of the skin. An accumulation of this sebaceous matter upon the skin of the fœtus furnishes the thick, cheesy, oily substance called the **vernix caseosa.**

Ceruminous glands. — The skin lining the external auditory canal contains modified sweat glands called ceruminous glands. They secrete a yellow, pasty substance resembling wax which is called cerumen.

Sweat-glands. — The sweat-glands are simple, convoluted, tubular glands with the blind ends coiled into little balls which are lodged in the true skin or subcutaneous tissue; from the ball the tube is continued as the excretory duct of the gland up through the true skin and epidermis, and finally opens on the surface by a slightly widened orifice called a pore. Each tube is lined by a secreting epithelium continuous with the epidermis. The coiled end is closely invested by a meshwork of capillaries, and the blood in the capillaries is only separated from the cavity of the glandular tube by the thin membranes which form their respective walls. The secretory apparatus in the skin is somewhat similar to that which obtains in the kidneys; in the one case the blood-vessels are coiled up within the tube, while in the other the tube is coiled up within the meshwork of blood-vessels.

FIG. 174. — COILED END OF A SWEAT-GLAND. *a*, the coiled end; *b*, the duct; *c*, network of capillaries, inside which the sweat-gland lies.

The sweat-glands are abundant over the whole skin, but they are largest and most numerous in the axillæ, the palms of the hands, soles of the feet, and the forehead.

Perspiration, or sweat. — The sweat is a watery, colorless liquid, slightly turbid, of a salty taste, with a strong, distinctive odor and an acid reaction. It is an excrement, the chief normal constituents of which are water, salts, fatty acids, a small quantity of carbon dioxide, and a slight amount of urea. In various forms of kidney disease urea may be present in considerable quantity, the skin supplementing to a certain extent the deficient work of the kidneys.

Quantity of perspiration. — Under ordinary circumstances, the perspiration that we are continually throwing off evaporates from the surface of the body without our becoming sensible of it, and is called **insensible perspiration.** When more sweat is poured upon the surface of the body than can be removed at once by evaporation, it appears on the skin in the form of drops, and we then speak of it as **sensible perspiration.**

The average amount discharged during twenty-four hours is about one quart (0.946 litre), but it may be increased to such an extent that even more may be discharged in an hour. The secretion of sweat is *increased* by: (1) a dilute condition of the blood, such as results from drinking large quantities of liquids, (2) increased temperature or humidity of the atmosphere, (3) exercise, (4) pain, (5) mental excitement or nervousness, (6) dyspnœa, (7) use of diaphoretics, (8) certain diseases such as tuberculosis, acute rheumatism, and malaria, (9) use of electricity to stimulate the secretory nerves.

The secretion of sweat is *decreased* by: (1) voiding of a large quantity of urine, (2) cold, (3) diarrhœa, (4) certain drugs, and (5) certain diseases, such as fevers, diabetes, and some cases of paralysis.

Activity of the sweat-glands. — The activity of the sweat-glands is supposed to be due to direct stimulation of the nerve endings in the glands, or indirect stimulation of the nerve centres controlling perspiration. An increase in perspiration following an increase in the temperature or humidity of the atmosphere is partly due to stimulation of the nerve endings in the sweat-glands, and partly due to the stimulation from the sensory nerves being carried to the nerve centres, and transmitted along motor nerves to the gland. The activity is also influenced by the vasomotor nerves, which control the size of the blood-vessels in the skin; an increase in the size of the vessels leads to increased, a constriction of the vessels to diminished, perspiration. That this is not the only factor is proven by the profuse perspiration that often accompanies a pallid skin, or the absence of perspiration that is characteristic of fever.

Excretory function of the skin. — While sweat is an excretion, its value lies not so much in the elimination of waste matter as in the loss of body heat by the evaporation of water. This loss of heat is necessary to balance the production of heat that is constantly taking place.

Less important functions of the skin. — The skin is to a slight extent an absorbing organ. Soluble substances are very readily absorbed if the epidermis is removed, but even when in solution they are sparingly absorbed by the unbroken skin. Oily substances, if well rubbed in, are readily absorbed, especially in those parts of the body where the epidermis is thinnest.

Oxygen in small amount is also taken in through the skin, but this gain to the body is counterbalanced by the carbon dioxide which is thrown off.

BODY HEAT

From the standpoint of heat production animals may be divided into two great classes: —

(1) **Constant temperature** animals, or those whose temperature remains practically constant whether the surrounding air is hotter or cooler than the body. The term warm-blooded is also applied to this class. It includes human beings.

(2) **Changeable temperature** animals, or those whose temperature varies with that of the surrounding medium. This class is also described as cold-blooded. The human fœtus is cold-blooded.

The great difference between these two classes is in their reactions to external temperature. A cold environment reduces the temperature of the cold-blooded creature, reduces the metabolism of all its tissues, and thus reduces its heat production. The warm-blooded animal reacts in precisely the opposite way. Since his temperature remains constant, his heat production must increase in order to neutralize the effect of cold surroundings.

Production of heat. — Heat in the body is produced by such chemical changes going on in the tissues as are associated with oxidation. Friction is a minor source of heat, *i.e.* that caused by the movements of the muscles, the circulation of the blood, and the ingestion of warm food.

Where heat is produced. — **Wherever metabolic changes are taking place, there heat is set free.** These changes take place more rapidly in some tissues than in others, and in the same tissues at different times. The muscles always manifest a far higher rate of activity than the connective tissues, and consequently the former evolve a larger proportion of the bodily heat than the latter. We might liken the different tissues of the body to so many fireplaces stored with fuel, the fuel in some of the fireplaces being more easily ignited and burning more rapidly than in others. The muscles and the secreting glands, especially the liver, are supposed to be the main sources of heat, as they are the seats of a very active metabolism.

Loss of heat. — The heat thus continually produced is as continually leaving the body by the skin and the lungs, and by the urine and feces. It has been calculated that in every 100 parts about: —

88 per cent is lost by conduction and radiation from the surface of the skin and the evaporation of the perspiration.

9 per cent is lost by warming the expired air and the evaporation of the water of respiration.

3 per cent is lost by warming the urine and feces.

The temperature and humidity of the atmosphere may cause considerable difference in the per cents given above. A low temperature will increase the loss of heat by radiation and decrease that by evaporation. A high temperature will decrease the loss of heat by radiation and increase that by evaporation owing to the greater production of sweat. From the above figures it is evident that the skin is the important factor in getting rid of body heat. This is due: (1) to the large surface offered for radiation, conduction, and evaporation; and (2) to the large amount of blood which it contains.

Distribution of heat. — The blood, as we know, permeates all the tissues in a system of tubes or blood-vessels. Wherever oxidation takes place and heat is generated, the temperature of the blood circulating in these tissues is raised. Wherever, on the other hand, the blood-vessels are exposed to evaporation, as in the moist membranes in the lungs, or the more or less moist skin, the temperature of the blood is lowered. The gain and loss of heat balance one another with great nicety, and the blood, circulating rapidly, now through warmer, and again through cooler, tubes, is kept at a uniform temperature of about 100° F. (37.8 C.).

In this way the whole body is warmed in somewhat the same way as we warm a house, the warm blood in the blood-vessels heating the tissues, as the hot water in the hot-water pipes heats the rooms in water-heated dwellings.

THE REGULATION OF HEAT

The maintenance of the normal temperature of the body is due: (1) to the control exerted by the nervous system, (2) to the regulation of muscular exercise and diet, (3) to the use of clothing, and (4) the use of hot and cold baths.

Control of nervous system. — As the amount of heat lost through the skin and lungs as well as the metabolism taking place in the body is under the control of the nervous system, it follows that this control is preëminently important. It is effected by means of the heat centres, the sensory nerves, the sweat nerves, and the vasomotor nerves of the skin.

Heat regulation by the skin. — When the external temperature is high, the nerve-endings which respond to heat are stimulated, and these impulses are transmitted over sensory nerves to the nerve centres controlling the motor nerves of the sweat-glands. The motor nerves stimulate the activity of the sweat-glands, and an increased amount of sweat is poured out upon the surface of the body. An increased amount of heat is required to vaporize this sweat, and thus heat is lost. Excessive humidity interferes with the evaporation of water, and thus interferes with the loss of heat; hence the discomfort experienced on hot, humid days.

The sensory nerves which are stimulated by heat not only transmit impulses that stimulate the sweat-glands to activity, but at the same time transmit impulses that result in the depression of the vaso-constrictor nerves of the arterioles of the skin. In consequence the arterioles dilate and more blood is sent to the surface to be cooled. When the external temperature is low, the sensory nerve endings which are stimulated by cold transmit impulses which result in stimulation of the vaso-constrictors, and consequent contraction of the arterioles of the skin. This lessens the amount of blood in the skin arterioles, and lessens the amount of heat lost.

Heat regulation by respiration. — The stimulation of the sensory nerves of the skin that are affected by cold influences the respiratory centres, increases the rate of the respirations, and consequently increases the loss of heat. In man respiration plays only a small part in heat regulation, but in animals that do not perspire, respiration is an important means of regulating the temperature.

Mechanism of heat regulation. — Just how the nervous system controls the amount of heat produced by metabolism is not known. Various theories are advanced, one being that there are special nerves and special heat centres: (1) thermogenetic, which is concerned in the production of heat, (2) thermolytic, which is concerned in the dissipation of heat, and (3) thermotactic, which is concerned in regulating the former two. Another theory is that the temperature of the blood influences the motor nerves of the muscles. Stimulation by cold causes increased contraction and increased oxidation. Heat causes relaxation and a decrease in oxidation. Metabolism is also influenced by the action of the vasomotor system, for under the influence of cold, the blood is driven to the interior of the body and metabolism is increased; under the influence of heat, the blood is driven to the surface of the body and metabolism is decreased.

Heat regulation by muscular exercise and diet. — Muscular contractions give rise to heat, therefore muscular activity is used as a means to counteract the effects of external cold. On the other hand, muscular activity does not increase the temperature in hot weather to any marked extent. This is accounted for by the fact that when muscular exertion causes the blood to circulate more quickly than usual, the blood-vessels in the skin dilate, the sweat-glands at the same time are excited to pour out a more abundant secretion, and the heated blood passing in larger quantities through the cutaneous vessels (which are kept well cooled by the evaporation of the perspiration), the general average temperature of the body is maintained.

During digestion heat is produced partly by the peristaltic action of the intestines, and partly by the activity of the various digestive glands (particularly the liver). The quantity of food eaten, and the relative amount of heat-producing food, influences the temperature of the body. In cold weather an increase in food (usually accompanied by an increase of fats) serves to replace the greater amount of heat lost. When muscular exercise is impossible, as in infants, an increase in fats serves the same purpose as exercise in a healthy adult.

Heat regulation by clothing. — By clothing we can aid the functions of the skin and the maintenance of heat; though, of course, clothes are not in themselves sources of heat. The object of clothing is, in winter, to prevent conduction, radiation, and evaporation of heat from the skin, and in summer to promote it. In considering the heat value of clothing the important properties are: (1) whether it is loosely or tightly woven, (2) its thickness, and (3) its color.

(1) Materials that are loosely woven will be warmer than those that are tightly woven, because the meshes in a loosely woven material are capable of holding air, which is a poor conductor of heat, and thus prevents radiation.

(2) Thick material does not allow cold air to penetrate to the skin.

(3) Dark colored materials absorb heat to some extent, hence they are warmer than light colored textiles. Thick, porous materials are used to keep the body warm. Wool has an additional advantage, as evaporation takes place more slowly from it than from linen, cotton, or silk. Thin and very porous materials help to keep the body cool, because they allow the air to penetrate to the skin, and thus assist the evaporation of sweat.

Heat regulation by baths. Hot baths. — The primary effect of a hot bath is to prevent radiation of heat from the surface of the body, and some increase in temperature may result. If the bath is not continued for too long a time, this effect is counteracted by the increased perspiration that follows.

Cold baths. — The primary effect of a cold bath is similar to the effect of cold air. The cold contracts the arterioles of the skin, drives the blood to the interior, and increases oxidation. If the bath is a short one and is followed by friction, the reaction is for the arterioles to dilate, the heated blood is sent to the surface, the circulation is quickened, and there is a consequent loss of heat. In health the gain in heat is usually balanced by the loss of heat, and the purpose of a cold bath is to exercise the arterioles and stimulate the circulation. If the bath is continued for some time, the temperature of the skin, and of the muscles lying beneath, is reduced, and either the heat-producing processes may be checked and a loss of temperature result; or shivering may intervene. In this case the muscular contractions and constriction of the blood-vessels stimulates metabolism and heat production. When cold baths are given for the purpose of increasing heat elimination, friction is used during the bath to prevent shivering. Friction stimulates the sensory nerves of the skin, causes dilatation of the arterioles, and favors the flow of hot blood to the surface, thus decreasing the sensation of cold and increasing heat elimination. If properly given, cold baths stimulate the nervous system, improve the tone of the muscles, including the muscles of the heart and blood-vessels, stimulate the circulation, and favor the elimination of heat.

VARIATIONS IN TEMPERATURE

Normal variations. — The temperature of the human body is usually measured by a thermometer placed in the mouth, axilla, or rectum. Such measurements show slight variations, as the temperature in the interior of the body is slightly higher than on the surface of the skin. The average temperature in the rectum [1] is 98.9° F., in the axilla is 98.4° F., in the mouth is 98.3° F.

Other normal variations depend upon the manner of living, time of eating, age, etc. The lowest temperature is usually in the early morning, it rises slowly during the day, reaches its maximum in the evening, and falls again during the night. This corresponds to the usual temperature ranges in fever, when the maximum is in the evening and the minimum in the early morning. Muscular activity and food may also cause slight increase in temperature during the day. Age has some influence. Infants and young children have a slightly higher temperature than adults. It is also true that the heat-regulating mechanism in infants [2] and young children is not so efficient as in adults, consequently they are more subject to changes of body temperature, and these changes are not as significant as they would be with adults. Aged people show a tendency to revert to infantile conditions, and their temperature is usually slightly higher than in middle life.

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[1] Rectal temperature is the most reliable, and that by mouth (if properly taken) is almost equally reliable. Axillary temperature has little value.

[2] At birth the heat-regulating mechanism is not "in working order," and during the first few weeks of life infants are not able to regulate their body temperature, hence the importance of keeping them warm. Premature infants are even less able to regulate their body temperature, hence need of special means to keep them warm.

Abnormal variations. Fever. — The term fever is applied to an abnormal condition, characterized by increased temperature, increased heart-beat, increased respiration, increased tissue waste, and faulty secretion.

Cause.—The exact cause of fever is unknown. It is the result of causes which disturb the balance between heat production and heat elimination. One theory is that there is a heat centre in the brain which controls the production and elimination of heat, and toxic substances circulating in the blood or abnormal conditions of the various organs of the body may interfere with the proper functioning of this centre. The toxic substances circulating in the blood may result from faulty metabolism, as in diabetes, gout, etc.; or from the action of bacteria, as in infectious diseases; or from injury to the tissues of a mechanical, thermal, or chemical nature.

Value of fever. — When fever is due to infection by bacteria, the body seems better able to fight the infection if the temperature is elevated. For this reason fever is thought to be a protective measure and antipyretics are not used unless the elevation is extreme, or long continued. In this case measures must be taken to reduce the temperature, or death may ensue from coagulation of the proteins present in the nerve-cells of the brain and spinal cord.

Subnormal temperature. — In some maladies the temperature falls distinctly below normal. This is no doubt chiefly due to diminished metabolism. In cases of starvation the fall of temperature is very marked, especially during the last days of life. The diminished activity of the tissues first affects the central nervous system; the patient becomes languid and drowsy, and finally unconscious; the heart beats more and more feebly, the breath comes more and more slowly, and the sleep of unconsciousness passes insensibly into the sleep of death.

SUMMARY

- **Skin**
  - **Functions**
    - 1. Protective covering for deeper tissues.
    - 2. As a sense organ.
    - 3. As an excretory organ — Elimination of waste matter in sweat.
    - 4. As an absorbing organ
      - Absorption through unbroken skin is limited.
      - Absorption rapid if epidermis is removed.
    - 5. **Most important** as organ in heat regulation.
    - 6. As a respiratory organ
      - Small amount oxygen taken in.
      - Small amount carbon dioxide is thrown off.
  - **Consists of**
    - **Epidermis** is a stratified epithelium
      - 1. Superficial or horny
        - *a.* Stratum corneum
        - *b.* Stratum lucidum
        - *c.* Stratum granulosum
          - Practically dead cells being constantly shed and renewed from germinative layer.
      - 2. Germinative or Malpighian
        - Soft protoplasmic cells that are constantly multiplying by cell division.
    - **Derma** is a layer of connective tissue
      - 1. Papillary layer — papillæ are minute conical elevations of the cutis vera. They contain looped blood-vessels and terminations of nerve-fibres called tactile corpuscles.
      - 2. Reticular layer
        - Bundles of fibrous and elastic tissue, with network of blood-vessels, lymphatics, and nerves.
  - **Blood-vessels** — They are found in derma only. Send branches to papillæ and glands of skin. Capable of holding one-half to two-thirds total amount of blood in body.
  - **Nerves**
    - 1. Vasomotor.
    - 2. Two sets concerned in temperature sense.
    - 3. Nerves concerned in sense of touch or pressure.
    - 4. Nerves stimulated by pain.
    - 5. Motor nerves from sympathetic system.
  - **Appendages**
    - Nails.
    - Hair.
    - Sebaceous glands.
    - Ceruminous glands.
    - Sweat-glands.

Nails . .
- Consist of clear, horny cells of epidermis.
- True skin forms a bed or matrix for nail.
- Root of nail is lodged in a deep fold of the skin.
- Nails grow from soft cells in germinative layer at root.

Hair . .
- The hair grows from the roots.
- The roots are bulbs of soft-growing cells contained in the hair follicles.
- Hair follicles are little pits developed in the derma.
- Stems of hair extend beyond the surface of the skin, consist of three layers of cells: (1) cuticle. (2) fibrous substance. (3) medulla.
- Found all over body, except
  - Palms of the hands.
  - Soles of the feet.
  - Last phalanges of the fingers and toes.
- Arrector muscles are attached to true skin and to each hair follicle.

Sebaceous Glands
- Saccular glands the ducts of which usually open into a hair follicle, but may discharge separately on the surface of the skin.
- Lie between arrector muscles and hairs.
- Found over entire skin surface except
  - Palms of hands.
  - Soles of feet.
- Secrete *sebum*, a fatty, oily substance, which keeps the hair glossy and the skin flexible, and forms a protective layer on surface of skin.

Ceruminous Glands
- Modified sweat-glands.
- Found in skin of external auditory canal.
- Secrete cerumen, a yellow, pasty substance, like wax.

Sweat-glands
- Tubular glands, consist of blind ends coiled in balls, lodged in subcutaneous tissue, and surrounded by a capillary plexus. Secrete sweat and discharge it by means of ducts which open exteriorly. (Pores.)

Sweat . .
- Watery, colorless, turbid liquid, salty taste, distinctive odor, and acid reaction.
- Consists of water, salts, fatty acids, urea, and carbon dioxide.
- Average quantity, one quart in twenty-four hours.
- Amount increased by
  1. Dilute condition of blood.
  2. Increased temperature or humidity of the atmosphere.
  3. Exercise.
  4. Pain.
  5. Mental excitement or nervousness.
  6. Dyspnœa.
  7. Use of diaphoretics.

- **Sweat**
  - Amount increased by
    - 8. Certain diseases
      - Tuberculosis.
      - Acute rheumatism.
      - Malaria.
    - 9. Use of electricity to stimulate secretory nerves.
  - Amount decreased by
    - 1. Voiding a large quantity of urine.
    - 2. Cold.
    - 3. Diarrhœa.
    - 4. Certain drugs.
    - 5. Certain diseases
      - Fevers.
      - Diabetes.
      - Some paralyses.
- **Activity of Sweat-glands**
  - 1. Direct stimulation of nerve-ending in sweat-glands.
  - 2. Indirect stimulation of nerve centres controlling perspiration.
  - 3. Action of vasomotor nerves on calibre of blood-vessels.
- **Body Heat**
  - Animals divided into 2 classes
    - 1. Warm-blooded or those which have an almost constant temperature. Human beings are in this class.
    - 2. Cold-blooded or those whose temperature varies with that of their environment. The human fœtus is cold blooded.
  - **Produced by**
    - 1. Chemical changes associated with oxidation.
    - 2. Friction of muscles, blood, etc.
    - 3. Ingestion of warm food.
    - Wherever metabolic changes are taking place.
  - **Lost by**
    - Skin 88 per cent
      - Offers large surface for radiation, conduction, and evaporation of sweat.
      - Contains large amount of blood.
    - Lungs — 9 per cent is lost warming the expired air and the evaporation of the water of respiration.
    - Urine and Feces — 3 per cent is lost warming the urine and feces.
  - **Distributed** — by the blood circulating through the blood vessels.
  - **Controlled by** — the nervous system
    - Heat centres.
    - Sensory nerves.
    - Sweat nerves.
    - Vasomotor nerves.

- **Body Heat**
  - **Regulated**
    - 1. Skin
      - Activity of sweat-glands.
      - Dilatation and contraction of skin arterioles.
    - 2. Respiration.
    - 3. Control of metabolism by nervous system.
    - 4. Muscular exercise and diet.
    - 5. Clothing.
    - 6. Baths
      - Hot.
      - Cold.
- **Variations in Temperature**
  - **Normal**
    - 1. Depends on where temperature is taken
      - Mouth.
      - Axilla.
      - Rectum.
    - 2. Depends on time of day
      - Lowest in early morning.
      - Highest in early evening.
    - 3. Slightly increased by muscular activity and the digestive processes.
    - 4. Age. Higher and more variable in
      - Infants, children, and the aged.
  - **Abnormal**
    - **Fever**
      - **Symptoms**
        - Increased temperature.
        - Increased pulse.
        - Increased respiration.
        - Increased tissue waste.
        - Faulty secretion.
      - **Cause** — not definitely known.
      - **Value** — thought to help the body to fight infection.
    - **Subnormal** — due to diminished metabolism.

CHAPTER XIX

THE NERVOUS SYSTEM

In Chapter III it was stated that eight systems of organs were found in the human body. Six of these systems have been studied, leaving the seventh, *i.e.* the nervous system, to form the subject matter of this chapter.

Parts of the nervous system. — The nervous system consists of: (1) the brain and spinal cord, which are contained within the cavities of the skull and spinal column; (2) masses of nerve cell-bodies called sympathetic ganglia, which are situated in the head and neck, also in the thoracic and abdominal cavities; (3) nerve trunks, which connect the brain, spinal cord, and sympathetic ganglia with each other, with the viscera, and with the periphery of the body. All of these structures are made up of nerve tissue. In addition the endings of the nerves distributed to the organs of the special senses, such as the eye, ear, and skin, are in close contact with modified epithelial cells sometimes called *organules*.

Functions of the nervous system. — The human nervous system makes possible all the higher functions of human life. It enables us to think and to will, to recognize our surroundings and to accommodate ourselves to them; to move, to talk, to hear, to see; and it guarantees equilibrium and muscular coördination.

Divisions of the nervous system. — For purposes of study the nervous system is arbitrarily divided into two parts: (1) the central nervous system or cerebro-spinal system, and (2) the sympathetic system. These two systems are not separate, distinct, and independent as the names might imply, but are intimately connected both structurally and functionally, and are really interdependent.

(1) **The central nervous system** consists of the *brain*, the *spinal cord*, and three sets of nerves.

(*a*) *Cerebro-spinal* nerves connect the brain and spinal cord and form a part of the cord.

(*b*) *Cranial nerves* pass to and from the brain through openings in or between the cranial bones, and are distributed to various organs. (See page 395.)

(*c*) *Spinal nerves* pass to and from the cord to different parts of the body. (See page 380.)

(2) **The sympathetic system** consists of masses of nerve cell-bodies, and the nerves connected with them. These masses are termed ganglia and are found in the thoracic and abdominal cavities. (See page 375.)

Properties of nerve tissue. — All of the organs included in the nervous system are made up of nerve tissue, which is the most highly specialized tissue in the body. It possesses the following marked characteristics: (1) irritability or the power to respond to stimulation, and (2) conductivity or the power to transmit the stimulus or nerve impulse to the muscles, viscera, etc. Just as all other tissues are composed of cells, so the structural unit of nerve tissue is the nerve-cell or neurone.

NEURONES

Although the neurones vary considerably in size and in form, there are certain structural characteristics which they all possess in common. They consist of: —

(1) The cell-body.
(2) The cell-processes.

These two parts make up a complete nervous entity called a neurone, and the entire nervous system consists of neurones supported by *neuroglia*[1] in the central nervous system, and by connective tissue in the nerve trunks.

(1) **The cell-body.** — The cell-bodies vary as to size and shape, but all varieties present certain common characteristics. A typical cell-body consists of a mass of granular cytoplasm surrounding a large, well-defined nucleus, it in turn containing a nucleolus, and the whole mass of cytoplasm may in some cases be surrounded by a cell-wall.

From the angles of the cell-body are given off the processes or poles, and the number of processes corresponds to the number of angles. Each cell-body usually has one process and may have several more.

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[1] See page 373.

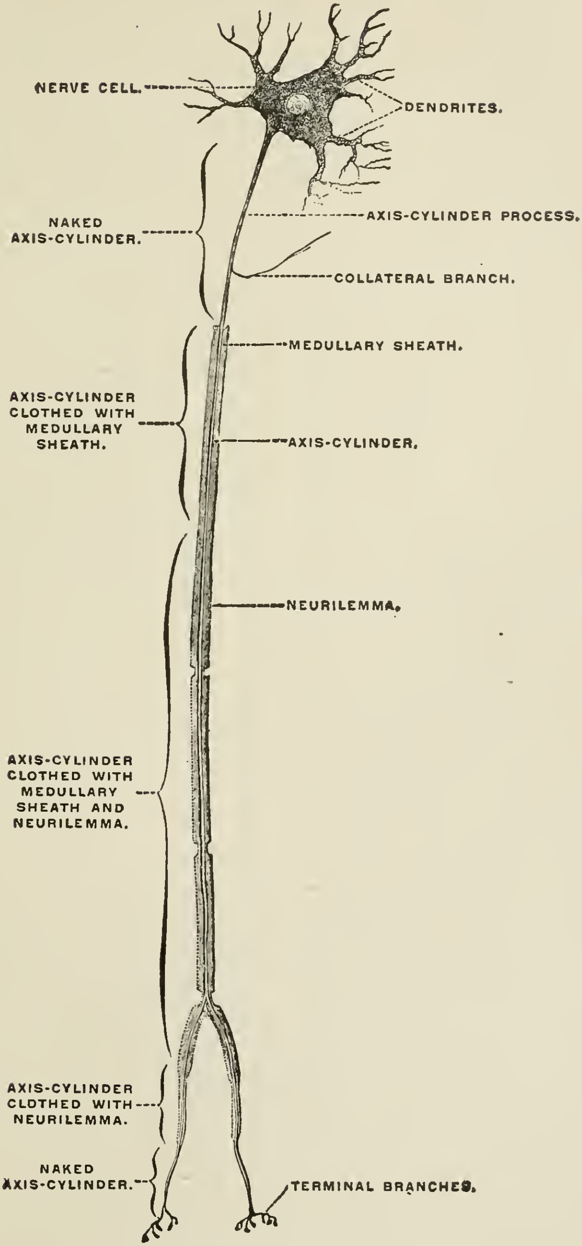

FIG. 175. — A NEURONE. (Gerrish.)

If the cell has but one process, that one is the **axis cylinder process**, and the cell is spoken of as a **unipolar** cell. If the cell has two processes, one is the axis cylinder process, and the cell is called **bipolar**; many processes, **multipolar.**

Function of the cell-body. — The cell-body affords nutriment to its processes, as is proven by the fact that if a nerve-fibre is cut, the part separated from the cell-body dies. It also bears the same relation to the cell that the battery does to many kinds of electrical apparatus: (1) it is the centre in which the action takes place which gives rise to nervous impulses; (2) the cell-bodies are capable of modifying impulses brought to them by their sensory processes. This modification may take the form of *inhibition* and either partially or completely block impulses; or it may take the form of *summation, i.e.* collect weak impulses, and combine them into one effective impulse before transmission to the motor nerves. As cell-bodies are found only in the brain, spinal cord, and ganglia, it is only in these parts of the nervous system that these activities can take place.

(2) **The cell-processes.** — The cell-processes are named as follows: —

(*a*) Dendrites or dendrons.
(*b*) Axis cylinder processes, named also neuraxones, or axones.
(*c*) Nerve-fibres $\begin{cases}\text{Medullated.}\\ \text{Non-medullated.}\end{cases}$
(*d*) Collaterals.
(*e*) Nerve-endings.

(*a*) **Dendrites.** — These processes are usually short, and rather thick at their attachment to the cell-body. They have a rough outline, diminish in calibre as they extend further from the cell-body, and branch rapidly in a tree-like manner. These branches are called arborizations. The number of dendrites varies.

Function. — The essential function of a dendrite is conduction of a nerve-impulse from the periphery to the cell-body. They collect nerve-impulses from the processes of other cells, and carry them always in one direction, *i.e.* to the cell-body.

Synapse. — In this connection it is important to emphasize that there is no true anastomosis of processes from different cells. The arborizations interlace and intermingle so that the nerve-impulse from one cell-process is able to bridge the gap and set up nerve-impulses in the contiguous process. This intermingling of arborizations is called a *synapse*.

(*b*) **Axis cylinder process.** — There is but one axis cylinder process given off from each cell, and it differs from the dendrites in the following particulars: —

(1) It is usually longer; in some instances it travels as much as 39.37 in. (1 meter) before breaking up into its terminal branches.

(2) It has a smooth outline and diminishes in calibre very little.

(3) It gives off minute side branches called *collaterals*. These are generally given off at right angles to the axis cylinder.

(4) It merges into a nerve-fibre and usually becomes enveloped in one or two coats.

Function. — The function of the axis cylinder process differs from that of the dendrites. The dendrites convey impulses *to* the cell-body, and the axis cylinder process conveys impulses *from* the cell-body. Some writers consider that the axis cylinder is capable of carrying impulses in either direction, but this is not the generally accepted view.

(*c*) **Nerve-fibre.** — While the nerve-fibre is really only the continuation of the axis cylinder process that has undergone some change in structure, it is advisable to describe the nerve-fibre separately as though it were a new subject.

Nerve-fibres are of two kinds: medullated, or white fibres, and non-medullated, or gray fibres.

Medullated fibre. — If one looks at a medullated nerve-fibre under the microscope, it is found to consist of three parts: (1) a central core called the axis cylinder which is a continuation of the axis cylinder process; (2) immediately surrounding the axis cylinder is a sheath, or covering, of a semi-fluid, fatty substance called the **medullary**, or **myelin, sheath.** It is to the refraction of light from this fatty substance that medullated nerve-fibres owe their white color; (3) external to the medullary sheath is a thin membrane completely enveloping the nerve-fibre and forming the outer covering called the **neurilemma.** This is comparable to the sarcolemma that invests muscle-fibres.

Function of the medullary sheath. — It is supposed that the medullary sheath serves: (1) as a source of nourishment, (2) as a protection, and (3) as a non-conducting medium for the axis cylinder. In the last-mentioned capacity it is thought that this sheath prevents the deflection of nerve-impulses from their intended course, in some such way as the insulation on an electric wire prevents the current from taking a path other than the one desired.

Nodes of Ranvier. — At regular intervals along the course of a medullated nerve-fibre there are noted ring-like constrictions about the nerve-fibre dividing the nerve-fibre into a series of links. These constrictions are the **nodes of Ranvier.**

At each node the constriction is due to a loss of continuity or absence of the medullary sheath, thus allowing the neurilemma to dip in, so to speak, and come in direct contact with the axis cylinder. Thus at each node the nerve-fibre is smaller in diameter, this change in diameter being entirely at the expense of the medullary sheath, the axis cylinder being unchanged. These nodes are about 1 mm. apart, and the portion between two consecutive nerves is called a nerve segment. If a nerve-fibre divides, the division occurs at one of these nodes. In each nerve segment the neurilemma is seen to have a nucleus. Medullated nerve-fibres may be very long, but the diameter is very minute.

Function of the nodes of Ranvier. — The passage of the blood-plasma into the axis cylinder is rendered easier by the absence of the medullary sheath at the nodes of Ranvier, and this is thought to be their function.

Non-medullated fibre. — Non-medullated nerve-fibres or, as they are sometimes called, the **fibres of Remak**, do not differ in any respect from the medullated nerve-fibres save in the absence of the medullary sheath, the axis cylinder being directly invested by the neurilemma. Owing to the absence of the refracting medium (the medullary sheath), the non-medullated fibres do not appear white, but present a grayish or yellow color.

(*d*) **Collaterals.** — The minute side branches given off at right angles from the axis cylinder process are called collaterals. These are found chiefly in the brain, spinal cord, and ganglia. They end either in bulbous enlargements, or in fine brush-like terminations, which come in contact (synapse) with the processes from other neurones.

(*e*) **Nerve-endings.** — Nerve-endings may be classified according to the part of the body in which they are found.

1. Nerve-fibres which terminate in the brain or spinal cord split up into *end arborizations.*
2. Sensory nerve-fibres ending at the periphery of the body terminate in two ways: —
   (*a*) *Inter-epithelial arborizations.*
   (*b*) *Organules.*
3. Motor nerve-fibres ending in voluntary muscles terminate in *motor plates.*
4. Motor nerve-fibres ending in involuntary muscles (such as in the viscera) terminate in a *plexus.*

End arborizations. — If the nerve-fibre is to terminate while still lying in the mass of the nervous system, its axis cylinder may split up at the termination into a number of short filaments called **end arborizations**, which interlock with the dendrites of another neurone, or the axis cylinder may send out collaterals which interlock with dendrites. Thus an individual neurone would serve only as a *relay station.*

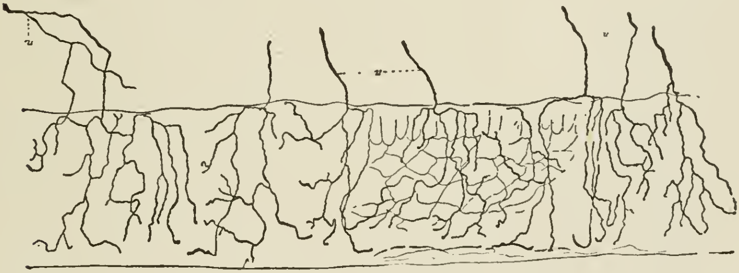

Fig. 176. — Sensory Nerve Terminations in Stratified Pavement Epithelium. (Kirkes.)

Inter-epithelial arborizations. — This is the most common mode of termination of sensory nerves. The nerve-fibres pass to the surface either in the skin or mucous membrane; the neurilemma and medullary sheath disappear, the naked axis cylinder subdividing into minute **arborizations** that ramify between the epithelial cells of the surface of the body. This method is the one in which nerves terminate in various glands, hairs, teeth, tendons, etc.

Organules. — Some of the highly complex special sensations need very complex end organs for their reception. These end organs are modified epithelial cells and are called organules. The axis cylinder subdivides into arborizations as described above;

and these enter and terminate in the organules. The different varieties of **tactile corpuscles**, the **organ of Corti**, for the auditory nerve, and the **rods** and **cones** of the retina may be cited as examples of organules.

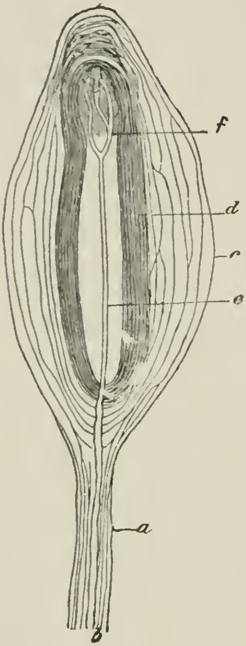

Fig. 177.— Pacini's Corpuscle. *a*, stalk; *b*, nerve-fibre entering it; *a*, *d*, connective-tissue envelope; *e*, axis cylinder, with its end divided at *f*. (Collins.)

Motor plates. — A nerve intended to stimulate a muscle to activity terminates by a subdivision of the axis cylinder (the neurilemma and medullary sheath fading out), each branch of the axis cylinder ending in a flat nodule of granular material lying on the muscle fibre. This terminal mass is the motor plate.

Plexus. — The nerve-fibres which are distributed to the viscera are non-medullated, and near their terminations each one divides into a number of branches which arborize with each other and form a network or plexus. From this plexus smaller branches are given off, these subdivide to form fibrils, and the fibrils terminate on the surface of the muscle cells. (See page 377.)

Nature of nerve-impulse. — Having examined the make-up of a complete nervous entity (the neurone), it now seems best to study the nature of nerve-impulses.

The nature of a nerve-impulse is not known. We know that nerve-fibres may be stimulated by several means, and the practical result is similar to the result obtained were the nerve stimulated by the natural physiological impulse. The nerve-fibre has no power to initiate a nerve-impulse, but serves merely as a conveyor of the impulse which has been started either in the end organs or in the nerve-cell.

Artificial nerve stimulation. — There are four means usually applied to the artificial stimulation of a nerve-fibre, viz.: **chemical**, **thermal**, **mechanical**, and **electrical**, — the latter the most usual. That the true physiological impulse is none of these can be readily proven. (See any standard work of physiology.)

Physiological nerve stimulation. — The best explanation is that the true nature of nerve-impulse is a **physical molecular vibration** set up either in the nerve-cell or the end organs and transmitted along the nerve-fibre.

Direction of nerve-impulse. — Within the body nerve-impulses travel in two directions: (1) from the cell-body to the periphery, and (2) from the periphery to the cell-body.

Afferent and efferent nerve-fibres. — From the previous paragraph it is deduced that the nerve-fibres are divided into two great classes: (1) efferent or centrifugal are those in which the direction for the nerve-impulses to travel is from the cell-body to the periphery; and (2) afferent or centripetal are those in which the impulses travel from the periphery to the cell-body.

The most striking example of efferent fibres are those which convey impulses that stimulate functional activity, *i.e.* muscular contraction or glandular secretion; hence the efferent nerve-fibres are often spoken of as *motor,* although motion is the manifestation of but a class of neurones. On the other hand, afferent fibres are often spoken of as sensory, because it is to them that sensation is due.

Reason for direction of nerve-impulse. — Normally the efferent fibres are stimulated only through the cell-bodies from which they spring, and the afferent fibres are stimulated only at their endings. For this reason a nerve-fibre can carry impulses only in one direction.

Classification of nerve-fibres. — In addition to classifying nerve-fibres as efferent and afferent, we may subdivide peripheral nerve-fibres into smaller groups depending upon their physiological differences. Numerous experiments have demonstrated that the effect of an impulse conveyed by nerve-fibres may be either excitatory or inhibitory; *i.e.* the tissue or cell may be stimulated to activity, or if already in activity it may be reduced to a condition of rest. On this basis both afferent and efferent fibres may be subdivided into excitatory and inhibitory fibres. Each of these subgroups may be further divided according to the kind of activity it excites or inhibits, and according to the kind of muscle or tissue in which it ends. The following classification, taken from "Text-book of Physiology," by William H. Howell, depends upon three principles: (1) the direction in which the impulse travels normally;

(2) whether this impulse excites or inhibits; and (3) the kind of action excited or inhibited, which in turn depends upon the kind of tissue in which the fibres end.

- **Efferent**
    - Excitatory
        - Motor
            - Motor.
            - Vasomotor.
            - Cardiomotor.
            - Visceromotor.
            - Pilomotor.
        - Secretory
            - Salivary.
            - Gastric.
            - Pancreatic.
            - Sweat.
    - Inhibitory
        - Inhibito-motor
            - Subdivisions corresponding to the varieties of motor fibres above.
        - Inhibito-secretory
            - Subdivisions corresponding to the varieties of secretory fibres above.
- **Afferent**
    - Excitatory
        - Sensory
            - Visual.
            - Auditory.
            - Olfactory.
            - Gustatory.
            - Pressure.
            - Temperature.
            - Pain.
            - Hunger.
            - Thirst, etc.
        - Reflex
            - According to the efferent fibres affected.
    - Inhibitory
        - Inhibito-reflex
            - Inhibitory effects upon the conscious sensations are not demonstrated.
            - The reflex fibres that cause unconscious reflexes are known to be inhibited in some cases at least.

Identity of nerve-impulses. — The generally accepted belief is that nerve-impulses are identical in character and vary only in intensity. According to this the impulses carried by a sensory nerve are similar in character to those carried by a motor nerve, and yet the result is different. The result is thought to be determined by the nature of the tissue in which a nerve-fibre ends, rather than by the nature of the fibre itself.

Speed of nerve-impulses. — The speed at which an impulse travels along an afferent nerve-fibre is found to be about 140 feet (42.6 m.) per second. The efferent impulses travel somewhat slower, 110 feet (33.5 m.) per second.

It may be interesting to note how very slow a nerve-impulse is when compared with light which travels at the rate of about 186,000 miles per second, and sound which travels about 1100 feet per second.

Reaction of nerve-endings. — A study of the previous classification shows that the sensory nerve-endings are not all affected by the same stimulus, nor do they react in the same way. Thus some of the sensory nerve-endings are affected by pressure, and others by temperature. The endings of the auditory nerve in the ear are affected only by sound, and the endings of the optic nerve in the eye are affected by light, though a similar effect may be produced by a blow on the head, or an accident which jars the spinal column.

Gray matter. — The cell-bodies, dendrites, commencement of the axis-cylinder processes, and their collaterals are not scattered promiscuously throughout the body, but are gathered together in certain definite regions or groups. These form the gray matter of the brain, spinal cord, and ganglia.

White matter. — The white matter consists of medullated nerve-fibres and is found in the brain, spinal cord, ganglia, and also in the nerve trunks distributed to all parts of the body.

Neuroglia. — Neuroglia is not nervous tissue, but is a special kind of tissue found in the brain and spinal cord, and serves the same purpose as connective tissue in other parts of the body. It consists of cells that give off many fine processes which extend in every direction and form a supporting and connecting network among the nerve-cells, nerve-fibres, and blood-vessels.

Formation of nerve-trunks. — The nerve-fibre of each neurone is, as has been described, of microscopic diameter, but when a number of these nerve-fibres are bound together in a bundle we have the plainly visible nerve-trunks, or nerves, such as are seen in dissections of the body.

Nerves are whitish cords which extend between cells situated in different parts of the brain, spinal cord, and ganglia, also between these centres and all parts of the body. They thus afford a means of communication between: (1) the different parts of the nervous system, (2) the nerve centres and the viscera, (3) the nerve centres and the periphery, and (4) the viscera and the surface of the body.

Fig. 178. — Diagram illustrating the General Arrangement of the Cerebrospinal System.

Between the nerve-fibres is a small amount of connective tissue which serves not only to bind the fibres together into bundles, or **funiculi**, but also to carry to or from the fibres the blood-vessels and the lymphatics necessary for their nutrition. Connective tissue also surrounds these bundles in the form of a sheath.

Although the nerves branch frequently throughout their course, and these branches often meet and fuse with one another, or with the branches of other nerves, yet each nerve-fibre always remains quite distinct, never branching until it reaches its termination, and never uniting with other nerve-fibres. The nerve-trunk is thus merely an association of individual fibres which have very different activities and which may function entirely independent of one another. Perhaps the best idea of the arrangement of nerve-fibres in a trunk can be obtained from a cross-section of a nerve such as is seen in Figure 179.

Nerve centres. — Groups of nerve-cells exercising control over some definite function are called *centres*. Each of these centres is influenced by impulses from various parts of the body which travel along special nerves to these centres. Many of these centres are situated in the medulla and spinal cord. Most of the centres in the medulla are concerned with processes that are absolutely necessary to life, hence are called *vital centres.* Examples of these are the centres controlling respiration and the cardiac centre.

Intercentral neurones and relays. — Neurones whose processes do not pass outside of the brain or spinal cord are called *intercentral* or connecting neurones. An impulse passing from say the foot to the brain, might have to pass through two or three, or even more, neurones; these neurones form a system of *relays.* A parallel may be found in sending a telegraphic message; the message may have to pass over several different systems of wires and eventually be carried by messenger before it reaches its destination. These relays only occur in the brain and spinal cord. In the illustration referred to above, one relay would take the impulse to the spinal cord; this naturally means a very long fibre; one or several might be required to take it from the spinal cord to the brain.

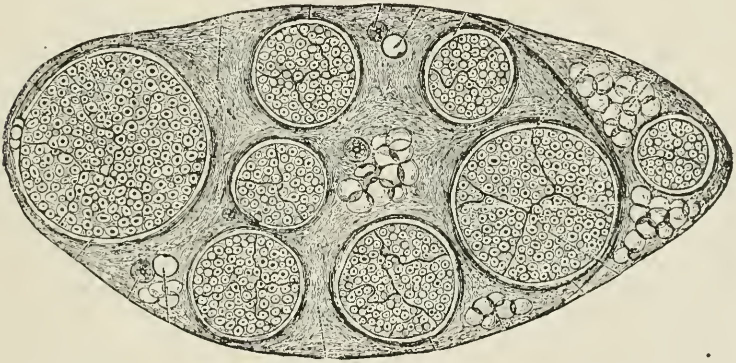

Fig. 179. — Transverse Section of the Sciatic Nerve of Cat about × 100. — It consists of bundles (*funiculi*) of nerve-fibers ensheathed in a fibrous supporting capsule.

THE SYMPATHETIC SYSTEM

The sympathetic system consists of three sets of ganglia and the nerves connected with them: —

1. Vertebral or lateral ganglia.
2. Collateral or prevertebral ganglia, and plexuses.
3. Terminal ganglia and plexuses.
4. Sympathetic ganglia in the brain and cord.

The vertebral ganglia. — The vertebral ganglia consist of a chain of ganglia situated on each side of the spinal column, and extending from the base of the skull to the coccyx. There are about forty-nine of these ganglia, twenty-four on each side of the spine, and one in front of the coccyx. They are connected with each other by nerve-fibres called ganglia cords, and with the spinal nerves by branches which are called *rami communicantes*.[1] They are also connected to the viscera and blood-vessels by branches which travel different pathways: (1) they pass directly to the viscera; (2) they converge to form three main nerve-trunks, called the great splanchnic, the small splanchnic, and the least splanchnic, and then send branches from these trunks to the viscera; (3) they join the collateral ganglia and plexuses; (4) they join the spinal nerves, and in them reach the part of the body for which they were destined.

The collateral ganglia. — The collateral or outlying ganglia consist of masses of gray matter and their nerves, which are located principally in the thoracic and abdominal cavities. They are connected with the spinal nerves, with the vertebral ganglia, and send branches to the viscera. These branches form plexuses, the most important of which are: (1) the cardiac plexus, located above the heart and supplying it with sympathetic fibres, (2) the solar plexus, located behind the stomach and supplying most of the abdominal viscera, (3) the hypogastric or pelvic plexus, located in the lower part of the abdomen and supplying the viscera of the pelvis.

The terminal ganglia. — The terminal ganglia include all the ganglia situated in the walls of the organs themselves, as for instance those in the walls of the heart, and in the walls of the alimentary canal. These ganglia are directly connected with the collateral ganglia, and in some instances the nerves derived from the collateral plexuses form a secondary or terminal plexus on the organs.

Sympathetic ganglia in the brain and spinal cord. — In connection with a few of the cranial nerves, such as the third and fifth, certain ganglia are found. Sympathetic ganglia are also found in the spinal canal and in the medulla. (See vasomotor centres.)[2]
Autonomic system is a name that has recently been suggested for the sympathetic system as outlined above. Prior to the introduc-

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[1] See page 377.

[2] See page 378.

tion of this name, the fourth group was not included in the sympathetic system. The term autonomic implies that these nerves are to some extent independent of the central nervous system and possess a certain amount of self-government.

Rami communicantes. — The nerve-fibres that connect the vertebral ganglia and the spinal nerves are called rami communicantes. Each connection consists of two rami, one white and the other gray. The white ramus consists of medullated fibres, and these pass from the cord to the ganglion. The gray ramus consists of non-medullated fibres that pass from the ganglion to join the spinal nerve.

Plexuses. — The term plexus has been used to designate a network of nerves. It is worthy of special mention because the nerve-fibres arborize with each other, and there is an interchange of fibres between the different nerve-trunks. The advantages of this arrangement are: (1) each nerve is less dependent on the unimpaired condition of any single portion of the nerve-trunk or nerve-centre, (2) each nerve has a wider communication with the nerve-centres, and (3) any given part of the body is not dependent on one nerve. The various plexuses of the sympathetic system serve all these purposes, and in addition the organs constituting any one system are brought into direct communication with each other. In this way coördination of action is secured.

Distribution of sympathetic nerves. — Nerve-fibres from the sympathetic system are distributed: (1) to the heart, (2) to the involuntary muscles of the blood-vessels, lymphatics, and viscera, (3) to the secretory glands, and (4) to some of the special senses, such as those that regulate the pupil of the eye.

Interdependence of the sympathetic and central nervous systems. — The fibres which connect the sympathetic ganglia and the spinal nerves form a direct pathway for impulses from all of the viscera to the spinal cord and brain. In addition many of the viscera are connected with the brain by the cranial nerves (see page 395). This means that there are often two sets of nerve-fibres distributed to an organ, and we know that in some instances the action of these fibres is antagonistic. This is true in the case of the inhibitory and accelerator fibres of the heart, and increased knowledge may prove it to be true in connection with all the organs of the body.

Vasomotor centres. — The chief vasomotor centres are situated in the medulla oblongata, but there are also subsidiary centres in the spinal cord. The vasomotor nerves are of two kinds, — vasoconstrictor and vaso-dilator. While these nerves are always considered as belonging to the sympathetic system, it should be noted that the centre that controls them is located in the medulla, which is part of the central nervous system.

SPINAL CORD

The spinal cord is that portion of the nervous system lodged within the spinal canal of the vertebral column. It consists of a collection of gray and white substance, extending from the foramen magnum of the skull, where it is continuous with the medulla oblongata of the brain, to about the second lumbar vertebra, where it tapers off into a fine thread. Before its termination it gives off a number of fibres which form a tail-like expansion, called the **cauda equina.**

Membranes of the cord. — Like the brain, the spinal cord is protected and nourished by three membranes. These membranes have the same names and practically exercise the same functions as those enveloping the brain (for description of which see page 384). The outer membrane is not attached to the walls of the spinal canal, being separated from them by a certain quantity or areolar and adipose tissue, and a network of veins.

Structure of the cord. — The spinal cord does not fit closely into the spinal canal, as the brain does in the cranial cavity, but is, as it were, suspended within it. It diminishes slightly in size from above downward, with the exception of presenting two enlargements in the cervical and lumbar regions, where the nerves are given off to the arms and legs respectively. It is usually from sixteen to seventeen inches (400 to 425 mm.) long, and has an average diameter of three-fourths of an inch (19 mm.). The spinal cord is almost completely divided into lateral halves by an anterior and posterior fissure, the anterior fissure dividing it in the middle line in front, and the posterior fissure in the middle line behind. In consequence of the presence of these fissures, only a narrow bridge of the substance of the cord connects its two halves. This bridge, also called isthmus, is traversed throughout its entire length by a minute central canal. On making a transverse section of the spinal cord, the gray matter is seen to be arranged in the form of a butterfly with extended wings. The tips of each wing are called its horns or cornua, the anterior horns being thicker and larger than the posterior. The transverse bar of gray matter found in the isthmus is called the gray commissure, and it connects the two lateral masses of gray matter. The white matter is arranged around and between the gray matter, tne proportion of gray and white varying in different regions of the cord. The

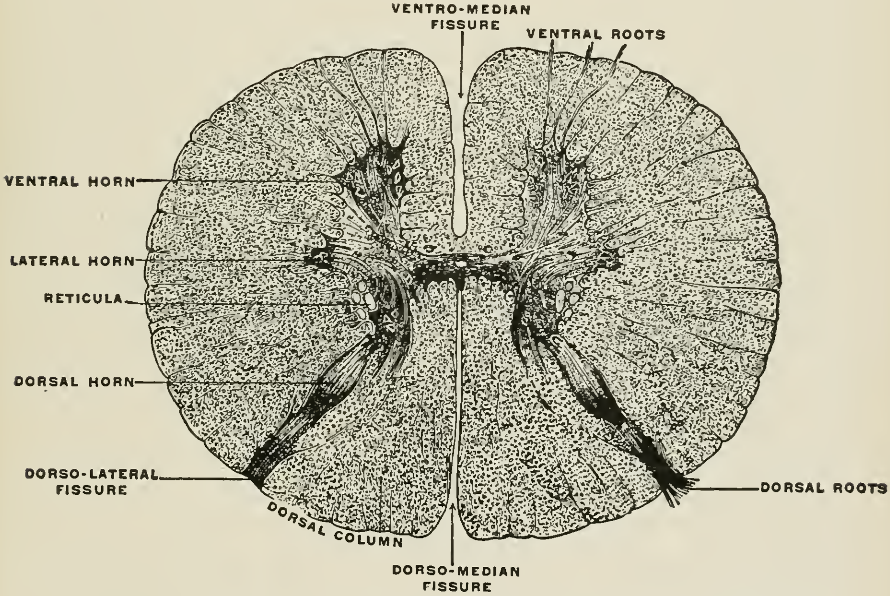

Fig. 180. — Transverse Section of the Spinal Cord at the Middle of the Thoracic Region. The neuroglia septum has been removed from between the dorsal columns. (Gerrish.)

white matter is composed of medullated nerves, and the gray matter consists of cell-bodies, dendrites, axis cylinder processes, and collaterals, all held together and supported by neuroglia. The medullated nerve-fibres are grouped in bundles known as tracts or columns, and the majority run in a longitudinal direction. These tracts are classified under two main headings: (1)sensory, or those which carry impulses upward to the brain; they begin in the gray matter of the cord, ascend, and terminate in the gray matter of the brain; (2) motor, or those which carry impulses downward; they begin in the gray matter of the brain, descend, and terminate in the gray matter of the cord. The most important tracts are: —

Ascending or Sensory	Postero internal tract or Columns of Goll.
	Postero external tract or Columns of Burdach.
	Antero lateral tracts.
	Postero lateral tracts.
Descending or Motor	Crossed pyramidal tract.
	Direct pyramidal tract.

In addition to these long tracts, there are shorter columns consisting of both sensory and motor nerves, which serve to connect centres at different levels in the cord, and on different sides of the cord. These are called lateral columns.

SPINAL NERVES

There are thirty-one pairs of spinal nerves, arranged in the following groups, and named from the region through which they pass. They are: —

Cervical	8 pairs.
Thoracic	12 pairs.
Lumbar	5 pairs.
Sacral	5 pairs.
Coccygeal	1 pair.

The first cervical nerve arises from the medulla oblongata and leaves the neural canal between the occipital bone and the altas. With this one exception the spinal nerves spring from both sides of the spinal cord, and with one exception — coccyxgeal — they pass out through the intervertebral foramina. The coccyxgeal passes through the lower extremity of the canal.

Mixed nerves. — The spinal nerves consist almost entirely of medullated nerve-fibres, and are called mixed nerves because they contain both sensory and motor fibres. Each spinal nerve has two roots, a ventral or anterior root and a dorsal or posterior root. The fibres connected with these two roots are collected into one bundle, and form one nerve just before leaving the canal through the intervertebral openings. Before joining to form a common trunk, the fibres connected with the dorsal root present an enlargement, this enlargement being due to a ganglion, or small nerve-centre, situated in the intervertebral foramina. The fibres of the ventral root **arise from the gray matter** in the ventral horn, and are direct prolongations from the cell-bodies there.

The fibres of the posterior root arise from the **cells composing the enlargement or ganglion** of the posterior root and pass toward the periphery; each cell of the ganglion, besides sending toward the periphery the nerve-fibres just described, sends a branch along the posterior root up into the gray matter of the posterior horn, there to break up into branches articulating with other cells or dendrites. All the fibres making up the ventral root are efferent fibres, and convey nervous impulses from the spinal cord to the periphery. The fibres making up the dorsal root are afferent fibres, and convey nervous impulses from the periphery to the spinal cord.

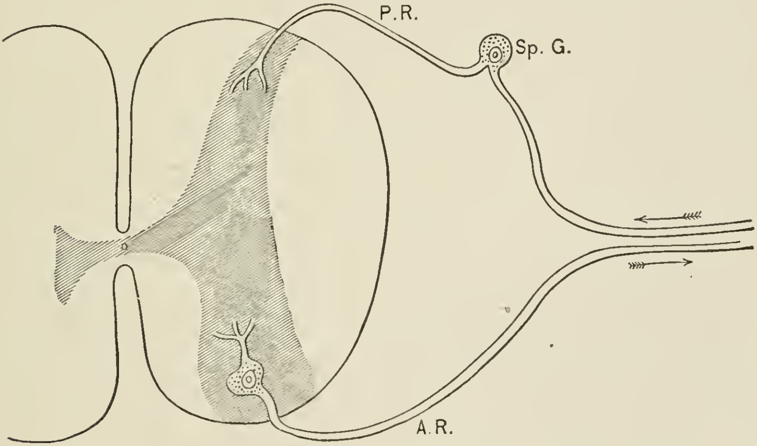

Fig. 181. — Diagram of Nerve Roots emerging from Spinal Cord. *P.R.* posterior root. *Sp.G.* posterior root ganglion. *A.R.* anterior root. (Schematic.) (Collins.)

It should be borne in mind that the dorsal roots contain only **sensory** fibres, and that these fibres always have their origin outside of the cord (*i.e.* in the spinal ganglia), while the ventral roots contain only **motor** fibres, and these have their origin within the central nervous system.

The relations of the roots, fibres, and so forth, can be best understood from a study of the accompanying diagrams (Figs. 181 and 182).

Degeneration and regeneration of nerves. — Since, as has been stated, the cell-body is essential for the nutrition of the whole cell, it follows that if the processes of a neurone are cut off, they will suffer from malnutrition and die. If, for instance, a spinal nerve be cut, all the peripheral part will die, since the fibres composing it have been cut off from their cell-bodies situated in the cord, or in the spinal ganglia. The divided ends of a nerve that has been cut across readily reunite by cicatricial tissue, — that is to say, the connective tissue framework unites, but the cut ends of the fibres themselves do not unite. On the contrary, the peripheral or severed portion of the nerve begins to degenerate, the medullary sheath breaks up into a mass of fatty molecules and is gradually absorbed, and finally the axis cylinder also disappears. In regeneration, the new fibres grow afresh from the axis cylinder of the central end of the severed nerve-trunk, and penetrating into the peripheral end of the neurilemma, grow along this as the axis cylinder of the new nerve, each axis cylinder becoming after a time surrounded with a medullary sheath. Restoration of function in the nerve may not occur for several months, during which time it is presumed the new nerve-fibres are slowly finding their way along the course of those which have been destroyed.

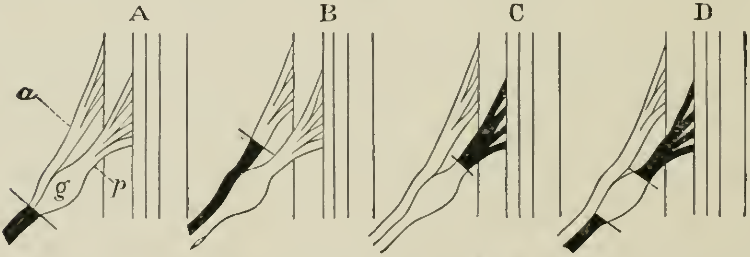

Fig. 182. — Degeneration of Spinal Nerves and Nerve-roots after Section. *A*, section of nerve-trunk beyond the ganglion; *B*, section of anterior root; *C*, section of posterior root; *D*, excision of ganglion; *a*, anterior root; *p*, posterior root; *g*, ganglion.

Distribution of the terminal branches of the spinal nerves. — After leaving the spinal canal each spinal nerve divides into two main trunks known as the anterior and posterior divisions. Each of these contain sensory and motor fibres. The anterior division supplies the extremities and parts of the body in front of the spine. The posterior division supplies the muscles and skin of the back of the head, neck, and trunk. Each anterior division connects with the sympathetic system by means of fibres which pass from the nerve to the sympathetic system and *vice versa.* Previous to their final distribution in the cervical, sacral, and lumbar regions these nerves form plexuses known as the cervical, sacral, and lumbar plexuses. In passing to the viscera, muscles, skin, etc., these terminal nerves follow the same pathway as the blood-vessels.

Names of peripheral nerves. — Many of the larger branches given off from the spinal nerves bear the same name as the artery which they accompany, or of the part which they supply. Thus the radial nerve passes down the radial side of the forearm, in company with the radial artery; the intercostal nerves pass between the ribs in company with the intercostal arteries.

Functions of the spinal cord: —

(*a*) **Conduction**, or the conveyance of impulses and sensations between the centres and the periphery.

(*b*) **Reflex action**, *i.e.* the origination of an impulse or action in response to a stimulation from the periphery, without of necessity involving the brain in the act or even without consciousness of the reflex act on the part of the individual.

(*c*) **Automatic acts**, *i.e.* acts set up primarily in the cells of the cord by the cells themselves, and not as a result of stimulation by brain cells (voluntary acts) nor as result of peripheral stimulation.

(*d*) **Inhibition of reflex acts.** — If every outside stimulation were allowed its full effects in the setting up of reflex acts, the body would be on " the jump " all the time. This overactivity is checked unconsciously by the cells of the spinal cord endowed with this function.

(*e*) **Transference**, *i.e.* an apparent transferring of impulses from one set of fibres to another.

BRAIN

The brain, the most complex and largest mass of nervous tissue in the body, is contained in the complete bony cavity formed by the bones of the cranium. It is covered by three membranes (also named meninges), — the dura mater, pia mater, and arachnoid.

The **dura mater** is a dense membrane of fibrous connective tissue containing a great many blood-vessels. It is arranged in two layers and the layers are attached except in a few places. The external layer is adherent to the bones of the skull, and forms their internal periosteum. The internal layer covers the brain and sends numerous prolongations inward for the support and protection of the different lobes of the brain. These projections also form sinuses that return the blood from the brain, and sheaths for the nerves that pass out of the skull. It may be called the protective membrane.

The **pia mater** is a delicate membrane of connective tissue, containing an exceedingly abundant network of blood and lymph vessels. It dips down into all the crevices and depressions of the brain, carrying the blood-vessels which go to every part. It may be called the vascular or nutritive membrane.

The **arachnoid** is a delicate serous membrane which is placed between the dura mater and the pia mater. With the exception of the longitudinal fissure,[1] it passes over the various eminences and depressions on the surface of the brain and does not dip down into them like the pia mater. Between the arachnoid and the pia mater is a space called the sub-arachnoid space in which is a certain amount of fluid. This fluid is secreted by the arachnoid and is called the cerebro-spinal fluid. It serves to lubricate the other membranes and prevent friction. In cases of meningitis, *i.e.* inflammation of these membranes, the amount of this fluid is very much increased.

Structure of the brain. — The whole brain appears to consist of a number of isolated masses of gray matter — some large, some small — connected together by a multitude of medullated fibres (white matter) arranged in perplexing intricacy. But a general arrangement may be recognized. The numerous masses of gray matter in the interior of the brain may be looked upon as forming a more or less continuous column, and as forming the **core** of the central nervous system, while around it are built up the great mass of the cerebrum and the smaller mass of the cerebellum. This central core is connected by various bundles of fibres with the

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[1] See page 389.

spinal cord, besides being, as it were, a continuation of the gray matter in the centre of the cord. It is also connected at its upper end by numberless fibres to the gray matter on the surface of the cerebrum.

Weight of the brain. — With the exception of the whale and the elephant, the human brain is heavier than that of any of the lower animals. The average weight of the brain in the male is forty-nine and a half ounces (1403 grams); in the female, forty-four ounces (1247 grams). It appears that the weight of the brain increases rapidly up to the seventh year, more slowly to between sixteen and twenty, and still more slowly to between thirty and forty, when it reaches its maximum weight. Beyond this age the brain diminishes slowly in weight, about an ounce every ten years.

Divisions of the brain. — The brain is divided into four principal parts: the cerebrum, the cerebellum, the pons Varolii, and the medulla oblongata.

The medulla oblongata. — The medulla oblongata, also known as the spinal bulb, is continuous with the spinal cord, which, on passing into the cranial cavity through the foramen magnum, widens into an oblong-shaped mass. It is directed backward and downward, its anterior surface resting on a groove in the occipital bone, and its posterior surface forming the floor of a cavity between the two halves, or hemispheres, of the cerebellum. It is hollow and the cavity, called the fourth ventricle, is an expanded continuation of the tiny central canal which runs throughout the whole length of the spinal cord. The gray matter is found in the interior, and the white matter on the exterior; most of the gray matter is found on the floor of the fourth ventricle, and from this gray matter arise most of the cranial nerves. The medulla has an anterior and a posterior median fissure; at the lower part of the anterior fissure are nerve-fibres which cross from one side to the other or *decussate*.

Functions of the medulla oblongata. — The functions of the medulla are similar to the first three listed under the functions of the cord, *i.e.* conduction, reflex action, and automatic action.

As all the impressions passing between the brain and spinal cord must be transmitted through the medulla, the function of conduction is a very important one. As previously stated, the medulla contains important vital and reflex centres. The principal ones are: —

(1) The respiratory centres for regulating the function of respiration.

(2) Accelerator centres for the heart.

(3) Vasomotor centre to regulate size of arterioles in any part of the body, thus controlling the amount of blood furnished to that part.

(4) Other centres, such as the vomiting centre, heat controlling centre, etc.

The student will readily appreciate that, the medulla being the seat of such important centres as those controlling respiration and the heart's action, if the medulla be seriously injured, death will result.

Cerebellum. — The cerebellum, or "little brain," occupies the lower and back of the skull cavity, overhanging the medulla oblongata. It is of a flattened, oblong shape, and measures from three and a half inches to four inches (87 to 100 mm.) transversely, and from two to two and a half inches (50 to 63 mm.) from before backward. It is divided in the middle line into two lateral lobes, or hemispheres, and a median lobe, by a central depression, each lobe being subdivided by fissures into smaller portions. The surface of the cerebellum consists of gray matter and is traversed by numerous curves, or furrows, which vary in depth. The interior consists of white matter.

Peduncles of cerebellum. — The cerebellum is connected with the rest of the cerebro-spinal system by many white nerve-fibres grouped in bundles called the peduncles.

The peduncles are arranged in three pairs. The anterior (superior) peduncles pass forward from the cerebellum to enter into the cerebrum. The posterior (inferior) peduncles pass down to the medulla, where they are known as the **restiform bodies.** The middle pair pass into and make up the larger portion of the pons Varolii, thus serving as a means of intercommunication between the two halves of the cerebellum. Thus it is seen that the cerebellum communicates most freely with the entire cerebro-spinal system.

Functions of the cerebellum. — The principal function of the cerebellum seems to be the coördination of ordinary movements, and the maintenance of equilibrium. The reason for this belief is that disease or destruction of the cerebellum apparently exerts no malign influence on sensory nerves nor upon the intellect. The motor system is, however, profoundly deranged. Motion is itself not destroyed, but coördination is so interfered with that movements of one part of the body cannot be adapted to other parts.

Pigeons deprived of the cerebellum will fly if thrown from a roof, but the delicacy of the coördination being lost, they turn a series of somersaults in the air and soon fall to the ground.

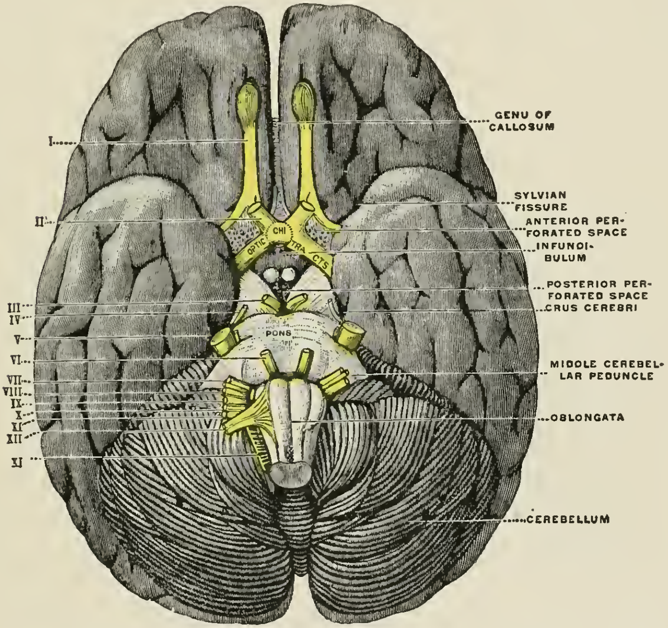

Fig. 183. — Under Surface of the Brain, showing the Superficial Origins of the Cranial Nerves. The Roman numerals indicate the nerves. (Gerrish.)

Pons Varolii. — The pons Varolii, or bridge of Varolius, lies in front of the upper part of the medulla oblongata. It consists of interlaced transverse and longitudinal white nerve-fibres intermixed with gray matter. The transverse fibres are those derived from the middle peduncles of the cerebellum and, as already stated, serve to join its two halves. The longitudinal fibres join the medulla with the cerebrum.

Functions of pons Varolii. — The pons is a bridge of union between the two halves of the cerebellum and a bridge between the medulla and the cerebrum. It is also a port of exit for the fifth, sixth, seventh, and eighth cranial nerves.

Cerebrum. — The cerebrum is by far the largest part of the brain. It is egg-shaped, or ovoidal, and fills the whole of the upper portion of the skull. The entire surface, both upper and under, is composed of layers of gray matter, and is called the cortex because, like the bark of a tree, it is on the outside. The bulk of the white matter in the interior of the cerebrum consists of very small fibres running in three principal directions: (1) from above downward, (2) from the front backward, and (3) from side to side. The fibres link the different parts of the brain together, and connect the brain with the spinal cord.

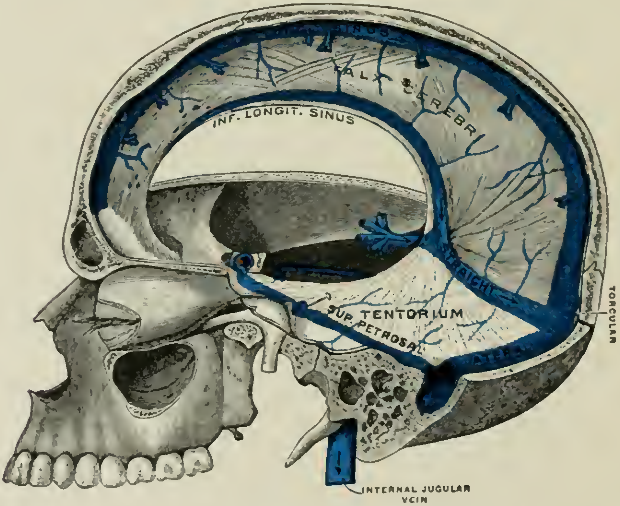

Fig. 184. — Falx Cerebri and Tentorium, Left Lateral View. (Gerrish.)

Fissures and convolutions. — In early life the cortex of the cerebrum is comparatively smooth, but as time passes and the brain develops, the surface becomes covered with depressions which vary in depth. The deeper depressions are called *fissures,* the more shallow ones *sulci,* and the ridges between the sulci are called *convolutions.* The fissures and sulci are infoldings of gray matter, consequently the more numerous and deeper they are, the greater is the amount of gray matter, and the greater is the extent of surface for the termination of fibres. The number and depth of these fissures and sulci is thought to bear a close relation to intellectual power; babies and idiots have few and shallow folds, while the brains of men of intellect are always markedly convoluted. There are five important fissures which are always present. They are the following: —

(1) The *Great Longitudinal Fissure*, which extends from the back to the front of the cerebrum, and almost completely divides it into two hemispheres, the two halves, however, being connected in the centre by a broad, transverse band of white fibres called the **corpus callosum**. A process of the dura mater extends down into this fissure and separates the two cerebral hemispheres. It is called the *falx cerebri*, because it is narrow in front, and broader behind, thus resembling a sickle in shape. In a previous chapter it was stated that the blood was returned from the brain in venous channels called sinuses. Two important sinuses are lodged between the layers of the falx cerebri. The superior longitudinal sinus is contained in the upper border, and the inferior longitudinal sinus in the lower border.

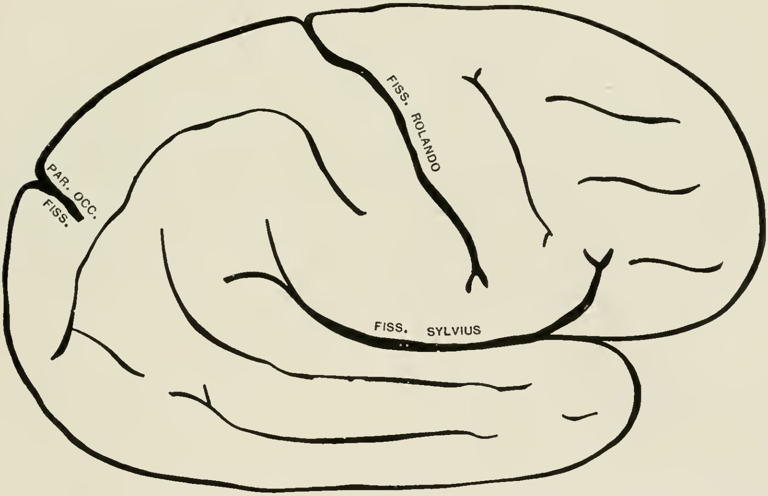

FIG. 185. — EXTERNAL VIEW OF OUTER SIDE OF RIGHT CEREBRAL HEMISPHERE, SHOWING ROLANDO, SYLVIAN, AND PARIETO-OCCIPITAL FISSURES TOGETHER WITH PRINCIPAL CONVOLUTIONS. (Collins.)

(2) The *Transverse Fissure*, which is between the cerebrum and the cerebellum. A process of the dura also extends into this fissure, and covers the upper surface of the cerebellum and the under surface of the cerebrum. It is called the *tentorium cerebelli*.

(3) Fissure of Rolando, or central fissure.
(4) Fissure of Sylvius.
(5) Parieto-occipital fissure.

There is one of each in each hemisphere. For location see Figs. 185 and 186.

Lobes of the cerebrum. — The longitudinal fissure divides the cerebrum into two hemispheres, and the transverse fissure divides the cerebrum from the cerebellum. The three remaining fissures divide each hemisphere into five lobes. With one exception these lobes were named from the bones of the cranium under which they lie; hence they are known as: —

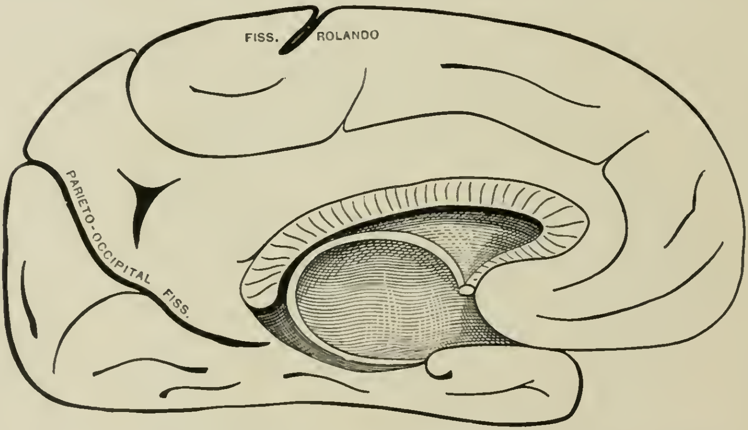

Fig. 186. — Mesial View of Left Cerebral Hemisphere, showing Rolandic and Parieto-occipital Fissures, together with the Principal Convolutions. (Collins.)

(1) Frontal lobe.
(2) Parietal lobe.
(3) Temporal lobe.
(4) Occipital lobe.
(5) Central lobe, or Island of Reil (the exception).

(1) The **frontal** lobe is that portion of the cerebrum lying in front of the fissure of Rolando, and usually consists of four main convolutions.

(2) **Parietal** lobe is bounded in front by the fissure of Rolando, and behind by the parieto-occipital fissure.

(3) **Temporal** lobe lies below the fissure of Sylvius and in front of the occipital lobe.

(4) **Occipital** lobe occupies the posterior extremity of the cerebral hemisphere. When one examines the external surface of the hemisphere, there is no marked separation of the occipital lobe from the parietal and temporal lobes that lie to the front; but when the surface of the longitudinal cleft is examined, the parieto-occipital fissure serves as a boundary anteriorly for the occipital lobe.

(5) **Central** lobe, or Island of Reil, is not seen when the surface of the hemisphere is examined, for it lies within the fissure of Sylvius, and the overlying convolutions of the parietal and frontal lobes must be lifted up before the central lobe comes into view.

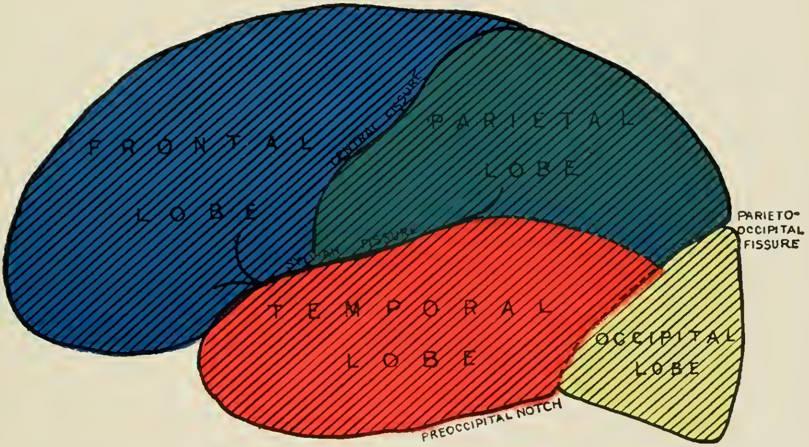

Fig. 187. — The Lobes of the Convex Surface of the Hemisphere, Left Side. (Gerrish.)

Ventricles of the brain. — In describing the spinal cord, reference was made to the **central canal**, being a minute canal running through the centre of the cord throughout its entire length, thus converting the cord into a tube with exceedingly thick walls but very small internal calibre. In the brain proper this same central channel persists, and just as the walls or solid portions of the brain are directly continuous with the wall or solid portion of the spinal cord, so is the internal hollow of the brain directly continuous with the hollow or central canal of the cord. The cavity in the brain presents some marked differences to that of the cord; while the latter is a straight, fairly uniform canal of very small diameter, the former is at some points very narrow, and at others much widened out so as to form quite good-sized chambers, and these chambers are called the **ventricles** of the brain. These ventricles are filled with cerebro-spinal fluid, just as the canal of the cord is likewise filled with the same material.

The ventricles are five in number. The most posterior is the enlargement or expansion of the central canal, occupying the substance of the medulla oblongata, and is called the "fourth ventricle." Leading forward from the anterior end of the fourth ventricle, the calibre of the canal again narrows to a very small diameter; the tube, on reaching the brain substance uniting the two halves of the cerebrum, again expands into a somewhat smaller chamber, called the "third ventricle." The small canal already mentioned as joining the third and fourth ventricles is known as the **aqueduct of Sylvius.**

Toward the forward end of the third ventricle there are noted two small channels, the **foramina of Monro**, one on either side leading in a direction forward, upward, and outward, each foramen leading into a very large ventricle occupying the centre of its corresponding cerebral hemisphere, called the **lateral ventricles.**

The fifth ventricle is very small, lies between the two lateral ventricles, and is not in communication with the other ventricles.

The student will thus see that both the brain and spinal cord are really hollow. In some portions, however (as the spinal cord), the interior cavity is so minute and the walls so exceedingly thick that the cavity is a negligible quantity, and the mass can practically be considered as solid; on the other hand, in the case of the ventricles, especially the lateral ventricles, the cavity is large enough to occupy an appreciable space, and may become overdistended with cerebro-spinal fluid in certain conditions of disease.

On the whole, the cavity of the brain and cord occupies a more or less central position, having its walls at any given point of about equal thickness; at certain points, however (the third and fourth ventricles especially), the cavity approaches so close to the surface that at these points one of its walls is thinned out to only a microscopic thickness.

Function of the cerebrum. — The nerve-centres which govern all our mental activities and the coördination of movements are centred in the cerebrum. These centres are the seat of reason, intelligence, will, memory, and all the higher emotions and feelings.

Localization of brain function. — As the result of numerous experiments on animals, and close observation of individuals suffering from cerebral diseases or wounds, physiologists have been able to localize certain areas in the brain which control motor and sensory activity. They have also been able to gain some knowledge of the areas in the cerebrum which are concerned with the higher mental activities.

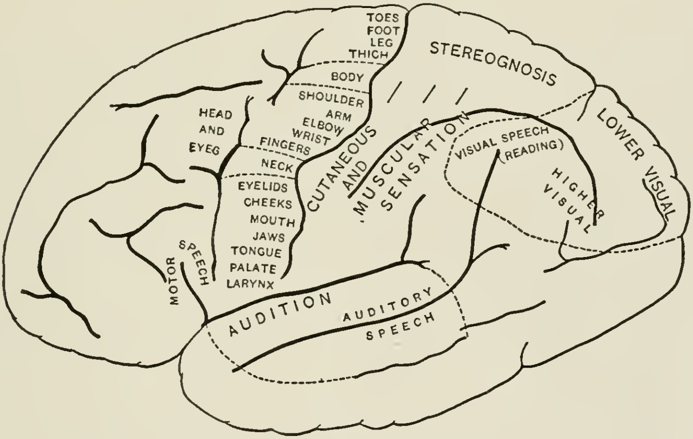

FIG. 188. — LOCALIZATION OF FUNCTION IN THE CEREBRAL CORTEX. (Woolsey's "Surgical Anatomy.")

Names of areas. — That portion of the cerebrum which governs muscular movement is known as the *motor area*, the portions controlling sensation as the *sensory areas*, and those connected with the higher faculties, such as reason and will, as *association areas*.

Motor areas. — The surface of the brain assigned to the function of motion is the posterior part of the frontal lobe, *i.e.* the gray matter immediately in front of the fissure of Rolando.

A knowledge of the motor area enables physicians and surgeons, in many cases of convulsions or paralysis, to locate the exact portion of the brain that is affected, by close observation of the part of the body involved in the convulsion or loss of function. In this connection it must be remembered that the fibres extending from the brain into the cord, and from the cord into the brain, decussate or cross in the medulla.

Sense areas. — The term "sense areas" is used to designate those parts of the brain to which sensation is due, and which control vision, hearing, smell, and taste. The visual area is situated in part of the occipital lobe; the auditory area in the superior part of the temporal lobe; and the olfactory and gustatory areas are in the anterior part of the temporal lobe.

Location of speech areas. — "The speech areas, four in number and in kind, are in the left hemisphere in right-handed persons and in the right in left-handed persons. There are two types of *aphasia*, which is the loss of the power of speech, known as motor and sensory aphasia. The motor speech centre lies in the posterior part of the third frontal convolution just in front of the centre of the muscles of speech. A lesion of the motor speech centre causes motor aphasia, in which there is a loss of the word-forming power, although the tongue is movable and the patient may understand spoken and written language and knows what he wants to say. It is as if memory of the motor combinations essential to produce speech were lost.

The power of writing is usually lost with motor speech. The probable location of its cortical centre is in the posterior two-thirds of the first, and perhaps in the second, temporal convolution. A lesion here causes ' word deafness,' a sensory aphasia in which the memory of the sounds of words is lost so that they are not understood, though hearing may be normal.

* * * * * * *

Word-blindness (*alexia*), or the loss of memory of printed or written language, is caused by a lesion in the occipital lobe, though sight itself may be normal.

"Thus the basis of language is a series of memory pictures: (1) of the sound of words; (2) of their appearance; (3) of the effort necessary to enunciate them; and (4) to write their symbols. As these memory pictures are connected with each other and with others that make up the concept by subcortical association fibres passing between them, a lesion in any of these association tracts also leads to a defect of speech." (Woolsey, "Applied Surgical Anatomy.")

Association areas. — Those parts of the cerebral cortex which are not the location of special centres are called association areas. It is here that the information received by the various sense centres is built up and coördinated into concepts or perceptions. The various parts of the association areas are connected with the sense centres by means of association fibres. The localization of function in the association areas is not yet determined.

THE CRANIAL NERVES

The cranial nerves consist of twelve pairs. They each have a superficial and a deep origin. The *superficial origin* is the point where they emerge from the under surface of the cerebrum and the medulla, but they can be traced back to various centres in the higher part of the brain, and these centres constitute their *deep origin.*

Classification. — The cranial nerves are of three varieties: (1) sensory nerves, (2) motor nerves, and (3) mixed nerves or those containing both sensory and motor fibres. Many of the cranial nerves arise from several nerve-centres, and therefore consist of several bundles of nerve-fibres. After these nerves leave the cranium they split up into branches that are widely distributed.

Numbers and names. — They are named numerically according to the order in which they arise from the brain. Other names are also given to them, derived from the parts to which they are distributed or from their functions. Taken in their order from before backward, they are as follows: —

1. Olfactory (sensory).
2. Optic (sensory).
3. Motor oculi (motor).
4. Pathetic, or trochlear (motor).
5. Trifacial, or trigeminal (mixed, but mainly sensory).
6. Abducens (motor).
7. Facial (motor).
8. Auditory (sensory).
9. Glossopharyngeal (mixed).
10. Pneumogastric, or vagus (mixed).

11. Spinal accessory (motor).
12. Hypoglossal (motor).

The following doggerel which has been handed down through countless generations of students may assist the beginner in learning the order of the cranial nerves. Each capital letter denotes a cranial nerve. On Old Manhattan's Peaked Tops A Finn And German Picked Some Hops.

(1) The **olfactory** nerve is the special nerve of the sense of smell Its origin is in the olfactory bulb, and its peripheral fibres are distributed to the upper third of the nasal cavity.

(2) The **optic** nerve is the special nerve of the sense of sight. Its cell-bodies are situated in the retinal coat of the eye.

(3) The **motor oculi** nerve supplies all the muscles of the eye except the superior oblique and the external rectus. It originates in the gray matter of the pons Varolii.

(4) The **pathetic, or trochlear,** nerve supplies only the superior oblique muscle of the eye. It arises close to the preceding nerve.

(5) The **trifacial** has two roots, — a dorsal, or sensory, and a ventral, or motor. The fibres from the two roots coalesce into one trunk, and then subdivide into three large branches: (1) the ophthalmic, (2) the superior maxillary, and (3) the inferior maxillary. The ophthalmic branch is the smallest, and is a sensory nerve. It supplies the eyeball, the lacrimal gland, the mucous lining of the eye and nose, and the skin and muscles of the eyebrow, forehead, and nose. The superior maxillary, the second division of the fifth, is also a sensory nerve, and supplies the skin of the temple and cheek, the upper teeth, and the mucous lining of the mouth and pharynx. The inferior maxillary is the largest of the three divisions of the fifth, and is both a sensory and a motor nerve. It sends branches to the temple and the external ear; to the teeth and lower jaw; to the muscles of mastication; it also supplies the tongue with a special nerve (the lingual) of the sense of taste. The cell-bodies of the motor fibres are situated in the pons; while those of the sensory fibres, as in the case of the spinal nerves, are situated in a ganglion. This ganglion is called the Gasserian ganglion.

(6) The **abducens** nerve supplies the external rectus muscle of the eye.

(7) The **facial** nerve is the motor nerve of all the muscles of expression in the face; it also supplies the neck and ear. Its

cells of origin, like those of the abducens nerve, are situated in the medulla.

(8) The **auditory** nerve is the special nerve of the sense of hearing. It arises from cells which compose the organ of Corti in the internal ear, to which its fibres are exclusively distributed.

(9) The **glossopharyngeal** nerve is distributed, as its name indicates, to the tongue and pharynx, being the nerve of sensation to the mucous membrane of the pharynx, of motion to the pharyngeal muscles, and the special nerve of taste to part of the tongue.

(10) The **pneumogastric** nerve has a more extensive distribution than any of the other cranial nerves, passing through the neck and thorax to the upper part of the abdomen. It contains both motor and sensory fibres. It supplies the organs of voice and respiration with motor and sensory filaments; and the pharynx, œsophagus, stomach, and heart with motor fibres (cardiac inhibitory).

(11) The **spinal-accessory** nerve consists of two parts: one, the spinal portion, and the other, the accessory portion to the tenth nerve. It is a motor nerve supplying certain muscles of the neck. It differs from the other cranial nerves in arising from the spinal cord, but it leaves the skull by the same aperture as the pneumogastric and glossopharyngeal.

(12) The **hypoglossal** nerve is the motor nerve of the tongue.

Reflex acts. — The student doubtless can understand from the preceding portions of this chapter the general arrangement of the nervous tissues, and how simple impulses arising in brain cells pass along nerve-fibres, and, terminating in the end organs, produce, for example, a muscular contraction (motor impulse), or how an outside stimulus applied to the skin will set up vibrations in suitable end organs to be transmitted along sensory nerve-fibres to end in sensory brain cells and produce the appreciation by the mind of the fact that the stimulus has been applied. All of these are simple, straightforward functions of the neurones. There is a host of other more complex acts in which, for example, two or more neurones take part, which carry out a train of functions, each depending on the other, and may carry out their destiny so smoothly and accurately, so that the perception of the mind or consciousness of the act be entirely wanting, thus saving the brain an enormous amount of wear and tear.

The simplest of these nervous mechanisms is the reflex arc, and the simplest form of nervous activity is "reflex action." Two neurones enter into the formation of a reflex arc, a sensory neurone and a motor neurone. On applying an appropriate stimulus to the peripheral end of the sensory neurone, an impulse is generated which passes along the sensory neurone to the nerve-centre, and back again to the periphery by the motor neurone; and, since the motor neurone terminates in a muscle (or some similar mechanism), we get a muscular response as the indirect result of stimulating the sensory nerve.

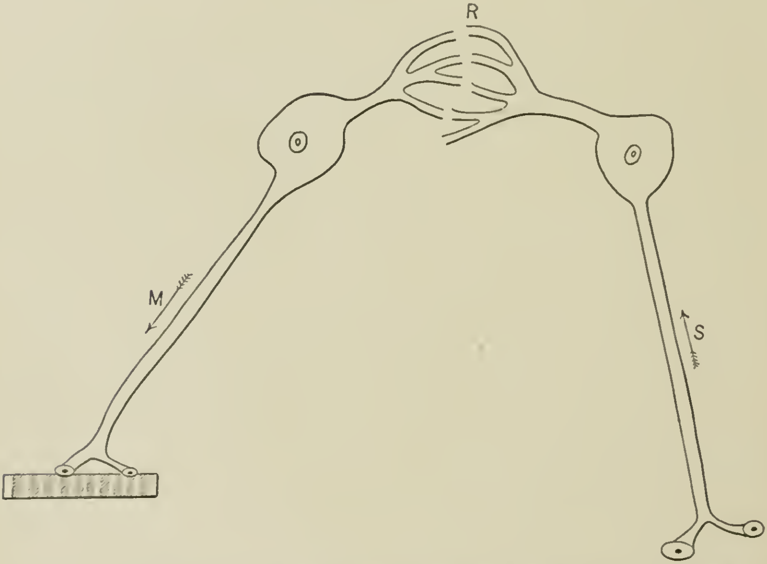

Fig. 189. — Reflex Arc. *S*, sensory neuron arising in tactile corpuscles. *M*, motor neuron ending in muscle fibres. *R*, interlacing of dendrites. (Collins.)

This is a **reflex act**, and usually the exchange between the sensory and motor impulse takes place in the spinal cord. The sensory impulse, after delivering its stimulus to the motor neurone, may continue on up the spinal cord to terminate in the brain and give to the individual the consciousness of the stimulus, or, on the other hand, the sensory impulse, after arousing the motor act, may cease, and no impulse be transmitted to the brain, the individual thus being totally oblivious to the reflex act. Even if the sensory impulse goes to the brain, the consciousness of the sensation by the individual is always later in point of time than the reflex act. For example: If, without a person's knowledge that the experiment is to be tried, one's finger be pricked with a pin, the finger is instantly pulled back and the act is done before the individual is conscious of the pain. In this experiment the sensory impulse of the pin prick passed to the spinal cord, set up the motor action necessary to withdraw the finger, and then passed on to the brain. Again, many sensory impulses produce their reflex without the brain bothering about the matter at all. An example of this is the act of walking. Walking is an exceedingly difficult accomplishment to learn, acquired in childhood only after laborious effort, not because the muscles are weak, but because the human individual, when erect, is in an exceedingly unstable state of equilibrium, and constant contraction and relaxation of groups of muscles is necessary to maintain the balance. Here the sensory impulses of being out of balance arouse motor impulses in first one set of muscles, then another, to restore the balance. At first this is only accomplished with mental appreciation of the performance; later on one learns the trick, and the act of walking or standing upright is performed without a moment's thought or even consciousness of the difficult task we are doing purely by reflex activity.

The **kind of stimulus** which will call forth the nerve-impulse **depends on the peripheral termination of the afferent nerve**, and the **kind of response** which an appropriate stimulus will call forth **depends on the mode of termination of the efferent nerve.** Thus, light falling on the retinal coat of the eye (the peripheral termination of the sensory nerve) generates an impulse which passes to the centre by the optic nerve, and returns again by the motor oculi nerve to the periphery; viz. the sphincter of the iris (the termination of the motor nerve), which by its contraction narrows the pupil. Hence arises the well-known phenomenon of the contraction of the pupil when light falls upon the eye.

Also stimulation of taste fibres in the mouth causes a reflex secretion of the salivary glands. Innumerable examples of this kind might be given. Indeed, since physical life has been well-defined as the continual response to external stimuli, reflex action, which is the chief method of response, is the most important vital phenomenon peculiar to animals possessing any nervous system whatsoever.

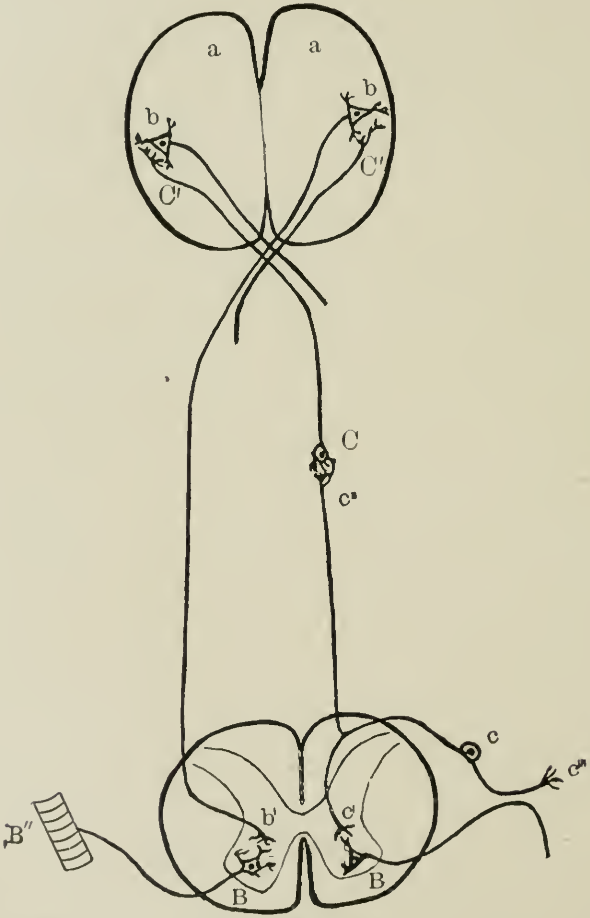

Fig. 190. — Diagram of Nervous System. *a*, *a*, cortex of cerebral hemispheres; *b*, *b*, cell-body and dendrites of upper motor neurone, situated in cerebral cortex; *b′*, axis cylinder of upper motor neurone, branching at its termination near the dendrites of lower motor neurone, situated in the ventral horn of gray matter in the spinal cord; *B*, axis cylinder of lower motor neurone passing to its termination in a voluntary muscle fibre *B″*; *C*, cell-body and dendrites of upper sensory neurone, situated in the medulla oblongata; *C′*, *C′*, axis cylinders of upper sensory neurone, terminating in cortex; *c*, cell-body of lower sensory neurone, situated in the dorsal root ganglion; *c‴*, dendrite of lower motor neurone, conducting impulses from the periphery to the central nervous system; *c″*, long branch of lower sensory neurone, conducting impulses toward the brain; *c′*, short branch of lower sensory neurone, conducting impulses direct to ventral horn. (For the sake of simplicity the connections with the cerebellum are omitted.)

A careful study of Figs. 189 and 190 will make the typical reflex path perfectly intelligible to the student, and should on no account be omitted.

All nervous action is fundamentally similar to this typical reflex action. Usually the number of neurones involved is greater, often very much greater, than two. The fewer the neurones, the simpler and more obviously machine-like the reaction. The more complex the path, the more uncertain and variable the reaction. When the path of the impulse does not involve the cerebrum, the reactions are unconscious and comparatively simple; but if the cerebral cortex be involved, the passage of the nerve-impulse is accompanied by the phenomenon of consciousness, and the reaction may be exceedingly complex, uncertain, and long delayed. These are the characteristics of what we call voluntary reactions. But, although the phrase "reflex action" is usually confined to those actions which are involuntary and of which we are unconscious, yet all nervous action is essentially the same, differing only in the complexity of the path followed by the impulse.

SUMMARY

- **Nervous System**
  - **Parts of Nervous System**
    - Brain.
    - Spinal cord.
    - Sympathetic ganglia.
    - Nerve-trunks.
    - Organules.
  - **Functions**
    - Makes possible mental activities.
    - Recognition of surroundings and accommodation to same.
    - Motion and sensation.
    - Equilibrium and coördination.
  - **Divisions**
    - Central nervous system
      - Brain.
      - Spinal cord.
      - Nerves
        - Cerebro-spinal.
        - Cranial nerves.
        - Spinal nerves.
    - Sympathetic system
      - 1. Vertebral ganglia.
      - 2. Collateral ganglia.
      - 3. Terminal ganglia and plexuses.
      - 4. Sympathetic ganglia in the brain and cord.

- **Property of nerve-tissue**
  - Irritability or the power to respond to stimulation.
  - Conductivity or the power to transmit stimuli.
- **Neurone or Nerve-cell**
  - **Cell-body**
  - **Cell-processes**
    - Dendrites.
    - Axis cylinder process.
    - Nerve-fibres.
    - Collaterals.
    - Nerve-endings.
- **Cell-body**
  - **Varieties**
    - Unipolar.
    - Bipolar.
    - Multipolar.
  - **Function**
    - Nutrition.
    - Gives rise to nervous impulses.
    - Modifies impulses
      - Inhibition.
      - Summation.
- **Dendrites**
  - Short, break up into many branches.
  - Rough outline — diminish in calibre.
  - May be one, or many.
  - **Function** — Collect and carry impulses to cell-body.

Synapse — Arborization of contiguous processes, *not* an anatomical continuation.

- **Axis Cylinder Process**
  - Long, smooth outline, diminishes very little.
  - Gives off collaterals.
  - Continued as core of nerve-fibre.
  - **Function** — Carry impulses from cell-body.
- **Nerve-fibre**
  - Medullated
    - Axis cylinder process.
    - Medullary sheath-function
      - Protection.
      - Non-conduction.
    - Neurilemma.
  - Non-medullated
    - Axis cylinder process.
    - Neurilemma.
- **Nodes of Ranvier**
  - Ring-like constrictions in medullated fibres, due to absence of medullary sheath.
  - **Function** — Render easier the passage of blood-plasma to fibre.

Collaterals — Minute side branches given off from axis cylinder processes, usually at nodes of Ranvier.

Nerve-endings

1. End arborizations — terminations in brain or cord.
2. Inter-epithelial arborizations, Organules — terminations of sensory fibres at the periphery of the body.
    - Inter-epithelial arborizations
    - Organules
3. Motor plates — terminations of motor nerve-fibres in voluntary muscle.
4. Plexus — terminations of motor nerve-fibres in involuntary muscle.

Nerve-impulse

- Nature not positively known.
- Presumably a physical molecular vibration.

Classification of Nerve-fibres

- **Efferent**
    - Excitatory
        - Motor
            - Motor.
            - Vasomotor.
            - Cardiomotor.
            - Visceromotor.
            - Pilomotor.
        - Secretory
            - Salivary.
            - Gastric.
            - Pancreatic.
            - Sweat.
    - Inhibitory
        - Inhibito-motor
            - Subdivisions corresponding to the varieties of motor fibres above.
        - Inhibito-secretory
            - Subdivisions corresponding to the varieties of secretory fibres above.
- **Afferent**
    - Excitatory
        - Sensory
            - Visual.
            - Auditory.
            - Olfactory.
            - Gustatory.
            - Pressure.
            - Temperature.
            - Pain.
            - Hunger.
            - Thirst, etc.
        - Reflex
            - According to the efferent fibres affected.
    - Inhibitory
        - Inhibito-reflex
            - Inhibitory effects upon the conscious sensations are not demonstrated.
            - The reflex fibres that cause unconscious reflexes are known to be inhibited in some cases at least.

- **Speed of Nerve-impulse**
  - Afferent fibre — 140 ft. per second.
  - Efferent fibre — 110 ft. per second.
  - Light — 186,000 miles per second.
  - Sound — 1100 feet per second.
- **Varieties of Nerve Tissue**
  - **Gray matter**
    - Consists of
      - Cell-bodies.
      - Dendrites.
      - Commencement of axones.
      - Collaterals.
    - Found in
      - Brain.
      - Spinal cord.
      - Ganglia.
  - **White matter**
    - Consists of medullated nerves.
    - Found in
      - Brain.
      - Spinal cord.
      - Ganglia.
      - Nerve-trunks.
  - **Neuroglia** — Special tissue found in brain and spinal cord — function — support.
- **Nerve-trunks**
  - Consist of
    - Bundles of nerve-fibres bound together to make funiculi.
    - Funiculi bound together to make nerve-trunks.
    - Connective tissue surrounds funiculi and nerve-trunks.
  - Function is connection of
    - 1. Different parts of nervous system.
    - 2. Nerve-centres and the viscera.
    - 3. Nerve-centres and the periphery.
    - 4. Viscera and the surface of the body.
- **Nerve-centres**
  - Groups of nerve-cells exercising control over some definite function.
  - Location
    - Brain.
    - Spinal cord.
- **Vertebral Ganglia**
  - **Ganglia** — Collection of nerve-cells.
  - **Number**
    - Twenty-four on either side of spinal column.
    - One in front of coccyx.
  - **Connected**
    - 1. With each other by ganglia cords.
    - 2. With spinal nerves by rami communicantes.
    - 3. With viscera
      - *a.* Pass directly to viscera.
      - *b.* Converge to form
        - Great splanchnic.
        - Small splanchnic.
        - Least splanchnic.
      - *c.* Join collaterals and plexuses.
      - *d.* Join spinal nerves.

- **Collateral Ganglia**
  - Located principally in thoracic and abdominal cavities.
  - **Connected**
    - With spinal nerves.
    - With vertebral ganglia.
    - With viscera.
  - **Form**
    - Cardiac plexus.
    - Solar plexus.
    - Hypogastric or pelvic plexus.
- **Terminal Ganglia**
  - Located on walls of organs themselves.
  - Connected with collateral ganglia.

Sympathetic Ganglia are found in the medulla, spinal canal, and in connection with some of the cranial nerves.

- **Distribution of Sympathetic Nerves**
  - To the heart.
  - To the involuntary muscles of the blood-vessels, lymphatics, and viscera.
  - To the secretory glands.
  - To some of the special senses.
- **Spinal Cord**
  - Located in spinal canal.
  - Extends from foramen magnum to second lumbar vertebra, 16–17 in. long.
  - **Meninges**
    - Dura mater (outer).
    - Arachnoid (middle).
    - Pia mater (inner).
  - Consists of
    - Gray matter in form of butterfly.
    - White matter in columns
      - Sensory.
      - Motor.
      - Mixed.
  - **Fissures**
    - Anterior divides front portion in lateral halves.
    - Posterior — divides back portion in lateral halves.
  - **Isthmus** — connects lateral halves.
  - **Canal** — centre of isthmus.
  - **Functions**
    1. Conduction.
    2. Reflex action.
    3. Automatism.
    4. Inhibition.
    5. Transference.

- **Spinal Nerves**
  - **Number**
    - Cervical . . . . 8 pairs.
    - Thoracic . . . . 12 pairs.
    - Lumbar . . . . 5 pairs.
    - Sacral . . . . 5 pairs.
    - Coccygeal . . . . 1 pair.
    - 31 pairs.
  - **Variety**
    - Medullated.
    - Mixed
      - Sensory.
      - Motor.
  - **Origin** — two roots
    - Anterior in gray matter of cord.
    - Posterior in spinal ganglia.
  - **Distribution** — two trunks
    - Anterior, supplies extremities, and parts of body in front of spine.
    - Posterior, supplies muscles and skin of back of head, neck, and trunk.
- **BRAIN**
  - Located in cranial cavity.
  - Covered by meninges — same as spinal cord.
  - Weight
    - Male — 49½ oz. average.
    - Female — 44 oz. average.
  - **Divisions**
    - **Medulla**
      - **Description**
        - Oblong-shaped mass, upward continuation of cord.
        - Gray matter in interior.
        - White matter on exterior.
      - **Function**
        - Respiratory centres.
        - Accelerator centre for heart.
        - Vasomotor centres.
    - **Cerebellum**
      - **Description**
        - Flat oblong-shaped mass, overhangs medulla.
        - 3–4½ in. transversely.
        - 2–2½ from before backward.
        - Gray matter on exterior.
        - White matter in interior.
      - **Function**
        - Coördination.
        - Maintenance of equilibrium.
    - **Pons Varolii**
      - **Description**
        - A bridge of nerve-fibres connecting two halves of cerebellum and also medulla with cerebrum.
      - **Function**
        - Connect two halves of cerebellum.
        - Connect medulla and cerebrum.
    - **Cerebrum** 2 **hemispheres**
      - **Description**
        - Egg-shaped or ovoidal.
        - Fills upper portion of skull.
        - Gray matter on outside
          - Fissures.
          - Sulci.
          - Convolutions.

- BRAIN
  - **Divisions**
    - **Cerebrum 2 hemispheres**
      - **Description**
        - White matter on inside.
        - **Fissures**
          - Great longitudinal fissure.
          - Transverse fissure.
          - Rolandic.
          - Sylvian.
          - Parieto-occipital.
        - **Lobes**
          - Frontal.
          - Parietal.
          - Occipital.
          - Temporal.
          - Central.
        - **Ventricles**
          - Fourth ventricle.
          - Third ventricle.
          - 2 lateral ventricles.
          - Fifth ventricle.
      - **Functions**
        - Motion.
        - Sensation.
        - Speech.
        - Hearing.
        - Memory and higher functions.

- **Names of Areas**
  - **Motor area** — in front of Fissure of Rolando.
  - **Sense areas**
    - Visual — occipital lobe.
    - Auditory — superior part of the temporal lobe.
    - Olfactory, Gustatory — anterior part of temporal lobe.
  - **Association areas** — parts of the cerebral cortex which are not the location of special centres.

- **Cranial Nerves**
  - I. Olfactory.
  - II. Optic.
  - III. Motor oculi.
  - IV. Pathetic.
  - V. Trifacial.
  - VI. Abducens.
  - VII. Facial.
  - VIII. Auditory.
  - IX. Glossopharyngeal.
  - X. Pneumogastric.
  - XI. Spinal accessory.
  - XII. Hypoglossal.

Reflex Act — Involuntary activity that is the result of stimulation by motor nerve-fibres. Impulses are transferred from sensory fibres and activate the motor fibres.

CHAPTER XX

INTERNAL AND EXTERNAL SENSES: TASTE, SMELL, HEARING, AND SIGHT

Definition of sensation. — Sensation is defined as perception through the sense organs, and is the result of stimulation of these organs.

Organs necessary for sensation. — A peripheral organ for the reception of a stimulus, a nerve for its conduction, and a centre in the brain for the perception and interpretation are the three essential parts of a sense organ. It is by means of impressions received by the peripheral organs and conducted by the nerves to the brain that the mind is able to control the body and to take cognizance of the external world.

Where sensations are interpreted. — Sensations are felt and interpreted in the brain. Our habit of projecting sensations to the part that is stimulated, tends to obscure this fact. In reality we see and hear with our brains, because the eye and ear serve only as end organs to receive the stimulus which must be carried to the brain and interpreted before we do see or hear.

CLASSIFICATION OF SENSATIONS

Sensations were formerly classified into two groups, *i.e.* special and common. The special senses were sight, hearing, touch, taste, and smell. All other sensations were grouped as common. A more recent classification is dependent on the part of the body to which the sensation is projected, and the two groups are named: (1) internal or interior senses, and (2) external or exterior senses. These classifications have much in common, but differ slightly.

Internal or interior senses are those in which the sensations are projected to the interior of the body. It is by means of these senses that we acquire a knowledge of the condition of our body. They include hunger, thirst, pain, muscular sense, fatigue, and various obscure sensations which proceed from the viscera and give us the feeling of well-being or the reverse, also the desire for defecation or urination.

External or exterior senses are those in which the sensations are projected to the exterior of the body. They form the means by which we become acquainted with the outside world. They include pressure and temperature sense, taste, smell, hearing, and sight. Even this classification is not absolutely distinctive, as some sensations may be projected either to the interior or exterior of the body. Temperature and pain are examples of this class.

Hunger. — Hunger occurs normally at a certain time after meals and is usually projected to the region of the stomach. It is presumably due to contractions of the empty stomach, which stimulate the nerves distributed to the mucous membrane. In abnormal conditions the stomach need not be empty, for it must be remembered that physiologically food is not considered as being inside the body until it has been digested and absorbed. Thus a diabetic may feel very hungry, although he has within a short time partaken of a huge meal.

Thirst. — This sensation is projected to the pharynx. We know very little about the nervous mechanism involved, but it is thought that when the water content in the tissues falls below a certain amount the sensory nerve fibres in the pharynx are stimulated and produce the sensation of thirst. The sense of thirst is more imperative than that of hunger; a person can live several days without food, provided he has water, but if this latter is denied, he will soon die of exhaustion.

Pain. — The sensation of pain is thought by some authorities to be due to stimulation of special nerves that give rise to the sense of pain.

Other authorities question the existence of special nerves for this sense, and think it is due to overstimulation of any of the sensory nerves. For instance, extreme pressure or extremes of temperature cause overstimulation of the nerves of pressure or temperature, and the result is painful.

Muscular sense. — The end organs of the muscular sense are situated in the tendons and between the fibres of the muscles. They convey to us the sense of resistance in the muscles when we attempt to lift anything. This is the muscular sense.

Through it precision of effort is rendered possible; for by it we learn to adjust the force exerted to the weight of the object to be lifted. Thus the function of muscular sense is to enable us to estimate weight or resistance. It also aids in preserving equilibrium and in coördinating muscular action.

Fatigue. — Prolonged or extreme muscular exercise results in the loss of nutrient material and the accumulation of waste products in the muscles. These chemical changes alter the stimulation of the nerves connected with muscular sense, and the sensation of fatigue results.

Visceral sensations. — Sensations which give rise to the feeling of well-being or the reverse, also to the acts of vomiting, coughing, defecation, or urination, are caused by stimulation of the sensory nerves contained in the part of the body immediately concerned in the state or act in question.

The sense of pressure or touch. — The nerves connected with the sense of pressure or touch are distributed over the entire surface of the body, being more or less numerous in all parts of the true skin and the adjoining mucous membrane. They end in two ways: (1) in a ring surrounding a hair follicle, so that pressure exerted upon the hair stimulates these end organs, and (2) in parts of the body where there are no hair follicles, in the tactile or Meissner corpuscles, which are also stimulated by pressure. The distribution of these nerves is not uniform. They are abundant and the pressure points are very close together on the lips and the tip of the tongue, also in parts of the hands and feet in which a delicate sense of pressure is present.

The temperature sense. — In addition to the end organs of the sense of touch, there are also structures in the skin which are only stimulated by changes in temperature. These structures are of two kinds: hot and cold spots, stimulation of one causing the feeling of heat; stimulation of the other, the feeling of cold.

In addition to heat and cold these end organs are stimulated by other substances, *i.e.* menthol stimulates the cold spots and gives rise to a sensation of cold, carbon dioxide stimulates the warm spots and gives rise to a sensation of heat, while certain mechanical and electrical stimuli will cause a sensation of cold on a cold spot and of heat upon a warm spot.

The hot and cold spots and the pressure points can be located by passing a metallic point slowly over the skin. At certain points a feeling of contact or pressure will be experienced, and at other points a feeling of cold or heat, depending on whether the temperature of the instrument is higher or lower than that of the skin.

TASTE

Necessary conditions. — Aside from the conditions which are always necessary for sense-perception, — viz. proper organs for receiving, communicating, and perceiving the sensory impulse, — there must be present a sapid substance which must be in solution. The solution in the case of dry substances is effected by saliva. It is also necessary that the surface of the organs of taste shall be moist. The substances which excite the special sensation of "taste" act by producing a change in the terminal filaments of the gustatory nerve (branch of the glossopharyngeal) and this change furnishes to it the required stimulant.

Organs of taste. — The special organs of the sense of taste are end organs of nerve filaments which are derived from the seventh and ninth cranial nerves. These end organs are called *taste buds* and are situated chiefly on the surface of the tongue, though there are some of these organs scattered over the soft palate, fauces, tonsils, and pharynx.

The tongue. — The tongue is a freely movable muscular organ consisting of two distinct halves united in the centre. The base or root of the tongue is directed backward and is attached to the hyoid bone by numerous muscles. It is connected with the epiglottis by three folds of mucous membrane, and with the soft palate by means of the anterior pillars of the fauces.

Papillæ of the tongue. — The tongue is covered and lined with mucous membrane. The mucous membrane on the under surface is similar to that lining the rest of the mouth, but the mucous membrane on the upper surface is studded with papillæ which project as minute prominences and give the tongue its characteristic rough appearance. Of these papillæ there are three varieties: —

(1) Circumvallate (walled in) papillæ are the largest, are circular in shape, and form a V-shaped row near the root of the tongue, with its open angle turned toward the lips. They serve to secrete mucus and contain *taste buds* in which the filaments of the glossopharyngeal nerve terminate.

(2) Fungiform papillæ are the next in size, and are so named because they resemble fungi in shape. They are found principally on the tip and sides of the tongue. Each fungiform papillæ contains a loop of capillaries and a nerve-fibre derived from the glossopharyngeal nerve.

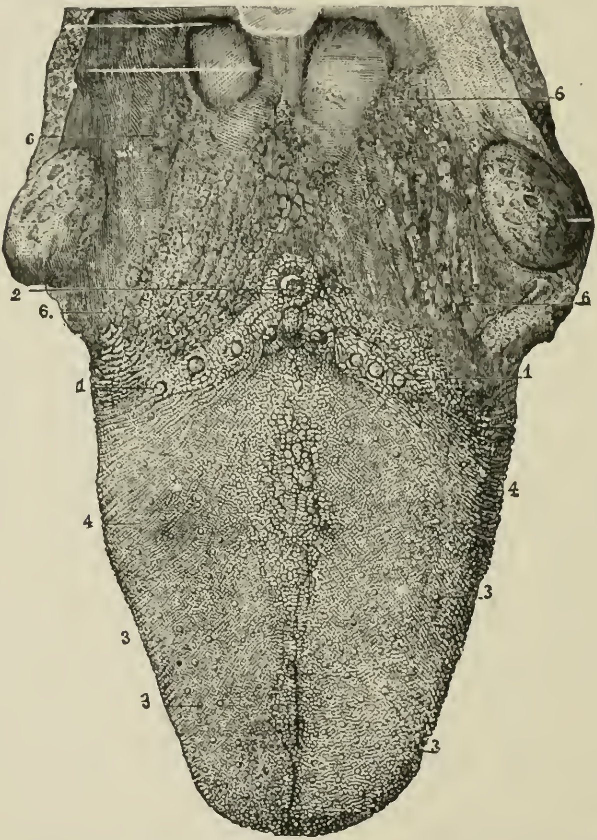

Fig. 191. — The Upper Surface of the Tongue. 1, 2, circumvallate papillæ; 3, fungiform papillæ; 4, filiform papillæ; 6, mucous glands. (Sappey.)

(3) Filiform papillæ are the smallest and most numerous. They are found all over the tongue, except at the root, and bear on their free surface delicate hair-like processes which seem to be specially connected with the sense of touch, which is very highly developed on the tip of the tongue.

Nerve supply of the tongue. — The nerve-fibres which terminate in the taste buds are: (1) filaments of the lingual nerve, which is a branch of the fifth or trifacial, (2) filaments of the chorda tympani, a branch of the seventh or facial, and (3) filaments of the ninth or glossopharyngeal nerve.[1] The twelfth or hypoglossal nerve is distributed to the tongue, but is a motor nerve and is not concerned in the sense of taste or touch.

Other sensations in the tongue. — The sense of touch is very highly developed here, and with it the sense of temperature, pain, etc.; upon these tactile and muscular senses to a great extent depend the accuracy of the tongue in many of its important uses — speech, mastication, deglutition, sucking.

We often confound taste with smell. Substances which have a strong odor, such as onions, are smelled as we hold them in our mouths; and if our sense of smell is temporarily suspended, as it sometimes is by a bad cold in the head, we may eat garlic and onions and not taste them. Hence the philosophy of holding the nose when we wish to swallow a nauseous dose.

SMELL

Necessary conditions. — The first essentials are a special nerve and nerve-centre, the changes in whose condition are perceived as sensations of odor. No other nerve structure is capable of such sensations, even when acted on by the same cause. The special organs for this sense must be in their normal condition, and a stimulus (odor) must be present to excite them.

Odors are caused either by minute particles of solid matter or by gases which are in the atmosphere, and they must be capable of solution in the mucus of the **pituitary** membrane. Odorous particles in the air, passing through the lower, wider air passages, pass by diffusion into the higher, narrower, nasal chambers, and falling on the membrane which is provided with olfactory nerve-endings, produce sensory impulses, which, ascending to the brain, give rise to the sensation of smell.

If we wish to smell anything particularly well, we sniff the air up into the higher nasal chambers, and thus bring the odorous particles more closely into contact with the olfactory nerves.

Each substance we smell causes its own particular sensation, and we are not only able to recognize a multitude of distinct

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[1] This is the generally accepted view, but other statements may be found in the various text-books.

odors, but also to distinguish individual odors in a mixed smell. The sensation takes some time to develop after the contact of the odorous stimulus, and may last a long time. When the stimulus is repeated, the sensation very soon dies out, the sensory terminal organs quickly becoming exhausted.[1]

Olfactory nerves. — The olfactory nerves are the special nerves of the sense of smell, and are spread out in a fine network over the surface of the superior turbinated processes of the ethmoid bone and on the upper third of the septum. The nerves end in special organs known as olfactory cells, which lie under the epithelium, but send prolongations between the mucous cells to the surface. The central portions of the olfactory cells are prolonged as nerve-fibres into a mass of gray matter, called the **olfactory bulb**, which rests upon the cribriform plate of the ethmoid bone.

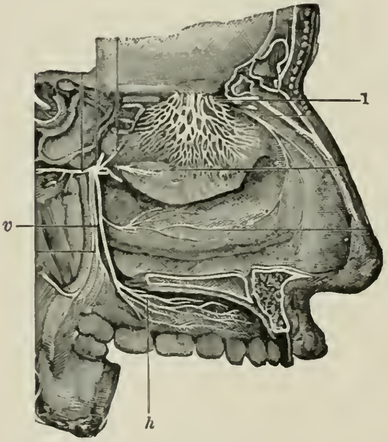

FIG. 192. — VERTICAL LONGITUDINAL SECTION OF NASAL CAVITY. 1, olfactory nerve; *v*, branch of fifth nerve; *h*, hard palate.

The nerves which ramify over the lower part of the lining membrane of the nasal cavity are branches of the fifth or trigeminal nerve. These nerves furnish the tactile sense and enable us to perceive, by the nose, the sensations of cold, heat, tickling, pain, and tension or pressure. It is this nerve which is affected when strong irritants, such as ammonia or pepper, are appreciated by the nose.

HEARING

The auditory apparatus consists of : (1) the external ear; (2) the middle ear; (3) the internal ear; and (4) the auditory nerve.

External ear. — The external ear consists of an expanded portion named **pinna**, or **auricle**, and the **auditory canal**, or **meatus.**

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[1] This accounts for the fact that one may easily become accustomed to foul odors, and is of special importance to nurses. Foul odors are quickly noticed by any one coming into a sick room from out of doors, but a nurse who is in the sick room constantly may become accustomed to such odors. Hence the importance of acting on the first sensation of a disagreeable odor.

The **auricle**, except the lower portion, consists of a framework of cartilage, containing some fatty tissue and a few muscles. In the lower portion, which is called the lobe, the cartilage is replaced by connective tissue. The auricle is covered with skin, and joined to the surrounding parts by ligaments and a few muscular fibres. It is very irregular in shape, and appears to be an unnecessary appendage to the organ of hearing, except that the central depression, the concha, serves to some extent to collect sound-waves, and to conduct them into the auditory canal.

The **auditory canal** is a tubular passage, about an inch (25 mm.) in length, leading from the concha to the drum-membrane. The exterior portion of the wall of the auditory canal consists of cartilage, which is continuous with that of the auricle; the posterior portion is hollowed out of the temporal bone. This canal is slightly curved upon itself so as to be higher in the middle than at either end, and its direction is forward and inward. Lifting the auricle upward and backward tends to straighten the canal; except in the case of children it is best straightened by drawing the auricle

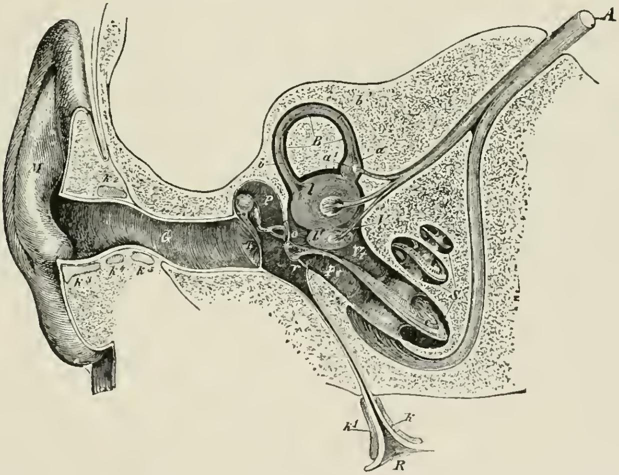

FIG. 193. — SEMI-DIAGRAMMATIC SECTION THROUGH THE RIGHT EAR. *M*, concha; *G*, the external auditory canal; *T*, tympanic, or drum-membrane; *P*, tympanum, or middle ear; *o*, oval window; *r*, round window. Extending from *T* to *o* is seen the chain of the tympanic bones; *R*, Eustachian tube; *V*, *B*, *S*, bony labyrinth; *V*, vestibule; *B*, semicircular canal; *S*, cochlea; *b*, *l*, *v*, membranous labyrinth in semicircular canal and in vestibule. *A*, auditory nerve dividing into branches for vestibule, semicircular canal, and cochlea.

downward and backward. It is lined by a prolongation of the skin, which in the outer half of the canal is very thick and not at all sensitive, and in the inner half is thin and highly sensitive. Near the orifice the skin is furnished with a few hairs, and farther inward with modified sweat-glands, the ceruminous glands, which secrete a yellow, pasty substance resembling wax. This wax is thought to be offensive to insects, and consequently a defence against their intrusion.

Middle ear. — The middle ear, or tympanum, is a small, irregular bony cavity, situated in the petrous portion of the temporal bone, and lined with mucous membrane. It is separated from the external auditory canal by the drum-membrane (**membrana tympani**), and from the internal ear by a very thin, bony wall in which there are two small openings covered with membrane — the oval window, or **fenestra ovalis**, and the round window, or **fenestra rotunda**. The cavity of the middle ear is so small that probably five or six drops of water would completely fill it. It communicates below with the pharynx by the small passage called the Eustachian tube.[1]

The function of this tube is to ventilate this cavity and keep the atmospheric pressure equal on each side of the drum-membrane. The middle ear also communicates above with a number of bony cavities in the mastoid portion of the temporal bone. These cavities, called **mastoid cells**, are lined with mucous membrane. which is continuous with that covering the cavity of the tympanum.

Membrana tympani (membrane of the drum). — It is a tough, fibrous membrane set in the bony opening of the external auditory canal. The degree of tension of the membrane is regulated by the tensor tympani muscle. This muscle is lodged in a bony canal that is above and parallel with the Eustachian tube.

Ossicles. — Stretching across the tympanic cavity is a chain of tiny, movable bones, three in number, and named from their shape the **malleus**, or hammer, the **incus**, or anvil, and the **stapes**, or stirrup. The handle of the hammer is attached to the drum-membrane, and the opposite end or head of the hammer is at-

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[1] This direct connection between the ear and the pharynx is one of the important reasons for the frequent cleansing of the mouth necessary in infectious and contagious diseases. The Eustachian tube forms a passageway for germs to travel from the mouth to the middle ear and there cause various infections.

tached to the base of the anvil. The long process of the anvil is attached to the stapes, and the footpiece of the stapes is attached to the fibrous membrane that is stretched across the oval window. These little bones are held in position, attached to the drum-membrane, to each other, and to the membrane of the oval window by minute ligaments and muscles. They are set in motion with every movement of the drum-membrane. Vibrations of the membrane are communicated to the hammer, taken up by the anvil, and transmitted to the stirrup, which rocks in the fenestra ovalis, and is therefore capable of transmitting to the fluid in the cavity of the labyrinth the impulses which it receives.

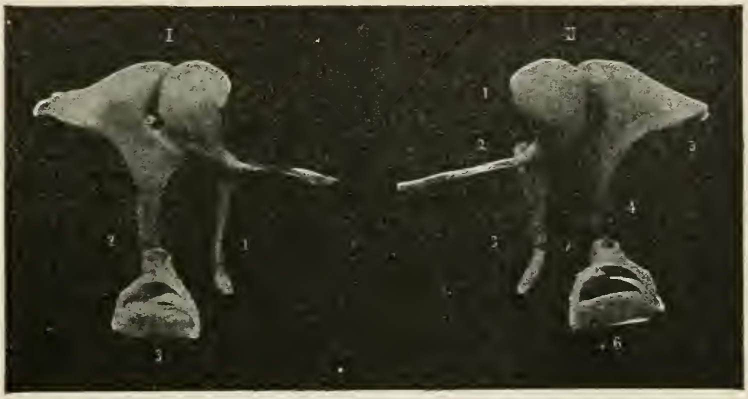

FIG. 194. — OSSICLES OF THE TYMPANUM, × 4. I, ossicles of the left ear; 1, malleus; 2, incus; 3, stapes. II, ossicles of the right ear; 1, malleus; 2, long process; 3, handle; 4, long process of the incus; 5, short process of the incus; 6, stapes. (Flint.)

Internal ear. — The **internal ear**, or **labyrinth**, receives the ultimate terminations of the auditory nerve, and is, therefore, the essential part of the organ of hearing. It consists of a **bony labyrinth**, which is composed of a series of peculiarly shaped cavities, hollowed out of the petrous portion of the temporal bone, and named from their shape: —

(*a*) The vestibule.
(*b*) The semicircular canals.
(*c*) The cochlea (snail-shell).

Within the bony labyrinth is a **membranous labyrinth**, which is composed of a series of sacs, or tubes, fitting more or less closely within the vestibule, semicircular canals, and cochlea. In some places it is attached to the bone by bands of fibrous tissue. The cavity within the membrane is filled with a fluid called **endolymph**, and the space between the membrane and the bone is filled with **perilymph**.

The vestibule is the central cavity situated between the cochlea in front and the semicircular canals behind. It communicates with the middle ear by means of the oval window in its outer wall. The vestibular membrane is constricted in the centre so that it consists of two small sacs, called respectively the **saccule** and the **utricle**. The saccule is in front and nearer the cochlea, and the utricle is back and nearer the semicircular canals. These sacs are connected by a tube called the endolymph duct, which is shaped like an inverted Y (⅄). The walls of these sacs contain numerous columnar cells provided with stiff hairs which project into the endolymph. These cells are in relation with fibres of the vestibular branch of the auditory nerve and serve as end organs. Among these hair-cells rest several small crystals of calcium carbonate which are called **otoliths**.

Fig. 195. — The Left Bony Labyrinth of a New-born Child, Forward and Outward View, × 4. From a photograph, and slightly reduced.

1, the wide canal, the beginning of the spiral canal of the cochlea; 2, the fenestra rotunda; 3, the second turn of the cochlea; 4, the final half-turn of the cochlea; 5, the border of the bony wall of the vestibule, situated between the cochlea and the semicircular canals; 6, the superior, or sagittal semicircular canal; 7, the portion of the semicircular canal bent outward; 8, the posterior, or transverse semicircular canal; 9, the portion of the posterior connected with the superior semicircular canal; 10, point of junction of the superior and the posterior semicircular canals; 11, the ampulla ossea externa; 12, the horizontal, or external semicircular canal. (Flint.)

The **cochlea** opens from the front end of the vestibule and saccule. It resembles a snail shell and consists of a spiral tube of two and one-half turns around a central pillar called the **modiolus.**

Projecting from the modiolus is a thin lamina or plate of bone. At its outer margin this lamina connects with a membrane which extends to the outer wall of the cochlea. This lamina and membrane divide the spiral canal into two passages or scalæ. The lower portion of this membrane is called the **basilar membrane**, and consists of a network of fibres which forms the foundation for thousands of cells which serve as the end organs of the auditory nerve. These end organs constitute a structure that is known as the **organ of Corti**. They receive nerve-fibres which arise in the ganglia contained in the cavity of the modiolus. Both the modiolus and lamina are pierced by numerous openings for the passage of these nerves.

The **semicircular canals** are three bony canals lying above and behind the vestibule, and communicating with it by five openings, in one of which two tubes join. They are known as the **posterior**, **vertical**, and **horizontal** canals, and their position is such that each one is at right angles to the other two. One end of each tube is enlarged and forms what is known as the ampulla. The membrane of the ampulla is covered with cells that are similar to those found in the utricle and saccule. These hair-cells serve as end organs for the vestibular branch of the auditory nerve.

The auditory nerve. — The eighth or auditory nerve is a sensory nerve and contains two distinct sets of fibres, which differ in their function, origin, and destination. One set of fibres is known as the cochlear division and the other as the vestibular.

The fibres of the **cochlear nerve** arise from bipolar cells that are situated in the modiolus of the cochlea. One axis cylinder from each cell passes through the foramina of the modiolus or lamina, and terminates in and around the cells that constitute the organ of Corti. The other axis cylinder passes through the internal auditory meatus to a portion of the brain, called the cochlear root of the auditory nerve. This root is located at the lower edge of the pons Varolii. The nerve-fibres which pass from the ear to the pons or from the pons to the ear are not continuous strands, as there are several relays of ganglia in which the axones of one cell interlock with the dendrites of another cell.

The fibres of the **vestibular nerve** have their origin in the gray matter of the pons Varolii. Some of these fibres extend to the cerebellum and to motor centres of the spinal nerves. Other fibres extend to the vestibule and are distributed around the hair-cells of the saccule, utricle, and the ampulla of the semicircular canals.

Physiology of hearing. — All bodies which produce sound are in a state of vibration, and communicate their vibrations to the air with which they are in contact.

When these air-waves, set in motion by sonorous bodies, enter the external auditory canal, they set the drum-membrane vibrating, stretched membranes taking up vibrations from the air with great readiness. These vibrations are communicated to the chain of tiny bones stretched across the middle ear, and their oscillations cause the membrane leading into the internal ear to be alternatively pushed in and drawn out, and vibrations are in this way transmitted to the perilymph. The movements of the perilymph are transmitted to the basilar membrane, and set some of the strings in motion. In some unknown way these movements are transmitted to the hair-cells and through them to the nerve-fibres at their base. By means of the nerve-fibres the stimulus is conveyed to the brain and interpreted there, so that it is with the brain that we hear.

The sense of equilibrium. — Among the various means (such as sight, touch, and muscular sense) whereby we are enabled to maintain our equilibrium, coördinate our movements, and become aware of our position in space, one of the most important is the action of the vestibule and semicircular canals. Though these structures are found in the inner ear and communicate with the cochlea, it is now thought that they are not connected with the sense of hearing. Just how they perform their function is not known, but it is thought that movements of the head set up movement in the endolymph of the canal, and this acts as a stimulus to the nerve-endings around the hair-cells.

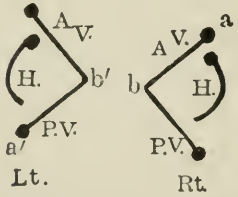

FIG. 196. — DIAGRAM SHOWING RELATIVE POSITION OF THE PLANES IN WHICH THE SEMICIRCULAR CANALS LIE. *Rt.*, right ear; *Lt.*, left ear; *A.V.*, anterior vertical canal; *P.V.*, posterior vertical canal; H., horizontal canal; *a*, ampulla of *Rt.* anterior vertical canal; *a′*, ampulla of *Lt.* posterior vertical canal.

The canals are so arranged (Fig. 196) that any movement of the head causes an increase in the pressure of the endolymph in one ampulla, and a corresponding diminution in the ampulla of the parallel canal on the opposite side. Thus, a nodding of the head to the right would cause a flow of the endolymph from *a* to *b* in the right anterior vertical canal, but from *b′* to *a′* in the left posterior vertical canal. Hence the pressure upon the hairs is decreased in *a*, but increased in *a′*. Such stimulations of the sensory hairs are transmitted by the dendrites of the vestibular nerve, through the cell-bodies of the vestibular ganglion and the axis cylinders of the auditory nerve, to the pons Varolii and thence to the cerebellum. It is thought that the cerebellum is the centre in the brain which interprets and adjusts the impulses that arise from stimulation of the sensory nerves concerned with muscular sense. It is also the centre that interprets and adjusts impulses that arise from stimulation of the vestibular nerve-endings. From this it follows that the cerebellum controls equilibrium.

SIGHT

The visual apparatus consists of the eyeballs, the optic nerves, and the nerve centres in the brain. In addition to these essential organs, there are accessory organs which are necessary for the protection and functioning of the eyeball.

Accessory organs of the eye. — Under this heading we class: (1) eyebrows, (2) eyelids, (3) lacrimal apparatus, and (4) muscles of the eyeball.

Eyebrows. — The eyebrows are composed of two arched eminences of thickened skin, covered with hairs. They are situated on the upper border of the orbits, and protect the eyes from too vivid light.

Eyelids. — The eyelids are two folds projecting from above and below in front of the eye. They are covered externally by the skin, and internally by a mucous membrane, the conjunctiva, which is reflected from them over the globe of the eye. They are composed for the most part of connective tissue, which is dense and fibrous under the conjunctiva, where it is known as the **tarsal cartilage**.

Arranged in a double or triple row at the margin of the lids are the **eyelashes**; those of the upper lid more numerous and longer than those of the lower. The upper lid is attached to a small muscle which is called the elevator of the upper lid (**levator palpebræ superioris**), and arranged as a sphincter around both lids is the **orbicularis palpebrarum** muscle, which closes the eyelids, and is the direct antagonist of the elevator of the upper lid.

The slit between the edges of the lids is called the palpebral fissure. It is the size of this fissure which causes the appearance of large and small eyes, as the size of the lobe itself varies but little. The outer angle of this fissure is called the **external canthus**; the inner angle, the **internal canthus**.

The eyelids are obviously provided for the protection of the eye; movable shades which by their closure exclude light, particles of dust, and other injurious substances.

Tarsal glands (Meibomian glands). — Embedded in the tarsal cartilage of each eyelid is a row of elongated sebaceous glands, — the tarsal[1] glands, — the ducts of which open on the edge of the eyelid. The secretion of these glands is provided to prevent adhesion of the eyelids.

Lacrimal apparatus. — This apparatus consists of: (1) the lacrimal gland, (2) canaliculi, (3) lacrimal sac, and (4) nasal duct.

The **lacrimal gland** is a compound gland, closely resembling the salivary glands in structure, and is lodged in a depression at the upper and outer angle of the orbit. It consists of two portions, an **upper** portion about the size and shape of an almond, and a **lower** portion consisting of a group of small glands arranged in a row. These two portions are only partially separated by a fibrous septum.

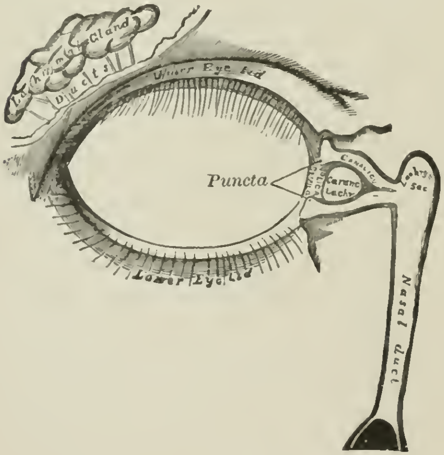

Fig. 197. — The Lacrimal Apparatus. (Note that preference is given to the spelling "lacrimal" as found in text, instead of "lachrymal" as found on illustration.)

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[1] By everting the eyelids, these glands may be seen through the conjunctiva lying in parallel rows.

Seven to twelve minute ducts lead from the gland to the surface of the conjunctiva of the upper lid. The secretion (tears) is usually just enough to keep the eye moist, and after passing over the surface of the eyeball is sucked into two tiny **canaliculi** through the **punctæ** and is conveyed into the **lacrimal sac**, which is the upper dilated portion of the nasal duct.

The **nasal duct** is a membranous canal, about three-quarters of an inch (19 mm.) in length, which extends from the lacrimal sac to the nose, into which it opens by a slightly expanded orifice.

The tears consist of water containing a little salt and albumin. They are ordinarily carried away as fast as formed, but under certain circumstances, as when the conjunctiva is irritated, or when painful emotions arise in the mind, the secretion of the lacrimal gland exceeds the drainage power of the nasal duct, and the fluid, accumulating between the lids, at length overflows and runs down the cheeks.

The conjunctiva. — The conjunctiva is the mucous membrane which lines the eyelids and is reflected over the front of the eyeball. It is often considered part of the lacrimal apparatus as it secretes a fluid like that of the lacrimal gland.

Muscles of the eye. — For purposes of description the muscles of the eye are divided into two groups: (1) intrinsic, and (2) extrinsic. The intrinsic muscles are the ciliary muscle, and the muscles of the iris. (See page 426.) The extrinsic muscles are those which move the eyeball and include the four straight, or recti, and the two oblique. They have been described in Chapter VII.

Nerves of the eye. — The nerves which are supplied to the eye are: (1) the optic nerve, which is concerned with vision only; (2) the motor oculi nerve controls the internal rectus, the superior rectus, the inferior rectus, and the inferior oblique muscles; (3) the pathetic nerve controls the superior oblique muscle; (4) the abducens controls the external rectus; and (5) the ophthalmic, which is a branch of the trifacial nerve, supplies general sensation.

The orbits. — The orbits are the bony cavities in which the eyeballs are contained.

Seven bones assist in the formation of each orbit, namely, frontal, malar, maxilla, palate, ethmoid, sphenoid, and lacrimal. As three of these bones are mesial (frontal, ethmoid, and sphenoid) there are only eleven bones forming both orbits.

The orbit is shaped like a four-sided pyramid; the apex, directed backward and inward, is pierced by a large opening — the optic foramen — through which the optic nerve and the ophthalmic artery pass from the cranial cavity to the eye. A larger opening to the outer side of the optic foramen — the sphenoidal fissure — provides a passage for the ophthalmic vein and the nerves which carry impulses to and from the muscles, *i.e.* the motor oculi, the pathetic, the abducens, and the ophthalmic. The base of the orbit, directed outward and forward, forms a strong, bony edge for protecting the eyeball from injury.

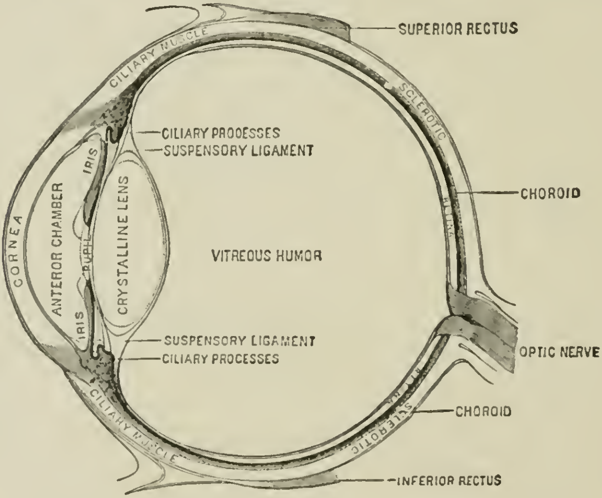

Fig. 198. — Diagrammatic Section of the Eye. (Flint.)

Each orbit averages about 2 inches (50 mm.) in depth, is lined with fibrous tissue, and contains a pad of fat, which serves as a support for the eyeball. A condition of emaciation is usually accompanied by sunken eyes, which results from the absorption of this fat, and the consequent sinking of the eyeballs in the orbits. Between the pad of fat and the eyeball is a serous sac — the *capsule of Tenon* — which envelops the eyeball from the optic nerve to the ciliary region and forms a socket in which the eyeball rotates. This sac secretes a lubricating fluid, the function of which is to prevent friction when the eyeball moves.

The eyeball. — The eyeball is spherical in shape, but its transverse diameter is less than the antero-posterior, so that it projects anteriorly, and looks as if a section of a smaller sphere had been engrafted on the front of it.

The eyeball is composed of three coats, or tunics, and contains three refracting media or humors. They are as follows: —

Tunics. — 1. Sclera and cornea.
2. Choroid, ciliary body, and iris.
3. Retina.

Refracting media. — 1. Aqueous.
2. Crystalline lens and capsule.
3. Vitreous.

The sclera. — The sclera, or "white of the eye," covers the posterior five-sixths of the eyeball. It is composed of a firm, unyielding, fibrous membrane, thicker behind than in front, and serves to protect the delicate structures contained within it, and maintain the shape of the eyeball. It is opaque, white, and smooth externally, and behind is pierced by the optic nerve. Internally it is stained brown where it comes in contact with the choroid coat. It is supplied with very few blood-vessels, and the existence of nerves in it is doubtful.

The cornea. — The cornea covers the anterior sixth of the eyeball. It is directly continuous with the sclera, which, however, overlaps it slightly above and below, as a watch crystal is overlapped by the case into which it is fitted. The cornea, like the sclera, is composed of fibrous tissue, which is both firm and unyielding, but, unlike the sclera, it has no color, and is perfectly transparent; it has been aptly termed the "window of the eye." The cornea is well supplied with nerves and lymph-spaces, but is destitute of blood-vessels, so that it is dependent on the lymph contained in the lymph-spaces for nutriment.

Choroid. — The choroid, or vascular coat of the eye, is a thin, dark brown membrane lining the inner surface of the sclera. It is composed of delicate connective tissue, the cells of which are large and filled with pigment, and it contains a close network of blood-vessels. The pigment cells and blood-vessels render this membrane dark and opaque, so that it darkens the chamber of the eye by preventing the reflection of light. It extends to within a short distance of the cornea.

The ciliary body. — The ciliary body is located between the choroid and the iris, and contains the ciliary processes, and the ciliary muscle. Just behind the edge of the cornea, the choroid is folded inward and arranged in radiating folds, like a plaited ruffle, around the lens. There are about seventy of these folds, and they constitute the ciliary processes. They are well supplied with nerves and blood-vessels, and also support a muscle, the ciliary muscle. The fibres of this muscle arise from the sclera near the cornea, and extending backward are inserted into the outer surface of the ciliary processes and the choroid. The action of this muscle determines the position of the lens.

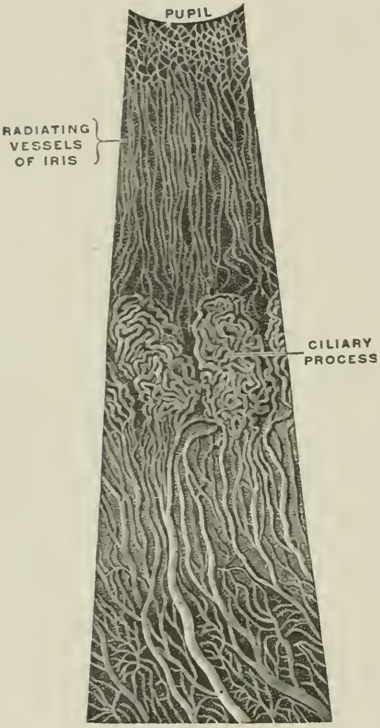

FIG. 199. — SEGMENT OF THE IRIS, CILIARY BODY, AND CHOROID. Viewed from the internal surface. (Gerrish.)

Iris. — The iris (**iris**, rainbow) is a colored, fibro-muscular curtain hanging in front of the lens and behind the cornea. It is attached at its circumference to the ciliary processes, with which it is practically continuous, and is also connected to the sclera and cornea at the point where they join one another. Except for this attachment at its circumference, it hangs free in the interior of the eyeball. In the middle of the iris is a circular hole — the **pupil** — through which light is admitted into the eye chamber. The iris, like the choroid, is composed of connective tissue containing a large number of pigment cells and numerous blood-vessels. It contains, in addition, two sets of muscular fibres. One set is arranged like a sphincter with its fibres encircling the pupil, and is called the **contractor of the pupil**. The other set consists of fibres which radiate from the pupil to the outer circumference of the iris, and is called the **dilator of the pupil.** The action of these muscle fibres is antagonistic.

The posterior surface of the iris is covered by a thick layer of pigment-cells designed to darken the curtain and prevent the entrance of light. The anterior surface of the iris is also covered with pigment cells, and it is chiefly these latter which cause the beautiful colors seen in the iris. The different colors of eyes, however, are mainly due to the amount, and not to the color, of the pigment deposited.

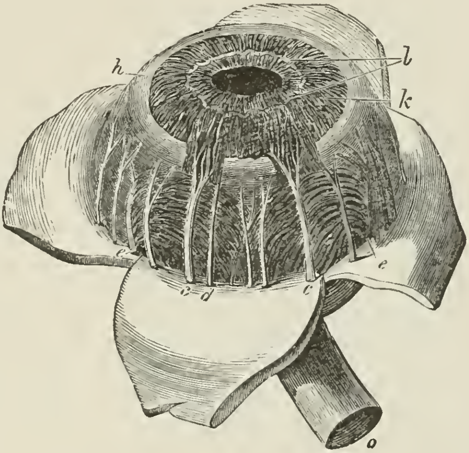

Fig. 200. — Choroid Membrane and Iris exposed by the Removal of the Sclera and Cornea. Twice the natural size. *d*, one of the segments of the sclera thrown back; *l* and *k*, iris; *c*, ciliary nerves; *e*, one of the veins of the choroid. The ciliary muscle is crossed by the line from *k*, and should be represented as radiating. (Collins.)

Function of the iris. — The function of the iris is to regulate the amount of light entering the eye, and thus assist in obtaining clear images. It is enabled to perform this function by the action of the muscles described above, as their contraction or relaxation determines the size of the pupil. When the eye is accommodated for a near object, or stimulated by a bright light, the sphincter muscle contracts and diminishes the size of the pupil. When, on the other hand, the eye is accommodated for a distant object, or the light is dim, the dilator muscle contracts, and the pupil is pulled wider open.

Retina. — The retina, the innermost coat of the eyeball, is the most essential part of the organ of sight, since it is the only one directly sensitive to light. The sclera is the protective, the choroid the vascular, or nutritive, and the retina is the visual, or perceptive, layer of the eyeball. It is a transparent membrane of a grayish color that is formed by the spreading out or expansion of the optic nerve. It is situated between the inner surface of the choroid and the outer surface of the vitreous humor, and extends from the entrance of the optic nerve forward to the margin of the pupil.

The retina is usually described as consisting of eight layers and two limiting membranes; of these layers, three are most important: —

(1) Eighth layer, or layer of nerve-fibres, is the internal layer.

(2) Seventh layer is the layer of nerve-cells.

(3) First layer, or layer of rods and cones, is the external layer. (See Summary, page 440.)

The fibres of the optic nerve, after piercing the sclera and choroid at the back of the eye, spread out and form the eighth, or innermost, layer of the retina. The fibres then pass, with more or less direct communications, peripherally through the other layers, until they may be said to terminate in the layer of rods and cones. Rays of light produce no effect upon the optic nerve without the intervention of the rods and cones, which act as end organs.

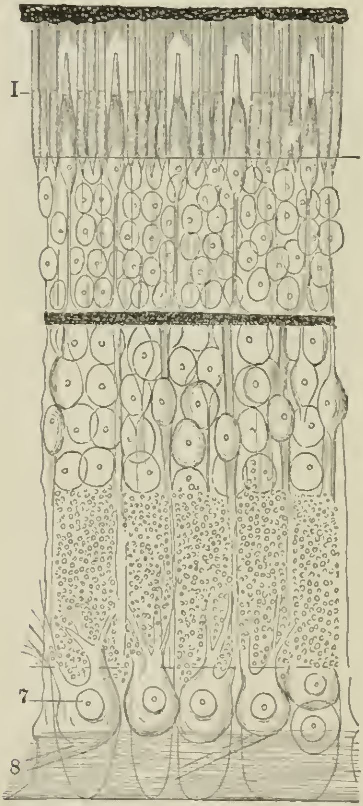

FIG. 201. — DIAGRAMMATIC SECTION OF THE HUMAN RETINA. 8, layer of nerve-fibres; 7, layer of nerve-cells; 1, layer of rods and cones. (M. Schultze.)

Blind spot. — The optic nerve pierces the eyeball not exactly at its most posterior point, but a little to the inner side. This point where the optic nerve enters is called the blind spot. There are no rods and cones at this spot, and rays of light falling upon it produce no sensation.

Macula lutea. — There is one point of the retina that is of great importance, and that is the macula lutea, or yellow spot. It is situated about one-twelfth inch (2.08 mm.) to the outer side of the exit of the optic nerve, and is the exact centre of the retina. In its centre is a tiny pit, — **fovea centralis**, — which is the centre of direct vision; that is, it is the part of the retina which is always turned towards the object looked at. From this point the sensitiveness of the retina grows less and less in all directions. At this point (fovea centralis) are found none of the fibres of the optic nerve, but a great increase in the number of cones, as well as in their size.

Perception of light. — When light waves fall upon the retina they act as a stimulus, and it is supposed that they cause chemical changes in the rods and cones which give rise to impulses that are carried by the optic nerve to the brain, and result in sight. Just how this is accomplished is not known, but the rods contain a kind of pigment which is called visual purple, and this as well as the pigment of the retina may function in these changes.

Fig. 202. — The Posterior Half of the Retina of the Left Eye viewed from Before. Twice its natural size. *s*, cut edge of the sclera; *ch*, choroid; *r*, retina; in the interior at the middle, the macula lutea with the depression of the fovea centralis is represented by a slight oval shade; toward the left side the light spot indicates the entrance of the optic nerve or blind spot. (Collins.)

The optic chiasm. — The fact that the two retinæ and the two eyeballs work in unison is largely due to the crossing of the nerve fibres at the optic chiasm. The optic nerve from each eye passes backward through the optic foramen, and shortly after leaving the orbit the two nerves come together, and the fibres from the inner portion of each nerve cross. This is called the optic chiasm, and is really an incomplete crossing of fibres, as the outer fibres do not cross. (See Fig. 203.)

Aqueous humor. — The space bounded by the cornea in front and by the lens, suspensory ligament, and ciliary body behind is filled with a colorless, transparent, watery fluid, the aqueous humor. This space is known as the **aqueous chamber**, and is partially divided by the iris into an anterior and posterior chamber.

Vitreous humor. — The posterior four-fifths of the globe of the eyeball is filled with a semi-fluid, gelatinous substance, the vitreous humor, or body, so called from its glassy and transparent appearance. It is enclosed in a thin membrane — the **hyaloid membrane.** This membrane is attached to the retina at the back of the eyeball, and furnishes a suspensory ligament to the lens. Elsewhere it is perfectly separable from its surroundings. The vitreous humor enclosed in this capsule distends the greater part of the sclera, supports the retina, which lies upon its surface, and preserves the spheroidal shape of the eyeball. Its refractive power, though slightly greater than that of the aqueous humor, does not differ much from that of water.

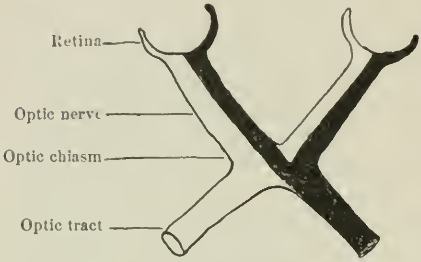

Fig. 203. — Diagram of Optic Chiasm.

Crystalline lens. — The crystalline lens is a transparent, refractive body, with convex anterior and posterior surfaces, placed directly behind the pupil, where it is retained in position by the counterbalancing pressure of the aqueous humor and vitreous body, and by its own suspensory ligament described above. The posterior surface is considerably more curved than the anterior, and the curvature of each varies with the period of life. In infancy, the lens is almost spherical; in the adult, of medium convexity; and in the aged, considerably flattened.

It is a fibrous body, enclosed in an elastic, non-vascular capsule. Just beneath the capsule the substance is soft and gelatinous, but deeper it becomes hard and firm. Its refractive power is much greater than that of the aqueous or vitreous humor.

Refraction. — Refraction is the bending or deviation in the course of rays of light in passing obliquely from one transparent medium into another of different density. (See page 496.)

The refractive apparatus. — In order that our vision of objects looked at should be clear and distinct it is necessary that the rays of light entering the eye should be focussed on the retina. In the normal eye this is secured by the mechanism of accommodation (see next paragraph). The refractive apparatus consists of the aqueous humor, the vitreous humor, and the crystalline lens which have just been described.

Accommodation. — Accommodation is the ability of the eye to adjust itself so that it can see objects at varying distances. The changes which occur in the eye during accommodation for near objects are three in number: (1) the pupil contracts, (2) the lens becomes more convex, and (3) the axes of the eyeballs are turned inward by the action of the internal recti muscles.

A normal eye is capable of distinct vision throughout an immense range. We can see the stars millions of miles away, and with the same eye, though not at the same time, we can see objects within a few inches of us. To be able to see objects millions of miles away and within a short range, the eye has to accommodate or adjust itself to different distances. This accommodation is accomplished mainly by the lens changing its convexity. In accommodation for near objects, the lens becomes more convex (advances), and the pupil of the eye likewise contracts. This convexity is brought about by the action of the ciliary muscle, and is always more or less fatiguing. The accommodation for distant objects is a passive condition, the convexity of the lens being unaltered and the pupil of the eye dilated, and it is on this account that the eye rests for an indefinite time upon remote objects without fatigue.

Common conditions that affect accommodation. — The conditions that affect accommodation are: (1) hypermetropia, (2) myopia, (3) presbyopia, and (4) astigmatism.

Hypermetropia. — Hypermetropia or far-sightedness is a condition in which rays of light from near objects do not converge soon enough and are brought to a focus behind the retina. This is usually caused by a flattened condition of the lens or cornea, or an eyeball that is too shallow, and convex glasses are used to concentrate and focus the rays more quickly.

Myopia. — Myopia or near-sightedness is a condition in which rays of light converge too soon. and are brought to a focus before reaching the retina. This is the opposite of hypermetropia and is caused by a cornea or lens that is too convex, or an eyeball of too great depth. To remedy this condition concave glasses are worn to disperse the rays and prevent their being focussed too soon.

Presbyopia. — Presbyopia is a defective condition of accommodation in which distant objects are seen distinctly, but near objects are indistinct. This is a physiological process which affects every eye sooner or later, and is not due to disease. It is said to be caused by a loss of elasticity of the lens.

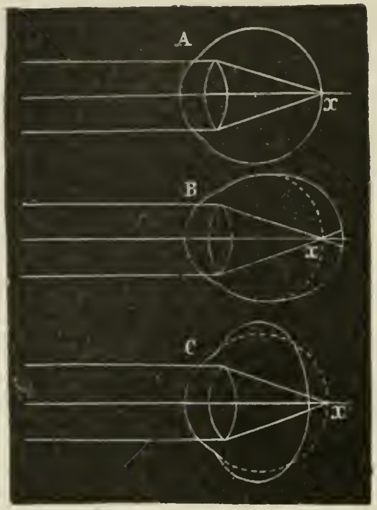

Fig. 204. — Diagram illustrating Rays of Light converging in (A) a Normal Eye, (B) a Myopic Eye, and (C) a Hypermetropic Eye.

Astigmatism. — Astigmatism is the condition in which the different meridians[1] of the cornea are not equally convex, and so there is interference with the formation of distinct images on the retina.

Inversion of images. — Following the general laws for the formation of images in connection with the lens, an inverted image of external objects is formed on the retina.

"The question then arises, Why is it that objects do not appear to us to be upside down? This cannot be satisfactorily answered without entering into matters which require a previous psychological training. Suffice it to say here that the localization of objects in space depends not only on the retina, but also on tactile and general experience; that the mind localizes objects with reference to its own body, and that from the first it knows nothing of the inversion of the retinal image, as its powers of localization only appear with developing general experience." (Halliburton.)

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[1] The meridian of the eye is an imaginary line drawn around the eyeball.

SUMMARY

- **Sensation**
  - Perception through the sense organs.
  - **Organs necessary for sensation**
    - End organ for the reception of a stimulus.
    - A nerve for conduction of the stimulus.
    - A centre in the brain for the perception and interpretation.
  - **Classification**
    - 1. Internal or those in which the sensations are projected to the interior of the body.
      - Hunger.
      - Thirst.
      - Pain.
      - Muscular sense.
      - Fatigue.
      - Visceral sensations.
    - 2. External or those in which the sensations are projected to the exterior of the body.
      - Pressure.
      - Temperature.
      - Taste.
      - Smell.
      - Hearing.
      - Sight.

- **Hunger** . .
  - Presumably due to contractions of empty stomach, acting on nerves distributed to mucous membrane.
  - In abnormal conditions it may be due to failure to assimilate food.

- **Thirst** . .
  - Presumably due to stimulation of nerves of pharynx by low water content in tissues.

- **Pain** . . .
  - May be due to stimulation of special nerve endings, or to overstimulation of any of the sensory nerves.

Muscular Sense — Due to stimulation of sensory nerves distributed to muscles. Weight or resistance serves as stimulus.

Fatigue — Due to stimulation of sensory nerves distributed to muscles. Loss of nutrient material or accumulation of waste products acts as stimulus.

Visceral Sensations — Due to stimulation of sensory nerves distributed to the viscera.

- **Pressure** .
  - End organs distributed over entire surface of body.
  - End organs
    - Nerve filaments surround hair follicles.
    - Tactile or Meissner corpuscles.

- **Temperature**
  - End organs distributed over entire surface of body.
  - **End organs**
    - Hot spots
      - Temperature higher than body.
      - Carbon dioxide.
      - Electricity.
    - Cold spots
      - Temperature lower than body.
      - Menthol.
      - Electricity.

Taste
- Sensory apparatus
  - 1. Taste-buds are end organs.
  - 2. Nerve-fibres of trifacial, facial, and glossopharyngeal nerves.
  - 3. Centre in brain.
- Solution of sapid substances must come in contact with taste-buds.
- Taste-buds are distributed over
  - Surface of tongue.
  - Soft palate and fauces.
  - Tonsils and pharynx.

Tongue
- Freely movable muscular organ.
- Attached to hyoid bone, epiglottis, and pillars of the fauces.
- Surface covered by papillæ
  - Circumvallate.
  - Fungiform.
  - Filiform.
- **Nerves**
  - Sensory
    - Lingual, branch of trifacial.
    - Chorda tympani, branch of the facial.
    - Glossopharyngeal.
  - Motor — Hypoglossal.
- **Sense of**
  - 1. Taste
  - 2. Temperature
  - 3. Pressure
  - 4. Pain
  - Are all well developed.

Smell
- Sensory apparatus
  - Olfactory nerve-endings.
  - Olfactory nerve-fibres.
  - Centre in brain — olfactory bulb.
- Odors
  - Minute particles of solid matter
  - Gases
  - Must be capable of solution in mucus.
- Olfactory nerve-ending found in lining upper part of nose (smell).
- Branches of trigeminal nerve found in lining of lower part of nose (pressure).

Hearing
- Auditory apparatus
  - External ear.
  - Middle ear.
  - Internal ear.
  - Auditory nerve.
  - Centre in brain.
- Air-waves enter external auditory canal and cause vibrations of drum-membrane. The vibrations are conveyed to nerve-endings of organ of Corti, and thence by the auditory nerve to the brain.

- **Ear** . . .
  - **External Ear**
    - Pinna, or auricle
      - **Structure**
        - Cartilaginous framework, some fatty and muscular tissue, covered with skin.
      - **Function**
        - Collects sound-waves and reflects them into the auditory canal.
    - Auditory canal
      - 1 in. long, partly cartilage, partly bone.
      - Closed internally by the drum-membrane
        - Membrana tympani.
      - Hairs directed outward.
      - Ceruminous glands secrete a yellow, pasty substance.
  - **Middle Ear**
    - An irregular cavity in the temporal bone.
    - Five or six drops of water will fill it.
    - **Bones**
      - Malleus (hammer).
      - Incus (anvil).
      - Stapes (stirrup).
    - **Openings**
      - Fenestra ovalis — closed by a membrane and the stapes.
      - Fenestra rotunda — closed by a membrane.
      - Eustachian tube — connects with the pharynx, allows entrance of air.

- **Ear** . . .
  - **Internal ear**
    - **Bony labyrinth**
      - Vestibule — antechamber just inside of fenestra ovalis.
      - Semicircular canals
        - Three in number.
        - Open into vestibule.
      - Vestibular branch of auditory nerve distributed to vestibule and semicircular canals.
      - Cochlea
        - A spiral tube.
        - 2½ turns around modiolus.
        - Fenestra rotunda.
        - Cochlear branch of the auditory nerve.
    - **Membranous labyrinth**
      - Surrounded by perilymph.
      - Contains endolymph.
      - Lines the vestibule
        - Saccule.
        - Utricle.
      - Lines the semicircular canals.
      - Lines the cochlea, and here it is called the canalis cochlearis, or scala media.
      - Membrana basilaris is name given to membrane at base of canal.
      - Organ of Corti, name given to end organs of auditory nerve lodged on membrana basilaris.
  - **Auditory nerve**
    - Cochlear — terminates in and around cells of organ of Corti.
    - Vestibular — terminate in hair-cells of saccule, utricle, and ampulla.

- **Sense of Equilibrium**
  - Function of the vestibule and semicircular canals.
  - Lining membrane supplied with sensory hairs which connect with vestibular nerve.
  - Contain several small otoliths which float in the endolymph.
  - Flowing of the endolymph stimulates the sensory hairs; this is transmitted to the vestibular nerve, thence to auditory nerve, thence to brain.
- **Sight** . . .
  - **Visual apparatus**
    - Eye.
    - Optic nerve.
    - Centre in brain.
    - Accessory organs
      - Eyebrows.
      - Eyelids.
      - Lacrimal apparatus.
      - Muscles.
  - Vibrations in the ether enter eye and strike on retina, which contains end organs of the optic nerve; thence sensation is carried to visual centre in brain.
- **Accessory Organs**
  - **Eyebrows**
    - Arched eminences of skin furnished with short, thick hairs.
    - Control to a limited extent amount of light admitted to eye.
  - **Eyelids**
    - Folds of connective tissue covered with skin, lined with mucous membrane (conjunctiva), which is also reflected over the eyeball. Provided with lashes.
    - Closed by orbicularis palpebrarum muscle.
    - Upper lid raised by levator palpebræ superioris.
    - Slit between lids called palpebral fissure.
    - Inner angle of slit called internal canthus.
    - Outer angle of slit called external canthus.
    - Function is protection. Serve as shades.
    - Tarsal glands are a row of glands embedded in tarsal cartilage of each lid.

- **Accessory Organs**
  - **Lacrimal apparatus**
    - Lacrimal gland — in the upper and outer part of the orbit. Secretes tears.
    - Ducts — 7 to 12 lead from gland to conjunctiva.
    - Canaliculi — 2 canals $\frac{1}{4}$ to $\frac{1}{3}$ in. long, begin at punctæ and open into lacrimal sac.
    - Lacrimal sac — upper dilated portion of the nasal duct.
    - Nasal duct — canal $\frac{3}{4}$ in. long, extends from lacrimal sac to the nose.
    - **Tears**
      - Secretion constant.
      - Moisten the eyeball and help to moisten inspired air.
      - Consist of
        - Water.
        - Salt.
        - Albumin.
      - Carried off by nasal duct.
  - **Muscles**
    - **Extrinsic**
      - Superior rectus.
      - Inferior rectus.
      - Internal rectus.
      - External rectus.
      - Superior oblique.
      - Inferior oblique.
    - **Intrinsic**
      - Ciliary muscle
        - Determines the position of the lens.
      - Muscles of iris
        - Contractor of pupil.
        - Dilator of pupil.
- **Nerves of Eye**
  1. Optic nerve concerned with vision only.
  2. Motor oculi controls
     - Internal rectus muscle.
     - Superior rectus muscle.
     - Inferior rectus muscle.
     - Inferior oblique muscle.
  3. Pathetic controls the superior oblique muscle.
  4. Abducens controls the external rectus muscle.
  5. Ophthalmic.

- **Orbit**
  - Bony cavity formed by seven bones
    - Frontal.
    - Malar.
    - Maxilla.
    - Palate.
    - Ethmoid.
    - Sphenoid.
    - Lacrimal.
  - Lined by fibrous tissue.
  - Contains pad of fat — supports eyeball.
  - Capsule of Tenon — prevents friction when eyeball moves.
  - Shaped like four-sided pyramid
    - Apex directed backward.
    - Base directed forward.
  - **Optic foramen** — opening for passage of optic nerve and ophthalmic artery.
  - **Sphenoidal fissure** — opening for passage of ophthalmic vein and motor oculi, pathetic and abducens nerves.
- **Eyeball**
  - Spherical in shape.
  - **Dimensions**
    - Transverse . . . 1.00 inch (25 mm.)
    - Vertical . . . . .96 inch (24 mm.)
    - Antero-posterior . .96 inch (24 mm.)
    - Optic nerve and sheath . . . . .16 inch (4 mm.)
    - Lens — antero-posterior . . . . .19 inch (4.75 mm.)
    - Lens — transverse .35 inch (8.75 mm.)
    - Pupil (average) . .14 inch (3.5 mm.)
  - **Tunics**
    1. Sclera and cornea.
    2. Choroid, ciliary body, and iris.
    3. Retina.
  - **Media**
    1. Aqueous.
    2. Crystalline lens and capsule.
    3. Vitreous.
- **Sclera**
  - Tough, fibrous, opaque. Protective.
  - Covers posterior $\frac{5}{6}$ of eyeball.
  - Stained brown internally.
- **Cornea**
  - Fibrous, transparent — covers anterior $\frac{1}{6}$ of eyeball.
  - Well supplied with nerves.
- **Choriod**
  - Vascular coat, lines the sclera.
  - Composed of connective tissue cells filled with pigment.
  - Terminates in front by the ciliary processes.
- **Ciliary Body**
  - Ciliary processes 70 to 80 parallel folds of the choroid, rising gradually from behind and forming a plaited zone between the choroid and iris.
  - Support ciliary muscle — action of this muscle determines the position of the lens.

Iris . . .
- A circular curtain. Central perforation — pupil.
- Pupil contracted by circular muscle-fibres.
- Pupil dilated by radial muscle-fibres.
- Contains pigment — amount of which determines color of the eyes.
- Hangs free except for attachment at circumference to the ciliary processes and choroid.
- **Function** — Regulates amount of light entering eye.

Retina . .
- Visual layer — transparent membrane of nervous and connective tissue situated between the choroid and vitreous humor. Formed by the spreading out of optic nerve.
- Has eight layers and two membranes. Counting from the choroid inward as follows: —
- Pigment layer, usually described as a membrane.
  1. Layer of rods and cones (perceptive layer) — external layer.
  2. Limitans externa.
  3. External granules.
  4. External molecular.
  5. Internal granules.
  6. Internal molecular.
  7. Ganglion or nerve-cells.
  8. Optic nerve-fibres — innermost layer.
- Membrana limitans interna.
- **Blind spot**
  - Entrance of optic nerve.
  - There are no rods and cones.
  - Totally insensitive to light.
- **Macula lutea**
  - 1½ in. outside the blind spot.
  - Central pit — fovea centralis — is the centre of direct vision.

Refractive Apparatus
- **Aqueous**
  - Aqueous chamber is between cornea in front and lens, suspensory ligament, and ciliary body behind. Aqueous humor is a colorless, transparent, watery fluid.
- **Vitreous**
  - Semi-fluid, gelatinous substance.
  - Fills the posterior four-fifths of the globe of the eyeball, and is enclosed in the hyaloid membrane. Distends the sclera and supports the retina.
- **Crystalline lens**
  - Situated behind the pupil. Double convex in shape.
  - Fibrous body enclosed in an elastic capsule.
  - Held in position by counterbalancing of the aqueous and vitreous humor and the suspensory ligament.

Refraction — Bending or deviation in the course of rays of light, in passing obliquely from one transparent medium into another of different density.

Accommodation — Ability of the eye to adjust itself so that it can see objects at varying distances.

- **Conditions that affect Accommodation**
  - **Hypermetropia**
    - Far-sightedness.
    - **Cause** — Rays of light do not converge soon enough.
  - **Myopia**
    - Near-sightedness.
    - **Cause** — Rays of light converge too soon.
  - **Presbyopia**
    - Defective condition of accommodation in which distant objects are seen distinctly, but near objects are indistinct.
  - **Astigmatism**
    - Condition in which the different meridians of the eye are not equally convex. Interferes with distinct vision.

CHAPTER XXI

THE ORGANS OF GENERATION: PHYSIOLOGY OF REPRODUCTION

Female generative organs. — The female generative organs are divided into an internal and an external group. The internal are contained within the pelvis, and the external are grouped under the name of vulva or pudendum.

INTERNAL GENERATIVE ORGANS

The internal generative organs comprise the following structures: —

(1) **Ovaries**, two glandular organs in which the ova are formed.

(2) **Fallopian** [uterine] tubes, two canals through which the ova reach the uterine cavity.

(3) **Uterus**, a hollow, pear-shaped organ, which receives the ovum.

(4) **Vagina**, a canal extending from the uterus to the vulva.

Ovaries. — The ovaries are two small, almond-shaped glandular bodies, situated one on each side of the uterus, in the posterior fold of the broad ligament, behind and below the Fallopian tubes. Each ovary is attached by its inner end to the uterus by a short ligament, — the ligament of the ovary, — and by its outer end to the Fallopian tube by one of the fringe-like processes of the fimbriated extremity. The ovaries each measure about one and a half inches (38 mm.) in length, three-fourths of an inch (19 mm.) in width, and one-third of an inch (8.5 mm.) in thickness, and weigh from one to two drachms (3.7 to 7.5 grams).

Function. — The function of the ovaries is to produce, develop, and mature the ova, and to discharge them when fully formed. In addition, the ovary doubtless furnishes an internal secretion, which is picked up by the blood.

Structure. — If the substance of an ovary be minutely examined it is found to consist of: (1) a stroma or bed composed of white and yellow fibrous tissue, blood-vessels, lymphatics, and nerves, (2) Graafian or vesicular follicles, and (3) a covering of columnar epithelial cells, called germinal epithelium, which is continuous with the peritoneum.

Graafian (vesicular) follicles. — The Graafian follicles are sacs or vesicles which contain the ova and are embedded in the meshes of the stroma.

Each follicle consists of: (1) an outer coat of fibrous tissue that is derived from the stroma, and connected with it by a plexus of blood-vessels, and (2) an inner layer of nucleated cells. With the exception of the smallest vesicles each one is filled with fluid, and suspended in this fluid is an *ovum* surrounded by a mass of cells, called the *discus proligerus.*

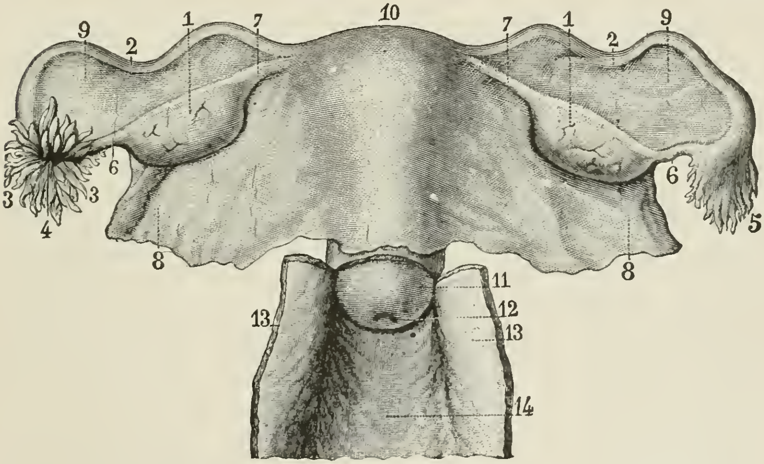

FIG. 205. — UTERUS, FALLOPIAN TUBES, AND OVARIES — POSTERIOR VIEW. 1, ovaries; 2, 2, uterine tubes; 3, 3, fimbriated extremity of the left uterine tube, seen from its concavity; 4, opening of the left tube; 5, fimbriated extremity of the right tube, posterior view; 6, 6, fimbriæ which attach the extremity of each tube to the ovary; 7, 7, ligaments of the ovary; 8, 8, 9, 9, broad ligaments; 10, uterus; 11, cervix uteri; 12, os uteri; 13, 13, 14, vagina. (Sappey.)

At birth the ovaries are said to contain about 36,000 vesicles, each measuring from $\frac{1}{800}$ to $\frac{1}{100}$ of an inch in diameter, but only a small number of these ever develop, as the great majority shrink and disappear. At the time of puberty the ovaries enlarge, become very vascular, and some of the follicles increase in size. As the follicles increase in size they approach the surface and begin to form small protuberances on the outside of the ovary. When fully matured the wall of the ovary and the wall of the follicle burst at the same point, and the contents of the follicle — the fluid, the ovum, and the surrounding cells — escape. This process of development, maturation, and rupture of a follicle is known as ovulation, and continues at regular intervals from puberty to the menopause.

The corpus luteum. — After the rupture of a follicle, and the escape of the ovum, the walls collapse and the cavity becomes filled with blood which forms a clot. Later this clot becomes surrounded by cells containing a yellow pigment, which gives the follicle a yellow color, and hence it is known as the corpus luteum. The size and duration of the corpus luteum is dependent on whether fertilization occurs or not. If fertilization does not occur the corpus luteum increases in size for two or three weeks and then is absorbed. If fertilization does occur and the woman becomes pregnant, the corpus luteum increases in size during the first few months, and does not show retrogressive changes until about the sixth month. The function of the corpus luteum is unknown. Some physiologists regard it as a protective mechanism by means of which the cavity resulting from the rupture of the follicle is filled with a tissue which can be easily absorbed. Others attribute to the corpus luteum the formation of the internal secretion of the ovaries. This will be discussed later.

Fallopian tubes. — The Fallopian tubes or oviducts are two in number, one on each side, and pass from the upper angles of the uterus in a somewhat tortuous course between the folds and along the upper margin of the broad ligament, towards the sides of the pelvis. They are about four inches (100 mm.) long, and at the point of attachment to the uterus are very narrow, but gradually increase in size so that the distal end is larger. The margin of the distal end is surrounded by a number of fringe-like processes called **fimbriæ**. One of these fimbriæ is attached to the ovary. The uterine opening of the tube is minute, and will only admit a fine bristle; the abdominal opening is comparatively much larger.

The uterine tube consists of three coats: —

(1) **Serous.** — The external, or serous, coat is derived from the peritoneum.

(2) **Muscular.** — The middle, or muscular, coat has two layers: one a layer of longitudinal fibres and the other of circular fibres.

(3) **Mucous.** — The internal, or mucous, coat is arranged in longitudinal folds and covered with ciliated epithelium. It is continuous at the inner end with the mucous lining of the uterus, and at the distal end with the serous lining of the abdominal cavity. This is the only instance in the body in which a mucous and serous lining are continuous with one another.

Function. — The function of the Fallopian tubes is to convey the ova from the ovaries to the uterus. Just how the ovum, after its discharge into the abdominal cavity, reaches the Fallopian tube is not known. It is thought that the movement of the cilia on the fimbriæ and in the tubes produces a current which draws the ovum into the tube. After the ovum enters the tube it is carried to the uterus by the peristaltic action of the tube and the movement of the cilia. It is considered probable that many of the ova discharged from the ovaries remain in the abdominal cavity, because of failure to reach the tubes. These ova disintegrate, are absorbed, and carried away by the blood. Occasionally such an ovum becomes impregnated and ectopic gestation results.

The Uterus. — The uterus is a hollow, pear-shaped organ. In the virgin state it is situated in the pelvic cavity between the bladder and the rectum. Its length is estimated to be about three inches (75 mm.), its width two inches (50 mm.), and its thickness one inch (25 mm.). During pregnancy the uterus becomes enormously enlarged, attains the length of a foot (300 mm.) or more, measures about eight to ten inches (200 to 250 mm.) transversely, and extends into the umbilical region. After parturition the uterus returns to almost its original size, but is always larger than before pregnancy. After the menopause, the uterus becomes smaller and atrophies.

Divisions. — For purposes of description the uterus is divided into three parts: the fundus, body, and neck.

The **fundus** is the convex part above the entrance of the tubes.

The **body** is the part between the fundus and the neck.

The **cervix** or neck is the lower constricted part and extends from the body of the uterus into the vagina.

The cavity of the uterus is small; that part within the body is triangular in shape (▽), and has three openings, one at each upper angle, communicating with the Fallopian tubes, and one, the internal orifice, opening into the cavity of the cervix below. The cavity of the cervix, which is, of course, continuous with the cavity in the body, is constricted above, where it opens into the body by means of the internal orifice (internal os), and below, where it opens into the vagina by means of the external orifice (external os).

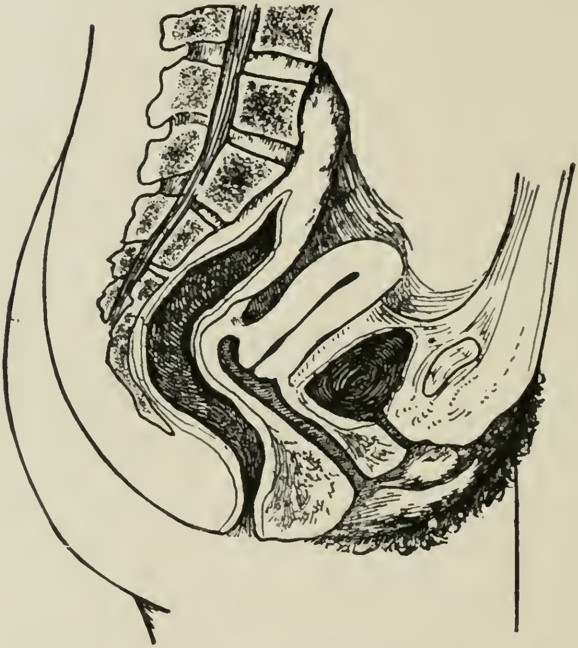

Fig. 206. — Internal Organs of Generation. Showing the uterus in its normal position between the bladder and the rectum. (Cooke.)

Between these two openings the canal of the cervix is somewhat enlarged.

Structure. — The walls of the uterus are thick and consist of three coats: —

(1) An external **serous** coat derived from the peritoneum. It covers all of the uterus, and the posterior surface of the cervix, but not the anterior surface.

(2) A middle **muscular** coat which forms the bulk of the uterine walls. It consists of layers of plain muscular tissue intermixed with blood-vessels, lymphatics, and nerves. The arrangement of the muscle fibres is very complex, as they run circularly, longitudinally, spirally, and cross and interlace in every direction.

(3) An internal **mucous** membrane, which is continuous with that lining the vagina and Fallopian tubes. It is highly vascular, pro-

vided with numerous mucous glands, and is covered with ciliated epithelium.

Blood supply of uterus. — The uterus is abundantly supplied with blood-vessels. The blood reaches the uterus by means of the uterine arteries from the internal iliacs, and the ovarian arteries from the aorta. Where the neck joins the body of the uterus, the arteries from both sides are united by a branch vessel, called the circumflex artery. If this branch is cut during a surgical operation, or a tear of the neck during parturition extends so far as to sever it, the hemorrhage is very profuse. The arteries are remarkable for their tortuous course and frequent anastomoses. The veins are of large size, and correspond in their behavior to the arteries.

Position of the uterus. — The uterus is not firmly attached or adherent to any part of the skeleton. It is, as it were, suspended in the pelvic cavity, and kept in position by ligaments. A full bladder pushes it backward; a distended rectum, forward. It alters its position, by gravity, or with change of posture. During gestation it rises into the abdominal cavity.

The fundus of the uterus is inclined forward, and the external orifice is directed downward and backward. (See Fig. 206.) *Anteversion* is the condition where the fundus turns too far forward. *Retroversion* is the condition where the fundus inclines backward. A bend may exist where the neck joins the body, and if the body is bent forward, it is described as *anteflexion;* if bent backward, *retroflexion.*

Ligaments. — The uterus is maintained in position by five ligaments. Three are arranged in pairs.

1. The **broad, or lateral ligaments**, two in number, are folds of peritoneum slung over the front and back of the uterus, and extending laterally to the walls of the pelvis. They are composed of two opposed, serous layers, and between these layers are found the following structures: (*a*) Fallopian tubes; (*b*) the ovaries and their ligaments; (*c*) the round ligaments; (*d*) blood-vessels and lymphatics; (*e*) nerves; (*f*) some smooth muscle-fibres.

The posterior fold covers the back of the uterus, and extends far enough below to also cover the upper one-fifth of the back wall of the vagina, when it turns up and is reflected over the anterior wall of the rectum. Thus the uterus, with and between its two broad ligaments, forms a transverse partition in the pelvic cavity, the bladder, vagina, and urethra being in the front compartment, and the rectum in the back compartment.

The smooth muscular fibres of the broad ligaments are derived from the superficial muscular layer of the uterus. They pass out between the serous folds and become attached to the pelvic fascia, and thus help to sustain the uterus.

2. The **round ligaments** are two rounded, fibro-muscular cords, situated between the folds of the broad ligament. They are about four and a half inches (113 mm.) long, and take their origin from the upper angle of the uterus (on either side) in front and a little below the attachment of the Fallopian tube. They extend forward and outward, and finally end in the tissues of the labia majora and mons Veneris. The round ligaments are composed of muscle-fibres, areolar tissue, blood-vessels, and nerves.

3. The **utero-sacral ligaments** extend between the cervix and sides of the rectum. They serve to connect the cervix and vagina with the sacrum, and are partly serous, partly of smooth muscular fibres.

4. **Anterior ligament.** — Between the bladder and uterus the peritoneum forms a shallow pouch called the utero-vesical pouch. This peritoneum, which forms the floor of the pouch, is described as the anterior ligament of the uterus.

5. **Recto-vaginal.** — Behind the uterus the peritoneum forms a second and deeper pouch called the recto-vaginal, or cul-de-sac, of Douglas. This peritoneum is described as the recto-vaginal ligament.

Function. — The function of the uterus is to receive the ovum from the Fallopian tubes, and if it becomes fertilized to retain it during its development. Later when the ovum has developed into a mature fœtus, it is expelled from the uterus, chiefly by the contraction of the uterine walls.

The Vagina. — The vagina is a musculo-membranous canal which encircles the lower portion of the cervix, and extends downward and forward from the uterus to the vulva.

The posterior wall is about three and a half inches (88 mm.) long, while the anterior wall is only three inches (75 mm.). The front, or anterior wall, is united by connective tissue with the posterior walls of the bladder and urethra, the partition, or septum, between the bladder and vagina being called the vesico-vaginal, and that between the urethra and vagina the urethro-vaginal, septum.

Structure. — The vagina is made up of three coats: an outer, **fibrous**; middle, **muscular**; and inner, **mucous**, which in the ordinary contracted state is thrown into fold, sits anterior and posterior walls being in contact. The muscular coat increases during pregnancy, and the mucous coat, because of the transverse folds, or rugæ, allow of dilatation of the canal during labor and birth.

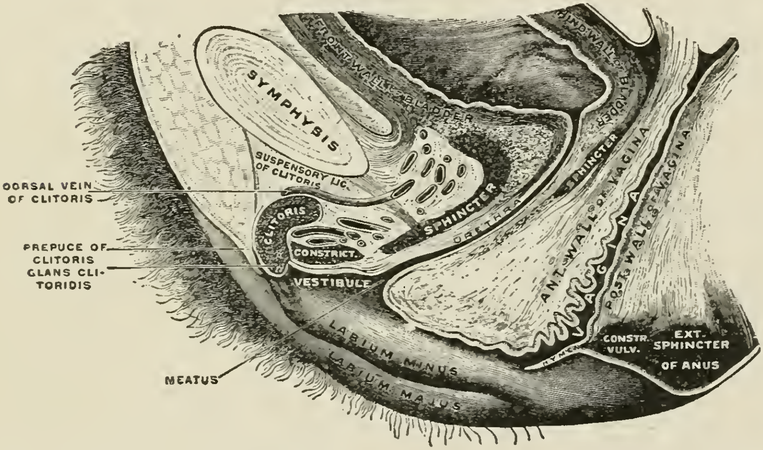

FIG. 207. — SAGITTAL SECTION OF THE VAGINA AND NEIGHBORING PARTS. (Gerrish.)

THE EXTERNAL ORGANS

As previously stated the external organs of generation are grouped under the name of vulva or pudendum and include the following: —

1. Mons Veneris
2. Labia Majora
3. Labia Minora
4. The Clitoris
5. The Hymen
6. Glands
   - Vulvo-vaginal
   - Urethral

Mons Veneris. — The mons Veneris is an eminence situated in front of the pubic bones. It consists of areolar, adipose, and fibrous tissue covered with skin and after puberty with hair.

Labia majora. — The labia majora ("greater lips") are two longitudinal folds of skin containing adipose and connective tissue. They are continuous with the mons Veneris in front, and extend to within an inch (25 mm.) of the anus behind.

Labia minora. — The labia minora ("smaller lips") are two longitudinal folds of modified epithelium situated between the labia majora. They are joined anteriorly in the hood or prepuce of the clitoris, and extend downward and backward for about one and one-half inches (38 mm.).

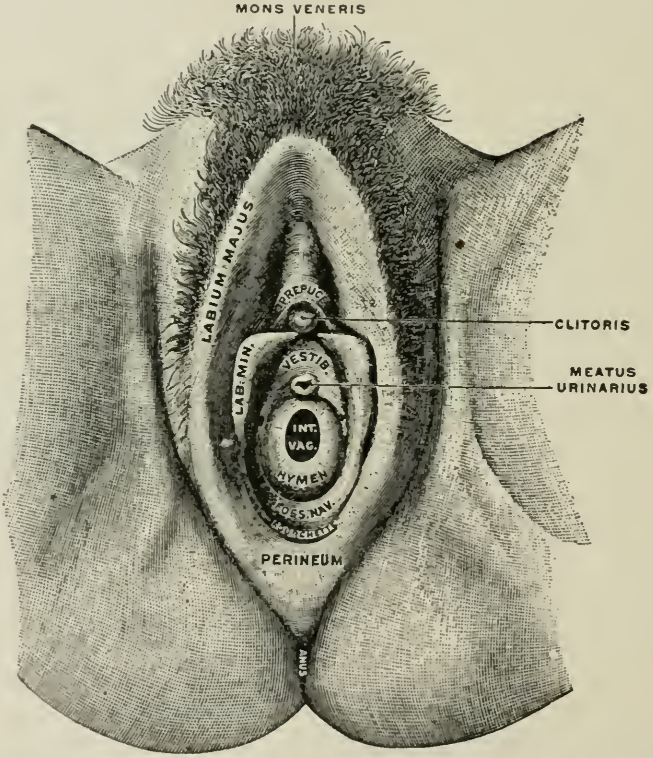

Fig. 208. — Vulva of a Virgin. The labia have been widely separated. Foss. Nav., fossa navicularis; Int. Vag., introitus vaginæ; Lab. Min., labium minus; Vestib., vestibule. (Gerrish.)

The clitoris. — The clitoris is a small body situated at the apex of the triangle formed by the junction of the labia minora. It contains many vessels and nerves and is almost completely covered by the hood or prepuce.

The hymen. — The hymen is a fold of mucous membrane which surrounds the lower part of the vaginal orifice and renders the orifice smaller. Occasionally it extends entirely across and closes the orifice altogether. This condition is spoken of as imperforate hymen.

Glands. — In connection with the vulva are found —

(1) Vulvo-vaginal glands or glands of Bartholin.
(2) Urethral glands.

The **vulvo-vaginal** are two round, or oval, glands, situated on either side of the vagina. Their ducts open into the vulval canal, one on either side, in the groove between the hymen and labia minora. Their secretion lubricates the vulval canal.

The **urethral** glands are found chiefly beneath the walls and floor of the urethra. They secrete mucus.

Perineum. — The perineum properly signifies the parts bounded by the outlet of the pelvis, but we generally apply it to the triangular portion between the vagina and rectum. It is made up of muscles strengthened with very strong fasciæ, and covered with skin. It is distensible, and stretches to a remarkable extent during labor. Nevertheless it is frequently torn, and when the tear is of any extent, and is not repaired, the vagina and uterus lose the support afforded by it, and various abnormal conditions follow.

PHYSIOLOGY OF THE FEMALE GENERATIVE ORGANS

Function. — The function of the female generative organs is: (1) the formation and development of the ovum, (2) the retention and sustenance of the fecundated ovum until it develops into a mature fœtus ready to live outside the body, and (3) the expulsion of the fœtus.

Puberty. — Puberty is the period at which the sexual organs become matured and functional and the girl develops into a woman. The event is not accomplished at once, but extends over considerable time. The girl undergoes a gradual change in figure, the hips broaden, the breasts develop, and for the first time a menstrual flow is noticed. At first the menstrual periods are scanty and irregular, but after a few months they settle down to the characteristic rate and duration. In temperate climates the age at which girls usually attain puberty is about fourteen years. In southern countries it is somewhat earlier, and in the arctic regions, a year or two later. However, no fixed rule can be given, as the time of arrival at puberty varies with every individual, depending on race, temperament, hygiene, and general surroundings.

The period preceding puberty, during which the physical changes are occurring, is known as the *period of adolescence.*

Ovulation. — Ovulation includes the process of the development and maturation of the follicle and its ovum, and the rupture of the follicle.

The commonly accepted theory is that about or shortly before the age of puberty the Graafian follicles begin to discharge their ova, and that this process continues until the menopause. The frequency with which well-developed ova are discharged is the subject of much dispute. The most conservative view is that there is one mature ovum discharged for each menstrual epoch, probably some days before the period occurs.

Menstruation. — Menstruation consists of the periodical discharge of bloody fluid from the uterine cavity. When once established it occurs on the average every twenty-eight days from the time of puberty to the menopause, with the exception of the periods of pregnancy and lactation. The average duration is from four to five days and the amount of blood lost is about six ounces. The menstrual fluid consists of mucus, epithelial cells, and blood. Some authorities are of the opinion that the mucous membrane of the uterus is normally shed during this process, others do not share this opinion.

The menopause or climacteric. — By menopause or climacteric is meant the physiological cessation of the menstrual flow, and the end of the period during which the Graafian follicles develop in the ovaries, and consequently the end of the child-bearing period. It is marked by atrophy of the breasts, uterus, tubes, and ovaries. The age of menopause varies as does the age of puberty; in general, we may say the earlier the puberty the later the menopause, and *vice versa.* In temperate climates the average period for the arrival of the menopause is at the age of forty-five years.

Changes in the generative organs in connection with menstruation. — At the beginning of menstruation there is a general congestion of the generative organs, including the breasts, accompanied by more or less discomfort and even pain. The mucous membrane of the uterus undergoes the following changes: (1) there is marked hypertrophy and congestion of the mucous membrane, (2) during menstruation there is capillary hemorrhage and the epithelium of the mucous membrane is cast off, (3) following menstruation a new epithelium is formed and the mucous membrane returns to its normal size.

Connection between ovulation and menstruation. — Whether ovulation depends upon menstruation or menstruation upon ovulation, or whether either has any connection with the other, is a matter of lengthy controversy. At the present time the generally accepted view is that menstruation is dependent upon the ovaries, and that their influence is exerted through the medium of the blood. It is thought that an internal secretion is formed in the ovaries, possibly by the corpus luteum. This secretion is carried to the uterus by the blood and is responsible for the hypertrophy and congestion that precedes menstruation. So far it has not been possible to decide whether the internal secretion is entirely responsible for menstruation, or whether it is partly due to a power inherent in the uterine muscle. The fact that operations for the removal of the ovaries are followed by atrophy of the uterus and cessation of menstruation, supports the theory that the ovaries are responsible for menstruation.

Purpose of menstruation. — The purpose of the hypertrophy and congestion of the uterus is thought to be nature's way of preparing the uterine walls for the reception of the ovum should it become fertilized.

Mammary glands. — The two mammary glands, or breasts, may be considered as accessory organs of generation.

Function. — The function of the mammary glands is to secrete the milk which is needed for the nourishment of the young infant.

Location. — Each breast covers a nearly circular space in front of the pectoral muscles, extending from the second to the sixth rib, and from the sternum to the border of the arm-pit.

Structure. — The breasts are covered externally by skin, are convex in shape, and about the centre of the convexity a papilla projects, which is called the nipple. The nipple contains the openings of the milk ducts, and is surrounded by a small circular area of pink or dark colored skin, which is called the *areola*. The areola is dotted over with projections formed by the sebaceous glands. They are compound glands, and are divided by connective tissue partitions into about twenty lobes, each of which possesses its own excretory duct, which as it approaches the top of the breast dilates and forms a small reservoir in which milk can be stored during the period when the gland is active. Each duct opens by a separate orifice upon the surface of the nipple. The lobes are subdivided, and the small lobes, or lobules, are made up of the terminal tubules of the duct, which lie in a mesh of fibrous areolar tissue containing considerable fat.

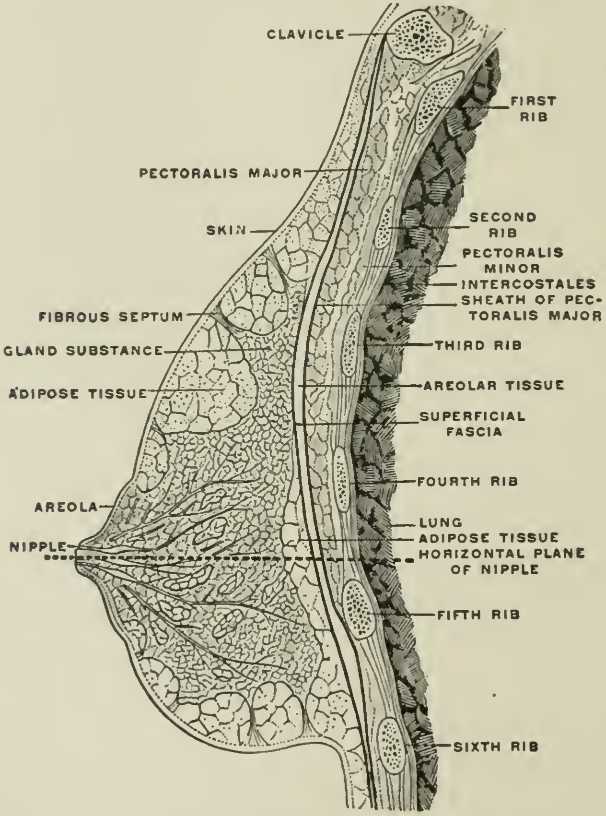

Fig. 209. — Right Breast in Sagittal Section, Inner Surface of Outer Segment. (Gerrish.)

Blood-vessels and nerves. — The mammary glands are well supplied with blood brought to them by branches of the axillary, internal mammary, and intercostal arteries. The nerves are chiefly intercostal nerves.

Development of the mammary glands. — The increase in the size of the mammary glands at the time of puberty is due to an increased development of the connective tissue and fat. The glandular tissue remains undeveloped and does not function unless conception takes place. When conception occurs the glandular tissue undergoes a process of gradual development that produces marked changes. The breasts become larger and harder, the veins on the surface become more noticeable, the areola becomes enlarged and darkened, the nipple becomes more prominent, and toward the end of pregnancy a fluid called colostrum can be squeezed from the orifice of the ducts. After delivery the amount of colostrum increases for a day or two, and then its composition changes to that of milk.

The primary development and later functioning of the mammary glands suggests an intimate connection between these glands and the uterus and ovaries. The present theory is that the increase in the size of the breasts at the time of puberty is influenced by the internal secretion of the ovaries, for if the ovaries are removed before puberty, the breasts do not develop, or if the ovaries are removed after puberty, the breasts are apt to atrophy. The development of the glandular tissue that follows conception is thought to be due to some chemical substance that results from the metabolism of the fœtus. The chemical nature of this substance is not known, but presumably it stimulates the development of the gland, and also prevents secretion, as active secretion does not commence until after delivery, and if conception occurs during the months of lactation, the character of the milk is changed and its secretion checked. The stimulus which causes the active secretion of milk is thought to result from the emptying of the milk ducts, because of the fact that when a woman does not nurse her infant, the secretion of milk is checked, and the breasts return to their usual size. The active secretion of milk is also influenced by the nervous system, and this influence is probably exerted through the vasomotor nerves which control the size of the blood-vessels, and consequently the amount of blood sent to the gland.

The secretion of milk. — The secretory portion of the mammary glands are the milk ducts, and these are lined with secreting cells. Some of the constituents of the milk, *i.e.* water, salts, and sugar, are secreted by these cells from the blood, but it is thought that the cells themselves disintegrate and form the proteins and fat. The sugar contained in the milk is lactose, and the sugar of the blood is glucose, so if the first is derived from the second, some chemical change must take place either during or after secretion.

Colostrum and milk. — The secretion of the mammary glands during the first few days of lactation is called colostrum. It is a thin, yellowish fluid, composed of proteins, fat, sugar, salts, and water, but not in the same proportion as in milk. It also contains numerous cells containing large masses of fat. These are called colostrum corpuscles, and are secreting cells that are not completely broken down.

Human milk is specially adapted to the requirements of the infant and so differs in some respects from that of all other animals. Cow's milk is most frequently substituted for human milk and the relative composition of the two can be seen in the following table: —

	Human (average)	Cow's (average)
Water	87.30 %	87.00 %
Proteins	1.50 %	4.00 %
Fat	4.00 %	4.00 %
Lactose	7.00 %	4.30 %
Salts	0.20 %	0.70 %

In substituting cow's milk for human milk the differences that must be taken into consideration are not only the different relative proportions, but also the following: (1) the difference in the proteins; the protein of human milk is one-third caseinogen, and two-thirds lactalbumin, and that of cow's milk is five-sixths caseinogen and one-sixth lactalbumin; (2) the difference in the curds formed in the stomach; human milk curdles in small flocculi, and cow's milk curdles in large heavy curds; and (3) the reaction of both human and cow's milk is amphoteric, but cow's milk is more nearly acid than human milk.

Male generative organs. — The male generative organs consist of the following structures: —

Testes, two glandular organs which produce the spermatozoa.
Vas Deferens
Seminal Vesicles
Ejaculatory Ducts
The Scrotum
The Spermatic Cords
The Penis
The Urethra
The Prostate Gland
Cowper's Glands

Testes. — The testes are two glandular organs which are suspended from the inguinal region by the spermatic cords, and are surrounded and supported by the scrotum. Each gland weighs from five to eight drachms (18.5 to 30 grams) and consists of two portions: (1) the testicle proper, and (2) the epididymis.

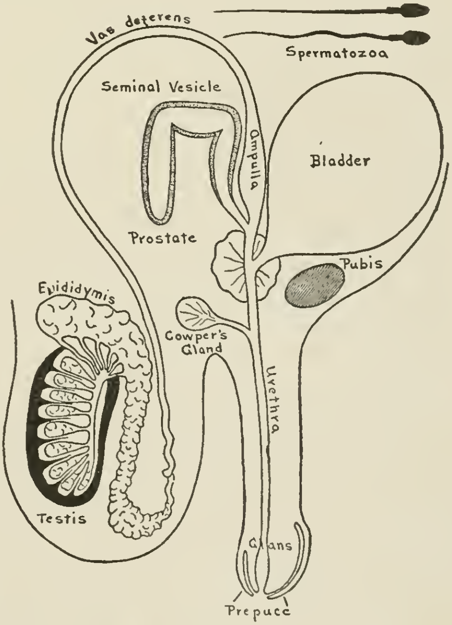

Fig. 210. — Male Sexual Apparatus. (Hall.)

(1) The **testicle proper** is ovoid in shape and covered exteriorly by fibrous tissue which sends incomplete partitions into the central portion of the gland, dividing it into communicating cavities. In these cavities are winding tubules which are surrounded by blood-vessels and held together by interstitial tissue. These tubules inosculate in a sort of mesh (rete testis) and finally all unite in the epididymis.

(2) The **epididymis** is a long, narrow body which lies along the posterior portion of the testicle and consists of a tortuous tubule, which is lined with mucous membrane, and contains some muscular tissue in its walls. If unravelled it is found to be about twenty feet (5 metres) long. It connects the testicle proper with the vas deferens.

Function. — The function of the testes is the production of spermatozoa. These spermatozoa are the essential part of the seminal fluid. The spermatozoa originate in the cells of the testes lining the tubules which compose the bulk of the testes. An internal secretion is also supposed to be formed here.

Descent of the testes. — In early fœtal life the testes are abdominal organs lying in front of and below the kidneys. During the process of growth they are drawn downward through the inguinal canal and shortly before birth are normally found in the scrotum. Sometimes, particularly in premature infants, the testis is found in the inguinal canal or even in the abdominal cavity; as a rule it soon descends and occupies its proper position; but occasionally it does not descend and an operation is necessary.

The vas deferens. — The vas deferens is a continuation of the epididymis, and is the excretory duct of the testicle. After a very devious course it joins the duct of the seminal vesicle at the base of the bladder. It consists of three coats, an external areolar, a middle muscular, and an internal mucous coat.

The seminal vesicles. — The seminal vesicles are two pouches which are placed each one on the outer side of each vas deferens, between the bladder and the rectum. They are pyramidal in form, with the broad ends directed backward and widely separated. The anterior portions converge, become narrowed, and unite on either side with the corresponding vas deferens to form the ejaculatory duct.

Function. — The seminal vesicles serve as a reservoir for the semen, to which they add a secretion of their own.

The ejaculatory ducts. — The ejaculatory ducts are two in number, one right and the other left. They are formed by the union of the seminal vesicle and vas deferens of each side. They run downward and converge as they descend, enter and pass between the lobes of the prostate gland and open into the floor of the prostatic portion of the urethra. Each has an external areolar, middle muscular, and internal mucous coat.

The scrotum. — The scrotum is a pouch which contains the testes and a part of each spermatic cord. It consists of a layer of skin, and the dartos. The skin is thick and dark, presents folds or rugæ, is furnished with sebaceous glands, and covered with short hairs. The dartos is a thin tunic of a reddish color consisting of muscular fibres and elastic tissue and containing numerous blood-vessels. It is continuous with the superficial fascia of the groin and perineum. It sends in a partition, which separates the two testes.

The spermatic cord. — The spermatic cord forms the pedicle of each testis and extends from the internal abdominal ring to the back of the testis. Each cord consists of the vas deferens, arteries, veins, lymphatics, nerves, the layers of fascia which cover the testis, and the remains of the peritoneal testicular process. These parts are connected together by areolar tissue.

The penis. — The penis consists of three more or less cylindrical bodies of erectile[1] tissue enclosed in fibrous sheaths. The two corpora cavernosa lie above and receive between them below the corpus spongiosum, in which the urethra is contained. The glans penis is continuous with the corpus spongiosum. The covering of the penis is of loose skin, but over the glans penis and lining the prepuce it resembles mucous membrane. In this region there is an abundant subcutaneous nerve plexus and numerous Pacinian[2] corpuscles, so that it is possessed of acute sensibility.

The urethra. — The urethra extends from the bladder through the corpus spongiosum to the end of the penis. It is usually divided into three parts: (1) the prostatic urethra, (2) the membranous urethra, and (3) the penile or spongy portion. The length is usually given as eight inches (200 mm.), a large part of which lies inside the pelvis. It is lined with mucous membrane and furnished with numerous muscular fibres.

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[1] Erectile tissue is found in the clitoris, penis, and the nipples. The form, size, and consistency of this tissue change according to the amount of blood contained in it. An increased amount of arterial blood causes swelling, and consequent pressure on, and occlusion of, the veins.

[2] Pacinian corpuscles are specialized nerve-endings found in the genital organs of both sexes, also in the palms of the hands, and the soles of the feet. (See Fig. 177.)

The prostate. — The prostate gland is situated in front of the neck of the bladder and around the commencement of the urethra. It resembles a chestnut in form and consists of a dense fibrous capsule containing glandular and muscular tissue. The glandular tissue consists of tubules which communicate with the urethra by minute orifices.

Function. — The function of the prostate gland is to secrete the prostatic fluid, which is an essential element of the seminal fluid.

Cowper's glands. — These are two small bodies about the size of a pea situated one on each side, adjacent to, and opening into the membranous urethra. They secrete a fluid which goes to form part of the seminal fluid.

Puberty. — This occurs in the male about a year later than in the female, about fifteen years of age. At this time the "Adam's Apple" develops, producing a marked change in the voice, the external genitals grow somewhat rapidly, hair grows on the face, pubes, axillæ, and other parts of the body, and seminal fluid begins to be secreted. At the same time sexual desires unknown before are experienced.

Semen. — The semen is a fluid derived from the various sexual glands in the male. The main elements in this fluid are the spermatozoa; the other constituents are derived from the seminal vesicles, prostate gland, and Cowper's glands.

PHYSIOLOGY OF REPRODUCTION

Reproduction. — The purpose of reproduction is the continuation of the species, and is accomplished by means of the reproductive organs, whose importance is in their adaptation to produce another being.

Impregnation. — The term impregnation or fertilization is applied to the union of the spermatozoon or male cell, with the ovum or female cell.

The ovum. — The ovum is a minute globular cell about $\frac{1}{125}$ inch (0.2 mm.) in diameter. The component parts have received special names.

The **cell-wall** is a thick, surrounding envelope, or membrane, called the vitelline membrane.

The **cell-body** is a mass of cytoplasm filled with fatty and albuminous granules, and usually called the vitellus.

The **cell nucleus**, or germinal vesicle, is a transparent, sharply outlined nucleus, embedded in the vitellus.

The **nucleolus**, or germinal spot, is a small, dark spot situated in the fluid nucleus.

The cell-body or cytoplasm contains the food material, and the nucleus contains chromatin material. Chromatin is of special interest because it is believed that it is through the chromatin material that hereditary characteristics are transmitted.

The spermatozoon. — The spermatozoon is the male generative cell and its function is to fertilize the ovum and produce impregnation. It is much smaller than the ovum, being only $\frac{1}{500}$ inch (0.1 mm.) in length. It consists of an elliptical head, a rod-shaped middle piece, and a tail that gradually tapers. The head contains nuclear material and chromatin. There is an active vibratory motion of the tail which allows it quite free motion in the seminal fluid. Because of this free motion the spermatozoa are able when deposited in the vagina to travel upward into the uterus, and into the tubes even against the current produced by the cilia of the tubes.

Site of impregnation. — It is thought that impregnation takes place in the Fallopian tubes. When the Graafian follicle ruptures and an ovum escapes into the abdominal cavity, the current produced by the cilia of the tubes is thought to draw it into the tube. Once in the tube the peristaltic action of the tube and the action of the cilia propel it slowly along to the uterus. If the ovum does not become impregnated it passes into the uterus and is cast off in the next menstrual flow. If, however, it comes in contact with the spermatozoon in its passage through the tube, the spermatozoon enters the ovum and segmentation or the process of cell division begins at once.

Segmentation. — After the union of these two, the cell rapidly divides into two, each of these two into other two, and so forth, until we have a number of cells where formerly there was one. At this stage the collection of cells is called the blastoderm. Gradually these cells which constitute the blastoderm become arranged in three layers, the outer called the ectoderm, an inner called the entoderm, and a middle layer called the mesoderm. (See page 27.)

The passage of the fertilized ovum through the tubes requires about eight days, and during this time many thousands of cells are formed and enclosed in a sac called the amnion. The collection of cells surrounded by the amnion is called an *embryo*. After entering the uterus the embryo attaches itself to the mucous membrane, in the upper portion, usually near the opening of the Fallopian tubes.

Changes in the uterine lining. — The preparation of the mucous membrane of the uterus for the reception of the impregnated ovum includes changes that are similar to those that precede menstruation. The mucous membrane becomes softer, thicker, and highly congested. In this condition it is known as the *decidua vera*, and the point to which the ovum becomes attached and which later develops into the placenta is called *decidua serotina*.

Intrauterine growth. — During the period of intrauterine life growth takes place rapidly. From the union of the ovum, which is $\frac{1}{125}$ inch (0.2 mm.) in diameter, and the spermatozoon, which is much smaller, there is developed in two weeks' time an embryo which is about the size of a bean. At the end of four weeks it is the size of a walnut, and at four months it is called a fœtus, because it has the appearance of a human being, with well-developed eyes, fingers and toes separated, and the external genitals sufficiently formed to determine the sex. The usual duration of pregnancy is nine lunar or ten calendar months, but at the end of six months the fœtus is sufficiently developed to live outside the mother's body, but it is fragile and requires a great deal of care.

For further details on the subject of reproduction the student is referred to standard works on physiology and obstetrics.

SUMMARY

- **Female Generative Organs**
  - **Internal organs**
    - Ovaries — two glandular organs in which the ova are formed.
    - Fallopian tubes — two canals through which the ova reach the uterine cavity.
    - Uterus — a hollow, pear-shaped organ which receives the ovum.
    - Vagina — a canal that extends from the uterus to the vulva.
  - **External organs**
    - Mons Veneris — a cushion of areolar fibrous and adipose tissue, in front of pubic bones, covered with skin and after puberty with hair.
    - Labia majora — two folds that extend from the mons Veneris to within an inch of the anus.
    - Labia minora — two folds situated between the labia majora.
    - Clitoris — small body, situated at apex of the triangle formed by junction of labia minora. Well supplied with nerves and blood-vessels.
    - Hymen — fold of mucous membrane that surrounds vaginal orifice.
    - **Glands**
      - Vulvo-vaginal — oval bodies situated on either side of the vagina.
      - Urethral — glands found chiefly beneath the walls and floor of urethra.
- **Ovaries**
  - Two almond-shaped glandular bodies.
  - Situated in posterior fold of broad ligament.
  - **Attached**
    - To uterus — by ligament of ovary.
    - To tubes — by fimbriæ.
  - **Size**
    - $1\frac{1}{2}$ inches long.
    - $\frac{3}{4}$ inch wide.
    - $\frac{1}{3}$ inch thick.
  - **Weight** — 1–2 drachms.
  - **Structure**
    - Stroma
      - Fibrous tissue.
      - Blood-vessels.
      - Lymphatics.
      - Nerves.
    - Graafian follicles
      - 1. Outer coat fibrous tissue.
      - 2. Inner layer of cells contain ovum.
    - Covering of germinal epithelium.
  - **Function**
    - Produce, develop, mature, and discharge ova.
    - Form an internal secretion.

- **Fallopian Tubes**
  - **Location**
    - Enclosed in layers of broad ligament.
    - Extend from upper angles of uterus to sides of pelvis.
  - **Divisions**
    - 1. Isthmus — or inner constricted portion near uterus.
    - 2. Ampulla — dilated portion which curves over ovary.
    - 3. Infundibulum — trumpet-shaped extremity — fimbriæ.
  - **Three coats**
    - 1. External, or serous.
    - 2. Middle, or muscular.
    - 3. Internal, or mucous, arrranged in longitudinal folds and covered with cilia.
  - **Function** — Convey ova to uterus.
- **Uterus**
  - Hollow, thick-walled organ, placed in pelvis between bladder and rectum.
  - **Divisions**
    - Fundus = rounded upper portion, above the entrance of the tubes.
    - Body = portion below fundus, above neck.
    - Cervix = lower and smaller portion which extends into vagina.
  - **Three coats**
    - External, or serous, derived from peritoneum.
    - Muscular
      - Circular fibres
      - Longitudinal fibres
      - Spiral fibres
      - Interlaced in every direction.
    - Mucous membrane, lines the uterus.
  - **Blood-vessels**
    - Uterine arteries from internal iliacs.
    - Ovarian arteries from aorta.
    - Remarkable for tortuous course and frequent anastomoses.
  - **Ligaments**
    - Broad, or lateral — two layers of serous membrane.
    - Round — two fibro-muscular cords.
    - Utero-sacral — two partly serous, partly muscular, ligaments.
    - Anterior — peritoneal floor of the utero-vesical pouch.
    - Recto-vaginal — peritoneal floor of the recto-vaginal pouch.
  - **Function** — To receive ovum, and if it becomes fertilized to retain it until developed and then to expel it.
- **Vagina**
  - **Canal** — Extends from uterus to vulva.
  - **Three coats**
    - Outer coat is fibrous.
    - Middle coat is muscular.
    - Mucous coat, or lining, arranged in rugæ.
  - **Location** — Placed between urethra and rectum.

- **Physiology of Generative Organs**
  - **Function**
    - Formation and development of ovum.
    - Retention and sustenance of fecundated ovum.
  - **Puberty** — Age at which sexual organs become matured and functional. Girl changes to woman.
  - **Ovulation**
    - Process of development and maturation of follicle and ovum, and discharge of ovum.
  - **Menstruation**
    - A flow of blood from the uterus. Occurs on an average every twenty-eight days. Extends from puberty (14 years) to the menopause, or climacteric (about 45 years). This period represents the child-bearing period of a woman's life.
    - Changes in connection with menstruation
      1. General congestion of generative organs including breasts.
      2. Hypertrophy and congestion of mucous membrane of uterus.
      3. Capillary hemorrhage. Epithelium is cast off.
      4. Following menstruation a new epithelium is formed.
    - Connection between ovulation and menstruation
      - Probably dependent on internal secretion of ovaries, and possibly is aided by power inherent in uterine muscle.
    - **Purpose** — Nature's way of preparing uterine walls for reception of fertilized ovum.
  - **Menopause** — Physiological cessation of the menstrual flow.
- **Mammary Glands**
  - Accessory organs of generation.
  - **Function** — To secrete milk to nourish infant.
  - **Location**
    - Extend from second to sixth rib.
    - Sternum to arm-pit.
  - **Structure**
    - Outer surface convex — papilla projects from centre — called nipple — contains openings of milk ducts. Nipple surrounded by areola.
    1. Consists of connective tissue framework which divides the gland into about twenty lobes.
    2. Lobes are subdivided into lobules.
    3. Lobules are made up of the terminal tubules of the duct.
    4. Each lobe possesses its own excretory duct, which is called lactiferous and is sacculated.
  - **Blood-vessels**
    - Axillary.
    - Internal mammary.
    - Intercostal.

Mammary Glands

- **Nerves** — Intercostal.
- **Development**
  - Primary development at time of puberty, probably due to internal secretion of ovaries.
  - Functional development follows conception, probably due to chemical substances that result from metabolism of fœtus. Active secretion stimulated by emptying milk ducts and influenced by nervous system.
- **Secretion of milk**
  - Water, Salts, Sugar — Secreted from blood.
  - Proteins, Fat — Formed by disintegration of cells lining lactiferous tubules.

Colostrum

- Thin yellowish fluid secreted during first few days of lactation.
- **Composition**

Proteins	5.71 per cent
Fat	2.04 per cent
Sugar	3.74 per cent
Salts	0.28 per cent
Water	88.23 per cent
	100.00 per cent

Milk

- **Composition**

	Human	*Cow's*
Water	87.30 %	87.00 %
Proteins	1.50 %	4.00 %
Fat	4.00 %	4.00 %
Lactose	7.00 %	4.30 %
Salts	0.20 %	0.70 %
	100.00 %	100.00 %

- **Differences**
  - Different relative proportions.
  - Difference in proteins
    - Human
      - Caseinogen $\frac{1}{3}$.
      - Lactalbumin $\frac{2}{3}$.
    - Cow's
      - Caseinogen $\frac{5}{6}$.
      - Lactalbumin $\frac{1}{6}$.
  - Difference in curds
    - Human — small flocculi.
    - Cow's — heavy curds.
  - Difference in reaction
    - Human — amphoteric.
    - Cow's — amphoteric, but more nearly acid.

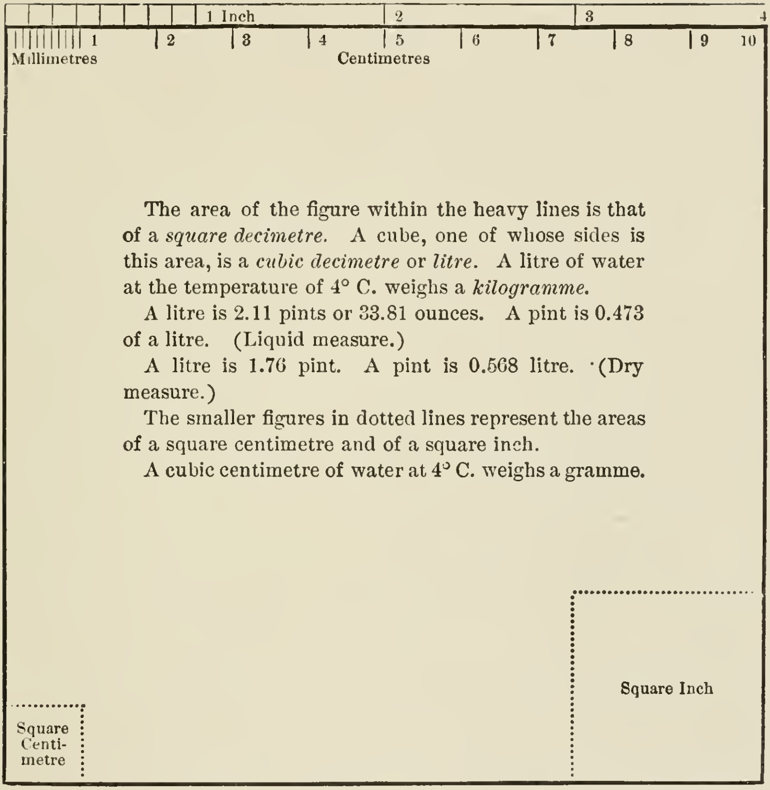
Male Generative Organs

- Testes.
- Vas deferens.
- Seminal vesicles.
- Ejaculatory ducts.
- The scrotum.
- Spermatic cords.
- The penis.
- The urethra.
- The prostate gland.
- Cowper glands.

- **Testes**
  - Two glandular organs which produce the spermatozoa.
  - **Structure**
    - **Testicle proper** — ovoid body covered by fibrous tissue. Central portion consists of irregular cavities filled with seminiferous tubules and blood-vessels.
    - **Epididymis** — tortuous tubule, forms long, narrow body which lies along posterior portion of testes.
  - **Location**
    - In early fœtal life in abdomen below kidneys.
    - Before birth is normally drawn downward to scrotum, and is suspended by spermatic cord.
  - **Function**
    - Production of spermatozoa.
    - Production of internal secretion.
- **Vas Deferens** — Continuation of epididymis, and serves to connect the epididymis and the seminal vesicle of each side.
- **Seminal Vesicles**
  - Two pouches located between bladder and rectum on outer side of each vas deferens. Connect vas deferens with ejaculatory duct.
  - **Function** — Serve as reservoirs for semen, to which they add a secretion of their own.
- **Ejaculatory Ducts**
  - Formed by union of seminal vesicles and vas deferens of each side.
  - Run downward, converge, pass between lobes of prostate gland and open into the floor of the prostatic portion of the urethra.
- **Scrotum**
  - Pouch which contains testes and part of each spermatic cord.
  - Structure
    - Covered with thick dark skin.
    - Dartos — reddish tunic under skin, consists of muscular and elastic tissue with numerous blood-vessels. Divided by septum into two halves.
- **Spermatic Cords**
  - Consists of the vas deferens, arteries, veins, lymphatics, nerves, and layers of fasciæ connected by areolar tissue and serving as pedicle for testes.
  - Extends from the internal abdominal ring to the back of the testes.
- **Penis**
  - Consists of three cylindrical bodies of erectile tissue
    - 1. Corpora cavernosa.
    - 2. Corpus spongiosum.
  - Contains urethra which extends from bladder to the end of penis.
  - Covered with skin and mucous membrane.
- **Urethra**
  - Extends from the bladder through the corpus spongiosum to the end of the penis. Length 8 inches.
  - Divisions
    - Prostatic portion.
    - Membranous portion.
    - Penile or spongy portion.
  - Consists of
    - Mucous lining.
    - Numerous muscular fibres.

- **The Prostate**
  - Situated in front of the neck of the bladder and around the commencement of urethra.
  - **Shape** — resembles chestnut.
  - **Consists of**
    - Fibrous capsule containing glandular and muscular tissue. Glandular tissue consists of tubules which empty into urethra.
  - **Function** — Secretion of prostatic fluid.
- **Cowper's Glands**
  - Located one on each side of membranous urethra into which they empty. About the size of a pea.
  - **Function** — Secretion of a fluid which forms part of seminal fluid.
- **Puberty**
  - Age at which sexual organs become matured and functional.
  - Boy changes to a man.
- **Semen**
  - Fluid derived from the various sexual glands in the male.
  - Spermatozoa are the main elements.
- **Reproduction**
  - **Function** — Produce another being.
  - **Impregnation**
    - Union of spermatozoon and ovum.
    - Occurs in Fallopian tubes.
  - **Ovum**
    - Globular cell formed in ovaries, $\frac{1}{125}$ inch in diameter.
    - Consists
      - Cell-wall = zona pellucida.
      - Cell-body = cytoplasm, serves as food.
      - Cell nucleus = germinal vesicle, contains chromatin.
      - Nucleolus = germinal spot.
  - **Spermatozoon**
    - A long, narrow cell formed in testes, $\frac{1}{500}$ of an inch in length.
    - Consists of
      - Elliptical head which contains nuclear material and chromatin.
      - Rod-shaped centre piece.
      - Tail.
    - Capable of independent motion in a fluid medium.
    - Function to fertilize ovum.
  - **Development of ovum**
    - Divides into many cells surrounded by amnion and called embryo. Attaches itself to upper part of uterine cavity in soft mucous membrane prepared for its reception.
    - Embryo — Blastoderm
      - Entoderm.
      - Mesoderm.
      - Ectoderm.
    - Two weeks — size of a bean.
    - Four weeks — size of a walnut.
    - Four months — fœtus — human characteristics are marked.

METRIC SYSTEM



The area of the figure within the heavy lines is that of a *square decimetre.* A cube, one of whose sides is this area, is a *cubic decimetre* or *litre.* A litre of water at the temperature of 4° C. weighs a *kilogramme.*

A litre is 2.11 pints or 33.81 ounces. A pint is 0.473 of a litre. (Liquid measure.)

A litre is 1.76 pint. A pint is 0.568 litre. (Dry measure.)

The smaller figures in dotted lines represent the areas of a square centimetre and of a square inch.

A cubic centimetre of water at 4° C. weighs a gramme.

1 Metre = 39.370432 inches.
1 Decimetre = 3.937043 inches.
1 Centimetre = .393704 inch.
1 Millimetre = .039370 inch.

1 Gramme = 15.432 grains.
1 Decigramme = 1.543 grains.
1 Centigramme = .154 grain.
1 Milligramme = .015 grain.
1 Dekagramme = 154.323 grains.
1 Hektogramme = 1543.235 grains.
1 Kilogramme = 15432.350 grains.
1 Kilogramme = 35.274 ounces.
1 Kilogramme = 2.204 pounds.

Avoirdupois weights are used in weighing the organs of the body. One ounce avoirdupois = 28.35 grammes.

GLOSSARY

Abdo'men. [From the Lat. *abdo,* to "conceal."] The largest cavity of the body, containing the liver, stomach, intestines, etc.; the belly.

Abdu'cens. [From the Lat. *ab,* "from," and *duco,* to "lead."] A term applied to the sixth pair of cranial nerves which supply the external recti (*abductor*), muscles of the eye.

Abduc'tion. [From the Lat. *ab,* "from," and *duco,* to "lead."] Drawn away from the middle line of the body.

Absorp'tion. [From the Lat. *ab,* "from," and *sorbeo,* to "suck up."] The process of taking up into the vascular system either digested food from the alimentary canal, or other substances from the various tissues.

Acetab'ulum. [From the Lat. *acetum,* "vinegar."] A name given to the cup-shaped cavity in the os innominatum, resembling in shape an old-fashioned *vinegar* vessel.

Acromeg'aly. [From the Gr. *akron,* an "extremity," and *megas,* "great."] A disease characterized by an overgrowth of the extremities and the face as well as the soft parts.

Acro'mion. [From the Gr. *akron,* "summit," and *ōmos,* the "shoulder."] The triangular-shaped process at the *summit* of the scapula.

Adduc'tion. [From the Lat. *ad,* "to," and *duco,* to "lead."] Brought to or nearer the middle line of the body.

Ad'enoid. [From the Gr. *adēn,* a "gland," and *eidos,* "form," or "resemblance."] Pertaining to, or *resembling a gland.*

Ad'ipose. [From the Lat. *adeps,* "fat."] Fatty.

Adre'nal. [From the Lat. *ad,* "to," and *ren,* the "kidney."] Same as supra-renal. A small gland situated on the top of the kidneys.

Af'ferent. [From the Lat. *ad,* "to," and *fero,* to "bear," to "carry."] *Bearing* or *carrying inwards,* as from the periphery to the centre.

Agminated. [From the Lat. *agmen,* a "multitude," a "group."] Arranged in clusters, grouped together as the agminated glands of Peyer in the small intestine.

Akine'sis. [From the Gr. *a,* "without," and *kinesis,* "motion."] Without motion. Fission or direct division of cells.

Albu'mins. [From the Lat. *albus,* "white."] Thick, viscous substances containing nitrogen, that are soluble in water, dilute acids, dilute salines, and concentrated solutions of magnesium sulphate and sodium chloride. They are coagulated by heat and strong acids. Examples are: egg albumin and serum albumin of blood.

Albuminu'ria. [A combination of the words "albumin" and "urine."] Presence of *albumin* in the *urine.*

Aliment'ary. [From the Lat. *alimentum,* "food."] Pertaining to *aliment,* or food.

Alve'oli. Plural of alveolus. [From the Lat. *alveolus,* a "little hollow."] Any little cell, pit, cavity, fossa, or socket. Socket of a tooth or an air-cell.

Amœ'ba. [From the Gr. *ameibō,* to "change."] A single-celled organism, which is constantly *changing* its form by protrusions and withdrawals of its substance.

Amphiarthro'sis. [From the Gr. *amphō,* "both," and *arthron,* a "joint."] A mixed articulation; one which allows slight motion.

Amphoteric. [From the Gr. *amphoteros,* "both."] Partly acid and partly alkaline in reaction; having the power of turning red litmus paper blue, and blue litmus paper red.

Ampul'la. [From the Lat. *ampulla,* a "globular vessel."] The dilated part of a canal.

Amylop'ins. [From the Gr. *amylum,* "starch," and *opsis,* "appearance."] An enzyme of the pancreatic juice that has the power to change starch into malt sugar, or maltose. Same as *diastase.*

Anabol'ism. [From the Gr. *anabole,* a "throwing up."] The process by means of which simpler substances are *built up* into more complex substances.

Anæsthe'sia. [From the Gr. *a, an,* "without," and *aisthanomai,* to "perceive," to "feel."] A condition of insensibility.

Anastomo'sis. [From the Gr. *ana,* "by," "through," and *stoma,* a "mouth."] Communication of branches of vessels with one another.

An'nular. [From the Lat. *annulus,* a "ring."] Ring-like, such as the ligaments found at some of the joints.

Aor'ta. [From *aortē,* to "carry."] The great artery that carries blood from the left ventricle of the heart.

Apnœ'a. [From the Gr. *a,* "without," and *pnœa,* "breath."] Absence of breathing.

Aponeuro'sis. [From the Gr. *apo,* "from," and *neuron,* a "sinew" or "tendon."] A flat wide band of fibrous tissue which is attached to a muscle.

Arach′noid. [From the Gr. *arachnē*, a "spider," a "spider's web," and *eidos*, "form," or "semblance."] *Resembling a web.* The middle of the three membranes of the brain and spinal cord.

Arboriza′tions. A growth or an appearance resembling the figure of a tree or plant.

Are′olar. [From the Lat. *areola*, a "small space," dim. of *area*.] A term applied to a connective tissue containing *small spaces;* also to the colored area surrounding the nipple.

Arrec′tor. [From the Lat. *arrectus*, "set up erect."] That which arrects. The arrector of the hair.

Arte′rioles. [Arteriola, dim. of Lat. *arteria*, "artery."] A small artery.

Arteriosclero′sis. [See artery below. Lat. *scleroticus*, from Gr. *sklēroō*, to "harden."] Hardening of the arteries.

Ar′tery. [From the Gr. *aēr*, "air," and *tereo*, to "keep."] Literally, an air-keeper (it being formerly believed that the arteries contained air). A blood-vessel which carries blood from the heart.

Arthro′dia. [From the Gr. *arthron*, a "joint."] A variety of movable joint.

Articula′tion. [From the Lat. *articulus*, "a joint."] The more or less movable union of bones, etc.; a joint.

Asphyx′ia. [From the Gr. *a*, "without," and *sphyxis*, the "pulse."] Literally, *without pulse.* Condition caused by non-oxygenation of the blood.

Assimila′tion. [From the Lat. *ad*, "to," and *similis*, "like."] The conversion of food into living tissue.

At′las. The first cervical vertebra by which the head articulates with the spinal column, so called because it supports the head as Atlas was fabled to support the world on his shoulders.

At′rophy. [From the Gr. *a*, "without," and *trophē*, "nourishment."] Wasting of a part from lack of nutrition.

Aud′itory. [From the Lat. *audio*, *auditum*, to "hear."] Pertaining to the sense or organ of *hearing*.

Augmenta′tion. The act of increasing or making larger.

Aur′icle. [From the dim. of Lat. *auris*, the "ear."] A *little ear*, a term applied to the *ear*-shaped cavities of the heart, also to the expanded portion of the external ear.

Automat′ic. [From the Gr. *automatos*, "self-moving."] Not voluntary, not under the control of or affected by volition.

Az′ygos. [From the Gr. *a*, "without," and *zygos*, a "yoke."] Without a fellow; hence, unpaired, single.

Bi′ceps. [From the Lat. *bis*, "twice," and *caput*, the "head."] A term applied to muscles having a double origin or *two heads*.

Bicus′pid. [From the Lat. *bis*, "twice," and *cuspis*, the "point of a spade."] Having *two points* or flaps.

Blas′toderm. [From the Gr. *blastos*, a "bud," and *derma*, "skin."] The primitive membrane or layer of cells resulting from the subdivision of the germ.

Brach′ial. [From the Lat. *brachium*, the "arm."] Belonging to the arm.

Brachio-cephal′ic. [From the Lat. *brachium*, the "arm," and *cephalicus*, "of or pertaining to the head."] Of or pertaining both to the upper arm and the head; as the brachio-cephalic (innominate) artery and veins.

Bron′chi, pl. of **Bronchus.** [From the Gr. *bronchos*, the "wind pipe."] The two main branches of the trachea.

Bron′chioles. A small bronchial tube.

Buc′cal. [From the Lat. *bucca*, the "cheek."] Pertaining to the mouth or *cheeks*.

Buc′cinator. [From the Lat. *buccinare*, "blow a trumpet."] The trumpeter's muscle. A thin, flat muscle that helps to form the wall of the cheek.

Bur′sal. [From the Gr. *bursa*, a "bag."] Pertaining to *bursæ*, membranous sacs.

But′tock. The part at the back of the hip, which in man, forms one of the protuberances on which he sits.

Butyr′ic Acid. [From the Lat. *butyrum*, "butter."] A colorless liquid having a strong rancid smell and acrid taste. C_3H_7COOH.

Cæ′cum. [From the Lat. *cæcus*, "blind."] The *blind gut*.

Calca′neum. [From the Lat. *calx*, the "heel."] The bone of the heel.

Cal′culi, pl. of **Cal′culus.** [From the Lat. *calculus*, "a pebble."] Stones.

Caly′ces, pl. of **Ca′lyx.** [From the Gr. *kalyx*, a "cup."] Anatomists have given this name to small *cup*-like membranous canals, which surround the papillæ of the kidney, and open into its pelvis.

Canalic′ulus, pl. **Canalic′uli.** [Dim. of Lat. *canalis*, a "channel."] A *small channel*, or vessel.

Can′cellated. [From the Lat. *cancellus*, "lattice-work."] A term used to describe the spongy *lattice-work* texture of bone.

Ca′nine. [From the Lat. *canis*, a " dog."] Name given to the third tooth on each side of the jaw; in the upper jaw it is also known as the eye-tooth, pointed like the tusks of a dog.

Can′thus. [From the Gr. *kanthos*, the " angle of the eye."] The angle formed by the junction of the eyelids, the internal being the greater, the external the lesser, canthus.

Cap′illary. [From the Lat. *capillus*, " hair."] A minutely fine vessel, resembling a *hair* in size.

Car′dio-inhib′itory. [From the Gr. *kardia*, " heart," and *inhibere*, to " restrain."] An agent which restrains the heart's action.

Carot′ids. [Perhaps from the Gr. *karos*, " stupor," because pressing on them produces stupor.] The great arteries conveying blood to the head.

Car′pus. [From the Gr. *karpos*, the " wrist."] The assemblage of bones forming the wrist.

Car′tilage. [From the Lat. *cartilago*, " gristle."] A solid but flexible material, forming a part of the joints, air-passages, nostrils, etc. *Gristle.*

Ca′seinogen. [From the Lat. *caseus*, "cheese."] The curd separated from milk by the addition of rennet, constituting the basis of cheese.

Cataly′zer. [From the Gr. *kata*, " down," and *luein*, to " loose."] A substance which hastens chemical reactions, but does not enter into the reactions. Enzymes are described as catalyzers.

Caud′a Equi′na. [Lat. " Horse-tail."] A term applied to the termination of the spinal cord, which gives off a large number of nerves which, when unravelled, resemble a *horse's tail.*

Cau′date. [From the Lat. *cauda*, a " tail."] Tail-like.

Centrif′ugal. [From the Lat. *centrum*, the " centre," and *fugere*, " flee."] Flying off or proceeding from the centre.

Centrip′etal. [From the Lat. *centrum*, the " centre," and *petere*, " seek, move toward."] Tending or moving toward the centre. Opposed to centrifugal.

Cen′trosome. [From the Gr. *kentron*, " centre," and *soma*, the " body."] A peculiar rounded body lying near the nucleus of the cell. It is regarded as the dynamic element by means of which the machinery of cell division is organized.

Cerebel′lum. [Dim. of Lat. *cerebrum*, the " brain."] The hinder and lower part of the brain; the *little brain.*

Cer′ebrum. [Lat. the " brain."] Chief portion of brain.

Ceru′minous. [From the Lat. *cerumen,* "ear-wax."] A term applied to the glands secreting cerumen, *ear-wax.*

Cer′vix. [Lat.] The neck (little used). Part of an organ likened to a neck.

Choles′terin. [From the Gr. *chole,* "bile," and *stear,* "fat."] A tasteless, inodorous, fatty substance found in small quantities in the protoplasm of all cells, especially in nerve tissue, blood corpuscles, and bile. Its origin and function are not known.

Chon′drin. [From the Gr. *chondros,* "cartilage."] A kind of gelatine obtained by boiling *cartilage.*

Chor′da Tym′pani. [Lat.] The tympanic cord, a branch of the facial, or seventh cranial, nerve which traverses the tympanic cavity and joins the gustatory, or lingual, nerve.

Chor′dæ Tendin′eæ. [Lat.] Tendinous cords.

Cho′roid. [From the Gr. *chorion,* "skin," and *eidos,* "form," or "resemblance."] A *skin-like* membrane; the second coat of the eye.

Chyle. [From the Gr. *chulos,* "juice."] Milky fluid of intestinal digestion, found in the lymphatics of the intestines.

Chyme. [From the Gr. *chumos,* "juice."] Food that has undergone gastric but not intestinal digestion. (Both chyle and chyme signify literally *liquid,* or *juice.*)

Cica′trix. [Lat. a "scar."] The mark, or *scar,* left after the healing of a wound.

Cil′ia. [Lat. the "eyelashes."] Hair-like processes of certain cells.

Circumval′late. [From the Lat. *circumvallo,* to "surround with a wall."] *Surrounded by a wall.*

Clav′icle. [From the dim. of Lat. *clavis,* a "key."] The collar-bone, so named from its shape.

Coagula′tion. [From the Lat. *coag′ulo,* to "curdle."] Applied to the process by which the blood clots or solidifies.

Coalesce′. [From the Lat. *con,* "together," and *alere,* to "nourish."] To grow together.

Coc′cyx. [Lat. the "cuckoo."] The lower curved bone of the spine, resembling a *cuckoo's* bill in shape.

Coch′lea. [Lat. a "snail," a "snail-shell"; hence, anything spiral.] A term applied to a cavity of the internal ear.

Cœ′liac. [From the Gr. *koilos,* "hollow."] Pertaining to the abdominal *cavity.*

Collat′erals. [From the Lat. *con,* "together," and *lateralis,* "of the side."] Situated at the side; hence, also secondary.

Co′lon. [Gr. *kolon.*] That portion of the large intestine which extends from the cæcum to the rectum.

Colum′næ Car′neæ. [Lat.] "Fleshy columns"; muscular projections in the ventricles of the heart.

Com′missure. [From the Lat. *con,* "together," and *mitto, missum,* to "send."] A joining or uniting together. Something which joins together.

Con′cave. [From the Lat. *con,* "together," and *cavus,* a "hollow."] The interior of a curved surface.

Con′cha. [Lat. a "shell."] A term applied to the hollow portion of the external ear.

Con′dyloid. [From the Gr. *kondulos,* a "knob," or "knuckle," and *eidos,* "likeness."] A term applied to joints and processes of bone having flattened *knobs* or heads.

Congen′ital. [From the Lat. *con,* "together," and *gignere,* to "beget."] Existing from birth.

Conjuncti′va. [From the Lat. *con,* "together," and *jungo, junctum,* to "join."] A term applied to the delicate mucous membrane which lines both eyelids and covers the external portion of the eyeball.

Contig′uous. [From the Lat. *contiguus,* akin to *contingere,* "to touch on all sides."] Adjacent; near; in actual contact.

Convec′tion. [From the Lat. *con,* "together," and *vehere,* to "carry."] A process of transfer or transmission as of heat or electricity. The term "convection currents" is used in the text, and applies to currents of air produced by differences in temperature and density. Warm air expands, becomes less dense, and is forced upward by the cooler air, which is heavier and sinks down. In this way convection currents are established.

Converge′. [From the Lat. *con,* "together," *vergere,* to "incline."] To join at a point.

Con′vex. [From the Lat. *convexus,* "vaulted."] The exterior of a curved surface.

Convolu′tions. [From the Lat. *con,* and *vol′vo,* to "roll together."] The tortuous foldings of the external surface of the brain.

Cor′acoid. [From the Gr. *korakos,* a "crow," and *eidos,* "form."] Process of the scapula, so named because it was thought to be the shape of a crow's beak.

Co′rium. [Lat. the "skin."] The deep layer of the skin; the derma.

Cor′nea. [From the Lat. *cornu*, a "horn."] The transparent anterior portion of the eyeball.

Cor′onary. [From the Lat. *corona*, a "crown."] A term applied to vessels, ligaments, and nerves which encircle parts like a *crown*, as the coronary arteries of the heart.

Cor′pora Aran′tii. [From the Lat. *corpus*, the "body."] Fibro-cartilaginous nodules situated one in the centre of the free edge of each of the segments of the aortic and pulmonary valves. Named from Aranzi, an Italian anatomist.

Cor′pus Callo′sum. [Lat.] "Callous body," or substance. A name given to the *hard substance* uniting the cerebral hemispheres.

Cor′tex. [Lat. "bark."] External or surface layer of an organ, such as the kidney or brain.

Cos′tal. [From the Lat. *costa*, a "rib."] Pertaining to the *ribs*.

Cox′a, pl. **Coxæ**. [From the Lat. *coxa*, "hip."] The hip bone, os coxæ or os innominatum.

Crena′ted. [From the Lat. *crena*, a "notch."] *Notched* on the edge.

Crib′riform. [From the Lat. *cribrum*, a "sieve," and *forma*, "form."] Perforated *like a sieve*.

Cri′coid. [From the Gr. *kri′kos*, a "ring."] A cartilage of the larynx resembling a seal-ring in shape.

Cru′ra Cer′ebri. [From the Lat. *crus* (pl. *crura*), a "leg."] *Legs*, or pillars, of the *cerebrum*.

Crypt. [From the Gr. *kryptō*, to "hide."] A *secreting* cavity; a follicle, or glandular cavity.

Cune′iform. [From the Lat. *cuneus*, a "wedge," and *forma*, "shape."] Having the shape or form of a wedge. Name given to two carpal and six tarsal bones.

Cu′ticle. [From the dim. of Lat. *cutis*, the "skin."] A term applied to the upper, or epidermal, layer of the *skin*.

Cu′tis Ve′ra. [Lat.] The true skin; that underneath the epidermal layer.

Cys′tic. [From the Gr. *kustis*, the "bladder."] Pertaining to a *cyst*, — a *bladder* or sac.

Cy′toplasm. [From the Gr. *kutos*, a "cell," and *plassō*, to "form."] The name given by Kölliker to the contents of a *cell;* same as protoplasm.

Decid′uous. [From the Lat. *deciduus,* "that falls down."] Falling or liable to fall. Not permanent.

Decussa′tion. [From the Lat. *decusso, decussatum,* to "cross."] To cross in the form of the letter X.

Degluti′tion. [From the Lat. *de,* "down," and *glutitio,* "swallow."] The act or power of swallowing.

Del′toid. Having a triangular shape; resembling the Greek letter Δ (*delta*).

Den′drite. [From the Gr. *dendrites,* "pertaining to a tree."] The name given to the branching processes of the neurone which begin to divide and subdivide as soon as they leave the nerve-cell.

Denti′tion. [From the Lat. *dentitio,* "teething."]

1. The process of cutting teeth.
2. The time during which teeth are being cut.
3. The kind, number, and arrangement of teeth proper to any animal.

Diabe′tes Mel′litus. [From the Gr. *dia,* "through," *bainō,* to "go," and Lat. *mel,* "honey."] Excessive flow of sugar-containing urine.

Diapede′sis. [From the Gr. *dia,* "through," and *pēdaō,* to "leap," to "go."] *Passing* of the red blood-corpuscles *through* vessel walls without rupture.

Di′aphragm. [From the Gr. *diaphrassō,* to "divide in the middle by a partition."] The *partition muscle dividing* the cavity of the chest from that of the abdomen.

Diarthro′sis. [From the Gr. *dia,* "through," as implying no impediment, and *arthron,* a "joint."] A freely movable articulation.

Di′astase. [From the Gr. *diastasis,* "separate."] An enzyme of the saliva and pancreatic juice capable of decomposing carbohydrates.

Dias′tole. [From the Gr. *diastellō,* to "dilate."] The *dilatation* of the heart.

Diath′esis. [From the Gr. *dia,* "through," and *tithenai,* to "place."] A congenital condition of the system which renders it peculiarly liable to some diseases.

Dichot′omous. [From the Gr. *dichotomos,* "cutting in two."] Pertaining to or consisting of a pair or pairs. Divided into two.

Diges′tion. [From the Lat. *digestio,* "arrangement."] The process of converting the food from the state in which it enters the mouth to that in which it can pass from the alimentary canal into the blood-vessels and lymphatics.

Dip′loë. [From the Gr. *diploō,* to "double," to "fold."] The osseous tissue between the tables of the skull.

Disac′charid. [From the Lat. *dis,* "twice," and *saccharon,* "sugar."] A complex sugar which on hydrolysis yields two molecules of a simple sugar.

$$\underset{\text{Disaccharid}}{C_{12}H_{22}O_{11}} + H_2O \rightarrow \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Fructose}}{C_6H_{12}O_6}$$

Dis′cus Prolig′erus, or **germ disk.** A term applied to a mass of cells clinging to the ovum when it is set free from the ovary. More recent term is "ovarian mound."

Disintegra′tion. [From the Lat. *dis,* "twice," and *integer,* "entire, whole."] A breaking apart.

Distilla′tion. [From the Lat. *distillatio,* a "dripping down."] The act of distilling or of falling in drops. The operation of driving off gas or vapor from volatile liquids or solids, by heat in a retort or still, and the condensation of the products as far as possible by a cool receiver.

Dor′sal. [From the Lat. *dorsum,* the "back."] Pertaining to the *back,* or posterior part, of an organ.

Duode′num. [From the Lat. *duodeni,* "twelve each."] First part of small intestines, so called because about *twelve* fingers' breadth in length.

Du′ra Ma′ter. [Lat.] The "hard mother," called *dura* because of its great resistance, and *mater* because it is the guardian or protector of the brain. The outer membrane of the brain and spinal cord.

Dyspnœ′a. [From the Gr. *dys,* "difficult," and *pneō,* to "breathe."] Difficult breathing.

Ec′toderm. [From the Gr. *ektos,* "outside," and *derma,* the "skin."] The completed outer layer of cells, or outer blastodermic membrane. Same as epiblast.

Ectop′ic. [From the Gr. *ek,* "out of," and *topos,* "place."] Characterized by being *out of place.*

Ef′ferent. [From the Lat. *ex,* "out," and *fero,* to "carry."] *Bearing* or *carrying outwards,* as from the centre to the periphery.

Elemen′tary. Pertaining to or of the nature of an element or elements.

Elimina′tion. [From the Lat. *e,* "out of," and *limen, liminis,* a "threshold."] The act of *expelling* waste matters. Eliminate signifies, literally, to throw out of doors.

Em′bolus. [From the Gr. *embolos,* a wedge.] A portion of a blood clot which has been formed in one of the larger vessels, and has afterward been forced into one of the smaller vessels where it may act as a wedge.

Em′bryo. The ovum and product of conception up to the fourth month, when it becomes known as the fœtus.

Emul′sion. [From the Lat. *emulgere*, to "milk."] A mixture of liquids, insoluble in one another, where one is suspended in the other in the form of minute globules, as the fat in milk.

Enarthro′sis. [From the Gr. *en*, "in," and *arthron*, a "joint."] An articulation in which the head of one bone is received into the cavity of another, and can be moved in all directions.

Endocar′dium. [From the Gr. *endon*, "within," and *kardia*, "heart."] Lining of the heart.

En′dolymph. [From the Gr. *endon*, "within," and Lat. *lympha*, "water."] The fluid in the membranous labyrinth of the ear.

Endos′teum. [From the Gr. *endon*, "within," and *osteon*, a "bone."] The lining membrane of the medullary cavity of a bone; the internal periosteum.

Endothe′lium. [From the Gr. *endon*, "within," and *thele*, the "nipple."] A term applied to single layers of flattened transparent cells, applied to each other at their edges and lining certain surfaces and cavities of the body. In contradistinction to epithelium.

En′siform. [From the Lat. *ensis*, a "sword," and *forma*, "form."] Shaped like a sword.

En′toderm. [From the Gr. *endon*, "within," and *derma*, the "skin."] The completed inner layer of cells, or inner blastodermic membrane. Opposed to ectoderm. Same as hypoblast.

En′zyme. [From the Gr. *en*, "in," and *zume*, "leaven."] A term applied to a class of ferments.

Ep′iblast. [From the Gr. *epi*, "upon," and *blastos*, a "germ," or "sprout."] The external, or upper, layer of the *germinal* membrane.

Epicra′nial. [From the Gr. *epi*, "upon," and *kranion*, "the cranium."] That which is upon the cranium or scalp.

Epider′mis. [From the Gr. *epi*, "upon," and *derma*, the "skin."] The outer layer of the skin.

Epigas′tric. [From the Gr. *epi*, "upon," and *gaster*, "stomach."] Lying upon, distributed over, or pertaining to the abdomen or the stomach.

Epiglot′tis. [From the Gr. *epi*, "upon," and *glottis*, the "glottis."] The cartilage at the root of the tongue which forms a lid or cover for the aperture of the larnyx.

Epimys'ium. [From the Gr. *epi*, "upon," and *mus*, "muscle."] The sheath of connective tissue surrounding an entire muscle.

Epistro'pheus. [From the Gr. *epi*, "upon," and *strephein*, "turn."] The second cervical or odontoid vertebra; the axis; so called because the atlas turns upon it.

Epithe'lial. [From the Gr. *epi*, "upon," and *thēlē*, the "nipple."] Pertaining to the epithelium, the cuticle covering the *nipple*, or any mucous membrane. The term epithelium is now applied to the tissue composed of cells covering or lining all surfaces of the body.

Eryth'rocyte. [From the Gr. *eruthros*, "red," and *kutos*, a "cell."] A fully developed red blood-corpuscle.

Eth'moid. [From the Gr. *ēthmos*, a "sieve," and *eidos*, "form," "resemblance."] *Sieve-like.* A bone of the cranium, part of which is pierced by a number of holes.

Evapora'tion. [From the Lat. *e*, "out," and *vapor*, "steam."] The act of resolving into vapor. In order to produce vapor, heat is necessary, and if not supplied, is taken from near objects. Thus the heat necessary for the evaporation of perspiration is taken from the body.

Excre'tion. [From the Lat. *excer'no*, to "separate."] The separation from the blood of the waste particles of the body; also the materials excreted.

Expira'tion. [From the Lat. *expi'ro*, to "breathe out."] The act of forcing air out of the lungs.

Fac'et. [From the Lat. *facies*, "face."] A small, flat, articular surface.]

Fal'ciform. [From the Lat. *falx*, a "sickle," and *forma*, "shape." Sickle-shaped.

Fallo'pian. A term applied to tubes and ligaments first pointed out by the anatomist *Fallopius*.

Fascic'ulus, pl. **Fasciculi.** [Lat. a "bundle."] A bundle of close-set fibres.

Fau'ces. [Lat., pl. of *faux*, *faucis*, the "throat."] The cavity at the back of the mouth from which the larynx and pharynx proceed.

Fecunda'tion. [From the Lat. *fecundatio*, "impregnation."] The act of making fruitful or prolific. Impregnation.

Fenes'tra. [Lat.] A window.

Fermenta'tion. [From the Lat. *fermentum*, "ferment"; perhaps from *fervere*, "to boil."] The process of undergoing an effervescent change as by the action of yeast. In physiology it refers to the transformation of an organic substance into new compounds by the action of a ferment.

Fibril′la, pl **Fibril′læ**. [Dim. of Lat. *fibra*, a "fibre."] A *little fibre.*

Fibrin′ogen. A protein in blood plasma, the main constituent of fibrin.

Fi′brous. [From the Lat. *fibra*, "fibre."] Containing or consisting of fibres. Having the character of fibres.

Fib′ula. [Lat. a "clasp."] The long splinter bone of the leg.

Fil′iform. [From the Lat. *filum*, a "thread," and *forma*, "form."] Thread-like.

Fim′briæ. [Lat. a "fringe."] A border, or *fringe.*

Fis′sion. [From the Lat. *findo, fissum*, to "cleave."] A *cleaving*, or breaking up into two parts.

Fo′cus. [From the Lat. *focus*, "hearth or fireplace."] A point at which the rays of light meet, after being reflected or refracted. Point at which an image is formed.

Fœ′tus. The child in utero from the fifth month of pregnancy till birth.

Fol′licle. [From the dim. of Lat. *follis*, a "bag."] A *little bag;* a small gland.

Fontanelle′. [Fr.] A little fountain. A term applied to the membranous spaces between the cranial bones in the new-born infant, in which the pulsation of the blood in the cranial arteries was imagined to rise and fall like the water in a fountain.

Fora′men, pl. **Foram′ina**. [Lat.] An opening, hole, or aperture.

Fos′sa, pl. **Fos′sæ**. [From the Lat. *fodio, fossum*, to "dig."] A depression, or sinus; literally, a ditch.

Fo′vea Centra′lis. [Lat.] Central depression of the macula lutea. The point of most acute vision.

Fun′giform. [From the Lat. *fungus*, a "mushroom," and *forma*, "form."] Having the *shape* of a *mushroom.*

Funic′ulus, pl. **Funic′uli**. [Dim. of Lat. *funis*, a "rope."] A *little* cord, or bundle, of aggregated fibres.

Fu′siform. [From the Lat. *fusus*, a "spindle," and *forma*, "form."] *Spindle-shaped.*

Gang′lia, pl. of **Gang′lion**. [From the Gr. *gagglion*, a "knot."] A collection of nerve-cells in the course of a nerve that has the appearance of a knot.

Gas′tric. [From the Gr. *gastēr*, the "stomach."] Pertaining to the *stomach.*

Gastrocne'mius. [From the Gr. *gastēr*, the "belly," and *knēmē*, the "leg."] The *belly*-shaped muscle of the *leg*.

Gas'tro-pul'monary. Same as gastro-pneumonic. [From the Gr. *gastēr*, "stomach," and *pneumon*, a "lung": Lat. *pulmo*, a "lung."] Pertaining to the stomach and the lungs: applied to the continuous mucous membrane of the respiratory and digestive tracts.

Gen'erative. [From the Lat. *generare*, to "beget."] Pertaining to generation, or propagation. Connected with or resulting from the process of begetting.

Genioglos'sus. [From the Gr. *geneion*, the "chin," and *glōssa*, the "tongue."] A muscle connected with the *chin* and *tongue*.

Gen'itals. [From the Lat. *genitalis*, "of or belonging to generation."] Pertaining to the organs of generation.

Gesta'tion. [From the Lat. *gestare*, "carry, bear."] The act or condition of carrying young in the womb from conception to delivery. Pregnancy.

Ging'lymus. [From the Gr. *gigglumos*, a "hinge."] A *hinge*-joint.

Gladi'olus. [Dim. of Lat. *gladius*, a "sword."] The middle piece of the sternum.

Glair'y. [From the Lat. *clarus*, "clear"; Fr. *clair*.] Like the *clear* white part of an egg.

Gland. [From the Lat. *glans*, an "acorn."] A secreting organ. An organ that abstracts certain materials from the blood and makes of them a new substance.

Gle'noid. [From the Gr. *glēnē*, a "cavity," and *eidos*, "form," "resemblance."] A name given to a shallow *cavity*.

Glob'ulins. [From the Lat. *globus*, perhaps akin to *glomus*, "a ball."] Protein substances somewhat similar to the albumins, but differing in their solubility.

Glomer'ulus. [Dim. of Lat. *glomus*, a "ball."] A botanical term signifying a small, dense, roundish cluster: a term applied to the ball-like tuft of vessels in cortical portion of the kidneys.

Glos'sopharynge'al. [From the Gr. *glōssa*, the "tongue," and *pharygx*, the "pharynx."] Belonging to the *tongue* and *pharynx*.

Glot'tis. [Gr. the "mouthpiece of a flute."] The aperture of the larynx.

Glute'i, pl. of **Glute'us.** [From the Gr. *gloutoi*, the "buttocks."] The muscles forming the *buttocks*.

Graaf'ian Fol'licles, or **Ves'icles.** A term applied to the sacs in the ovaries, which contain the ova or cells.

Granula′tions. [From the Lat. *granulum*, diminutive of *granum*, "grain."] Grain-like, fleshy bodies that form on the surface of wounds and ulcers.

Gus′tatory. [From the Lat. *gusto, gustatum*, to "taste."] Belonging to the sense of *taste*.

Hæmoglo′bin. [From the Gr. *haima*, "blood," and Lat. *globus*, a "globe," or "globule."] A compound protein found in the red corpuscles of the blood; its molecules consist of a protein portion and of a pigment portion, the latter containing one atom of iron.

Hæmorrhoi′dal. [From the Gr. *haima*, "blood," and *rheō*, to "flow."] Pertaining to hæmorrhoids, small tumors of the rectum, which frequently *bleed*.

Haver′sian Canals. Canals in the bone, so called from their discoverer, Dr. Clopton Havers.

Hemophil′ia. [From the Gr. *haima*, "blood," and *philein*, "to love."] A congenital, morbid condition, characterized by a tendency to bleed immoderately from any insignificant wound, or even spontaneously.

Hepat′ic. [From the Gr. *hépar*, the "liver."] Pertaining to the *liver*.

Hi′lum, sometimes written **Hi′lus.** [Lat.] It is the depression (usually on concave side) of a gland, where vessels, nerves, and ducts enter or leave.

Histol′ogy. [From the Gr. *histos*, a "web, tissue," and *logos*, "word."] That branch of anatomy which is concerned with the structure, especially the microscopic structure, of the tissues of the body.

Homoge′neous. [From the Gr. *homos*, "the same," and *genos*, "kind."] Of the *same kind* or quality throughout; uniform in nature, — the reverse of heterogeneous.

Hor′mone. [From the Gr. *hormao*, "to set in motion."] A chemical substance which is produced in one organ, and on being carried by the blood to another organ, stimulates this latter to functional activity.

Hu′merus. [Lat. the "shoulder."] The arm-bone which concurs in forming the *shoulder*.

Hy′aline. [From the Gr. *hyalos*, "glass."] *Glass*-like, resembling *glass* in transparency.

Hy′aloid. [From the Gr. *hyalos*, "glass," and *eidos*, "form."] The name given the membrane which encloses the vitreous humor of the eye. It invests the vitreous humor except in front, where it is continuous with the suspensory ligament of the crystalline lens.

Hydrother′apy. [From the Gr. *hudor,* "water," and *therapeuein,* to "heal."] A mode of treating disease by the copious use of pure water, both internally and externally.

Hy′oid. [From the Gr. letter upsilon, *v,* and *eidos,* "form," "resemblance."] The bone at the root of the tongue, shaped like the Greek letter upsilon, *v.*

Hypermetro′pia. [From the Gr. *hyper,* "over," "beyond," *metron,* "measure," and *ōps,* the "eye."] Far-sightedness.

Hyperpnœ′a. [From the Gr. *hyper,* "over," and *pneō,* to "breathe."] Energetic or labored respiration.

Hyper′trophy. [From the Gr. *hyper,* "over," and *trophé,* "nourishment."] Excessive growth; thickening or enlargement of any part or organ.

Hy′poblast. [From the Gr. *hypo,* "under," and *blastos,* a "sprout," or "germ."] The internal, or *under,* layer of the *germinal* membrane.

Hypochon′driac. [From the Gr. *hypo,* "under," and *chondros,* a "cartilage."] A term applied to the region of the abdomen *under* the *cartilages* of the false ribs.

Hypogas′tric. [From the Gr. *hypo,* "under," and *gastēr,* "stomach."] Situated below the stomach. Pertaining to the hypogastrium.

Hypoglos′sal. [From the Gr. *hypo,* "under," and *glōssa,* the "tongue."] A name given to the motor nerve of the tongue.

Hypoph′ysis. [From the Gr. *hypo,* "under," and *phusis,* a "growing."] The pituitary body of the brain which is lodged in the central depression of the sphenoid bone.

Il′eum. [From the Gr. *eileō,* to "twist."] The *twisted* portion of the small intestine.

Il′ium, pl. **Il′ia.** [From the Lat. *ilium,* the "flank."] The upper part of the os innominatum.

Inci′sor. [From the Lat. *inci′so,* to "cut."] Applied to the front teeth of both jaws, which have sharp cutting edges.

In′cus. [Lat.] An anvil; the name of one of the bones of the middle ear.

Inflamma′tion. [From the Lat. *inflammatio,* a "setting on fire."] A morbid condition characterized by pain, heat, redness, swelling, and usually loss of function.

Infundib′ula. [Lat. pl. of *infundibulum,* a "funnel."] *Funnel*-shaped canals.

Ingest′. [From the Lat. *in,* "in," and *gerere,* to "bear."] Taking food into the stomach.

In′guinal. [From the Lat. *inguen,* the "groin."] Pertaining to the *groin.*

Inhibi′tion. [From the Lat. *inhibere,* "restrain."] The lowering of the action of a nervous mechanism by nervous impulses reaching it from a connected mechanism.

Innom′inate. [From the Lat. *innominatus,* "nameless."] A name given an artery, vein, and a bone.

Inoc′ulate. [From the Lat. *in,* "in," and *oculus,* "bud."] The insertion of virus into a wound or abrasion for the purpose of communicating a disease.

Inos′culate. [From the Lat. *in,* "into," and *osculum,* a "little mouth."] To unite, to open into each other.

In′sulate. [From the Lat. *insula,* an "island."] To isolate or separate from surroundings.

Integ′ument. [From the Lat. *in,* and *te′go,* to "cover."] The skin, or outer covering of the body.

Intercel′lular. Lying *between cells.*

Intercos′tal. [From the Lat. *inter,* "between," and *costa,* "rib."] Situated or intervening between successive ribs of the same side of the body.

Interlob′ular. That which lies *between* the *lobules* of any organ.

Inter′stice. [From the Lat. *inter,* "between," and *sto,* or *sisto,* to "stand."] The space which *stands between* things; spaces between parts.

Intersti′tial. Pertaining to or containing *interstices.*

Intes′tine. [From the Lat. *in′tus,* "within."] The part of the alimentary canal which is continuous with the lower end of the stomach; also called the bowels.

Intralob′ular. That which lies *within* the *lobules* of any organ.

I′ris. [Lat. the "rainbow."] The colored membrane suspended behind the cornea of the eye. It receives its name from the variety of its colors.

Is′chium. [From the Gr. *ischiō,* to "support."] The lower portion of the os innominatum; that upon which the body is *supported* in a sitting posture.

Jeju′num. [From the Lat. *jejunus,* "fasting," "empty."] The part of the small intestine comprised between the duodenum and ileum. It has been so called because it is almost always found *empty* after death.

Ju′gular. [From the Lat. *jugulum*, the "throat."] Pertaining to the *throat.*

Katabol′ism. [From the Gr. *katabole*, "a throwing down."] Pertaining to *katabolism*, the process by means of which complex substances are rendered more simple and less complex. The opposite of anabolism.

Karyokine′sis. [From the Gr. *karuon*, "a nut," and *kinein* "to move."] The indirect division of cells, in which prior to the division of the cell protoplasm complicated changes take place in the nucleus, attended with movement of the nuclear fibrils.

Lac′rimal. [From the Lat. *lacrima*, "tear."] Of or pertaining to tears.

Lacta′tion. [From the Lat. *lac, lactis*, "milk."] The period of giving *milk.*

Lactif′erous. [From the Lat. *lac*, "milk," and *ferre*, "bear."] Bearing, or conveying, milk, as a lactiferous duct.

Lacu′na, pl. **Lacu′næ.** [Lat. a "cavity," an "opening."] A little *hollow space.*

Lambdoi′dal. [From the Gr. letter Λ (*Lambda*), and *eidos*, "form," "resemblance."] Resembling the Gr. letter Λ.

Lamel′la, pl. **Lamel′læ.** [Lat.] A thin plate, or layer.

Laryn′goscope. [From the Gr. *larygx*, the "larynx," and *skopeo*, to "look at."] The instrument by which the larynx may be examined in the living subject.

Lar′ynx. The upper part of the air-passage, between the trachea and the base of the tongue.

Latis′simus Dor′si. [Lat. superlative of *latus*, "broad," "wide," and *dorsum*, the "back."] The *widest* muscle of the *back.*

Lens. [From the Lat. *lens*, "a lentil."] A transparent substance, ground with two opposite regular surfaces, either both curved, or one curved and one plane. There are two general classes of lenses: (1) concave, which are thinner at the centre than at the edges; and (2) convex, which are thicker at the centre than at the edges. (See page 431.)

Lip′ase. [From the Gr. *lipos*, "fat."] An enzyme of the pancreatic juice, capable of decomposing fats. Same as *steapsin.*

Lob′ule. [From the dim. of Lat. *lobus*, a "lobe."] A *small lobe.*

Lum′bar. [From the Lat. *lumbaris*, the "loin."] Pertaining to the *loins.*

Lymph. [From the Lat. *lympha,* "water."] A colorless fluid, resembling *water* in appearance.

Lymph'ocyte. [From the Lat. *lympha,* "water," and Gr. *kutos,* "a cell."] Name given to recently formed white blood-corpuscles that later become leucocytes.

Lymph'oid. [From the Lat. *lympha,* "water," and Gr. *eidos,* "form," "resemblance."] Having *resemblance* to *lymph.*

Mac'ula Lute'a. [Lat.] Yellow spot.

Ma'lar. [From the Lat. *mala,* the "cheek."] Pertaining to the *cheek.*

Malle'olus, pl. **Malle'oli.** [Dim. of Lat. *malleus,* a "hammer."] A name given to the pointed projections formed by the bones of the leg at the ankle-joint.

Malpigh'ian Bod'ies. [So called in honor of *Malpighi,* a celebrated Italian anatomist.] A term applied to small bodies, or corpuscles, found in the kidney and spleen.

Mam'mary. [From the Lat. *mamma,* the "breast."] Of or pertaining to the *breast.*

Man'dible. [From the Lat. *mandere,* "chew," "masticate."] The under jaw, or inferior maxillary, as distinguished from the upper jaw, or superior maxillary.

Manu'brium. [Lat. a "haft," a "handle."] Name given to the upper portion of the sternum or breast bone.

Mas'seter. [From the Gr. *massaomai,* to "chew."] One of the muscles of *mastication.*

Mas'toid. [From the Gr. *mastos,* the "breast," and *eidos,* "form," "resemblance."] Shaped *like the breast.*

Ma'trix. [Lat.] The womb. Producing or containing substance.

Matura'tion. [From the Lat. *maturatio,* a "hastening."] The process of bringing, or of coming to maturity.

Medul'la Oblonga'ta. [Lat.] The "oblong marrow"; that portion of the brain which lies within the skull, upon the basilar process of the occipital bone.

Meibo'mian. A term applied to the small glands between the conjunctiva and tarsal cartilages, discovered by *Meibomius.* More recent term is tarsal glands.

Mem'brane. [From the Gr. *membrane,* "parchment."] An enveloping or a lining tissue of the body.

Menin′ges. [The pl. of Gr. *menigx*, "membrane."] Term applied to the three membranes that invest the brain and spinal cord.

Mes′entery. [From the Gr. *mesos*, "middle," and *enteron*, the "intestine."] A duplicature of the peritoneum covering the small *intestine*, which occupies the *middle*, or centre, of the abdominal cavity.

Mes′oblast. [From the Gr. *mesos*, "middle," and *blastos*, a "germ" or "sprout."] The *middle* layer of the *germinal* membrane.

Mesoco′lon. A duplicature of the peritoneum covering the colon.

Mes′oderm. [From the Gr. *mesos*, "middle," and *derma*, the "skin." The middle germinal layer of cells lying between the ectoderm and entoderm. Same as mesoblast.

Metab′olism. [From the Gr. *metabolē*, "change."] The *changes* taking place in cells, whereby they become more complex and contain more force, or less complex and contain less force. The former is constructive metabolism, or anabolism; the latter, destructive metabolism, or katabolism.

Metacar′pus. [From the Gr. *meta*, "after," or "beyond," and *karpos*, the "wrist."] The part of the hand comprised between the *wrist* and fingers.

Metatar′sus. [From the Gr. *meta*, "after," or "beyond," and *tarsos*, the "instep."] That part of the foot comprised between the *instep* and toes.

Mi′tral. Resembling a mitre.

Mo′lar. [From the Lat. *mola*, a "mill."] A term applied to the teeth, which bruise, or *grind*, the food.

Monosaccharid. [From the Gr. *monos*, "one, single," and *sakcharis*, "sugar."] A simple sugar. $C_6H_{12}O_6$.

Mo′tor Oc′uli. [Lat.] Mover of the eye.

Mu′cin, the chief constituent of mucus.

Mus′cle. [From the Gr. *mus*, "muscle."] A kind of animal tissue consisting of bundles of fibres whose essential physiological characteristic is contractility.

Myocar′dium. [From the Gr. *mus*, *muos*, a "muscle," and *kardia*, the "heart."] The *muscular* structure of the *heart*.

Myo′pia. [From the Gr. *muō*, to "contract," and *ōps*, the "eye."] Nearsightedness.

My′osin. Chief protein substance of muscle.

Na'ris, pl. **Na'res.** [Lat.] A nostril.

Neurax'on. [From the Gr. *neuron*, " nerve," and *axon.*] An axis cylinder process.

Neurilem'ma. [From the Gr. *neuron*, a " nerve," and *lemma*, a " coat," or " covering."] Nerve-sheath.

Neu'rone. [From the Gr. *neuron*, a " nerve."] The nerve-cell, inclusive of all its processes.

Node. [From the Lat. *nodus*, a " knot."] A knot, or what resembles one. A lymphatic ganglion.

Nucle'olus, pl. **Nucle'oli.** [Dim. of Lat. *nucleus*, a " kernel."] A smaller nucleus within the nucleus.

Nu'cleus, pl. **Nu'clei.** [Lat. a " kernel."] A minute vesicle embedded in the cell protoplasm (cytoplasm).

Nutri'tion. [From the Lat. *nu'trio*, to " nourish."] The processes by which the nourishment of the body is accomplished.

Occip'ital. [From the Lat. *occiput, occipitis*, the " back of the head."] Pertaining to the *occiput*, the *back* part *of the head.*

Odon'toid. [From the Gr. *odous, odontos*, a " tooth," and *eidos*, " form," " resemblance."] Tooth-like.

Œde'ma. [From the Gr. *oideō*, to " swell."] A *swelling* from effusion of serous fluid into the areolar tissue.

Œsoph'agus. [Gr. *oisophagos*, from *oisō* (fut. of *oio*) to " carry," and *phagein*, " to eat."] The gullet.

Olec'ranon. [From the Gr. *ōlenē*, the " elbow," and *kranion*, the " head." The *head* of the *elbow.*

Olfac'tory. [From the Lat. *olfacio, olfactum*, to " smell."] Belonging to the sense of *smell.*

Omen'tum. [Lat. " coverlet."] A duplicature of the peritoneum, which hangs in front of the intestines.

Ophthal'mic. [From the Gr. *ophthalmos*, the " eye."] Belonging to the eye.

Op'sonins. [From the Gr. *opsono*, " prepare food for."] A name given to chemical substances found in blood plasma which make microbes more susceptible to phagocytes.

Op'tic. [From the Gr. *opsis*, " sight."] That which relates to *sight.*

Orbicula'ris. [From dim. of Lat. *orbis*, an " orb," or " circle."] Name of the *circular* muscles.

Or'bital. [From the Lat. *orbita*, a " track," " rut of a wheel."] Pertaining to the *orbit*, the bony cavity in which the eyeball is suspended.

Or′gan. [From the Gr. *organon*, an "instrument, implement, tool."] Any part of the body with a special function.

O′rifice. [From the Lat. *os*, *oris*, a "mouth," and *facere*, "to make."] An opening.

Ōs, pl. **Ōra.** [Lat.] A mouth.

Os, pl. **Ossa.** [Lat.] A bone.

Os Cox′æ. The hip bone, or os innominatum.

Oscilla′tion. [From the Lat. *oscillare*, "to swing."] Swinging backward and forward; vibration.

Os′sa Innomina′ta, pl. of **Os Innomina′tum.** [Lat.] "Unnamed bones." The irregular *bones* of the pelvis, *unnamed* on account of their non-resemblance to any known object.

Os′seous. [From the Lat. *os*, a "bone."] Consisting of or resembling bone.

Os′sicle. [From the Lat. *ossiculum*, dim. of *os*, a "bone."] A small bone.

Os′teoblasts. [From the Gr. *osteon*, a "bone," and *blastos*, a "germ," or "sprout."] The *germinal* cells deposited in the development of *bone*.

O′toliths. [From the Gr. *ous*, *otos*, the "*ear*," and *lithos*, a "stone."] *Particles* of calcium carbonate and phosphate found in the internal *ear*.

O′vum, pl. **O′va.** [Lat. an "egg."] The human germ-cell.

Pal′ate. [From the Lat. *pala′tum*, the "palate."] The roof of the mouth, consisting of the hard and soft palate.

Pal′pebra, pl. **Pal′pebræ.** [Lat.] The eyelid.

Pan′creas. [From the Gr. *pan*, "all," and *kreas*, "flesh."] A compound secreting gland; one of the accessory organs of nutrition. The sweetbread of animals.

Papil′læ. [Lat. pl. of *papilla*, a "nipple," a "pimple."] Minute eminences on various surfaces of the body.

Pari′etal. [From the Lat. *paries*, *parietis*, a "wall."] Pertaining to a *wall*.

Parot′id. [From the Gr. *para*, "near," and *ous*, *otōs*, the "ear."] The large salivary gland *near the ear*.

Parturi′tion. [From the Lat. *parturio*, *parturitum*, to "bring forth."] The act of *bringing forth*, of giving birth to young.

Patel′la. [Lat. "a little dish."] A small, *bowl*-shaped bone; the knee-*pan*.

Pec'toral. [From the Lat. *pectus, pectoris,* the "breast."] Pertaining to the *breast,* or chest.

Ped'icle. [From the dim. of Lat. *pes, pedis,* a "foot."] A stalk.

Pedun'cle. [From the Lat. *pedunculus,* dim. of *pes,* a "stalk," a "foot."] A narrow part acting as a support.

Pel'vic. [From the Lat. *pelvis,* a "basin."] Pertaining to the *pelvis,* the *basin,* or bony cavity, forming the lower part of the abdomen.

Pep'sin. [From the Gr. *peptō,* to "digest."] A ferment found in gastric juice, having power to convert proteins into peptones.

Pep'tone. [From the Gr. *peptō,* to "digest."] A term applied to protein material *digested* by the action of the digestive juices.

Pericar'dium. [From the Gr. *peri,* "about," "around," and *kardia,* the "heart."] The serous membrane *covering the heart.*

Perichon'drium. [From the Gr. *peri,* "about," "around," and *chondros,* a "cartilage."] The serous membrane *covering the cartilages.*

Per'ilymph. [From the Gr. *peri,* "about," "around," and the Lat. *lympha,* "water."] The *fluid* in the osseous, and *surrounding* the membranous labyrinth of the ear.

Perimys'ium. [From the Gr. *peri,* "around," and *mus,* "muscle."] The connective tissue septa connecting and enveloping the separate fasciculi of a muscle.

Perine'um. [From the Gr. *perinaion.*] The region of the body between the thighs, extending from the anus to the fourchette in the female, or to the scrotum in the male.

Perios'teum. [From the Gr. *peri,* "about," "around," and *osteon,* a "bone."] The membrane *covering the bones.*

Periph'eral. [From the Gr. *peri,* "about," "around," and *phero,* to "bear."] Pertaining to the *periphery,* or *circumference;* that which is away from the centre and towards the circumference.

Peristal'sis. [From the Gr. *peristellō,* to "compress."] Peristaltic action. A term applied to the worm-like movement of the intestines by which its contents are propelled downward.

Peritone'um. [From the Gr. *periteinō,* to "stretch around," to "stretch all over."] The serous membrane lining the walls and covering the contents of the abdomen.

Permeable. [From the Lat. *per,* "through" and *meare,* "to pass."] Capable of being passed through; substances which allow the passage of fluids.

Perone′al. [From the Gr. *peronē*, the "fibula."] Pertaining to the *fibula;* a term applied to muscles, or vessels, in relation to the fibula.

Pe′trous. [From the Gr. *petra*, a "rock."] Having the hardness of *rock*.

Phag′ocytes. [From the Gr. *phagein*, "eat," and *kútos*, a "cell." A lymph-corpuscle, or white blood-corpuscle, regarded as an organism capable of devouring what it meets, especially pathogenic microbes.

Phalan′ges. [Lat. pl. of *phalanx*, a "closely serried array of soldiers."] A name given to the small bones forming the fingers and toes, because placed alongside one another like a *phalanx*.

Phar′ynx. [From the Gr. *pharugx*, the "throat."] The cavity forming the upper part of the gullet.

Phonation. [From the Gr. *phone*, the "voice."] Utterance of vocal sounds.

Phren′ic. [From the Gr. *phrēn*, the "diaphragm."] Pertaining to the *diaphragm*.

Pi′a Ma′ter. [From the Lat. *pia* (fem.), "tender," "delicate," and *mater*, "mother."] The most internal of the three membranes of the brain.

Pig′ment. [From the Lat. *pigmentum*, "paint," "color."] *Coloring* matter.

Pin′na. [Lat. a "feather," or "wing."] External cartilaginous flap of the ear. Same as auricle.

Pi′siform. [From the Lat. *pisum*, a "pea," and *forma*, "form."] Having the *form* of a *pea*. One of the carpal bones.

Pitu′itary. [From the Lat. *pituita* "phlegm."] Secreting or containing mucus, or supposed to do so. (It was formerly supposed that the secretions of the nose proceeded from the brain.)

Placen′ta. [From the Gr. *plakous*, a "cake."] A *flat*, circular, vascular *substance* which forms the organ of nutrition and excretion for the fœtus in utero.

Plan′tar. [From the Lat. *planta*, "the sole of the foot."] Pertaining to the *sole of the foot*.

Platys′ma. [From the Gr. *platus*, "broad."] A thin, *broad* muscle situated immediately beneath the skin at the side of the neck, and extending from the chest and shoulder to the face.

Plex′us. [From the Lat. *plĕcto*, *plexum*, to "knit," or "weave."] A *network* of nerves or veins.

Pneumogas′tric. [From the Gr. *pneumōn*, a "lung," and *gaster*, the "stomach."] Pertaining to the *lungs* and *stomach*.

Polyhe'dral. [From the Gr. *polys,* "many," and *hedra,* a "side."] Many-sided.

Polysaccharid. From the Gr. *polys,* "many," and Lat. *saccharum,* "sugar."] A complex sugar, which when decomposed gives many molecules of a simple sugar.

Poplite'al. [From the Lat. *poples, poplitis,* the "ham," the "back part of the knee."] The space *behind the knee-joint* is called the *popliteal* space.

Premo'lar. [From the Lat. *præ,* "before," and *molaris,* "molar."] Anterior in position to a molar; as premolar tooth.

Prismat'ic. Resembling a *prism,* which, in optics, is a solid, triangular-shaped glass body.

Prona'tion. [From the Lat. *pronus,* "inclined forwards."] The turning of the hand with the palm downward.

Prona'tor. The group of muscles which turn the hand palm downward.

Pro'toplasm. [From the Gr. *protos,* "first," and *plassō,* to "form."] A *first-formed,* organized substance; primitive organic cell matter.

Pso'as Mag'nus. [From the Gr. *psoa,* "loin," and Lat. *magnus,* "great."] A muscle of the loins and pelvis. The tenderloin.

Psy'chical. [From the Gr. *psyche,* the "soul."] Pertaining to the mind.

Pter'ygoid. [From the Gr. *pterux,* a "wing," and *eidos,* "form," "resemblance."] Wing-like.

Pty'alin. [From the Gr. *ptyalon,* "saliva."] A ferment principle in *saliva,* having power to convert starch into sugar.

Pu'berty. [From the Lat. *puber,* "adult."] The age at which reproduction becomes possible; sexual maturity in the human race.

Pu'bes, gen. **Pu'bis.** [Lat.] The hairy region above the genitals, also used for os pubis, the portion of the os innominatum forming the front of the pelvis.

Pul'monary. [From the Lat. *pulmo,* pl. *pulmones,* the "lungs."] Relating to the *lungs.*

Pulse. [From the Lat. *pello, pulsum,* to "beat."] The striking of an artery against the finger, occasioned by the contraction of the heart; commonly felt at the wrist.

Pylo'rus. [From the Gr. *pulouros,* a "gate keeper."] The lower orifice of the stomach, furnished with a circular valve which closes during stomach digestion.

Pyrex'ia. [From the Gr. *pyresso,* (fut.) *pyrexo,* to "have a fever."] Elevation of temperature; fever.

Quad'rate. [From the Lat. *quadratus,* "make four-cornered, or square."] Square. (A small lobe of the liver.)

Quad'riceps. [From the Lat. *quatuor,* "four," and *caput,* the "head."] A term applied to the extensor muscle of the leg, having *four heads,* or parts.

Rac'emose. [From the Lat. *racemus,* a "bunch of grapes."] Term applied to compound, saccular glands, from their supposed resemblance to a bunch of grapes.

Radia'tion. [From the Lat. *radiare,* to "furnish with spokes or wheels."] The diffusion of rays of light.

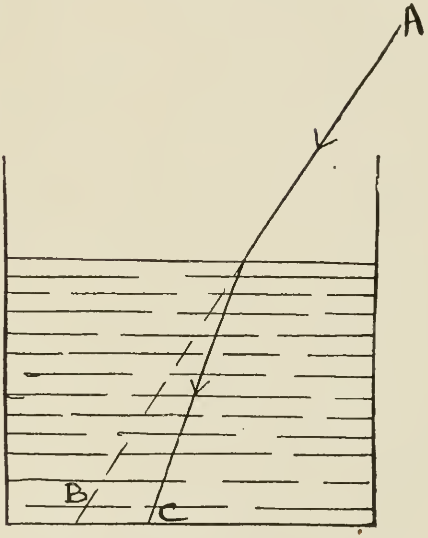
Ra'dius. [Lat. a "rod," the "spoke of a wheel."] The outer bone of the forearm, so called from its shape.

Râle. [From the Fr. *râler,* to "rattle in the throat."] A rattling, bubbling sound attending the circulation of air in the lungs. Different from the murmur produced in health.

Rec'tus, pl. **Rec'ti.** [Lat.] Straight.

Reflec'tion. [From the Lat. *re + flectere,* to "bend or turn."] The return of rays, beams, sound, or the like from a surface. Reflection of light is of two kinds, *regular* and *diffused.* When a beam of light enters a darkened room through a small opening and strikes a mirror, a reflected beam will be seen travelling along some definite path. This is called *regular reflection.* Should the light, however, fall on a piece of white paper, it would be reflected and scattered in all directions. This is called *diffused reflection* and is caused by the inequalities of the reflecting surface. All rough surfaces, as well as dust and moisture in the atmosphere, serve to diffuse light. If this were not the case, it would be dark everywhere except in the direct path of light from some luminous body.

Refrac'tion. [From the Lat. *re + frangere,* to "break."] The bending or deviation in the course of rays of light in passing obliquely from one transparent medium into another of different density. Light waves travel with different velocities in mediums of different densities, the more dense the medium, the less the velocity. For instance, light will travel less rapidly in water than in air. For this reason where a ray of light in air strikes a body of water obliquely, it will be bent out of a straight line, as shown in the following diagram; the light ray *AC*, instead of following the straight line *AB*, is bent on striking the surface of the dense medium, thereby being bent from its direct path toward *C*.



Re'nal. [From the Lat. *ren*, *renis*, the "kidney."] Pertaining to the *kidneys*.

Ren'nin. [Rennet.] The milk-curdling enzyme which constitutes the active principle of rennet.

Resil'iency. [From the Lat. *re*, "back," and *silere*, to "leap."] The act of resiling, leaping, or springing back; the act of rebounding.

Respira'tion. [From the Lat. *res'piro*, to "breathe frequently."] The function of breathing, comprising two acts, — *inspiration*, or breathing in, and *expiration*, or breathing out.

Res'tiform. [From the Lat. *restis*, a "cord, rope," and *forma*, "form."] In anatomy denoting a part of the medulla oblongata, called the restiform body.

Retic'ular. [From the Lat. *reticulum*, a "small net."] Resembling a *small net*.

Ret'iform. [From the Lat. *rete*, a "net," and *forma*, "form."] Having the *form*, or structure, of a *net*.

Ret'ina. [From the Lat, *rete*, a "net."] The most internal membrane of the eye; the expansion of the optic nerve.

Ru'gæ. [Lat. pl. of *ruga*, a "wrinkle."] A term applied to the folds, or *wrinkles*, in the mucous membrane, especially of the stomach and vagina.

Sa'crum. [Lat. neut. of *sacer*, "sacred."] The large triangular bone above the coccyx, so named because it was supposed to protect the organs contained in the pelvis, which were offered in sacrifice and considered *sacred*.

Sag'ittal. [From the Lat. *sagitta*, an "arrow."] Arrow-like.

Saliva'tion. [From the Lat. *salivare*, to "salivate."] An excessive secretion of saliva.

Sapid. [From the Lat. *sapere*, to "taste."] Possessing savor or flavor.

Saphe'nous. [From the Gr. *saphēs*, "manifest."] A name given to the two large superficial veins of the lower limbs.

Saponifica'tion. [From the Lat. *sapo, saponis*, "soap," and *facio*, to "make."] Conversion into soap.

Sarcolem'ma. [From the Gr. *sarx, sarkos*, "flesh," and *lemma*, a "covering."] The *covering* of the individual muscle-fibrils.

Sarto'rius. [From the Lat. *sartor*, a "tailor."] The name of the muscle used in crossing the legs, as a *tailor* does when he sits and sews.

Scaph'oid. [From the Gr. *skaphe*, a "boat," and *eidos*, "form."] Boat-shaped. The bone on the radial side of the proximal row of the carpus. Also called *navicular*.

Scap'ula. [Lat.] The shoulder-blade.

Scle'ra. [Lat. *scleroticus*, from Gr. *sklēroō*, to "harden."] *Hard*, tough.

Se'bum, or Se'vum. [Lat. *sevum*, "suet."] A fatty secretion resembling *suet*, which lubricates the surface of the skin.

Secre'tion. [From the Lat. *secer'no, secre'tum*, to "separate."] The process of separating from the blood some essential, important fluid; which fluid is also called a secretion.

Semilu'nar. [From the Lat. *semis*, "half," and *luna*, the "moon."] Having the shape of a *half-moon*.

Ses'amoid. [From the Gr. *sēsamon*, a "seed of the sesamum," and *eidos*, "form," "resemblance."] *Resembling a grain of sesamum.* A term applied to the small bones situate in the substance of tendons, near certain joints.

Sig'moid. [From the Gr. letter Σ, *sigma*, and *eidos*, "form," "resemblance."] Curved *like the letter* S.

Sole'us. [From the Lat. *solea*, a "sandal."] A name given to a muscle shaped like the *sole* of a *shoe*.

Spermatozo'on. [From the Gr. *sperma*, "sperm" (from *speirein*, "to sow"), and *zoōn*, an "animal."] The male generative cell.

Sphe'noid. [From the Gr. *sphēn*, a "wedge," and *eidos*, "form," "resemblance."] *Like a wedge.*

Sphinc'ter. [From the Gr. *sphiggō*, to "bind tight," to "close."] A circular muscle which contracts the aperture to which it is attached.

Splanch′nic. [From the Gr. *splagchnon*, an "entrail."] Of or pertaining to the viscera.

Squa′mous. [From the Lat. *squama*, a "scale."] *Scale*-like.

Sta′sis. [From the Gr. *staō*, to "stop."] Stagnation of the blood current.

Steap′sin. An enzyme of the pancreatic juice which has the power of decomposing fats. Same as lipase.

Stereogno′sis. [From the Gr. *stereos*, "solid," and *gnosis*, "knowledge." The faculty of recognizing the form or outline of an object by touching it.

Stim′ulus, pl. **Stim′uli.** [Lat. a "goad."] Anything that excites to action.

Sto′ma, pl. **Sto′mata.** [From the Gr. *stoma, stomatos*, a "mouth."] A *mouth;* a small opening.

Stom′ach. [From the Lat. *stomachus*, the "throat," "gullet," also the "stomach."] A more or less sac-like part of the body where food is partially digested.

Strat′ified. [From the Lat. *stratum*, a "layer," and *facio*, to "make."] Formed or composed of *strata*, or layers.

Stri′ated. [From the Lat. *strio, striatum*, to "make furrows."] That which has *striæ*, furrows or lines.

Stro′ma. [From the Gr. *strōma*, a "bed."] The foundation, or *bed*, tissue of an organ.

Styloglos′sus. [From the Gr. *stylos*, a "pillar," and *glōssa*, the "tongue."] A muscle connected with a *pointed style-like process* of the temporal bone and the tongue.

Sty′loid. [From the Gr. *stylos*, a "pillar," and *eidos*, "form."] A long and slender process from the lower side of the temporal bone.

Suc′cus Enter′icus. [From the Lat. *succus*, "juice, moisture," and *enteron*, "intestine."] Intestinal juice, secreted by the intestinal glands.

Sudorif′erous. [From the Lat. *sudor*, "sweat," and *fero*, to "carry," to "bear."] A term applied to the glands secreting *sweat.*

Sul′cus. [From the Lat. *sulcus*, a "furrow," "trench," "ditch," "wrinkle."] A fissure between two convolutions of the surface of the brain.

Supina′tion. [From the Lat. *supino, supinatum*, to "bend backward," to "place on the back."] The turning of the hand with the palm upward.

Su′pinators. The muscles which turn the hand with palm upward.

Supra-re′nal. [From the Lat. *super,* "over," and *ren, renis,* the "kidney."] Same as adrenal. A small gland above each kidney.

Su′ture. [From the Lat. *suo, sutum,* to "sew together."] That which is *sewn together,* a seam; the seam uniting bones of the skull.

Sym′physis. [From the Gr. *syn,* "together," and *phyō,* to "produce," to "grow."] A *union* of bones, usually of symmetrical bones in the median line, as the pubic bones and bones of the jaw.

Syn′apse. [From the Gr. *syn,* "with," and *aptein,* "to fasten."] Interlacing of terminal arborizations of nerves.

Synarthro′sis. [From the Gr. *syn,* "together," and *arthron,* a "joint."] A form of articulation in which the bones are immovably joined together.

Synchrondro′sis. [From the Gr. *syn,* "together," and *chrondros,* "cartilage."] Union by an intervening growth of cartilage.

Syndesmo′sis. [From the Gr. *syn,* "together," and *desmos,* a "ligament."] Union by ligaments.

Syno′via. [Supposed to be from the Gr. *syn,* "together," implying union or close resemblance, and *ōon,* an "egg."] A fluid resembling the white of an *egg.*

Sys′tole. [From the Gr. *systellō,* to "draw together," to "contract."] The *contraction* of the heart.

Tac′tile. [From the Lat. *tac′tus,* "touch."] Relating to the sense of touch.

Tar′sus. [From the Gr. *tarsos,* the "instep."] The *instep;* also the cartilage of the eyelid.

Tem′poral. [From the Lat. *tem′pus,* "time," and *tem′pora,* the "temples."] Pertaining to the temples; the name of an artery and of a bone.

Ten′do Achil′lis. [Lat.] "Tendon of Achilles." The *tendon* attached to the heel, so named because *Achilles* is supposed to have been held by the heel when his mother dipped him in the river Styx to render him invulnerable.

Ten′don. [From the Lat. *ten′do,* to "stretch."] The white, fibrous cord, or band, by which a muscle is attached to a bone; a sinew.

Thermogenet′ic. [From the Gr. *therme,* "heat," and *gignere,* "to beget."] Name given to centre in brain, supposed to be concerned with the production of heat.

Thermolyt′ic. [From the Gr. *therme,* "heat," and *luein,* "to loose."] Name given to centre in brain supposed to be concerned in the dissipation of heat.

Thermotac′tic. [From the Gr. *therme,* "heat," and *taxis,* "arrangement."] Name given to centre supposed to regulate the thermogenetic and thermolytic centres.

Thorac′ic. [From the Gr. *thōrax,* a "breastplate," the "breast."] Pertaining to the *thorax.*

Throm′bus. [From the Gr. *thrombus,* a "lump," a "piece."] Name given to a clot formed in a blood-vessel.

Thy′mus. [From the Gr. *thymo,* "thyme."] The shape of the thymus gland was thought to resemble the flowers of thyme, hence the name.

Thy′roid. [From the Gr. *thyreos,* an "oblong shield," and *eidos,* "form," "resemblance."] *Resembling a shield.* A name given to an opening in the ossa innominata; to the piece of cartilage forming the anterior prominence of the larynx; and to the gland placed in front of the larynx.

Tib′ia. [Lat. a "flute," or "pipe."] The shin-bone, called *tibia,* from its fancied resemblance to a *reed-pipe.*

Tibia′lis Ante′rior. [Lat.] The muscle situated at the *anterior* part of the *tibia.*

Tis′sue. [From the Lat. *texere,* "weave."] An aggregate of similar cells and cell-products in a definite fabric.

Tox′ic. [From the Lat. *toxicum,* "poison."] Poisonous.

Trabec′ulæ. [Lat. pl. of *trabecula,* a "little beam."] A term applied to prolongations of fibrous membranes which form septa, or partitions.

Transversa′lis. [Lat. from *trans,* "across," and *verto, versum,* to "turn," to "direct."] A term applied to a muscle which runs in a *transverse* direction.

Trape′zius. [From the Gr. *trapeza,* "table."] A name given to the two upper superficial muscles of the back, because together they resemble a *trapezium,* or diamond-shaped quadrangle.

Trapezoid′. [From the Gr. *trapeza,* "table," and *eidos,* "form."] One of the bones of the wrist. The second one of the distal row on the radial or thumb side.

Tri′ceps. [From the Lat. *tres,* "three," and *caput,* the "head."] A term applied to a muscle having a triple origin, or *three heads.*

Tricus′pid. [From the Lat. *tres,* "three," and *cuspis, cuspidis,* a "point."] Having *three points.*

Trochan′ter. [From the Gr. *trochaō*, to "turn," to "revolve."] Name given to two projections on the upper extremities of the femur, which give attachment to the rotator muscles of the thigh.

Tryp′sin. The enzyme in pancreatic juice which converts protein material into peptones.

Tuberos′ity. [From the Lat. *tuber, tuberis*, a "swelling."] A *protuberance.*

Tu′bular. [From the Lat. *tubulus*, a "small pipe."] Having the form of a tube, or pipe.

Tur′binated. [Lat. *turbinatus*, from *turbo, turbinis*, a "top."] Formed like a top; a name given to the bones in the outer wall of the nasal fossæ.

Tym′panum. [From the Gr. *tympanon*, a "drum."] The *drum*, or hollow part, of the middle ear.

Ul′na. [Lat. the "elbow."] The inner bone of the forearm, the olecranon process of which forms the elbow.

Umbili′cus. [Lat. the "navel."] A round cicatrix, or scar, in the median line of the abdomen.

Un′ciform. [From the Lat. *uncus*, a "hook," and *forma*, "form."] Hooked, or crooked. One of the bones of the wrist, so called from its hook-like process.

U′rea. [From the Lat. *urina*, "urine."] Chief solid constituent of *urine.*

Ure′ter. [From the Gr. *oureō*, to "pass urine."] The tube through which the *urine* is conveyed from the kidney to the bladder.

Ure′thra. [From the Gr. *oureō*, to "pass urine."] The canal through which the urine is conveyed from the bladder to the meatus urinarius.

Urinif′erous. [From the Lat. *urina*, "urine," and *ferre*, "bear."] Conveying urine, as urinferous tubes, or ducts.

U′vula. [Dim. of Lat. *uva*, a "grape."] The small, elongated, fleshy body hanging from the soft palate.

Vag′inal. [From the Lat. *vagina*, a "sheath."] *Sheath*-like.

Val′vulæ Conniven′tes. [Lat.] A name given to transverse folds of the mucous membrane in the small intestine. More recent term is "circular folds."

Vas′cular. [From the Lat. *vasculum*, a "little vessel."] Relating to *vessels;* full of vessels.

Va′so-constric′tor. [From the Lat. *vas*, a "vessel," and *constringo*, to "constrict."] An agent which brings about *constriction* of blood-

vessels ; specifically a nerve when stimulated, or a drug which acts in this way when administered.

Va′so-dila′tor. [From the Lat. *vas*, a " vessel," and *dilator*, a " dilator."] An agent which brings about *dilatation* of blood-vessels.

Ve′næ Ca′væ, pl. of **Ve′na Ca′va.** [Lat.] " Hollow veins." A name given to the two great veins of the body which convey the blood to the right auricle of the heart.

Ven′tral. [From the Lat. *venter*, *ventris*, the " belly."] The front surface of the body.

Ven′tricle. [From the dim. of Lat. *venter*, the " belly."] A small cavity.

Ver′miform. [From the Lat. *vermis*, a " worm," and *forma*, " form."] Worm-shaped.

Ver′nix Caseo′sa. [Lat.] " Cheesy varnish." The *fatty varnish* found on the new-born infant, which is secreted by the sebaceous glands of the skin.

Ver′tebræ, pl. of **Ver′tebra.** [Lat. from *verto*, to " turn."] The bones of the spine.

Vibration. [From the Lat. *vibrare*, to shake.] The act of moving rapidly to and fro.

Vil′li. [Lat. pl. of *villus*, " shaggy hair."] The conical projections on the valvulæ conniventes, making the mucous membrane look *shaggy*.

Vitel′lus. [Lat. *vitellus*, a " yolk."] The yolk of an egg.

Vit′reous. [From the Lat. *vitrum*, " glass."] *Glass*-like. A name applied to the transparent, jelly-like substance which fills the back part of the eyeball behind the crystalline lens.

Vo′mer. [Lat. a " ploughshare."] The thin plate of bone shaped somewhat like a *ploughshare* which separates the nostrils.

Xi′phoid. [From the Gr. *xiphos*, " sword," and *eidos*, " form."] Shaped like or resembling a sword, ensiform.

Zygomat′ic. [From the Gr. *zygos*, " yoke," " join."] Of or pertaining to the malar bone or this bone and its connections. Constituting or entering into the formation of the zygoma.

Zymogen. [From the Gr. *zume*, "leaven" and *gignere*, " to beget."] A mother substance or antecedent of an enzyme.

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