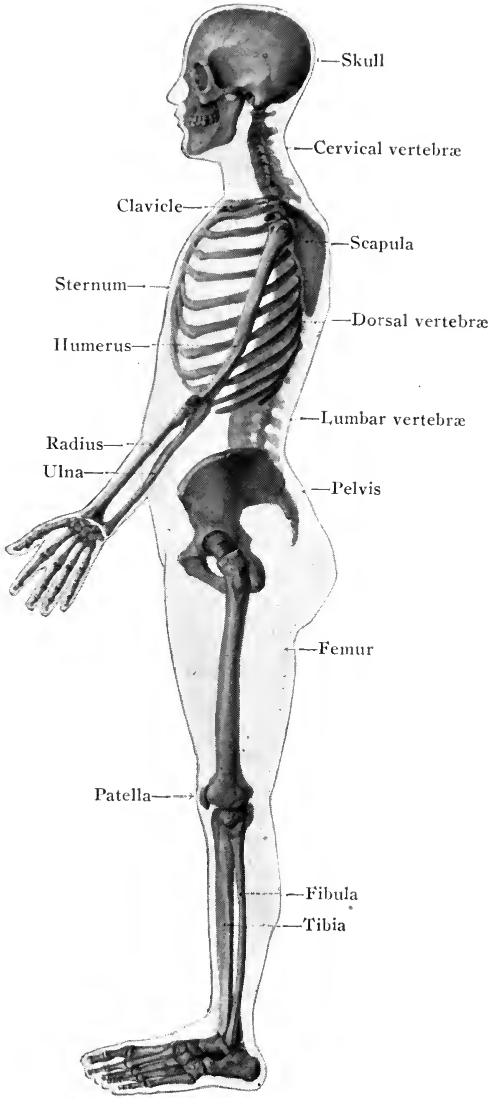
PHYSIOLOGY FOR NURSES



PROFILE OF SKELETON.

A TEXTBOOK OF PHYSIOLOGY FOR NURSES

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PREFACE

It is presumed that the pupil nurse, for whom this book has been compiled, is familiar with the writer's *Anatomy for Nurses,* and has a similar knowledge of physics and chemistry. Technical terms have been employed, without full explanation, upon this assumption. A brief appendix containing an outline of some physical and chemical phenomena has been added for those who have not received a proper introduction to these subjects.

In the preparation of the work we have chiefly relied on the work of Luciana, Howell, Pearce-Macleod, Jones and Bunce, Mallet's *Syllabus of Chemistry,* Ganot's *Physics,* and Bliss and Olive's *Physics and Chemistry for Nurses.* The work is an elementary one and has no claim to originality except in arrangement and treatment.

W. G. Christian.
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CHAPTER I

CIRCULATION

Just as anatomy is a study of *form*, physiology is a study of *function*. Anatomy studies the appearances of the bones, ligaments, muscles, vessels, nerves and viscera, by dissecting the dead body. Physiology explains that bones are supports and levers; ligaments, binding tissue; muscles, moving agents; vessels, channels for circulating fluids; nerves, conducting agents; viscera, agents of secretion or excretion necessary for life and growth. Physiology can not be learned from the dead body, though some of it can be guessed at, but must be discovered by observation of the living animal or plant. Examination and analysis of the cells of which bodies are composed may reveal their physical and chemical character, but the more thorough the analysis, the more complete the destruction of the cells and the more impossible it is to investigate their vital activities. Hence many vital phenomena are still unexplained, though the number is daily decreasing.

The most widely distributed of all the tissues of the body is the blood. It is the universal solvent for all material used in building other tissues, in keeping them in a state of health by carrying food to them and by removing worn out or injurious material from them. The functions of the blood and the forces of the circulation make,

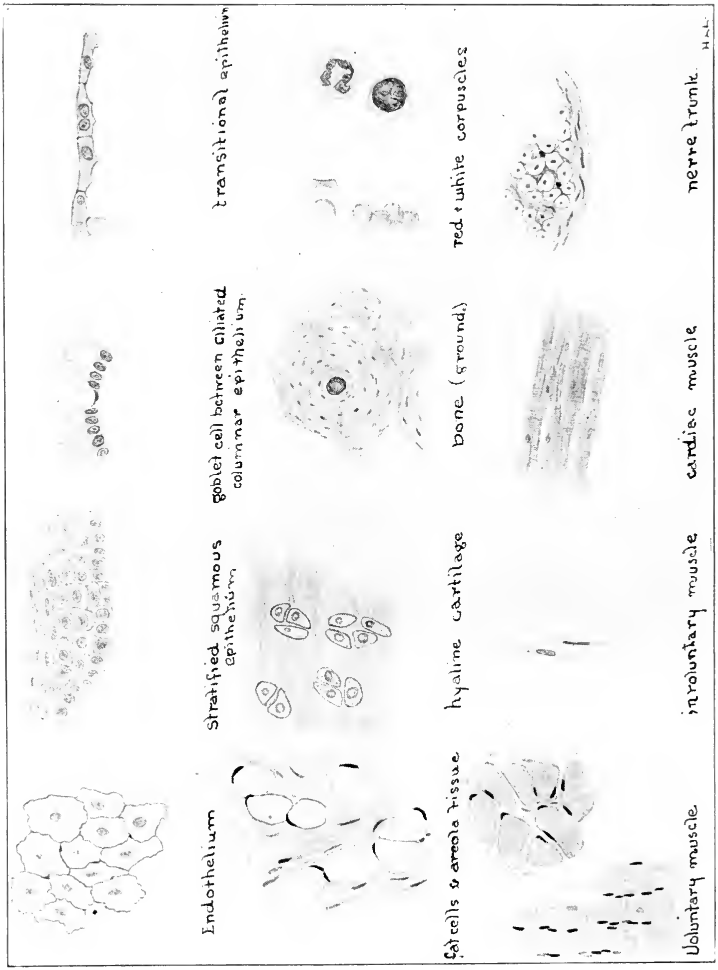

Fig. 1.—Simple tissues.

therefore, a convenient point of departure in beginning the study of physiology.

The **blood** consists of a liquid, *plasma,* and solid bodies, red corpuscles, or *erythrocytes,* blood platelets; and white corpuscles, which are of two kinds, *leucocytes* and *lymphocytes.*

The plasma is all of the liquid part of the blood as it exists in the living animal and is to be distinguished from "serum," which is the liquid part *after coagulation has occurred.* Plasma consists chiefly of water, but contains other substances of the greatest importance. The inorganic salts, such as sodium chloride, calcium chloride, and potassium chloride, as well as compounds of these bases with other acid radicals, are of importance in regard to the phenomena of osmosis, as influencing the irritability of muscle and nerve, and are supposed to play an important role in the maintenance of the heart beat. Calcium salts cause an increased vigor of contraction and if present alone, cause the heart to stop tightly contracted; while the salts of potassium tend to cause relaxation. It is suggested that the presence of these salts in proper concentrations causes the alternate contraction and relaxation of the heart during life.

Among the organic constituents are proteins, which are known as *fibrinogen, serum albumin,* and *serum globulin* or *paraglobulin.* In addition, there are what may be designated as temporary constituents of the plasma, substances on their way from the digestive canal to the tissues, such as fat, sugar, the results of protein digestion; as well as waste products on their way to the organs of excretion; bodies known as *hormones,* which are produced at one part of the body and sent elsewhere to influence other structures; substances which are manufactured to enable the animal to overcome bacterial invasion; and certain substances which resemble ferments in their action. Among the latter may be mentioned *prothrombin,* which, as we shall see, is active, in causing blood-clotting or coagulation.

Of the formed elements of the blood, the red corpuscles or erythrocytes are the most numerous. There are about five million of these to the cubic millimeter of the blood of a healthy man; women are supposed to have about five hundred thousand less. They contain a substance known as *hemoglobin,* which, by virtue of its iron content, is capable of forming unions with gases, especially with oxygen, and to a less extent with carbon dioxide. These unions, as we shall find, are essential for the processes of respiration. The number of these corpuscles is reduced under certain pathologic condition, as in the various *anemias;* and may be increased when there is a great loss of fluid from the body, as in cholera or where there is a diminution in the amount of oxygen in the surrounding air, as in ascents to great heights.

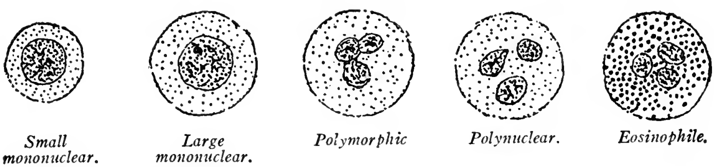

Fig. 2.—White blood-corpuscles from man. (Hill's *Histology.*)

The **white cells** serve an entirely different function in the body. There are from five to ten thousand to the cubic millimeter of blood on the average, but this number is subject to wide variations under altered conditions. The white cells are of assistance in the digestion of protein and in the transportation of fat in the blood, which probably explains the increase in their numbers following a meal. Cold baths and pregnancy are other "physiologic" causes of increased numbers of leucocytes. A very important duty of the white cells is to combat bacterial invasion, and it is found that many infectious diseases are accompanied by an increase in the number of the leucocytes, this **leucocytosis** often being of value in the diagnosis. In pneumonia, for instance, the number not infrequently is increased to forty or fifty thousand to the cubic millimeter. In the leucemias, there is often a still larger increase; while in some other diseases, such as typhoid fever, there is a reduction in the number, this being known as a **leucopenia.**

There are about three hundred thousand platelets to the cubic millimeter. These are small disc-shaped bodies when examined with proper care, but usually disintegrate and appear simply as detritus in the ordinary stained specimens of blood. Their functions are imperfectly understood; they appear to be of importance in the coagulation of the blood, and it is claimed that their number is reduced in the hemorrhagic diseases.

Lymph.—It must be understood that the tissue cells are not bathed direct in blood. The blood, carried in its system of vessels, has been likened to a wholesaler, and the part of the retailer, coming in intimate contact with the consuming tissue cells, is taken by the lymph. The lymph is derived from the blood by the processes of filtration and osmosis, and is poured out into the spaces surrounding the cells. Containing the nutritive substances derived from the blood, it turns these over to the cells and receives waste products from the latter. It is forced into special vessels, known as lymphatic channels, and finally is carried back into the blood stream through the right and left lymphatic ducts. Along the course of the lymphatic channels are found the lymphatic glands, which act as filters, attempting to prevent the entrance of bacteria or toxins into the circulation. The "waxen kernels" are lymphatic glands that have become inflamed and swollen as the result of the action of some toxic agent.

Coagulation.—The clotting or coagulation of the blood is nature's way of stopping hemorrhage and where there is derangement of the process, serious or even fatal hemorrhage may occur from an apparently trivial wound. A substance known as **prothrombin** and salts of calcium is found in the blood. If calcium acts on prothrombin, it converts the latter into **thrombin** and thrombin causes **fibrinogen,** a soluble protein of the blood plasma, to assume an insoluble form, known as **fibrin,** this latter constituting the clot, enclosing the red corpuscles in its meshes. The white cells possess the power of movement, so they are not included in the clot to any considerable extent. That blood does not normally clot in the vessels, is explained by the presence of a substance known as **antithrombin,** which prevents the action of the calcium salts on the prothrombin. When tissues are wounded, another substance, known as **kephalin** or "thromboplastic" substance, neutralizes the antithrombin and allows the conversion of prothrombin into active thrombin. If blood is obtained by puncturing a vein and drawing the blood into a perfectly clean syringe, contact with wounded tissue is prevented and coagulation is delayed, because the thromboplastic substance is not derived from passing over wounded tissue. Clotting will occur, however, because the platelets will gradually disintegrate and furnish the requisite thromboplastic material. The hemorrhagic diseases which have been mentioned, are accompanied by a marked increase in the

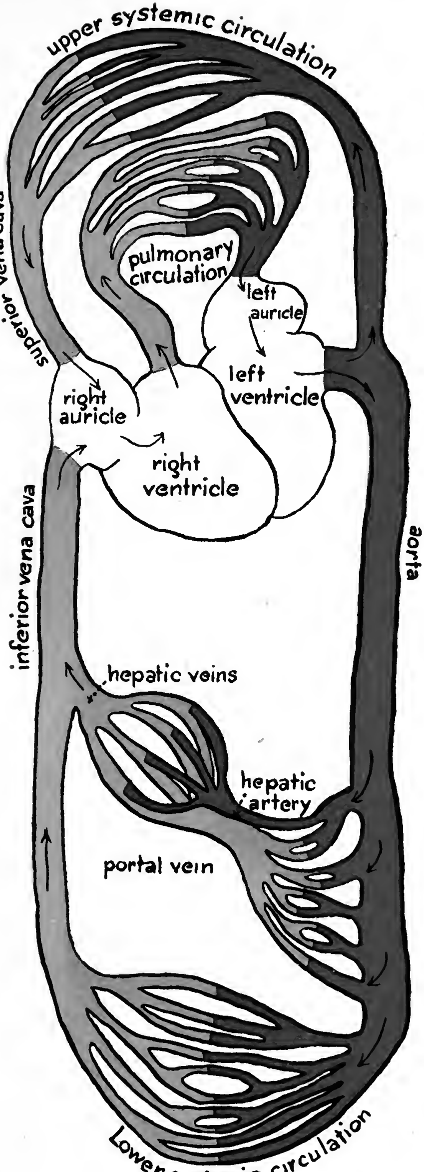

Fig. 3.—Diagram of entire circulation.

coagulation time, so that individuals have bled to death after the extraction of a tooth or the production of similar small wounds.

The circulatory apparatus consists of a central pumping station, the heart; a set of vessels leading from the heart to all portions of the body, the *arteries;* an immense number of small thin-walled vessels, the *capillaries,* in which the arteries terminate; and a set of vessels, the *veins,* which return the blood to the heart. The schematic drawing shows that arteries constantly diminish in size as they get further from the heart, that the capillaries are the terminations of arteries and beginning of veins, and that the veins, by one vein joining another, increase in size as they approach the heart. The total area of capillaries is greater than that of the veins and much greater than that of the arteries. If the blood in the arteries differs from that in the veins, it is obvious that there must be a sort of midpoint in the capillary system where arterial changes to venous blood; and if this is true, it is apparent that the arteries carry something to the tissues which they need and that the veins take something away which is either useless or injurious. The object of the circulation of the blood is, therefore, briefly, to feed or irrigate the tissues through the arteries and to drain them through the veins. But the veins can not pour out the blood so charged, because it would waste the blood which can be purified; so the lungs have been provided to burn up the waste material and change venous back to arterial blood which is further cleansed by the liver and kidneys. The course of the circulation is then from the heart through the arteries and capillaries to the tissues where arterial is changed to venous blood; through venous capillaries and veins to the heart and thence to the lungs where venous is changed to arterial blood and thence back to the heart to go over the same route as long as life lasts. The heart is, therefore, the main force of the circulation. Anatomy has taught us that it is a four-chambered hollow muscle. The two thin-walled chambers at the base are called *auricles,* the two thick-walled chambers forming the apex, the *ventricles.* Both the left auricle and ventricle are thicker than the right, but the left ventricle is much thicker than any other part of the organ. The right half is concerned with venous blood and the pulmonary circulation. The blood from the upper extremities, head and neck is collected and poured into the right auricle through the superior vena cava; that from the lower part of the body enters the same cavity through the inferior vena cava. From the right auricle the course is into the right ventricle through the *auriculoventricular* opening, thence through the pulmonary artery into the lungs whence it is collected by the four pulmonary veins and carried into the left auricle from which it flows through the left auriculoventricular opening into the left ventricle from which it is pumped through the *aorta* to all parts of the body.

The auriculoventricular openings are guarded by valves composed of triangular flaps, the right—*tricuspid*—having three, and the left—*bicuspid,* or *mitral*—having two. The two auricles fill at the same time. As the blood flows in through cavæ or pulmonary veins, it passes through the auriculoventricular openings into the corresponding ventricle until that cavity is nearly full. As the blood rises in the ventricle it floats the valve flaps away from the walls of the ventricles and toward the opening. This action continues until there is but a slit-like aperture between the flaps. Just at this moment the auricle contracts, forces into the ventricle all the blood it will hold and presses the valves tightly across the opening into which it would project if the papillary muscles did not contract and hold the edges of the valve at just the right angle. This action of the auricles is called *auricular systole* (from a Greek word meaning to contract). With a barely perceptible pause ventricular systole begins, the blood is forced into the aorta and pulmonary artery, whose openings are guarded by three cuplike folds called *semilunar* valves. As the blood rushes between these cups some of it gets into three lit-

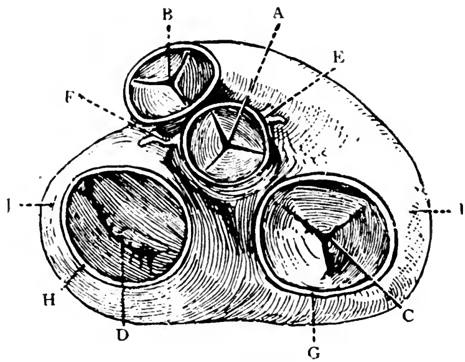

Fig. 4.—Diagram of valves of the heart. The valves are supposed to be viewed from above, the auricles having been partially removed. *A*, aorta with semilunar valve; *B*, pulmonary artery and valve; *C*, tricuspid, and *D*, mitral valve; *E*, right, and *F*, left coronary artery; *G*, wall of right, and *H*, of left auricle; *I*, wall of right, and *J*, of left ventricle. (Stewart's *Physiology*.)

tle pockets, *sinuses of Valsalva*, between the valve folds and the arterial walls, so that when the force from behind ceases the weight of the blood and the elastic recoil of the vessels force each flap towards the opening, and, the three flaps coming together, the return of blood to the heart is prevented. This completes the contractile or *systolic* period of the heart cycle and the period of rest, *diastole*, begins. A cardiac cycle, therefore, consists of two distinct parts; i.e., auricular systole, ventricular systole, and diastole, or rest. The closure of the auriculoventricular valves takes place at the same instant; that of the semilunar valves a little later. The sound of the first, dull and low pitched and confused with the sound made by contracting muscle, is called the *first* sound of the heart; the sharp, high, short click of the semilunar valves, make the *second* sound. Cardiac systole lasts about the tenth of a second, diastole about five tenths; so that the heart is at rest about sixty per cent of the time.

Exact closure of all the valves is necessary to prevent leakage. It follows, therefore, that if any valve is too short or too long, has a rough place on it either through the presence of a foreign body or a wound, it will not meet its fellows exactly and there will be a falling back of blood into the chamber which that valve guards. Or if the opening is too small from any cause, there will be greater difficulty in driving the blood through, or it would take a longer time. Either defect would cause a change in the heart sounds.

Various infectious processes are apt to cause such damage to the valves through the production of "endocarditis," an acute inflammatory process involving the inner lining of the heart. When the inflammation subsides, scar tissue appears and, as is always the case with such tissue, contraction causes a distortion of the leaflets with a resultant leakage. Rheumatic fever, tonsillitis, chorea, and pneumonia are the commonest predisposing causes for endocarditis.

The heart is the chief, but not the only, force of the circulation. The arteries are lined by a thin coat—the *intima*—continuous with the lining membrane of the heart; but around this their walls are composed of fibrous, muscular and elastic tissue. The latter is particularly important. If fluid is put into an iron pipe until it is full, no force will get any more of the liquid in; but if the same experiment is tried with a rubber tube, not only can an additional amount be forced into the stretched tube, but, as soon as the power is withdrawn, the additional fluid will be squeezed out, even against gravity, by the elastic contraction of the tube. When the heart forces blood into the aorta, that tube expands. As soon as the heart ceases to contract, the elastic coat

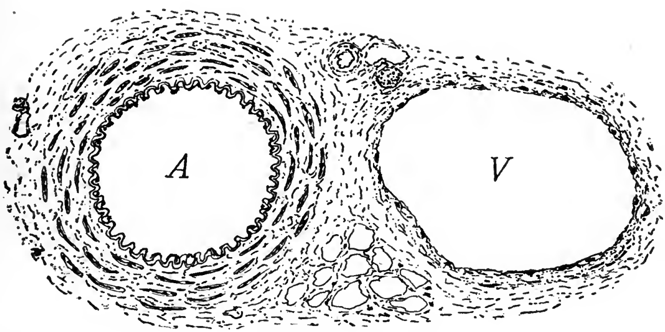

Fig. 5.—Cross section of small artery and vein: *A*, artery; *V*, vein. (Hill's *Histology*.)

of the artery contracts. If the semilunar valves hold, no blood can return to the heart and the contraction of the elastic artery must drive the blood onward into the smaller arteries. The elastic recoil of the arteries themselves, is, therefore, the second great force of the circulation and one which acts continuously. The heart acts only during systole, the recoil of the arteries continues during diastole. As the arteries diminish in size they offer greater resistance, partly by friction, to the passage of the blood; and as their distance from the heart increases and their strength diminishes, the heart's impact and the elastic recoil both lose power until, in minute arteries the blood flow approaches the character of a steady stream instead of the jet-like type of the larger arteries. In the arteries the blood leaps in jets; in the capillaries it oozes; in the veins it flows. It is like a swift torrent which spreads into a marsh where movement is barely perceptible until its outlet is found in a deep, dirty, sluggish stream.

The **venous current** is collected by the veins from the capillaries. The blood, through capillaries and veins, still receives an impulse from the heart, but not in sufficient strength to complete the return circulation. Certain accessory forces are, therefore, called into play. The first of these is the suction of the thorax caused by inspiration, and described under that head. A more widespread factor is that of the valves in the veins, particularly those so located that gravity habitually retards the flow. These valves are half cup shaped, concavity upward, very much like the semilunar valves, so arranged that the blood flows easily over their free surface, but is caught in the hollow cup when it attempts to fall back. From this position it is forced on to the next valve partly by the push of the heart from behind, partly by suction of the thorax in front and largely by the massage-like action of the muscles which squeeze and compress the veins and drive the blood to the next valve, where the same process is repeated.

Circulation Time.—The circulation time can not be definitely stated. The usual estimate is that from twenty-five to thirty beats of the heart are required to complete the circulation; i.e., to drive the blood throughout the body. About a fourth of this number completes the pulmonary circulation. The velocity through different vessels also varies as does the quantity supplied to each

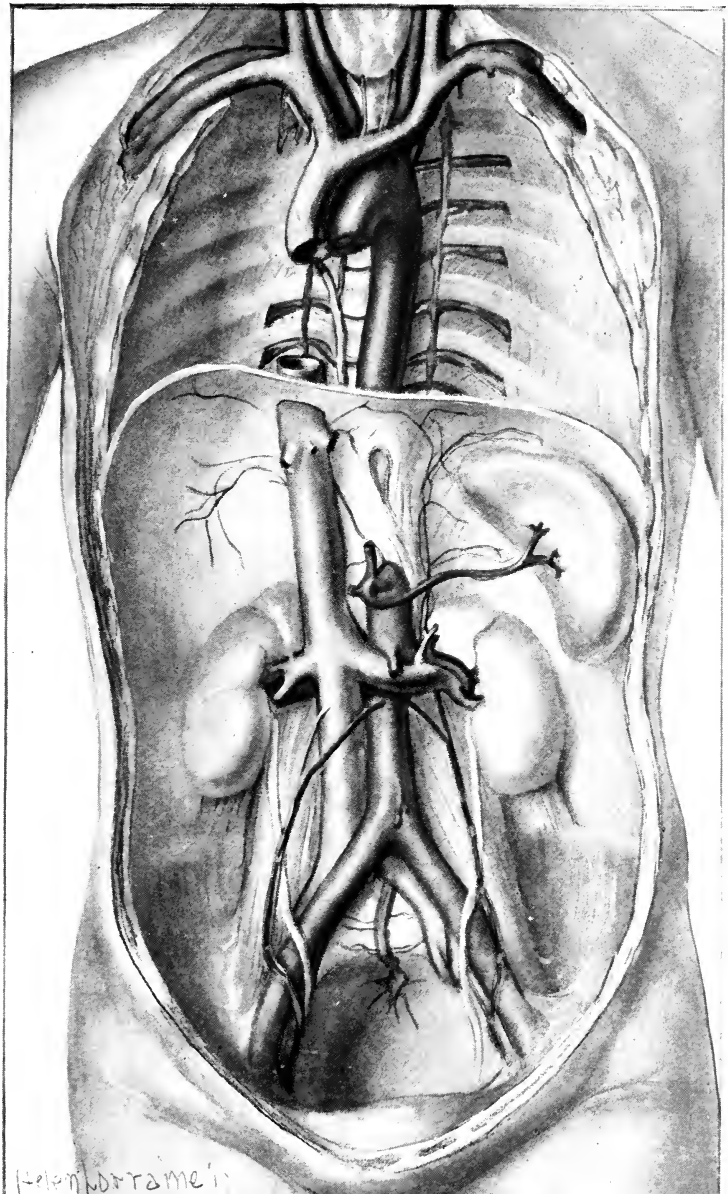

Fig. 6 —The aorta and its branches.

organ. The latter has been determined by experiments which prove that in every minute each hundred grams of the leg receive 5 c.c. of blood; while the same weight of spleen would receive 58 c.c., of brain 136 c.c. and of the thyroid no less than 560 c.c. in the same time.

Circulation Velocity.—Circulation velocity does not refer to the rapidity of flow through any given vessel, but to the time it takes for a given portion of blood to pass between two points as from one jugular vein through the heart, pulmonary artery, veins, left heart, aorta and capillaries of the head to the opposite jugular. This is determined by putting some methylene blue in one jugular and watching for its appearance in the other. This has been accurately determined in many lower animals and is estimated to be about thirty-two seconds in man. As the rate of flow is much more rapid in the largest than in the smallest arteries, in the arteries than in the capillaries, and in the veins than in the capillaries, it can not be calculated by simply watching the speed with which corpuscles pass through one of the vessels. Of course the velocity of the blood current will not be confounded with the rate of the pulse, which is an impact rather than a current.

The Pulse.—The pulse is seen and normally felt only in the arteries. The capillary and venous systems are so much wider than the arterial, that the force of the heart-beat is not displayed in the pulsatile or expansile manner so characteristic of the latter. The column of blood extending from the heart throughout the arteries may be compared to a series of balls suspended by strings and each touching the other. If the first of the series is struck sharply the power will be transmitted throughout the series, but it will visibly affect the last only. If fresh blood is pumped into the aorta, that particular blood will immediately flow but a short distance, but the force will be applied to every drop of blood in every artery. Each artery will expand and contract just as the aorta does and the expansion will be synchronous with the heartbeat; but that particular jet of blood will not reach the artery being felt for several seconds. It follows from this that the greater the power of the heartbeat the stronger will be the pulse; the more frequent the heartbeat, the more rapid the pulse, the more the capillaries are expanded, the less the resistance to the outflow, the more compressible the pulse and the lower the blood pressure.

In the lungs the blood circulates under the same general conditions as in other parts of the body. Pressure is less in the pulmonary vessels because the right ventricle is weaker than the left. Inspiration and expiration also affect both the systemic and pulmonary circulation. In inspiration about one-twelfth of all the blood in the body is in the lungs, while expiration reduces this to one-fifteenth or eighteenth.

Blood Pressure.—If liquid be pumped into an inelastic tube, the pressure will be exactly proportionate to the quantity of fluid and the force of the pump. As soon as the pump ceases to act, the pressure falls to zero. If the same experiment be conducted with an elastic tube pressure will again be equal to force and quantity, but the elastic recoil of the tube will maintain some pressure after the pump ceases to act. If the tube be converted into two whose combined area is as great as that of the single tube, but with thinner walls, pressure will decrease because friction will be greater; and if the process of division be continued until each tube is of microscopic size, but their combined area is much greater than that of the original tube, pressure will be very greatly diminished. If now several small tubes unite to form one, and this is joined by another formed in the same way and the process is repeated until there is but one tube, the pressure in that will be less than the pressure in the numerous microscopic tubes, and much lower than it was in the one large elastic tube because friction so

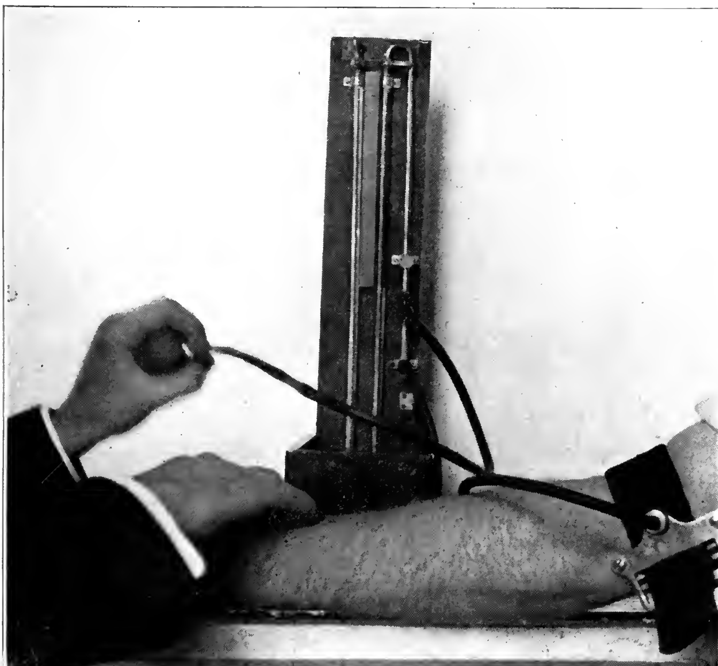

Fig. 7.—Apparatus for measuring the arterial blood pressure in man. The pressure in the cuff is raised by means of the syringe until the pulse can no longer be felt at the wrist. This pressure is read off on the mercury manometer (systolic pressure). (Pearce-Macleod, *Fundamentals of Human Physiology*.)

retards the flow that the larger tube can never be filled. The arteries, capillaries, and veins form such a set of tubes and blood pressure varies in these sets of vessels.

As ordinarily understood blood pressure means arterial pressure and is taken during systole, *systolic* pressure or, during diastole, *diastolic* pressure. The method of determining pressure is to encircle the arm (because there is but one bone and the muscles, when compressed, squeeze the arteries uniformly) with a long rubber sac, enclosed in leather, which is connected by tubing with a column of mercury and an air pump. When air is pumped into the sac until the blood can no longer pass under it, as shown by disappearance of the radial pulse, the height of the column of mercury is read. This is systolic pressure and, in healthy young men, varies between 110 and 130 mm. of mercury.

Pressure Forces.—Pressure forces are three in number: i.e., the power of the heart, the resistance ot the vessels, and the quantity of blood. In normal animals, the two former change with changing conditions, so that a practically constant level of pressure is maintained the greater part of the time. Decrease in the volume of the blood tends to lower the pressure, but, within certain limits, this is compensated for by increase in the rate of the heart and a constriction of the vessels. Likewise, if fluid is introduced into the vessels, it does not cause a marked and persistent rise in the pressure, due to the same factors working in the opposite direction. The volume of the blood remaining the same, certain drugs are capable of causing vascular contraction, as *epinephrine*, which, uninterfered with, would cause an enormous rise in pressure. Injecting this drug into the circulation does cause a rise in the pressure, but when this reaches a certain level, the heart is slowed, in order to prevent an undue strain. On the other hand, when the vessels are caused to dilate by *nitrites*, the heart beats more rapidly in the attempt to raise the pressure back to the normal level.

Occasionally, this compensatory action fails. Such is the case in fainting or syncope. Here, the vessels, especially in the abdominal region, dilate, and insufficient pressure is maintained to supply the brain properly with blood, so unconsciousness occurs. In moderate hemorrhage, the loss of blood is compensated for in the manner described, but when the loss has assumed very serious proportions, the pressure falls and unconsciousness results. It is obvious that this fall of pressure is conservative; if it did not take place, great difficulty would occur in regard to clotting. Therefore, it may be unwise to resort to measures aimed to raise the blood pressure before the bleeding point has been located and the hemorrhage checked.

Diseases which harden the walls of small vessels, converting them into inelastic tubes, have the effect of constricting vessels, increasing resistance and raising blood pressure. Many drugs affect blood pressure either, like digitalis, increasing the power of the heart, or, like the nitrites (amyl, sodium, etc.) by dilating peripheral vessels and causing a fall of blood pressure. Others act upon the nervous mechanism of the heart, which, roughly, consists of a set of sympathetic fibers which accelerate or augment the action of the heart and a set of vagus or pneumogastric fibers which slow or inhibit its action. This subject will be discussed under the nervous system.

CHAPTER II

RESPIRATION

The air which surrounds us is in the main composed of two gases, oxygen and nitrogen, thoroughly mixed but not chemically combined. Of these the nitrogen is inert while the oxygen is essential to animal life. The organ which enables us to bring this gas in contact with the blood is the lung, while its use in the animal economy is called *respiration.* But taking oxygen into the lungs, would be of no service if the process stopped there. It is, therefore, carried by the blood into all parts of the body where the oxygen is used and injurious matter taken up and removed. If two gases be placed one on either side of a wet membrane, like parchment, they will mix with each other by a process called osmosis. If, therefore, a liquid, like blood, containing oxygen be brought in contact with tissues containing carbon dioxide, the two gases would interchange even if there were no chemical activity to promote the change. Blood going to all parts of the body carries oxygen in combination with hemoglobin. When in contact with live tissue this oxygen is given up to the tissue and carbon dioxide is taken up and carried by the venous blood to the lungs where, in the cells of those organs, a re-exchange is effected, the carbon dioxide being given up and oxygen, derived from the inspired air, takes its place. The last exchange is called the *external* and the first the *internal respiration.*

The organs of respiration are the nose, pharynx, larynx, trachea and lungs. Except the last, and in all but the ultimate air cells of the lungs, these organs are but variously modified tubes through which the air is drawn, heated and moistened. It is in the air cells that the thin walls of the pulmonary capillaries bring the blood close enough to the inspired air for the exchange to take place.

Respiratory Forces.—For normal respiration the respiratory forces are the *diaphragm* and certain muscles

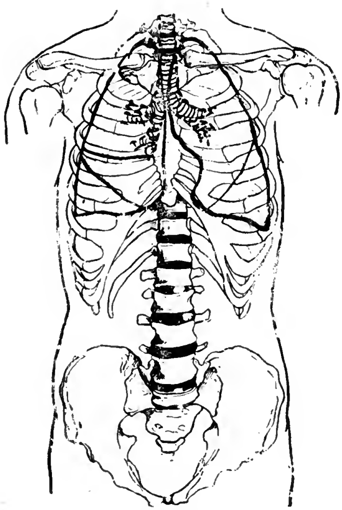

Fig. 8.—The position of the lungs in the thorax. (T. Wingate Todd.) (Pearce-Macleod, *Fundamentals of Human Physiology.*)

which move the ribs. Essentially the lungs are a pair of elastic bags, communicating with atmospheric air through the breathing tubes, enclosed in a movable bony framework which is covered by soft tissues and lined, for each lung, by a frictionless membrane completely air-tight. If the framework increases in size, the lungs must either follow it or leave a vacuum between lung and frame. An increase in the size of the thorax, therefore, makes the air pressure in the lungs less than the pressure of the atmosphere and air enters the lungs until the pressure is equalized. Forced inspiration means simply forced increase in the size of the thorax requiring a corresponding amount of air to establish equilibrium. The ribs slope downward and forward and are fixed behind. Consequently when the anterior end is pulled upward they must push the sternum forward and increase the diameter of the chest from before backwards. At the same time the spaces between them in-

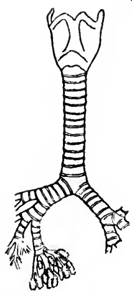

Fig. 9.—Diagram of structure of lungs showing larynx, bronchi, bronchioles, and alveoli. (Pearce-Macleod, *Fundamentals of Human Physiology*.)

crease and the chest grows from above downwards. If, now, the diaphragm, which is fastened around the barrel-like chest, convex upwards, contracts, it must flatten the dome and greatly increase the space within the thorax. It must be borne in mind that this space contains not only the heart and lungs, but the great vessels, and that the force which causes inrush of air can not but produce some suction (aspiration) which will influence their contents. As soon as the inspiratory muscles cease to act, the abdominal contents, resting against the under surface of the diaphragm, and held in place by the powerful and elastic muscles of the abdominal wall, begin to press on the diaphragm and force it to resume its dome shape. The ribs drop back into their position of rest, the elastic lungs contract and drive out the air and thorax, diaphragm and lungs are ready to repeat the act of inspiration. The descent of the diaphragm pushes the abdominal viscera downwards and forward and this movement communicated to the abdominal wall gives its name to this type of breathing, abdominal, which is most noticed in children. When the lower ribs only move the type is said to be *inferior costal;* when the clavicles and upper ribs move the type is *superior costal.* The latter is characteristic of civilized women and is a possible provision for pregnancy, though many observations indicate improper dress as a cause of this type of inspiration.

In forced inspiration, as in asthma, other muscles are brought into play. The same is true of forced expiration where the abdominal muscles play a large part.

Respiratory Cycle.—This consists of two parts, the intake of air, *inspiration,* and the output or *expiration.* Inspiration takes a slightly shorter time than expiration, the average difference being the proportion of five to six; though in children, women, and the aged the proportion may be six to eight or even nine. There is a slight pause after expiration.

Respiratory Sounds.—If the ear be applied to the chest during inspiration a soft murmur, like the rustling of leaves in a gentle wind, is heard, followed, during expiration, by a similar sound during a shorter time. Note the apparent contradiction: The time of inspiration is shorter than that of expiration, but the inspiratory sound lasts three times as long as the expiratory. Both sounds seem to be caused by the friction of air entering and leaving the infundibula and alveoli. If the air vesicles are filled up, or the listening is done over large bronchi, the second is modified and becomes *tubular*. It is the difference in sound caused by the air moving in small tubes and large ones.

Quantity of Air.—The total quantity of movable air in the lungs of an average man is about 230 cubic inches. Of this amount about 20 cubic inches is taken in at each inspiration, about 110 cubic inches can be taken in after an ordinary inspiration and about 100 cubic inches is the amount which can be forcibly expelled after an ordinary expiration. The amount passing in and out in each ordinary respiratory cycle is called *tidal air,* that taken in by forced inspiration, *complemental* air and that which can be expelled by the greatest effort *supplemental.* Tidal, complemental, and supplemental air together constitute one's *vital capacity.*

Not the utmost effort will expel all the air from lungs which have once been filled, a fact which causes lung tissue to float in water, which no other tissue will do. The fact that once filled lung tissue floats and that never filled sinks, often enables experts to determine whether a dead child has ever breathed or was born dead. The air remaining after fullest expiration is termed *residual* air and amounts to about 100 cubic inches.

Number of Respirations.—Within the limits of health respirations may vary from sixteen to twenty-four per minute, or one respiration to four heartbeats. In childhood breathing is more rapid and at all ages it varies with exercise or the position of the body, while in febrile diseases the rate greatly increases. Some pathologic conditions diminish the rate.

Modifications of Respiration.—When breathing is difficult for any reason it is termed *dyspnea,* from two

Greek words signifying "bad breathing;" when it is totally arrested, the condition is called *asphyxia* and when there is an excess of oxygen or too little carbon dioxide in the blood, so that respiration can be suspended without injury, a condition of *apnea* exists.

Modifications of respiration are seen in sighing, yawning, laughing and sobbing, snoring, hiccoughing and coughing.

Sighing is a slow, large inspiration, followed by an audible rapid expiration.

Yawning is practically an involuntary sigh accompanied by a widely opened mouth. It may be caused by stomach pain (hunger) as well as the torpor which precedes sleep.

Hiccough is a spasmodic contraction of the diaphragm accompanied by closure of the glottis. It is often pathologic and uncontrollable.

Coughing is a reflex act caused by irritation of the nerves of the larynx. The mechanism of the act is a full inspiration followed by a sudden strong expiration.

Laughing and **sobbing** are, mechanically, identical. The diaphragm is the muscle employed in each act and the face is the organ of expression.

Snoring is the vibration of the soft palate.

CHEMISTRY OF RESPIRATION

If two or more gases are confined in the same vessel they will mix or *diffuse* throughout the space. If water or other fluid be in the space, some of each gas will enter the fluid, or be *dissolved* in it; and, under some conditions, some of the gases may enter into chemical combination with the liquid. The amount of gas dissolved and the amount in combination, will vary somewhat with the pressure applied. As the essential function of the respiratory act is to convey one gas to the tissues and another away; and as experiments prove that some of the gas is in solution, but most of it in combination, there must be pressure changes, or differences, in the lungs and in the tissues to facilitate the exchange.

If the tidal air is analyzed we shall find that inspired rich in oxygen and that expired rich in carbon dioxide. The reserved air must, therefore, contain a larger amount of CO_2 than the complemental. Now as tidal air enters the alveoli and finds them filled with air containing a high percentage of CO_2, there must be a diffusion or mixing of air in the alveoli. This process of mixing goes on at all times.

When arterial blood passes to the tissues it finds them filled with CO_2 existing under a pressure which causes it to enter into chemical combination as well as solution. The oxygen in the arterial blood, chiefly in combination with hemoglobin, finds the pressure lowered as soon as it reaches the tissues. Pressure on the oxygen being low, it escapes into the tissues; that on CO_2 being high, it combines with the blood. Upon reaching the lungs the reverse of this action takes place, venous blood giving up its CO_2 and taking oxygen instead because the air in the alveoli is rich in oxygen and poor in CO_2, while the blood is rich in CO_2 and poor in oxygen, the tendency being for oxygen to escape from the alveoli and CO_2 to escape from the blood into the alveoli until the pressure on each gas is equalized.

Oxygen and carbon dioxide are the chief, but not the only, gases inhaled and exhaled. Atmospheric air contains, in a hundred parts, approximately 79 parts of nitrogen, 20.96 parts of oxygen, .04 parts of carbon dioxide and minute quantities of other gases with about 1 per cent of water. Nitrogen has no injurious effect, except by excluding oxygen. Like all nonpoisonous gases it may cause asphyxia if breathed pure, but would cause it no more quickly than lack of oxygen if the nitrogen were absent. Carbon dioxide is poisonous, but less fatal than carbon monoxide which acts by combining with the hemoglobin of the blood and excluding oxygen, because its compound with hemoglobin is much more stable than that of oxygen. The injurious effects of rarefied air, like that on high mountains, is due to lack of oxygen in the blood.

Ventilation.—Briefly stated the problem of ventilation is to maintain, in a closed space like a room, the nearest possible approximation to atmospheric conditions. The problem would be simple if it were not for the necessity of heating. A healthy adult gives off about six-tenths of a foot of CO_2 per hour, that is he changes the contents of a hundred feet of air from four-tenths to one foot of CO_2. If this process be carried too far, he will not only increase the actual CO_2 but, by using up the oxygen, still more increase the relative content. If a supply of 1,000 cubic feet of fresh air is furnished per hour for each well person, the room is sufficiently ventilated; but in hospitals the amount required is 3,000 cubic feet.

Nervous Mechanism.—Nervous mechanism is almost automatic. A center to control respiration is located in the medulla. The normal stimulus to which it responds is carbon dioxide. When the venous blood is sufficiently charged with that gas, the center sends a message, which is carried by the nerves to the muscles of inspiration which contract and cause an inrush of air. If there be an impediment to the intake, accessory muscles of inspiration are called upon until the obstacle is overcome.

If part of the lung is occupied by a foreign substance, as in pneumonia, the respiratory efforts are made more frequently because there is more CO_2 in the blood and the center is stimulated to greater activity. If there is too little CO_2, the center is less excited and the number of inspirations per minute will decrease, to rise again as soon as the proper amount of CO_2 is restored.

CHAPTER III

FOOD AND DIGESTION

Digestion is the process by which physical and chemical alterations of foodstuffs, which fit them for absorption, are effected. Animal and vegetable tissues contain foodstuffs of the same chemical composition; but some animals can not convert certain forms of vegetable matter into food, while others can. When an animal feeds upon other animals it is called *carnivorous* and feeds upon tissues similar to its own. When it feeds upon vegetables it is called *herbivorous* and feeds upon tissues containing the same chemical elements but so arranged as to be not easily digested by carnivorous animals. With the aid of light, heat and moisture, vegetables take up chemical elements from air and soil and combine them into the proper constituents of food for herbivorous animals, and these in turn, convert them into the similar, but more digestible foodstuffs required by man.

Of the elements of the chemist, only about twenty enter into the composition of our tissues; and of these, five form so much of our bulk that the others may be mentioned as traces. The elements which chiefly concern us occur as follows, in every hundred parts:

Carbon,	53
Oxygen,	22
Nitrogen,	16
Hydrogen,	7
Sulphur,	2

The various constituents of the body may be divided into two great classes, *organic* and *inorganic,* and the first into those which contain nitrogen and those which do not.

The Inorganic constituents are water and the various salts, that is minerals like iron, potash, soda, etc., in combination with some acid.

Water is the most widely distributed inorganic material, constituting more than half the body weight. It is the solvent for all materials which are carried from one part of the body to another for its nourishment or to remove the worn-out, useless or injurious substances which result from our life processes. We get water by drinking it in the form of water, milk, tea or coffee, soups, etc.; but a small portion is made in the body by burning up hydrogen.

Salts are combinations of soda and lime with hydrochloric or some other acid and of soda, potash, lime and magnesium with phosphoric acid. In the first case we have *chlorates* or *chlorides* of soda, lime, etc.; and in the latter, *phosphates* of potash, magnesium, etc.

The most important and widely distributed of the salts is the one with which we are most familiar, *chloride* of *soda,* or common table salt. Phosphate of lime is a necessary element of bone and iron is an indispensable element of hemoglobin.

Organic Compounds consist of *nitrogenous* compounds which are subdivided into *proteins,* like the red flesh of animals, white of eggs, etc.; *albuminoids* like gelatin and some bodies of simpler composition, like urea, which are largely for excretion; and *nonnitrogenous* compounds which are *fats* (butter, fat meat etc.), *carbohydrates* (starch, sugar) and certain other organic bodies like *alcohol* not so widely used as the preceding. Translated into simple language this means that we require for health lean meat (protein), fat meat, (hydrocarbon or fat) and vegetables (starch and sugar), with enough water to dissolve them after digestion and carry the products of digestion to every part of the body.

Carbohydrates.—Carbohydrates are, chemically, compounds of carbon, hydrogen and oxygen, the last two occurring in the proportions found in water. Thus glucose ($C_6H_{12}O_6$) is composed of six elements of carbon, twelve of hydrogen, and six of oxygen, which is practically the same as saying six elements of carbon in three of water, which is composed of hydrogen two and oxygen one (H_2O). There are various types of carbohydrates—glucose, amylose—but special attention need here be called to none but *glycogen* which is the peculiar form of starch formed in animals.

Fats or **Lipoids,** are found, in varying amounts, in animal tissues, lying under the skin in large amounts, between the muscles, in the marrow of bones and in smaller amounts in other situations. Fats, in the form of oils, are found in many vegetables—olive, cottonseed, nuts, etc. Chemically, fats are compounds of *glycerin* and a fatty acid. They are insoluble in water, and, being bad conductors, serve to keep the other tissues warm. Normal fats belong to one of three types.

Stearin, solid and melting only at comparatively high temperatures. Mutton suet is a fine example of this type.

Palmitin, is the principal constituent of most animal and vegetable fats. It melts at a lower temperature than stearin.

Olein, always fluid except in low temperatures, is found chiefly in vegetable fats, but occurs in that of animals.

Fats, when boiled with soda or potash, break up into glycerin and fatty acids, which latter combine with soda or potash and form soap.

If fats, soap and water be thoroughly shaken together the fat breaks up into small particles which are held in suspension in the water forming an *emulsion.* Milk is an excellent emulsion whose fat gradually rises to the top in the form of cream.

Nitrogenous Bodies.—The chief constituents of muscles, glands, nervous tissue, serum, blood and lymph are complex bodies called *proteins.* They occur in vegetables as well as in animals, but much vegetable protein is indigestible by human organs and comes to us only after furnishing food for the lower animals. Thus peas and beans contain 23.7 per cent protein as compared with 22.7 in fowls and 20 per cent in beef; but so much of the protein of peas is unusable by the human digestive organs, that this vegetable can not be used as a substitute for meat. Various names are employed to designate the protein derived from different sources. One found in milk or cheese is called *casein;* that in the yolk of eggs *vitellin* and that in muscle either *myosin,* or *syntonin.*

Not all bodies which contain nitrogen are capable of maintaining health. The familiar body called *gelatin,* derived from the skin and connective tissue, contains a considerable proportion of nitrogen and yet an animal fed upon it alone will starve almost as quickly as one deprived of food entirely. This seems to be due to the absence of certain *amino* bodies which are formed of nitrogen and hydrogen in the proportion of one part of N to two of H or NH_2. That it is the absence of these amino bodies, or *amino acids,* which keeps gelatin from maintaining a nitrogen balance, is proved by feeding the animal on gelatin plus a suitable amount of an amino acid, which diet maintains health. The following tables copied from Jones and Bunce will be useful for reference:

COMPOSITION OF MILK	HUMAN	COW'S
	%	%
Protein,	1.7	3.5
Butter (fat),	3.4	3.7
Lactose (carbohydrate),	6.2	4.9
Salts,	0.2	0.7

COMPOSITION OF EGGS	%
Total solids,	13.3
Protein,	12.2
Sugar,	0.5
Fats, lecithin, cholesterin (traces), salts,	0.6

MEATS	OX	CALF	PIG	FOWL	PIKE
	%	%	%	%	%
Water,	76.7	75.6	72.6	70.8	79.3
Solids,	23.3	24.4	27.4	29.2	20.7
Proteins,	20.0	19.4	19.6	22.7	18.3
Fats,	1.5	2.9	6.2	4.1	0.7
Carbohydrates,	0.6	0.8	0.6	1.3	0.9
Salts,	1.2	1.3	1.1	1.1	0.8

VEGETABLE FOODS	WHEAT	BARLEY	OATS	RICE	PEAS	POTATOES
	%	%	%	%	%	%
Water,	13.6	13.8	12.4	13.1	14.8	76.0
Protein,	12.4	11.1	10.4	7.9	23.7	2.0
Fat,	1.4	2.2	5.2	0.9	1.6	0.2
Starch,	67.9	64.9	57.8	76.5	49.3	20.6
Cellulose,	2.5	5.3	11.2	0.6	7.5	0.7
Mineral salts,	1.8	2.7	3.0	1.0	3.1	1.0

Theoretically peas should be more valuable than any other vegetable, particularly the potato, because they are rich in protein, starch, fat and salts; while the potato is poor, comparatively, in everything but water. Practically the high protein value of the pea is not available while its large percentage of indigestible cellulose renders it objectionable when eaten to excess.

DIGESTION

That digestion is chiefly a chemical process is perfectly true; but it involves a process, which may be called *vital* chemistry, which the test tube has not, and may not, imitate completely. An essential part of digestion is carried out by bodies called *enzymes* or ferments. Another is the production, in proper proportion, of the acid or alkali in the presence of which alone these ferments will act; while yet another is the preparation of food, by chewing, swallowing, etc., and its agitation in the intestinal canal where it is exposed to the ferments on the one hand and on the other is brought in contact with the vessels by which the products of digestion will be carried into the body.

The Enzymes, or ferments without which food cannot be digested, are of three chief types: (1) **amylolytic,** which convert starch into sugar; (2) **fat splitting,** which convert fats into *glycerin* and *fatty* acids; and (3) **proteolytic,** or those which convert protein into simpler bodies.

Besides these there are *sugar splitting* ferments which change the nonabsorbable into absorbable sugars, and a body which coagulates protein, as in the change of milk to clabber.

The ferments which act on starchy foods are *ptyalin,* secreted by the salivary glands, and *amylase,* formed by the pancreas.

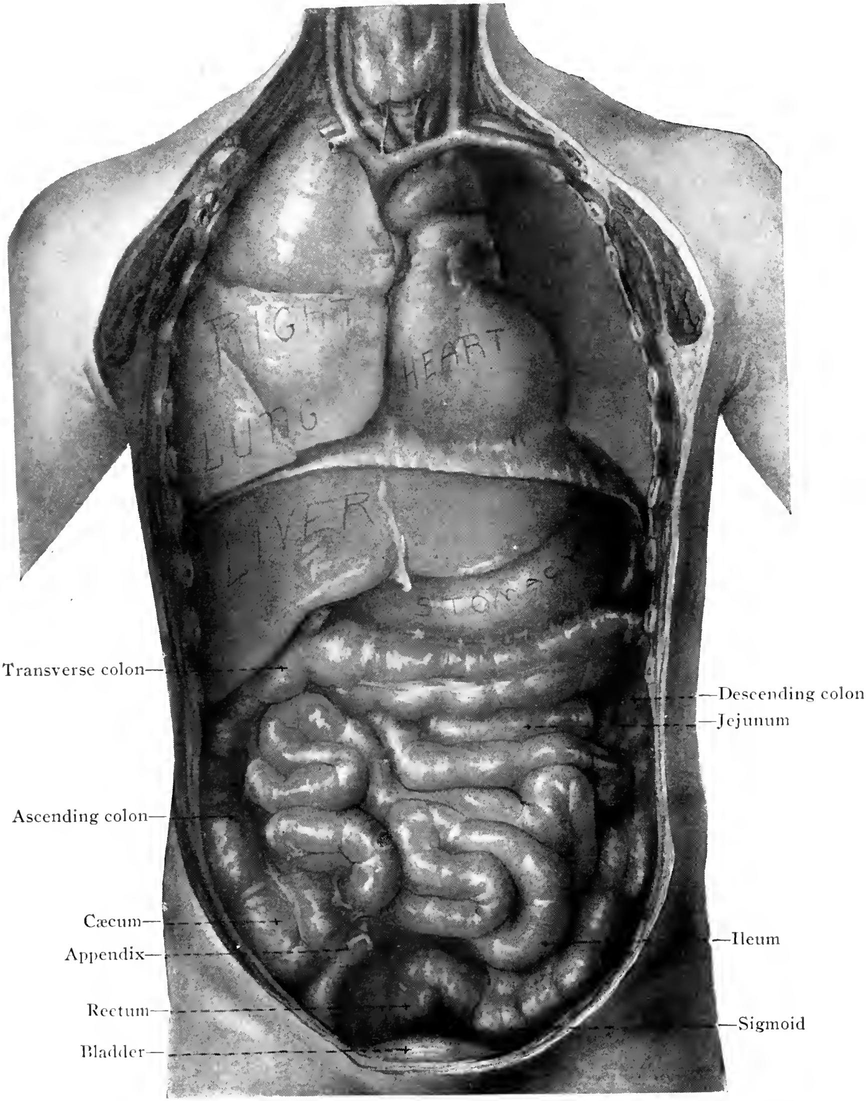

Fig. 10.—Front view of organs. Semidiagrammatic.

The fat splitting *enzyme, lipase,* or *steapsin,* is formed by the pancreas.

Proteolytic ferments are *pepsin,* formed in the glands of the stomach and acting only in the presence of an acid, and *trypsin,* formed by the pancreas and acting in an alkaline medium.

Besides these well-known ferments, the glands in the wall of the small intestines furnish various enzymes which act upon the partly digested food poured into the intestinal canal by the stomach. Their action is not so well understood as is that of the secretions of the stomach and pancreas.

Before considering the action of the digestive ferments, an account of the mechanics of the alimentary canal will be given.

The simplest form of feeding and digesting is in an unicellular organ, a single cell of protoplasm, which wraps itself around its food and becomes, in its entirety, a chewing, swallowing, digesting, absorbing and discharging organism. In man, and the higher animals, after food has been procured, the successive steps are chewing (*mastication*), swallowing (*deglutition*), and digestion. The organs concerned are the mouth, containing the teeth, tongue, and salivary gland; the pharynx and esophagus, the swallowing organs; the stomach and intestines which are the digesting, absorbing and evacuating organs.

Food is held between the grinding teeth by the muscles of the cheek (chiefly the buccinator) on the outside and the tongue between the teeth. Here it is not only thoroughly crushed, but is mixed with the saliva which begins the digestion of starchy food. When this process is completed, the larynx is pressed up under the hyoid bone and the base of the tongue, the top of which organ, aided by the mylohyoid muscles, crowds the food against the roof of the mouth and, exerting pressure from before backwards, forces the food under the soft palate, which it drives upward to protect the back entrance of the nostrils, and over the epiglottis, which is pressed down over the air passage (larynx) and the food is driven within the grasp of the pharynx and esophagus over which a wave of contraction passes from above downward until the bolus is forced into the stomach.

Stomach Movements.—The walls of the stomach, when empty, are in close contact, like any other empty bag. When food enters it separates these walls only in proportion to the bulk of the food, and closely adheres to them. Hence, when the next mouthful is swallowed, it does not come into direct contact with the stomach, but with the coating of food which has already lined that organ. Successive deposits of food will form successive layers, millers' law of "first come first served" determining the order of digestion. It follows that the hydrochloric acid of the stomach, essential to the action of pepsin but fatal to that of ptyalin, does not necessarily come in contact with any but the first food swallowed; and that the action of saliva on starch may continue for an indeterminate time in the stomach. This result is further promoted by the peculiar action of the stomach muscle, which does not communicate a churning movement to all the food contained in the organ, but seems to divide into two sets of activity, one confined to the large or *cardiac* end of the stomach and the other to the small, *pyloric*, extremity. At the large end there is little muscular action, this portion of the organ acting as a reservoir for the undigested food; while, about the middle of the stomach, the waves of contraction start which force the food toward the pyloric end, mix it with the gastric juice and reduce it to the thin liquid, *chyme*, which is the end of stomach digestion. Between the admission of food to the stomach and the appearance of chyme in the intestine, several hours elapse. During this time contraction waves, at intervals of about twenty

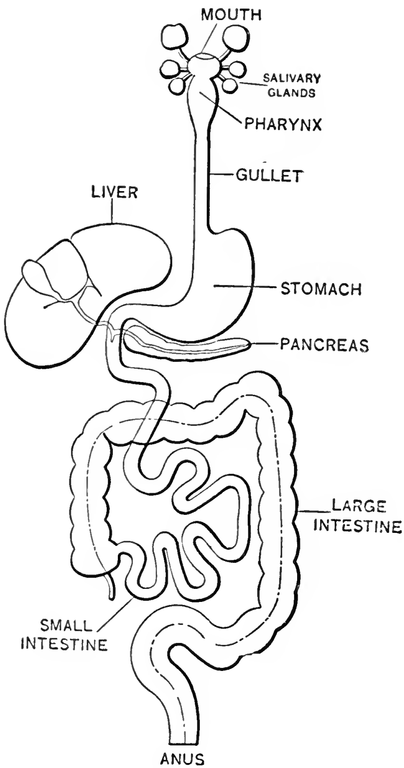

Fig. 11.—Diagram of the alimentary tube and its appendages. (After Testut.)

seconds, press the liquefying food against the pyloric valve, which does not yield until the food is in a liquid form. It then opens and the liquid part escapes into the duodenum, where the reaction is alkaline and where intestinal digestion begins. Finally undigested and indigestible articles are allowed to pass.

Intestinal Movements.—The muscular coats of the intestine are arranged in two layers, an outer longitudinal and an inner circular. Obviously if each band of circular fibers contracted in succession a wave of constriction would finally pass over the entire length of the tube from stomach to large intestine; and, if each band relaxed directly after contraction, there would be an inactive or dilated area always both above and below the wave of contraction—the dilated area above constantly increasing and the one below decreasing in length. This is the normal or *peristaltic* movement of the intestine. At the same time the longitudinal fibers seem to contract and draw the entire tube over the advancing food. If, from disease or other cause, a wave can be excited below and made to pass upwards, the contents of the intestine would be forced into the stomach, as in obstruction of the bowel when fecal vomiting is seen. This action is termed *antiperistalsis.* There seem to be local constrictions at various points, in addition to normal peristalsis, which serve to break the column of food into many segments and both promote mixing with the intestinal and pancreatic ferments and exposure to absorptive channels.

Nervous Control.—Both the stomach and intestines receive nerve fibers through the vagi (pneumogastric or tenth cranial nerve) and the sympathetic system of nerves.

Movements of Large Intestines.—The opening of the small intestine into the large is guarded by the ileocecal valve and by a sphincter muscle, normally in a state of contraction. Food passing into the large intestine is still in a semifluid state, but becomes solid about the middle of the transverse colon. Waves of contraction of the same general character as those seen in the small intestine determine the onward movement in the large. There seems to be a normal antiperistaltic wave from the middle of the transverse colon back to the ileocecal valve to retard movement and allow longer time for absorption. Beyond the transverse colon we can properly speak of feces instead of food. The material continues to lose water until the sigmoid flexure is reached. This is a sort of reservoir for fecal matter where it remains until just before defecation, the rectum apparently remaining empty until that time.

Defecation.—This is partly a voluntary and partly an involuntary act. The normal stimulus seems to be the passing of fecal matter from the sigmoid into the rectum. This excites the center for defecation in the lumbar part of the spinal cord, the sphincters of the rectum, only partly under the control of the will, are relaxed, the diaphragm contracts drawing a full supply of air into the lungs, and remains fixed while the abdominal muscles contract forcibly and force out the contents of the bowel.

Vomiting.—Vomiting is the ejection of the contents of the stomach through the esophagus and mouth. The order of events is, a feeling of nausea, a flow of saliva, a contraction of the stomach from the middle towards the esophageal opening, descent of the diaphragm so as to press on the stomach, a sudden and violent contraction of the abdominal muscles, exerting still further pressure on the stomach whose contents are forced along the esophagus and out of the mouth. As the soft palate can not be so well carried over the posterior nares from behind, these cavities are often unprotected and some of the ejected matter is forced into them.

Nervous Mechanism.—The nervous mechanism is a very complex reflex action. A vomiting center may exist in the medulla. Many sensory nerves may be concerned, particularly those connected with vision and equilibrium. Irritation of the sensory nerves of the stomach is, however, the most constant cause.

Hunger and Thirst.—These sensations are the cry of cells throughout the body for food and drink, with a local manifestation in the stomach and throat. The empty stomach contracts at irregular intervals and these contractions are attended by slightly painful sensations, "hunger pains," until food or some substitute is taken. Thirst is felt whenever the total amount of water in the body falls below a certain point. It occurs, therefore, as a symptom following loss of blood, perspiration or frequent urination. The sense of distress is felt in the pharynx chiefly and is transmitted by the ninth cranial (glossopharyngeal) nerve.

Action of Digestive Secretions

The Salivary Glands.—These are three in number, **parotid,** much the largest, situated between the lower jaw and the base of the skull; **submaxillary,** under the body of the lower jaw, and the **sublingual,** just under the tongue. The mixed secretion of these glands contains 994 parts of water and only six parts of solid material in a thousand parts. The solids are some salts of potash, soda and magnesia, mucin and ptyalin.

Nervous Mechanism.—As the nervous control of these glands is well understood and is very similar to other complex reflexes, it is explained at some length as an example. The simplest form of reflex arc is a spot in the central nervous system connected by at least two nerves with a given gland or other structure. One nerve conveys impulses from center to organ and is called an *efferent* nerve; the other carrying impulses from periphery to center, is called an *afferent nerve.* Thus if a little salt be placed on the tongue a message is sent to the center which controls secretion which acknowledges it by sending a message to the gland cells to begin secretion. Two other nerve impulses, however, are

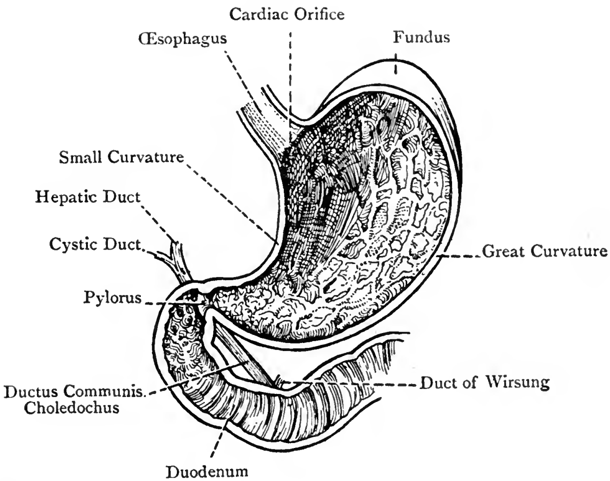

Fig. 12.—The stomach and duodenum opened. (Buchanan's *Anatomy.*)

needed before the gland can function properly—one increasing and one decreasing the blood supply. These are called *vasodilator* and *vasoconstrictor* fibers. The function of the first is to increase the amount of blood on which the gland can act. Vasodilator fibers are carried along with the secretory fibers in the cranial nerve called *chorda tympani,* while vasoconstrictor fibers come from the sympathetic. Afferent fibers are carried by many nerves, chiefly those of smell and taste, stimulation of which will excite a flow of saliva. Dilatation of the blood vessels in a gland will produce two chief effects. First it brings into contact with the gland cells a larger quantity of blood containing the material from which that particular secretion is made; and, second by increasing the pressure it will force a larger quantity of the watery constituents of the blood through the vessel wall and into the glandular structure. There are thus two distinct acts, *filtration,* which is mechanical, and *secretion,* or manufacture, which is a vital function performed by living tissue.

Mouth Digestion

Saliva.—The salivary secretion acts mechanically to moisten dry food, thus getting it into a suitable condition for swallowing; through the mucin contained to lubricate the mass, and by the ptyalin, to digest some of the starch. This is accomplished by causing the starch molecules to take up water, in chemical combination, thus converting it into *maltose* and *dextrine,* two forms of sugar which are not absorbed as such but have to be converted into *dextrose* in the intestines. Ptyalin digestion, therefore, is simply preparatory. Food is retained in the mouth for too short a time to be digested, but recent evidence shows that it may be held in the fundus of the stomach for more than an hour before the hydrochloric acid arrests ptyalin digestion.

Stomach Digestion

Gastric juice is secreted by glands in the mucous lining of the stomach. It is a watery solution containing *pepsin,* and *rennin,* the first to act on proteins, the second to coagulate the albumin of milk. In addition about five-tenths of one per cent of gastric juice is *hydrochloric acid,* a strong mineral acid which promotes the activity of pepsin.

Mechanism of Secretion.—The mere smell or taste of appetizing food is enough to start gastric secretion and, indeed, seems to be its normal stimulus. Some foods, however, appear to contain substances called *secretogogues,* which continue to excite secretion after introduction into the stomach. Meat extracts and juices ap-

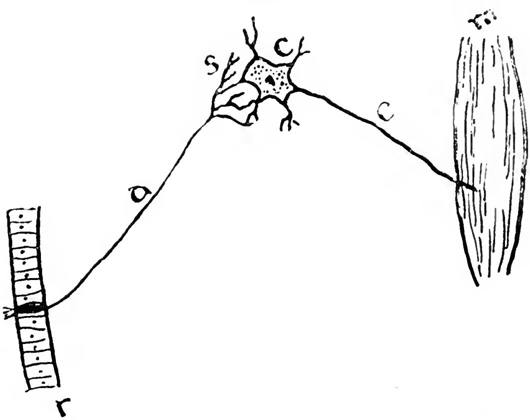

Fig. 13.—Schema of simple reflex arc: *r,* receptor in an epithelial membrane; *a,* afferent fiber; *s,* synapsis; *c,* nerve cell of center; *e,* efferent fiber; *m,* effector organ. (Pearce-Macleod, *Fundamentals of Human Physiology.*)

pear to possess these substances in a high degree, while they seem almost absent from bread and white of egg and present in but small quantity in milk.

Pepsin can not act in an alkaline solution and acts best in the presence of hydrochloric or other mineral acid. It acts on protein alone which it finally converts into *peptones,* a soluble protein more ready for absorption than pure protein. There are intermediate steps before the peptones appear. First the protein swells up and changes into an acid albumin called *syntonin,* which passes through two successive stages—primary and secondary proteoses—before peptone is produced.

Rennin is the ferment which changes milk to clabber. It acts well in the presence of hydrochloric acid. Cow's milk forms a solid mass, or firm clot, not unlike the clot of blood save in color, which squeezes out the *whey* after standing. Human milk forms a loose flocculent clot, probably more easily mixed with gastric juice. Rennin does not digest the casein, which is digested by pepsin as are other proteins. The clotting is probably to prevent the immediate passage of milk into the duodenum before stomach digestion could begin. There seems to be no other food substance on which rennin acts.

The stomach has no power of digesting starchy foods which leave it in the condition in which mouth digestion has left them. Fats are not appreciably acted upon by the gastric ferment, but are more or less liquefied and mixed with the other foods in the chyme. By soaking into and around particles of bread or other food, fats may interfere with stomach digestion.

Stomach digestion is more preparatory than complete. Apparently about half of the proteins pass into the duodenum as either peptones or proteoses, 20 per cent as unchanged proteins while but a small part of the remainder is absorbed from the stomach. Some native proteins are not acted on by the pancreatic juice and must receive preparatory treatment in the stomach. Mixing the foods, warming them, separating the fats from other foods with which they are mechanically mixed, emulsifying them, partly digesting protein and regulating the amount poured into the duodenum seem the chief functions of the stomach.

Absorption from the stomach seems to be slight, even water passing into the duodenum almost at once. Alcohol, however, is readily and rapidly absorbed.

Chyme is defined as "the semiliquid mass of partly digested food passed from the stomach into the duodenum." It contains: (1) digested protein in the form of peptones or proteoses; (2) carbohydrates which have been partly digested by ptyalin; (3) fat warmed and

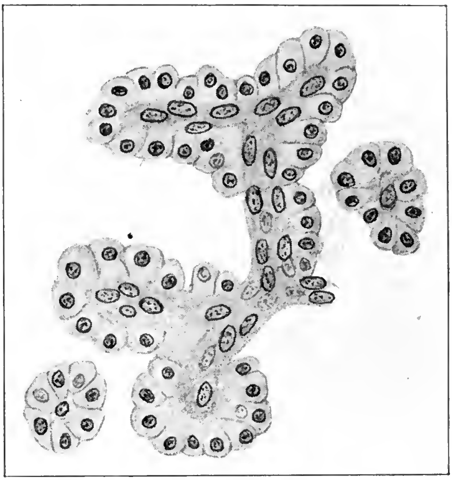

Fig. 14.—Cross section of pancreatic tubule (modified from Sabotta).

mixed in an emulsion but otherwise not appreciably changed; (4) undigested proteins and carbohydrates; and (5) indigestible substances which enter the duodenum late and are not proper constituents of chyme but are mixed with it.

Pancreatic and Intestinal Digestion

The product of stomach digestion meets, in the intestines, with three digestive fluids; i.e., **pancreatic**

juice, succus entericus (intestinal juice) and **bile.** The action of the three is simultaneous, but a separate description must be given of each to be intelligible.

Pancreatic juice contains three ferments, *trypsin, amylase* and *lipase* to act on proteins, carbohydrates and fats. The *pancreas* is an elongated body reaching from the hollow of the duodenum to the spleen and is a compound tubular gland like the salivary glands. Its secretion is poured through a long tube (duct of Wirsung) which, after joining the common bile duct, opens into the duodenum. The secretion is a clear, watery fluid in man, very abundant, amounting to from 500 to 800 c.c. a day. The nerve supply is derived from the vagus and the celiac plexus. The secretion appears to begin soon after food is placed in the stomach and continues from two to four hours; the first acid chyme which enters the duodenum appears to incite the pancreas to activity. This activity is probably not produced by reflex nerve action, but by the production of a chemical body, *secretin,* which is absorbed by the blood, carried to the pancreas and stimulates the organ. A similar explanation is given of the secretion of gastric juice. Bodies which are thus formed and act in this manner are termed *hormones.* The character of the food determines the type of the secretion; i.e., if meats alone are eaten the juice will be rich in trypsin; if fats, in lipase; if bread, in amylase.

Trypsinogen alone, the immediate enzyme of the pancreas, is not able to act on proteins but requires the presence of another substance, *kinase* or *enterokinase,* which is formed by the mucous membrane of the small intestine, by which it is converted into trypsin.

Trypsin differs from pepsin in the following particulars: It can act in *neutral,* slightly *acid* or distinctly *alkaline* solutions.

Its effect on proteins is not only more powerful but more rapid than that of pepsin.

It breaks up the protein molecule more completely. The joint action of trypsin and pepsin changes the complex structure of the many kinds of protein into simple bodies of the amino-acid type more soluble than the original form and prepares them for the action of *erepsin* (the protein enzyme of the intestinal juice) which breaks up the products of peptic and tryptic digestion into such simple forms that the human body can use them as building stones out of which its own peculiar form of proteins can be constructed.

Amylase acts upon starches in the same way as ptyalin, converting them into *maltose* and *achroodextrin,* a preparatory step to their final conversion into *dextrose* by the maltase of the intestinal juice. This digestion is completed by the time the food gets to the ileocecal valve.

Lipase or **Steapsin** is the first of the fat splitting ferments. This ferment splits fats into *glycerin* and a *fatty acid* and the latter combines with some of the salts present to form a soap which is used to hold the fats in an emulsion, in which form they are more readily acted on by the lipase. This is the only ferment which seems to have the power of acting in either direction; i.e., it can either split fats or it can take the component parts (glycerin and fatty acid) and combine them to form fat. Lipase acts best in the presence of bile.

Succus entericus, intestinal juice is secreted by the tubular glands, crypts of Lieberkühn, which line the intestinal canal. It seems to act only on starchy foods; but there are several enzymes in the juice which can be extracted from the mucous membrane of the intestines which act on various foods, breaking the products of gastric and intestinal digestion into simpler bodies, better fitted either for absorption or to be employed as tissue builders. The action of *enterokinase, erepsin* and *secretin* have been alluded to.

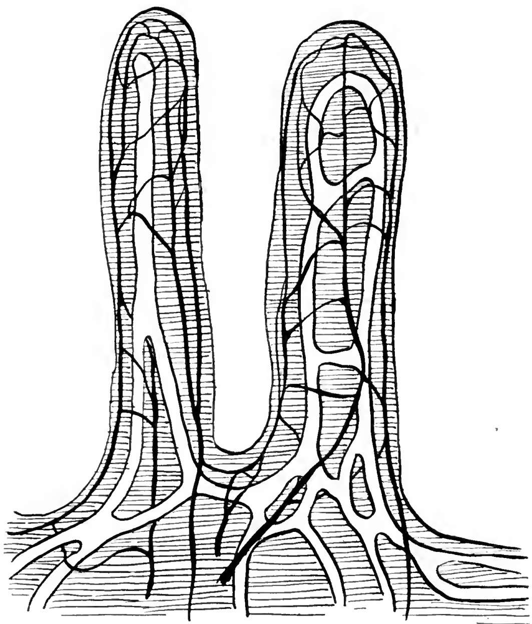

Fig. 15.—Injected lacteal vessels in two villi of human intestine. (Teichmann.) X 100. Lacteals filled with white substance and blood vessels with dark.

Bile is not a digestive fluid, but it so largely promotes the splitting and absorption of fats that its presence as an auxiliary is essential to health.

Absorption in Small Intestines

Absorption of Proteins.—The greater part of digested proteins is absorbed by the blood vessels of the intestinal villi. This is proved by tying the thoracic duct so the fluid it carries can not get into the blood. Animals thus treated continue to absorb and utilize proteins as before. The actual form in which nitrogenous foods enter the blood current is that of the amino acids, which are carried to the various tissues which, in turn, select such acids as are suitable for their repair or upbuilding. Some of the organs, notably the liver, have the power of converting these acids not into tissue but into some other nitrogenous compound—urea in the case of the liver.

If the contents of the small intestine be examined at the ileocecal valve, it will be found that from 97 to 99 per cent of such foods as milk, eggs and meats have been absorbed, while the proportion of vegetable protein absorbed is much smaller—from 70 to 80 per cent. This seems due to the entanglement of the vegetable proteins in indigestible cellulose.

Absorption of Carbohydrates.—Starchy food is absorbed as simple sugars. Rather more than a pound (500 grams) may be utilized in a day, all, in the form of dextrose, is stored up as glycogen, keeping the amount of sugar in the blood constant about 15 per cent. When excessive amounts of starchy food or sugar are eaten, the liver may be, for the time, overworked and sugar may temporarily appear in the urine.

Absorption of Fats.—The fatty acids and glycerin of intestinal digestion are absorbed as such and appear, to some extent at any rate, to be recombined in the epithelial cells of the villi. After passing the epithelium the fat is taken up by the lacteals of the villi and carried by the thoracic duct to the beginning of the left innominate vein where it is poured into the blood stream. A small amount, however, appears to be absorbed directly by blood vessels of the villi. Different fats are absorbed in varying degrees—of olive oil nearly 98 per cent is absorbed while only about 90 per cent of mutton fat is so accounted for.

Large Intestine—Digestion and Absorption

The secretion of the large intestine contains no enzyme. Hence, such digestion as occurs in that area is simply a continuation of activity of the ferments carried in from the small intestine. Absorption, particularly of water, does take place. Water is absorbed in the small intestine, but is replaced by osmosis, since the contents of the intestine at the ileocecal valve are as fluid as at the pylorus; but, there being no such compensation in the large intestine, fluid is rapidly lost and the contents quickly attain the fecal character. The reaction in the large intestine, as in the small, is alkaline and promotes the growth of bacteria, particularly those which attack protein. Putrefaction, therefore, is a normal activity in the large intestine. By it the remnants of proteins are split into end products some of which are carried off in the feces, others in the urine. Some of these products may be injurious if absorbed in the blood, explaining some of the ill effects of constipation.

Composition of Feces.—The amount of fecal matter will vary with the amount and character of the blood. When meats alone are used, small dark colored actions result. If the diet consists largely or wholly of vegetables, particularly of those containing much cellulose or woody fiber, the amount of fecal matter will increase in amount up to even 500 grams—a little more than a pound—as compared with 170 grams—about a third of a pound. Fecal matter is composed of indigestible bodies, seeds, grains of corn, ligaments; undigested fragments of digestible food; some results of intestinal secretion; inorganic salts, mucus, pigment, the results of putrefaction, etc.

End Results—Summary

The processes of digestion are merely preparatory: the food is reduced by these processes to such a form that it may be absorbed. Changes fully as important take place after the food has left the alimentary canal, constituting what is known as "metabolism." Unfortunately, our knowledge regarding these changes is still very poor, but it is to be hoped that much more will be learned about them in the near future and more light shed on the *etiology* (science of cause of disease) of the diseases which are the result of "metabolic disturbances."

When starch has been digested; that is, has been reduced by the action of ptyalin, amylase, and maltase to the absorbable dextrose, it enters the capillaries of the intestinal villi and is carried in the portal circulation to the liver. Normally, we have 1 to 2 per cent of dextrose in our blood, but it is evident that after a meal containing much starch or sugar, the amount in the portal vein must be much more than this. Should this sugar-laden blood escape into the general circulation and eventually pass through the kidneys, these organs would not be able to retain the sugar in the blood, and it would be passed out in the urine, giving rise to a "glycosuria." The liver, however, has the power of fixing this dextrose in a form in which it may be stored; changing it into the *glycogen* or animal starch which has already been mentioned. Therefore, after a meal containing carbohydrate, this compound can be easily detected in increased amounts in the liver. The voluntary muscles also possess the same "glycogenic" function, and glycogen is deposited in them also. If excessive amounts of a readily absorbable sugar is fed, the amount entering the portal circulation is too great for the liver and muscles to handle, and some of the dextrose appears in the urine. This condition is known as "alimentary glycosuria" to distinguish it from the forms of glycosuria due to disease. When need arises the glycogen is reconverted into dextrose and is used to yield energy to contracting muscles or secreting glands or to other functioning tissues. This energy-yielding process is strongly suggestive of a similar yield of energy when fuel containing carbon and hydrogen is burned outside the body, and the end results of the combustion of carbohydrate either in the body or outside are the same, namely, water and the gas, carbon dioxide. Occasionally, we see persons whose tissues can not utilize the dextrose furnished them, and here, as in the alimentary glycosuria, the amount of dextrose in the blood increases beyond the amount that the kidneys can hold back and sugar appears in the urine. This condition constitutes "diabetes mellitus." The wasting away that usually accompanies severe cases illustrates the importance of the carbohydrates in the diet.

When larger amounts of carbohydrates are fed, amounts larger than are needed for the energy requirements, much of it may be converted into fat and stored. The well-known effects of excessive candy eating are explainable on this basis. To a very small extent, carbohydrate may be used to help build up the tissues of the body, but this occurs in such a limited way as to be negligible.

Under the influence of lipase, fats are broken up into glycerin and free fatty acid. Alkaline salts of sodium, potassium, magnesium, and calcium are present in the small intestine, and these bases unite with the fatty acids to form soaps. The ordinary toilet soap is a similar union of sodium with fatty acid. The soaps of sodium and potassium, certainly, pass into the small lymph channels of the intestinal villi, being reconverted, in passing through the absorbing cells, back into neutral fat; i.e., the union of glycerin and fatty acid. This food fat passes on in the lymph channels until it finally gains entrance to the veins by means of the thoracic duct and the right lymphatic duct, and by this means it is distributed to the various parts of the body. Fat, like carbohydrate, is an important source of energy. In the body, it is finally reduced to the same forms that carbohydrate is, carbon dioxide and water, being excreted by the lungs and kidneys. A considerable amount of the fat, if fed in excess, may be deposited in the tissues, to serve as a reserve for possible subsequent need. The amount of fat that is used for constructive purposes may be disregarded.

Under certain circumstances, there may be a disturbance in the process of changing the fats to carbon dioxide and water. In such cases, incompletely oxidized substances accumulate in the blood; the so-called "acetone bodies," acetone, diacetic, and β-oxybutric acid. This condition is known as "acidosis," and may arise in the course of diabetes mellitus or even in simple starvation. The sodium carbonate of the blood plays an important part in carrying carbon dioxide from the tissues to be excreted by the lungs, but these acetone bodies require a considerable amount of alkali to neutralize them, so that the normal sodium carbonate content of the blood is reduced and carbon dioxide is not carried away promptly. This explains the cyanosis and the labored breathing.

As has been stated, protein may be broken up in the body to yield energy, but this is extravagant for two reasons; first, because protein food is actually much more expensive and, second, that it probably causes more wear and tear than carbohydrate on the body when used in excessive amounts. The most important role of protein is to serve as tissue-building material, a role for which it is indispensable, carbohydrate and fat being unable to replace protein for this purpose.

Under normal conditions, all, or nearly all, of the protein is absorbed in the form of what is known as "amino acids." These are organic acids containing the NH or amid group, and are known as the "building stones" of the proteins. Under the combined action of pepsin, trypsin, and erepsin, this decomposition takes place, and the amino acids enter the blood vessels of the intestinal villi and are carried to the liver in the portal vein. It is probable that the liver does not effect any change in them at this time, but allows them to pass through the tissues where they may be utilized. Wherever there is need of building material, the "building stones" are taken from the blood and utilized to construct the particular kind of protoplasm needed.

Even with the ordinary amounts of protein in the diet, only a part is used for tissue building or repair; a considerable portion being burned to yield energy. The end products of this breaking up of protein are not so simple as are those representing the final results of carbohydrate and fat decomposition. Under the action of tissue enzymes, the nitrogen is split off and is carried to the liver. Here it is converted into "urea," which passes in the blood to the kidneys and is excreted in the urine, constituting the chief organic substance in the urine under normal conditions. Tissues which wear out and are broken down likewise give rise to the production of urea, since they are protein material.

Though under normal conditions, proteins are broken down into amino acids before absorption, nevertheless the tissues possess the power to break down more complex protein bodies that may enter the circulation. The occurrence of *anaphylaxis* (literally "without a guard") or anaphylactic shock is explained in this way. A complex protein body is introduced into the circulation, either by subcutaneous or intravenous injection or by passing through an abnormal mucous membrane. Having entered the circulation, the tissue cells elaborate an enzyme capable of decomposing it into its constituent "building stones." It is assumed that this process is rather slow and gradual; the enzyme is produced in small amounts so that there is no poisoning as a result of the first introduction of the foreign protein. Once the enzyme is produced by the tissue cells, however, it remains active for some time. Now, at some later time, if the same protein is introduced into the circulation, its decomposition starts rapidly, since there is still the necessary enzyme present. As a result of this rapid action, intermediate products of the decomposition are produced in large enough numbers to produce mild, severe, or even fatal poisoning. The *urticaria* (nettle rash) often seen after injection of diphtheria antitoxin, asthmatic attacks, and similar manifestations are now considered to be instances of anaphylaxis.

It has already been pointed out that carbohydrate, fat, and protein are required for proper nutrition. Protein is absolutely essential for constructive processes;

any of the three may yield energy, but on an exclusive protein diet, serious disturbances soon arise. Therefore, we may regard protein as the material from which new tissue is built or by which old, worn-out tissue is to be replaced, while fats, and especially carbohydrates, are the fuel foods; all three being needed in order that growth may occur or that health may be preserved.

It becomes a matter of much practical importance as to how much of each constituent should be included in the diet and what the total should be. Fortunately, most individuals in health instinctively select the proper amounts needed for nutrition, but where it is necessary for the physician to select a diet, the importance of this knowledge is obvious.

It has been learned that when a substance is burned, it gives off a definite amount of heat, and by suitable means, this heat can be measured. The amount of heat required to raise one gram of water one degree centigrade is known as the **small calorie,** and is designated by the symbol "**c**;" the amount to raise the temperature of a kilogram of water a similar amount is known as the **large calorie,** and its symbol is "**C.**" If one gram of carbohydrate is burned under suitable conditions, it is found that it yields approximately 4.1 large calories; while a gram of fat under similar conditions yields over twice as much heat, namely, 9.3 large calories. Moreover, the amount of heat produced in the animal body by the oxidation of foods can be measured, and it is found that this is the same for carbohydrate and fat as that produced by burning these substances outside the body. In the oxidation of protein in the body, it has been found that a gram also yields about 4.1 large calories, though the combustion of this amount of protein outside the body gives off more heat. This is due to the fact that protein is not completely burned in the body but some of the end results of its metabolism are still capable of further oxidation.

By studying the diets of large numbers of individuals engaged in different vocations, it has been learned what the average amount of each constituent in the diet is and what the total caloric value of the food taken in 24 hours should be. The following are samples of average dietaries:

INVESTIGATOR	CARBOHYDRATE	FAT	PROTEIN	TOTAL CALORIES
Moleschott.	550 gm.	40 gm.	130 gm.	2980
Ranke.	240 "	100 "	100 "	2324
Voit.	500 "	56 "	118 "	3053

It is seen from these figures that the amount of protein is not subject to wide variations, while reduction in the amount of carbohydrate in some of the diets is accompanied by increase in the amount of fat and vice versa. These energy-yielding foods are to a certain extent mutually replaceable, but there is a limit to this: fat being more difficult of digestion and also more expensive. On the other hand, when fat is not absorbed properly or not handled properly after absorption, even though there be no evidence of disturbance with the metabolism of protein and carbohydrates, severe nutritional disturbances occur, as illustrated by cases of injury to the thoracic duct or of faulty fat digestion, the latter occurring in infancy.

Agreement has not yet been reached in regard to the amount of protein required in the diet. As shown above, in no instance is it below 100 grams in 24 hours in the average diet. This amount is in excess of what is required for repair of tissue in the adult under normal conditions, a considerable part of the ingested protein being split up to yield energy. Since protein is more expensive, both in actual cost and, possibly, on account of its influence on the cells of the animal using it, the question has arisen whether we could not advantageously reduce the amount in our diets. It has, indeed, been shown that for considerable periods of time the amount may be reduced to less than a half of the amount given in the dietaries above with no apparent impairment of the person's health or efficiency. Against this, however, is the fact that, left to himself, normal man takes the larger amount of protein in his diet, regardless of his condition or occupation. When one is engaged in work necessitating much muscular exertion, a greater number of calories is required, but when this is the case, the increase is made largely with the carbohydrate and fat, the laborer using actually little more protein than the clerk who leads a sedentary life.

Since urea, resulting from protein decomposition in the body, is excreted by the kidneys, it has been suggested that large amounts of protein in the diet will throw extra work on these organs and tend to injure them. Then, too, it has been pointed out that the putrefaction of proteins that may take place in the intestines, gives rise to poisonous substances, which entering the circulation, may damage both liver and kidneys. These are theoretical conditions, however, which are still far from proved.

In some recent work, it has been pointed out that not all proteins are "adequate" for nutrition. It is essential that certain of the "building stones" be present, and if the protein is deficient in these it does not suffice for the purposes of maintenance or for the promotion of growth. Gelatin is an illustration of one of the inadequate proteins. It was formerly believed that gelatin was capable of supplying the protein in the diet, and the experiment was tried on a large scale in France, but this experiment was a failure, for the reason already given.

The mineral salts are absolutely indispensable in the diet, and it is stated that death will occur in an animal fed on an abundance of salt-free food sooner than with one deprived entirely of all food. This is because the organic food leads to the excretion of the salts in the tissues.

Sodium chloride, or ordinary salt, is the only one of the salts that we consciously add to our diet. When the diet consists of a considerable amount of vegetable food, the need of sodium chloride becomes more apparent, and herbivorous animals show the same desire for salt that human beings do.

The sodium chloride plays a very important role in our bodies. It is the chief inorganic constituent of our blood plasma and it is essential for the production of hydrochloric acid of the gastric juice. It is also supposed to exert an influence on the contractions of the heart. The urine contains a considerable amount of this salt, and in certain cases of diseased kidneys, difficulty is experienced by these organs in eliminating the sodium chloride. As a result of this, there occurs a salt retention and the salt also retains fluid, giving rise to the accumulation of fluid in the tissues, known as edema or dropsy.

Salts of calcium are also important. They influence the contraction of the heart and also the irritability of muscle and nerve. Calcium is found in large amounts in the bones, and clotting of blood and curdling of milk can not take place in the absence of calcium. Potassium salts influence the heart, while the salts of iron are of importance in constituting an essential part of hemoglobin, the oxygen-carrying pigment of the blood.

Even if the diet contains sufficient amounts of carbohydrate, fat, and protein, with an adequate supply of mineral salts and water, it is found that nutritional disturbances will occur eventually, unless certain organic substances in addition be included. These substances may be nitrogenous in nature or may be free from nitrogen. They are not energy-yielding foods, nor are they used for constructive purposes; but, apparently, they exert a very marked influence on the processes of metabolism. They are known as "vitamines" or as "growth-promoting factors." The first one to be studied is that occurring in the *pericarp* (the part which surrounds the kernel) of rice, the absence of which gives rise to the peculiar disease known as "beriberi." Scurvy, also, was formerly held to be a disease due to the absence of vitamines from the diet, though this has been denied recently. Certain fats contain the requisite "growth-promoting" factors, while others do not; butter and cod-liver oil being instances of the former, while lard is an example of the latter class.

CHAPTER IV

THE FUNCTIONS OF THE LIVER

That the liver plays an important part in the nutrition of the body might be inferred both from the size of the organ and the enormous stream of blood poured into it by the portal vein; for in addition to the *hepatic* artery, which carries blood to nourish the tissue of the organ, the *portal vein,* which receives blood from the entire digestive and absorptive tract, pours this great stream of blood into the doorway of the liver, plainly not for the benefit of that organ, but that it may effect necessary changes in the material of which this blood alone is the bearer. Three such changes appear; i.e., the secretion of **bile** and the formation of **glycogen** and **urea.**

Bile is partly an *excretion* of substances to be removed and partly a *secretion* of a product useful but not essential to digestion. It is secreted at all times but, in man, is stored in the gall bladder and ejected into the duodenum only when needed. The quantity formed in a day is from 500 to 800 c.c. The color, in man, is a greenish yellow. It contains about 97½ per cent water and about 2½ per cent solids of which the chief are *bile pigment,* derived from broken-down red blood corpuscles, *bile acids, taurocholate,* and *glycocholate* of soda,—fats, soaps, *lecithin,* a substance which occurs in greatest quantity in the white matter of the nervous system, and *cholesterin.*

Bile pigment is called *bilirubin* when red, and *biliverdin* when green. The pigments appear to be reabsorbed from the intestines into the portal circulation and carried to the liver which again extracts them from the blood. This is called the *circulation of the bile.*

Secretion of Bile.—It is believed that there are no special secretory nerve fibers whose stimulation excites the secretion of bile. Apparently the flow is automatically regulated by the blood flow, since stimulation of the *splanchic* nerves, which carry vasomotor fibers to the liver, increases the flow of bile. **Secretin,** whose

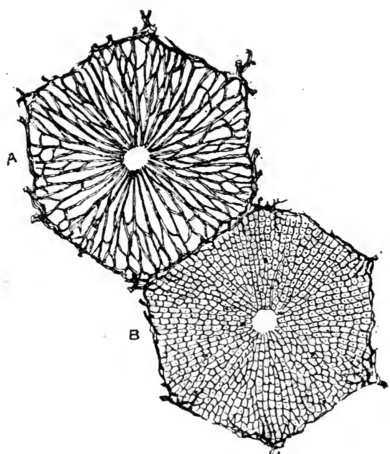

Fig. 16.—The microscopic structure of the liver. (Highly magnified.) *A,* Lobule, showing the intralobular plexus; *B,* Lobule showing the hepatic cells. (Buchanan's *Anatomy.*)

action on pancreatic secretion has been related, stimulates the flow of bile. As soon as the acid chyme is thrown into the duodenum, not only is the activity of the liver excited, but the gall bladder is stimulated to contract and there is an outflow of ready formed bile into the duodenum. When this is prevented, as by a gallstone plugging the bile duct, or from any cause, bile gets into the blood and the condition of *jaundice* is produced.

Function of Bile.—Whatever its other effects, the chief known use of bile is in promoting the digestion and absorption of fats. It, in some way, prevents putrefaction in the intestines, though this is not the result of germicidal action, which bile does not possess.

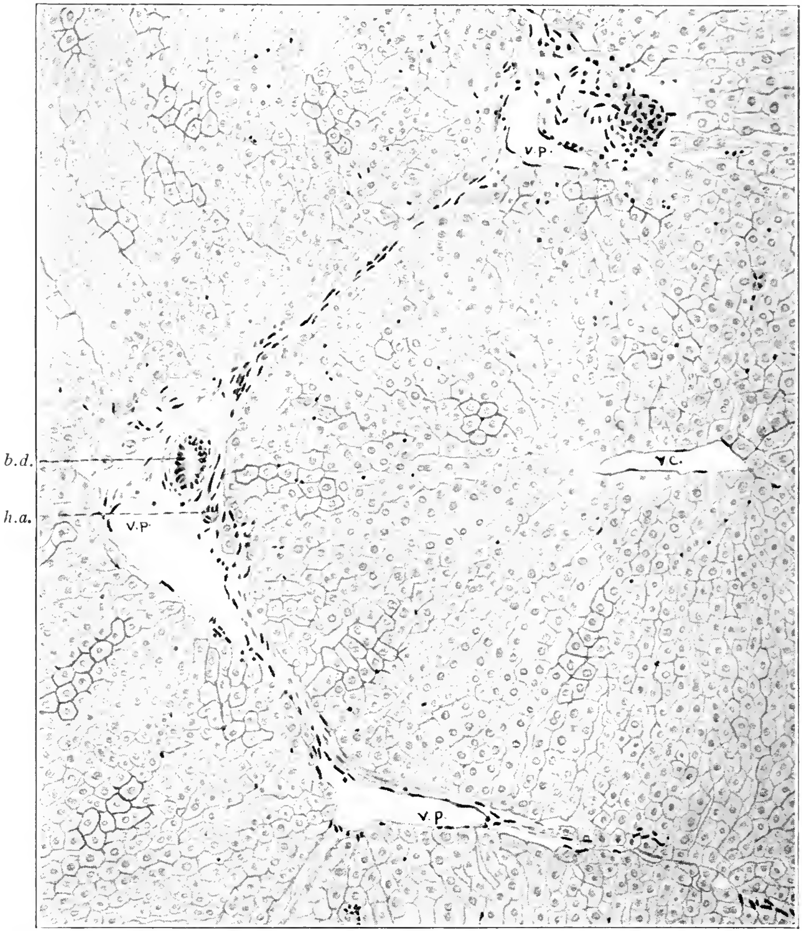

Fig. 17.—Portion of transverse section of human liver. X. 100. *h.a.*, hepatic artery; *v.c.*, intralobular vein; *v.p.*, interlobular vein; *b.d.*, bile duct.

Glycogenic Function of the Liver.—Glycogen, or *animal starch* can be detected by the microscope in the cells of the liver, increasing after meals and decreasing during the hours of fasting, and varying with the kind and quantity of food, exercise, etc. The amount in the liver varies between 1.5 and 4 per cent of the weight of the liver. Glycogen is chiefly derived from starchy foods, though proteins may furnish small amounts. Fats seem to increase the amount of glycogen in the liver by preventing its consumption in other parts of the body.

Glycogen Theory.—The theory of this function of the liver is that it maintains the sugar equilibrium of the body; that is, that an increase of carbohydrate food would always be followed by an increase of sugar in the blood if the liver did not convert the dextrose and other sugars into animal starch which it stores up until a fasting period, or at least decrease of the normal sugar content of the blood, calls for a renewal of the supply, when the stored glycogen of the liver is reconverted into sugar and given up to supply the deficiency. This conversion appears to be accomplished by a special enzyme formed for the purpose in the liver.

The liver is not the only store house for glycogen. It is estimated that the red muscles of the body contain as much of this starch as the liver itself, and that it is used up more rapidly when the muscle is active than when passive.

Urea-Forming Function of the Liver.—Urea is the chief form in which nitrogen is removed from the body. This product of protein food is eliminated from the blood by the kidneys, but it is formed in the liver and sent to the kidneys only to be extracted. No doubt the liver is not the only source of urea, but it is at least a demonstrated source of this end product of protein digestion.

CHAPTER V

THE SPLEEN

A chapter on the physiology of the spleen may be almost as brief as the history of snakes in Ireland, for al-

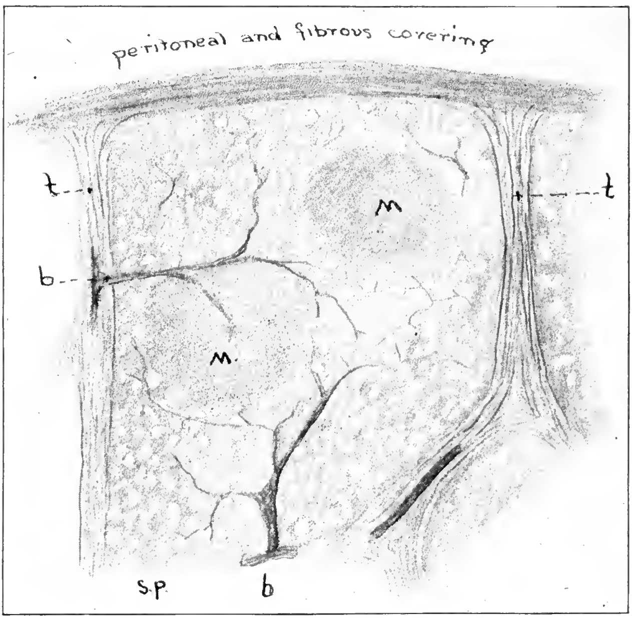

Fig. 18.—Vertical section of human spleen (modified from Kölliker), low power. *t*, trabeculæ; *m*, Malpighian corpuscles; *b*, injected arterial twigs; *s.p.*, spleen pulp. The clear spaces are the venous sinuses.

most nothing is positively known of the function of the organ. It not only has, in proportion to its size, a very abundant blood supply, but its return circulation is carried into the portal vein and thence through the liver, indicating that it effects some changes in the blood which the liver must perfect; yet its removal neither causes the death of the animal nor effects any permanent changes in the character of the blood.

That it is associated with digestive processes is shown by the fact that it slowly increases in size after a meal for about five hours and then returns to its normal size.

Its activity is supposed to be directed to

I. The formation of new red blood corpuscles, a work which it certainly does during fetal life.

II. The destruction of old and damaged red blood corpuscles, a supposition founded largely on the spleen's richness in iron.

III. The production of *uric acid,* an inference from the presence of other bodies from which uric acid can be
the presence of other bodies from which uric acid can be
formed.

CHAPTER VI

FUNCTIONS OF THE KIDNEY

All the waste matter of digestion and of bodily activity is not carried away in the feces. Some elimination, particularly of water, takes place through the lungs, some through the skin, but the major part through the kidneys. The product of the activity of this pair of organs is the *urine*.

Urine, in man, is a more or less straw-colored fluid, the color varying greatly even in health and still more in disease, from an almost colorless liquid to a dusky red. Urine, in health, shows a slightly acid reaction, i.e., turns blue litmus paper red, due to the presence of salts, chiefly sodium, so combined as to form *acid phosphates.* This activity is increased on an animal diet and diminished on a vegetable diet, sometimes even disappearing so that the urine is neutral,—has no action on litmus paper or even turns red litmus blue; the urine becomes *alkaline* in reaction. The average specific gravity of urine is 1.020. The amount passed in a day is from two to three pints but varies under so many conditions, even in health, that a specific amount can not be stated. In general the statement may be made that the amount of urine varies more from the activity of the skin than from any other single condition. Thus, in warm weather, when one perspires freely, the amount of urine will decrease and the color will be high. Exercise, or any other condition, which increases the formation of sweat, will decrease the amount of urine. A cold bath or a sudden change of weather to a lower temperature, increases the urinary secretion. Children discharge more urine than adults, and women, relatively more than men. Even mental conditions affect the flow, as is evidenced in hysteria when loss of nervous control enormously increases the output. Diet largely affects both the quantity and the contents; and, of course, the amount of liquid taken will act even more decidedly and more rapidly. Drinking a quantity of water will increase the flow; but drinking the same amount of beer will not only cause a greater flow, but the increase will occur earlier. Many drugs, called *diuretics,* produce the same effect, while others will diminish the quantity.

Composition of Urine.—Urine holds a large number of different bodies in solution, but is chiefly notable because it takes away the product of the digestion of nitrogenous food in the form mainly of *urea.*

Urea is the most important nitrogenous element in the urine. That urea, or some antecedent substance, is formed largely in the liver seems certain. It is present in the blood and other tissues and so large a part of the total output is removed by the kidneys that the removal of both of these organs always causes death. The average amount excreted in twenty-four hours is from 350 to 450 grams. Drinking large quantities of water will decrease the *relative* but increase the *actual* amount of urea, while an increase in nitrogenous food increases, and of vegetable food, diminishes, the output of urea. Exercise, or anything which increases metabolism of tissue, increases the amount of urea.

Uric acid as such does not occur in urine in health, but in the form of *urates,* chiefly of sodium though similar salts of potash, lime, magnesia and ammonia are found. From ten to fifteen grains of urates are excreted daily. They are not formed in the kidneys, but exist in the blood and are merely extracted from it by those organs. They increase greatly in gout.

Creatinin, xanthin, hypoxanthin are other nitrogenous bodies which exist in small quantities in the urine.

Hippuric acid, in the form of *hippurates,* has the peculiarity of being a body formed by the kidneys and not preexisting in the blood. It is increased by a vegetable diet.

Of the nonnitrogenous bodies occurring in normal urine, sodium chloride, common table salt, is the most abundant. About 151 grains are eliminated daily. Some *mucus* derived from the bladder, is a constituent of normal urine.

Urochrome, said to be formed from hemoglobin, is the coloring matter of the urine.

Any of the bodies mentioned above, may be increased or decreased in diseased conditions and others may be present, from disease or injury, which do not exist in normal urine. The examination of the urine in health and disease is, therefore, a routine matter for the doctor and one with which the nurse should be familiar.

Some of the chief abnormal constituents are *blood, pus* or cells derived from any part of the urinary tract —kidneys, ureters, bladder or urethra; *albumin,* which coagulates when urine is heated; *sugar,* in the form of *grape sugar* most frequently; *casts* from the tubules of the kidney; free *uric acid; stones* formed of salts normally found in the urine and many others too numerous to mention. The tests for these substances will be found in works on urinary analysis.

Urinary Organs.—The urinary organs are the *kidneys,* which extract urine from the blood; the *ureters,* ducts of the kidneys, one for each, which convey urine to the *bladder* or reservoir which retains the fluid until its distention calls for relief, and the *urethra,* or tube, or duct, of the bladder through which the urine is voided.

The **kidney** is a compound tubular gland which, when split from outer to inner border, is seen to consist of an outer or *cortical* portion; an inner *pyramidal* or *medullary* portion and a deep concavity, the *hilum,* filled by

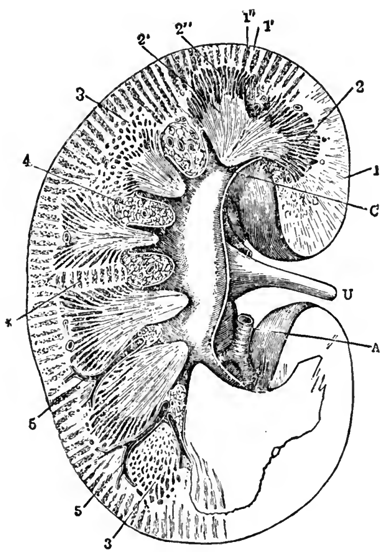

Fig. 19.—Longitudinal section through the kidney: *1,* Cortex; *1',* medullary rays; *1",* labyrinth; *2,* medulla; *2',* papillary portion of medulla; *2",* boundary layer of medulla; *3,* transverse section of tubules in the boundary layer; *4,* fat of renal sinus; *5,* artery; *, transverse medullary rays; *A,* branch of renal artery; *C,* renal calyx; *U,* ureter (after Tyson and Henle).

blood vessels and the *pelvis* or beginning of the ureter. The cortical area, about two-thirds of the organ, is the active, secretory portion of the kidney, the remainder being the collecting area. In the cortical portion are found the *glomeruli* and convoluted tubules which remove the urine from the blood, while in the medullary

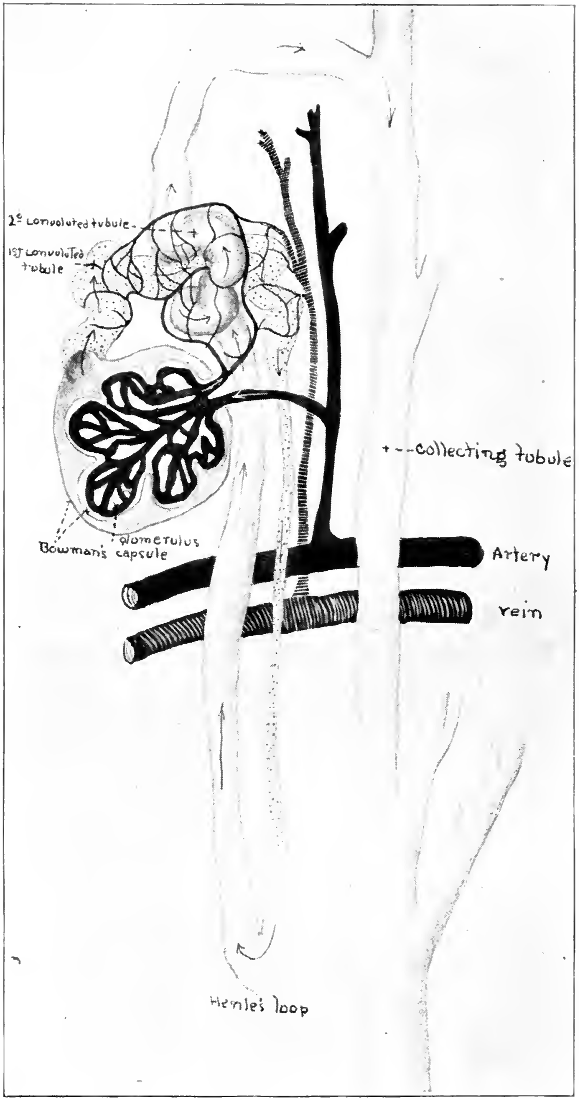

Fig. 20.—Diagrammatic representation of the course of the uriniferous tubules and the kidney vessels.

substance are seen the pyramids of Malpighi, whose apices open into the *calices* or first branches of the ureter. Histology must be consulted for the minute anatomy of the organ.

As no distinct secretory nerve fibers have been demonstrated in the kidney, the mechanism of the secretion of urine can be explained only by supposing that a part of the process is simple filtration or osmosis, depending on an abundant blood supply with sufficient pressure, while the remainder is due to the "vital action" of the cells lining the glomeruli and tubules. "Assuming that nearly all the constituents of urine preexist in the blood and are simply taken out of the circulation by the kidney, it may be stated that, for the most part, the water and salts are extracted by the cells of the Malpighian bodies, while the *urea* and related *nitrogenous solids* are removed by the cells of the convoluted tubes; so that the specific gravity of the fluid is raised by passing down the tubes." (Jones and Bunce). Diuretics may act, therefore, by increasing the amount of blood flowing through the kidney, by increasing the pressure of the blood, by promoting osmosis or by stimulating cell activity.

After urine has been formed in the kidney it is collected in the pelvis of the ureter, which contracts to the ureter proper, a long slender tube partly composed of nonstriated muscle fiber, which runs behind the peritoneum to the bladder, and enters the bladder so obliquely that the weight of urine in that organ presses on and closes the ureteral openings and prevents any back flow of urine. It is well to remember that, in the female the neck of the uterus is between the two ureters just before they enter the bladder.

The *bladder* is an ovoid muscular sac which receives and retains the urine until distended moderately when there is a desire to urinate. The neck of the bladder is surrounded by a thickening of plain muscle fiber forming a *sphincter,* or ring-like, muscle, whose constant contraction prevents the dribbling away of urine as fast as it enters the bladder.

Micturition is the act of emptying the bladder. The urine is forced along the ureters by contraction of the muscular coats of those tubes every ten or twenty seconds so that it enters the bladder in small jets and not as a steady flow. When the bladder is being filled, the pressure causes a stimulation of the fibers of the sphincter, through the sensory nerves, and the contraction of this muscle prevents the escape of the urine. A further accumulation of urine increases the pressure on the sensory nerves and, by a reflex act, causes a contraction of the muscular coats of the bladder, an inhibition of the center in the lumbar part of the spinal cord which controls the sphincter, which is consequently relaxed, allowing the urine to flow freely along the urethra.

Fullness of the bladder is not the only stimulus that causes a desire to urinate. An irritating quality in the urine itself, which may be caused by some drugs, mental conditions, like anxiety or other emotion, may create a desire to void the urine when the bladder is not only not full, but when nearly empty. This seems to be due to changes of tone in the bladder muscle itself.

The urethra in the female is a much shorter channel than in the male. As the catheter is an instrument very frequently used by the nurse, she should be familiar with the normal urethra. In woman the canal is so short and wide that the passage of the catheter is usually very easy. In man, however, the contraction of the muscular fibers around the bulbous part of the urethra frequently offers a temporary obstacle which is overcome by gentle pressure. The elongated urethra of old prostatic cases need only be mentioned.

Nerve Control.—The subject of nerve control is not completely understood. That there is a center controlling micturition in the lumbar cord and that sensory nerves pass from the bladder to the cord and motor nerves from the cord to the bladder, is clear, but the exact paths are not so well known. That this center, like that for defecation, is under the control of the will in adult life is a matter of daily observation; but that this control is acquired is plain from the habits of infancy and from the involuntary passages of urine and feces in the unconsciousness of severe illness, is equally obvious.

CHAPTER VII

THE FUNCTIONS OF THE SKIN

The importance of the skin is made apparent when one considers that the destruction of a third of that covering is nearly always fatal. Primarily its function is protective, as is shown by its position between the easily injured inner tissues and the outer world. It contains those nerve terminals which give the inner consciousness warning against pain, pressure, heat or cold, sharp, rough or otherwise injurious objects. It contains the sweat glands which aid in the elimination of harmful matter and assist in regulating the body temperature; and, in the female, through the mammary gland, it supplies nourishment to the infant.

Sweat, or **Perspiration,** is the secretion of the sweat glands which are found in nearly every part of the skin, though most abundant in the palms of the hands and soles of the feet. The number for the entire body is estimated to be about two million. They are simple tubular glands, lined by columnar epithelium, usually coiled and having a thin muscular coat surrounding the larger ducts. The average quantity of sweat in twenty-four hours is from 700 to 900 grams, though the amount varies greatly with the temperature and moisture of the atmosphere and the exertion of the individual. It is a thin watery fluid with a low specific gravity and an alkaline reaction, which contains chloride of soda, urea, uric acid and various other organic bodies. The influence of profuse sweating on the amount of urine has already been stated. To a limited degree the skin, through the sweat glands, can relieve the overburdened kidneys, a fact which is taken advantage of to induce sweating, by drugs or other means, when the kidneys do not properly perform their function, as in the condition of *eclampsia* which sometimes endangers a woman in child-bearing.

Nerve Control.—There is reason to conclude that there is a sweat center, probably, in the medulla and perhaps subsidiary centers in the cord. Secretory fibers are carried directly to the glands and are ordinarily excited by high temperature, which acts reflexly through the central nervous system. Heat alone will not cause sweating. In the high temperatures of fever, sweating is notably absent, while present in profuse degree in the pale skin of the terror stricken. This proves, also, that an increase in the amount of blood in the skin is not enough to cause sweat, and that a decrease does not prevent its secretion. Many drugs, like *pilocarpin* will increase the activity of the sweat glands and some, like *atropin* will paralyze the secretory fibers.

Sebaceous Glands.—These simple or compound alveolar glands are usually found associated with the hairs, when their ducts open directly into the hair follicles. The cells which line them are cast off apparently as a part of the secretion of the glands, *sebum*, which is an oily semiliquid which sets into a cheesy mass, such as can be squeezed from the pimples or *comedones*, which disfigure many people when the ducts become stopped. The secretion of those glands located in the ear, when mixed with that of other glands, forms *ear wax*. The secretion of the sebaceous glands probably forms an oily coating for the skin and hairs which protects the former by preventing too rapid evaporation and keeps the latter from becoming too dry and brittle.

In addition to these active and important excretory functions of the skin, there is a slight power of removing carbon dioxide.

Cutaneous Sensations.—Everyone is aware of a capacity to *feel;* i.e., a sense of touch, or tactile sense; and to distinguish between rough and smooth, sharp and blunt, hot and cold, heavy and light objects, etc. These are among our cutaneous sensations, though the last two are more properly muscle sensations. The capacity to feel pain is more widely distributed than the other skin sensations.

Nerves which convey information to the brain from any portion of the body are called *sensory,* or *afferent,* and each nerve ending *responds to but one stimulus;* i.e.. can carry information of but one kind. Thus if the nerve of sight is cut, no pain is felt, but only a flash of light will be recognized by the brain.

Observation has proved that there are four stimuli which can excite the nerves distributed to the skin, which will convey four kinds of information to the brain. These four sensations are *heat, cold, pressure* or *touch* and *pain.* Careful experiments have shown that minute areas of skin are sensitive to one or another of these stimuli and to no other. Such areas are designated *heat spots, cold spots, pressure* or *pain spots.* If one touches, with a delicate instrument, a cold spot, a sensation of cold will be experienced, *even if the instrument itself is warmer than the skin.* Cold spots are more numerous than warm; pressure points more numerous than either and pain spots the most numerous of all. Some portions of the body envelope, like the membrane covering the eyeball, have no nerve spots except those of pain, which are present in great numbers. Pressure spots, supposed to number about half a million for the entire body, are found in rings around hair follicles, the hairs acting like levers can thus give rise to the sense of pressure or touch when nothing has touched the skin, as when an insect crawls over the hair or when the wind moves it.

Certain areas, like the tips of the fingers, and the tip of the tongue are very abundantly supplied with touch nerves, while other parts, like the middle of the back, have pressure spots only at comparatively wide intervals, and it would seem that the number may be increased by use, as is seen in the delicate sense of touch possessed by the blind, or in the fingers of a trained surgeon. At least the nerve terminals may be educated and become more sensitive. Skin sensations are as much organs of special sense as the eye or ear and capable of as much improvement by training. From this it would appear that some persons not only cry out more than others under the effects of pain, but that they actually suffer more pain.

Two modifications of cutaneous sensibility, itching and tickling, deserve particular mention. Neither is clearly explained, but it would appear that itching is never a normal nerve impulse, but is always the result of injury or disease; while tickling seems to be a modification of tactile sensation due to rapidly repeated stimulation. Some observers think itching a mild stimulation of nerves conveying painful sensation.

The function of the mammary gland will be described with the reproductive organs.

CHAPTER VIII

THE DUCTLESS GLANDS

The glands the functions of which have been studied have ducts which carry the results of their labor to the point at which it is to be used in the animal economy. There remain a number of glandular organs, with no ducts, which, nevertheless, exert a great influence on the vital changes of the body, in some instances being of such power that their removal is followed by death within a brief period of time.

These glands are the **thyroid,** with its accompanying **parathyroids,** situated on the trachea near the root of the neck; the **thymus,** located in front of the great vessels just above the heart; the **adrenal** bodies, or **suprarenal** capsules, perched on the top of each kidney; the **pituitary,** located at the base of the brain in a peculiar depression of the skull called *sella turcica;* the **pineal gland** imbedded in the brain substance near the connecting link between the third and fourth ventricles; and the **spleen** in the abdominal cavity, the largest of all the ductless glands. The secretion of each of these glands is poured directly into the current of the blood and acts through that organ. It is designated an *internal* secretion because there is no obvious apparatus for its discharge. Some of the work done by glands with ducts, like the formation of urea by the liver, partakes of the nature of internal secretion. Like the *secretin,* noticed in the discussion of digestion, these internal secretions excite activity in other organs, except in a few cases where they inhibit such activity. They have, therefore, been named **hormones,** meaning to excite, and **chalones** when they inhibit or prevent activity.

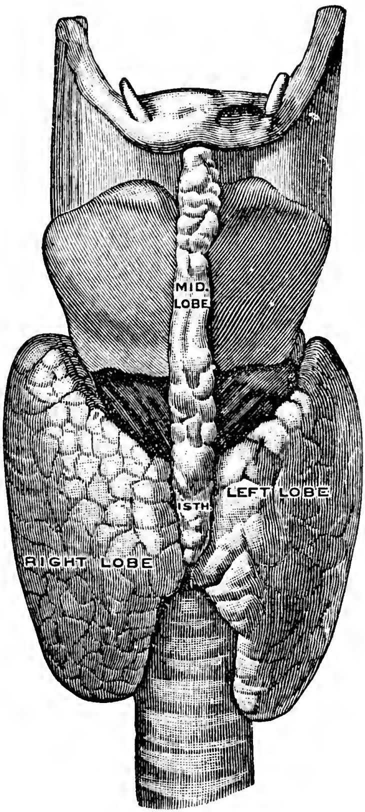

Fig. 21.—The thyroid gland. (Gray's *Anatomy,* after Spalteholz.)

While no adequate explanation of the function of the thyroid and parathyroids can be given, it seems clear that the former forms a hormone which stimulates other tissues and increases their metabolism; i.e., the process by which living cells incorporate substances taken from blood into parts of their own bodies, a sort of cellular digestion or rather building up. Feeding thyroid extract will cause an increase in the output of nitrogen and an increase in the oxidation, or burning up, of fat. That the gland is intimately connected with nutrition is shown by the production of idiocy and arrested growth when it atrophies in the young. The parathyroids are even less understood. Their complete removal causes rapid death. That they are connected with the metabolism of calcium (lime) salts, seems clear. When the thyroid fails to develop in early childhood, a condition called *cretinism* occurs, in which there is a failure to grow in height or intelligence. In fact the person, though reaching adult life, remains an idiotic dwarf.

Removal of the parathyroids results in a condition of *tetany*. muscular tremors, which end fatally after producing convulsive movements especially of the respiratory muscles. The condition is called *hypothyroidism* and may be relieved by calcium salts.

Hyperthyroidism is produced by overactivity of the thyroid and is attended by nervousness, muscular wasting, weakness and protrusion of the eyeballs, from which symptom the name *exophthalmic goiter* has been derived.

The active principle of the **adrenal bodies** is called *epinephrine* (the trade name of which is *adrenalin*) which slows the heart ultimately by acting reflexly through the central nervous system, and at the same time causes a great rise in blood pressure by exciting constricton of the arterioles. It also seems to affect carbohydrate metabolism. While so little can be said of the exact functions of the adrenal bodies, their importance in our economy is obviously immense, since their entire removal always ends fatally.

Nothing need be said of the **thymus** except that its partial atrophy and disappearance at puberty indicates that it is connected with the development of the organs of reproduction.

The **pituitary** consists of lobes having different functions, if, indeed, they are not separate glands. The hormone of the anterior lobe presides over and stimulates growth of the skeleton and perhaps all connective tissues; while that of the posterior lobe seems directed to the activity of some glands and to preside over the glycogen store in the liver which it appears to dole out in appropriate measure. An extract of the pituitary body called *pituitrin* excites contraction of plain muscle fiber, so especially marked in the uterus that it has been used in obstetric work to augment uterine power.

Of the **pineal body** too little is known positively to justify a statement of its functions, though possibly they are concerned with growth.

In the **pancreas** certain masses are found called islands of Langerhans. There is some evidence that these furnish an inhibitory chalone which prevents the too rapid use of the glycogen in the liver.

Not a great deal, it must be confessed, is positively known about the function of the ductless glands. But there is at least enough undisputed to warrant the assertion that they are of very great, and, until recently, of unsuspected importance in the general work of keeping in repair and regulating many of the most essential organs. When the removal of an organ weighing only a few grains produces such changes that an animal wastes away and dies, its vital necessity is demonstrated. To state then that we can not explain its mode of action does, indeed, expose our ignorance, but does not lessen the need which our bodies have of the organ in question.

CHAPTER IX

THE NERVOUS SYSTEM

The **nervous system** may be compared to the telephone system of a large community—the brain representing the central office, where calls are answered and connections made; the spinal cord corresponding to the large cables conducting the mass of wires to and from the office, the peripheral nerves to the wires of the individual subscribers. The analogy is, of course, imperfect, but serves the same purpose as a diagrammatic drawing. Nerves carrying impulses from the periphery to center are like wires running from individual to central; while those which run to muscles, glands, etc., would resemble wires running to the individuals called, after the connection has been made—central in this instance resembling the function of a nerve cell in a reflex arc in its simplest form—i.e., an afferent nerve passing to a cell and an efferent nerve from another connected cell to periphery. Such an arc would be complete if we conceive of an organism possessed of a skin with a sensory nerve, a muscle to move the organism, a nerve cell to respond to an appeal from the surface and a nerve fiber from cell to muscle. If we imagine that such an organism encounters something painful, the course of the nerve impulse would be from the nerve ending in the skin to the cell, where the danger is recognized and an order sent along the efferent nerve to the muscle to contract and remove the organism from danger.

The elements of the central nervous system are the **brain,** divided into the two hemispheres of the *cerebrum,* two *crura,* connecting links between the cerebrum and the lower portions of the nervous system, the *pons,* the *medulla* or *bulb,* the two hemispheres of the *cerebellum* and the *spinal cord.* All of these component parts, except the last, are found in the skull, enclosed in the three membranes of the brain, while the cord, also enclosed in three similar membranes, continuous with

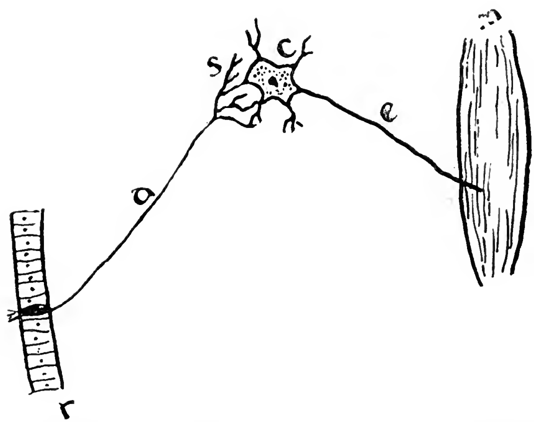

Fig. 22.—Schema of simple reflex arc: *r,* receptor in an epithelial membrane; *a,* afferent fiber; *s,* synapsis; *c,* nerve cell of center; *e,* efferent fiber; *m,* effector organ. (Pearce-Macleod, *Fundamentals of Human Physiology.*)

those of the brain, is in the spinal canal which runs through the vertebral column.

The **peripheral** nervous system is made up of the cranial and spinal nerve trunks and ganglia and their numerous endings in various parts of the body.

The **sympathetic** system is a chain of ganglia and connecting fibers situated on each side of the spinal column, connected with both cranial and spinal nerves, and widely distributed.

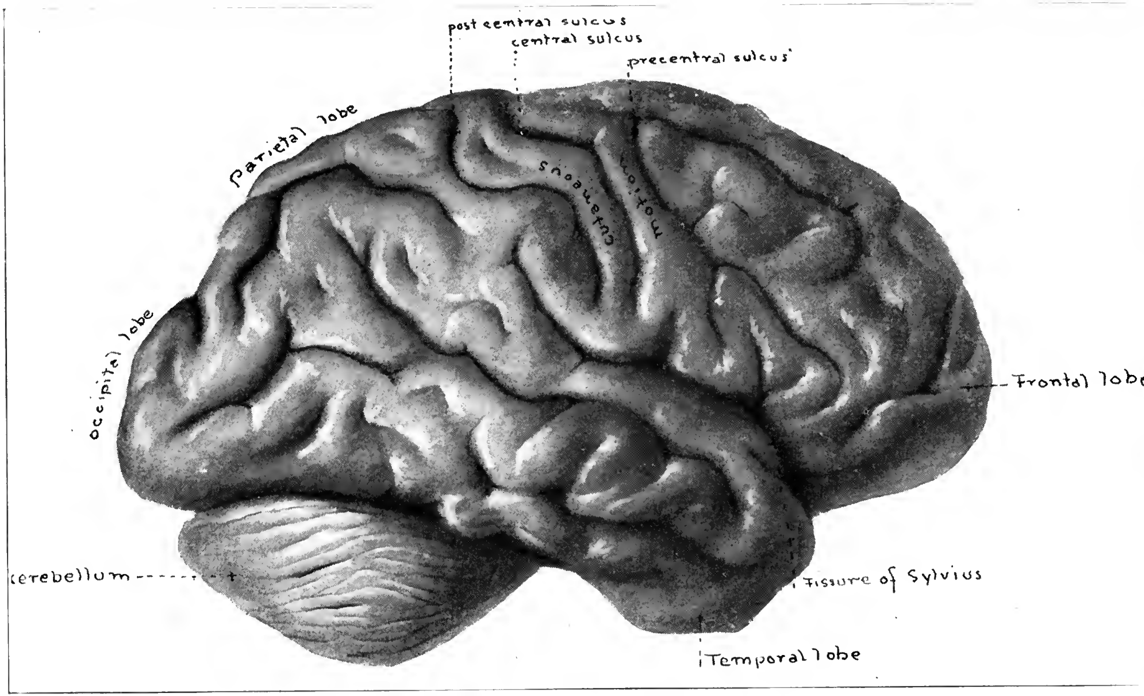

Fig. 23.—Brain, lateral view.

A broad view of the entire nervous system reveals that the brain is the highest development of the system, presiding over the work of the rest, thinking, ordering, and governing through its subsidiaries. Some of its impressions are received directly, and some of its orders given, through the medium of the cranial nerves; but from the larger portion of the body its various sensations and actions must be transmitted to the brain through the spinal cord. In this transmission the cord, like a good subordinate officer, finds many things of such simple and routine nature that the conscious brain need not be troubled with them and itself interprets the information and gives the necessary instructions. Thus it appears that while much of the tissue of the cord is solely employed in conducting impulses to or from the periphery of the body, it is capable of action, not absolutely independent, but under general orders of the brain.

The **sympathetic,** or more properly **autonomic system** is much more independent. While connected with the brain and spinal cord, its functions are, in large measure, performed without the conscious will of either.

The Cerebral Hemispheres.—In these subdivisions of the *fore brain* we find the higher centers. Here reside those intellectual functions which we are thinking of when we say "we think." In that part of the cortical matter—like bark, surrounding other matter—which is found over the anterior part of the frontal lobe probably originate the highest philosophic conceptions; in front of the central sulcus (*fissure of Rolando*) lies the long area stretching from the top to near the bottom of the brain which presides over all motor activity, with the special centers for the lower extremity at the top, those for the upper extremity in the middle and for the face at the bottom. Behind the same fissure lies an area of nearly like size and shape which receives and interprets those sensations communicated from the periphery, like pain, pressure, heat and cold, which were discussed with the skin. Around the end of the Sylvian fissure is an angular area concerned in word and object seeing. Just below the same fissure lies the center for hearing and one still lower for the interpretation of words. In the

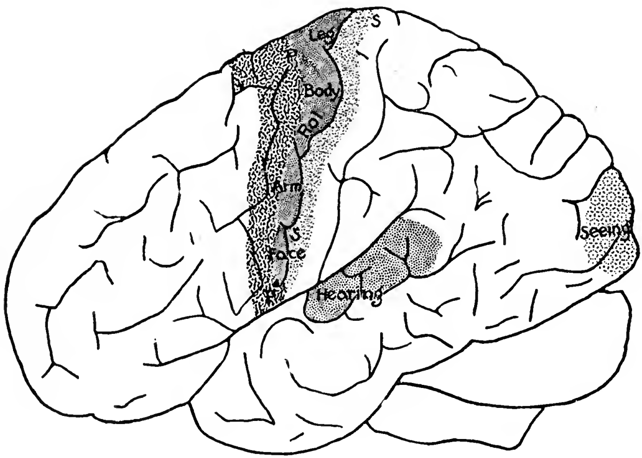

Fig. 24.—Cortical centers in man. Of the three shaded areas bordering on the Rolandic fissure (*Rol.*), the most anterior is the precentral associational area, the middle one is the motor area (the position of the body areas are indicated on it), and the most posterior is the sensory area, to the cells of which the fillet fibers proceed. The centers for seeing and hearing are also shown. The unshaded portion in front of the Rolandic area is the precentral; the portions behind, the parietal and temperosphenoidal. (Pearce-Macleod, *Fundamentals of Human Physiology*.)

occipital lobe is the center for vision, while the centers for smelling and tasting, closely associated, appear to be on the inner surface of the temporosphenoidal lobe near its anterior end. A glance at the surface of the brain, or a good picture of the cortex, will show how small a surface is employed in the functions of motion and in receiving sensations from the skin and tissues. This indicates that the amount employed in the mere sensations of seeing, hearing, tasting and smelling is equally small, and that the remainder of the cortex, a very large portion of the whole, must be occupied, as *association areas* in analyzing the sensations brought in

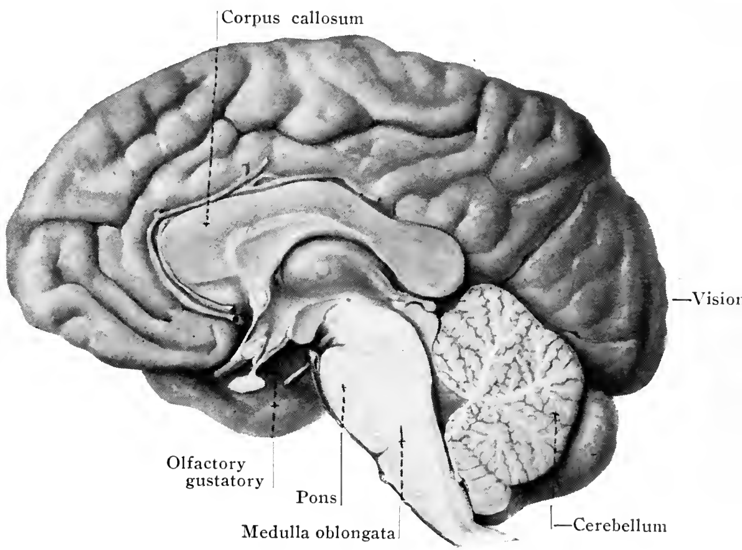

Fig. 25.—Brain, mesial view.

by these highly trained and developed nerves. Thus, the uneducated may *see* a word as distinctly as the trained, but it conveys no meaning, any more than would a word in an unknown tongue. We can, therefore, readily comprehend that we have not only memory for words and their definitions, but that special areas of the brain may be taught to preside over these functions and so associate certain characters, which we call letters, with a certain meaning, when combined in a definite way, which always conveys the same idea to one's mind. Education, therefore, would be, in this sense, simply the formation of certain habits; and as the frequent repetition of the same act leaves each time a firmer impress on the mind, the habit may finally become automatic and be performed without definite consciousness. As the thoughts of at least a large majority of mankind are always dependent on sensations received from without, it is apparent that without the association areas the highest intellectual functions, which are entirely dependent on such associations, can not be performed; and it follows that disturbance in any of the areas, or in the conducting paths which lead between them, may give rise to an interruption of function, or at least such a disturbed condition, that connected thought becomes impossible. Temporarily such an interruption occurs in the delirium of illness and permanently in various types of insanity. Neither is it surprising that parts of an area alone may be affected. Thus a symptom of "word blindness" may, and does occur in which there is a complete failure to recognize printed or written words though speech is not affected.

The association areas referred to must not be confounded with those fibers—the *corpus callosum*—which run between the two halves of the cerebrum and associate, or coordinate, the action of similar centers, for example, make the centers for the two upper extremities act in concert, as in swimming.

The most widely scattered, and one of the most important, association areas is that called the "language area." In order that the fullest use may be made of a language, it must be spoken, heard, written and read. This necessitates not only the highly specialized nerves of vision and hearing, but the use of all muscles involved in uttering articulate sounds, moving the eyeballs in unison or the hand in writing, and the centers for each must not only be associated with each other, but each in turn must be closely connected with those centers which originate the thought to be expressed, select words with the proper shade of meaning, or comprehend the full meaning of a writer or speaker; while the sensory nerves of lips and tongue must also be in harmony. The area involved, therefore, would be large segments of the frontal, parietal, occipital and temporosphenoidal lobes. Probably, too, special sections are devoted to musical sense, associated with language, at least in vocal music, since we find some children devoid of all ideas of music while others, at an equally early age, have what we call a "good ear" for musical sounds.

THE CRURA, PONS, CEREBELLUM, MEDULLA

Our knowledge of the remaining segments of the brain is neither so extensive nor so definite as that which we possess of the cerebrum.

The **crura cerebri** are in the main composed of white fibers which convey nerve impulses to and from the cortex through the pons to the medulla, and thence to the spinal cord; though they contain gray matter supposed to be concerned in coordinating the movements of the eyeball and iris.

The **pons** consists, superficially, of transverse fibers which connect the hemispheres of the cerebellum with each other and deeply of longitudinal fibers, derived from the crura, running to the medulla. It may assist in regulating automatic voluntary movements (Flint).

The **corpora striata** and **optic thalami** are masses of gray matter imbedded in the cerebrum, the first intimately connected with the anterior part of the *internal capsule* and the latter with its posterior third. Since these bundles carry respectively motor (efferent) and sensory (afferent) impulses, the corpora are supposed to be connected with motion and the thalami with sensation.

Four small bodies—corpora quadrigemina—are situated just back of the thalami. The first pair are connected with vision and the posterior with hearing.

The **cerebellum** is so much larger than the portions of brain just discussed that mere size would indicate its possession of important functions. We are, however, almost entirely ignorant of its work and so many theories have been advanced that one hesitates to speak of *knowledge* of the subject. Its removal certainly causes a loss of the power of coordinating voluntary muscular action in animals; so that if a coordinating center for this purpose exists, it is highly probable that it is located in the cerebellum, and aids in maintaining equilibrium.

The Medulla Oblongata.—Here we are on firmer ground. This somewhat pear-shaped body seems to continue the conducting fibers from all parts of the brain lying above it into the spinal cord. Its *conducting* function, a large part of its work, is, therefore, obvious. The paths of conduction of motor impulses are in the *anterior pyramids*, whose fibers cross to the opposite side of the cord as the *crossed pyramidal tracts*—explaining why an injury to the motor area of one cerebral hemisphere causes paralysis of the other side of the body.

The sensory fibers finally pass through the medulla into that region of the cord around the posterior roots of the spinal nerves with which they are connected.

They do not all cross at one point, but successively as they pass down the spinal cord.

The medulla is an important reflex nerve center differing somewhat from a similar action of the cord which will be discussed later.

Respiratory Center.—Among these centers that presiding over *respiration* is so important that the point at which it is located has long been called the "vital spot." To carry on a function so essential as breathing, a mechanism must be employed which can act independently of the will, which functions when one is asleep or unconscious—as in anesthesia. This center is located in the lower part of the medulla and consists of two parts, one on each side of the midline, each presiding over its own side of the body. Its neurons descend in the spinal cord and are connected through the gray matter with the spinal nerves at their points of origin at different levels. Motor impulses, therefore, originate in the medullary center and are distributed to the lower centers in the cord, or to the centers of the vagus or facial nerve. Essentially the center is automatic and is normally stimulated by the amount of carbon dioxide in the blood; i.e., if the amount of CO_2 is small, the respirations will be fewer, if the amount is increased the respiratory movements will increase in number. This fact, and the extent of the control which the brain exerts over the center, is illustrated in "holding the breath." One may voluntarily cease to breathe for a time, but when CO_2 has sufficiently accumulated in the venous blood in the center, an inspiration takes place regardless of one's attempts to prevent it.

The chief motor (efferent) nerve which carries the impulses of the center is the *phrenic,* a branch of the cervical plexus, though the intercostal, lumbar and other nerves also play an important part. The sensory nerve chiefly concerned is the *tenth* cranial or *vagus* which is in part distributed directly to the lung tissue, but almost any sensory nerve may convey impulses to this center. The vagus appears to carry two sets of fibers, inspiration stimulating the inhibitory fibers by expansion of the lung, while the partial collapse of the lung at expiration stimulates the inspiratory fibers. That the sensory nerves of the skin affect the center anyone may prove by dashing cold water over the person and noting the "gasp for breath" which immediately follows. The sensory nerves of the face, breathing and swallowing passages (fifth and ninth) can inhibit inspiration. This is a protective arrangement whose action can be shown by swallowing when the reflex through the ninth temporarily arrests respiratory movements; by breathing or attempting to breathe, any irritating gas, like ammonia, the inhibitory impulses in this case following the fibers of the fifth in the nose.

At birth the first inspiration of the newborn child seems to be caused mainly by the accumulation of CO_2 in the infant's blood as a result of cutting off its connection with the mother through the placenta; though a contributing stimulation is the exposure of the skin, with its sensory nerves, to the air. Obstetricians must often take advantage of this to start the inspirations which do not always begin at once after prolonged and difficult labor.

Apnea and Dyspnea.—The first of these terms means absence of breathing literally, but is employed in physiology to describe a condition of respiratory rest when the lungs and blood are full of oxygen. A fleeting condition of apnea is produced by a very full inspiration.

Dyspnea, difficult or labored breathing, is the condition produced by a marked increase of carbon dioxide or a similar decrease in oxygen. It could be produced by diminishing the amount of oxygen in the respired air, by blocking up the air passages, as by choking, or decreasing available lung space. When carried to excess as by hanging, a condition of *asphyxia* results.

The vagus nerve carries two sets of fibers to the muscles of the bronchioles—those which excite contraction when stimulated, and those which cause dilatation. They are called *bronchoconstrictor* and *bronchodilator* fibers.

Cardiac Center.—This center is found in the neighborhood of the roots of the vagus nerve, through which it exerts a slowing and regulating influence on the heartbeats, and is, therefore, called the *cardioinhibitory* center. Whether there be a distinct *accelerating* center in the medulla is disputed. It is certain that nerve fibers sent to the heart by the sympathetic system increase the rate of the heartbeat. Other nerves affect the action of the heart reflexly. Painful sensations, particularly from the viscera, slow the heart. These sensations are carried into the central nervous system and act reflexly on the inhibitory center stimulating it to greater activity. On the other hand, emotion may stimulate the accelerator center and cause a more rapid beat, sometimes *attended by less power*. Hence it has been inferred that accelerator nerves carry two sets of fibers, one simply to increase the rate of action of the heart and the other to augment its power. Fear, therefore, might increase the rapidity with loss of strength, while anger could augment both.

Vasomotor Center.—The action of the blood vessels consists in dilating to increase and constricting to diminish their capacity.

A **vasoconstrictor** center in the medulla is demonstrated, but there seems to be no vasodilator center. Changes in the size of the blood vessels are caused by the constriction of the muscular coat to reduce the size and relaxation to increase size. Constriction diminishes and dilatation increases the quantity of blood in the area of distribution of the vessels involved. The impulses are carried by the sympathetic autonomic sys-

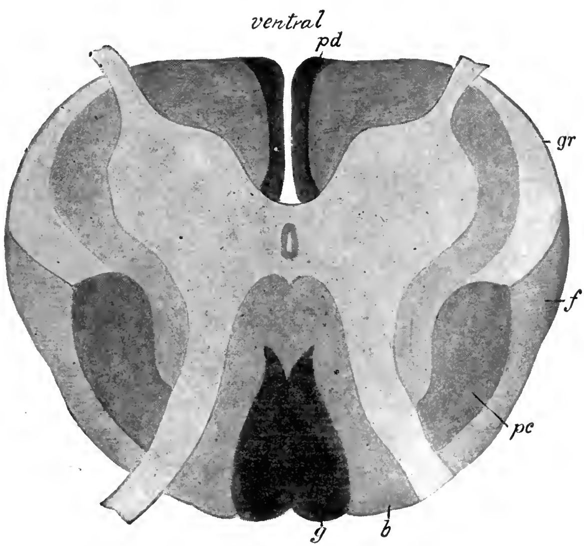

Fig. 26.—Diagram of section of spinal cord, showing tracts. (After Kölliker); *g*, posterior median, and *b*, postero-lateral columns; *p.c.*, crossed pyramidal, and *p.d.*, direct pyramidal tracts; *f*, cerebellar tract. (After Howell.)

tem and are not under the control of the conscious will, though the higher centers of the brain can excite them as may be seen in blushing—a vasodilatation of the vessels of the face. Ordinarily the center is excited reflexly, as when exposure to cold causes a constriction of the vessels in the part affected. Fright, grief, the reception of bad news may cause the temporary unconsciousness called fainting by inhibiting the constrictor center and allowing such dilatation of the great venous channels, particularly those of the abdomen, that there is too little blood in the brain to maintain its normal state. Nature indicates the remedy by throwing the fainting person down.

Parts of the medulla are supposed to contain various other centers, such as for the control of salivary secretion, swallowing, vomiting, etc.

The Spinal Cord.—Like other parts of the central nervous system, the spinal cord consists of gray and white matter, the gray being in the center and the white on the outside, a converse arrangement to that of the brain. While mainly employed in conducting impulses to and from the brain, the cord contains many reflex centers more or less under the control of the higher centers.

The fissures on the front and back of the cord indicate a partial subdivision into hemispheres, similar to the subdivision of the cerebrum, while the large mass stretching from one half to the other suggests the presence of commissural fibers connecting and coordinating the two. The gray matter, projected in the form of irregular horns into the front and back of each half of the cord, contains the cells, the branches of which connect on the one hand with the fibers of the entering nerves and on the other with branches of other cells in turn connected with the fibers of nerves leaving the cord either on the same or the opposite side. Such an arrangement completes the formation of a reflex arc, composed of a nerve fiber connecting a sensory terminal with the receiving branch of the cell in the gray column, the dispatching branch of which connects with the receiving branch of a cell in the motor area, the dispatching branch

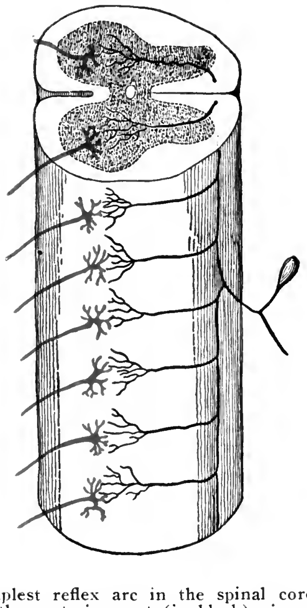

Fig. 27.—The simplest reflex arc in the spinal cord. (After Kölliker.) The afferent fiber in the posterior root (in black) gives off collaterals, which end by synapses around the cells of the anterior horn (in red), the axons of which form the efferent fibers of the anterior roots. (Howell's *Physiology*.)

of which in turn joins a departing—motor or secretory—fiber, the peripheral termination of which is in the muscle or gland which is to receive the stimulus to activity. Moreover there are ascending branches connected with similar cells which put the entire arc in communication with the brain, and radiating branches which form connections with other sensory and motor centers, so that all may be under the control of the higher centers and all coordinated with each other.

The conducting fibers for descending impulses—efferent—cross at the lower part of the medulla and form the anterior pillars or columns of the cord. The ascending impulses are carried in the posterior columns and cross at various levels as they ascend, though many cross in the lower part of the medulla forming the posterior or sensory, *decussation*. Other afferent fibers are connected with lateral tracts of the cord, near the entrance of the posterior roots of the spinal nerves, and are carried through the restiform bodies of the medulla into the cerebellum on the same side. Apparently the paths in the cord along which tactile impressions are carried are not the same as those traveled by pain and temperature sensations, as indicated by a disease in which there is, in affected regions, loss of the power of feeling pain or detecting differences in temperature, while the pressure sense is not affected; but these paths are not clearly defined.

As the motor fibers all decussate (cross to the opposite side) near the junction of the medulla and cord, and many of the sensory fibers are crossing all the way from the entrance of the sensory roots upward, injury to one-half of the cord will produce total motor paralysis of the same side and partial sensory paralysis of the same side, but all sensation is not abolished below the injury.

Injury to the area of the surface matter of the brain governing these paths causes both motor and sensory paralysis of the opposite side, because all the fibers of both kinds cross before reaching the origin of the spinal nerves which convey these impulses to or from the tissues.

Centers of the Spinal Cord.—There are two enlargements of the spinal cord, one situated in the cervical and the other in the lumbar portion. While these "secondary brains" can not be located with exactness, there is sufficient evidence to show that the cervical enlargement contains groups of cells or centers which preside over the movements of the upper extremity, accelerate the action of the heart, cause dilatation of the pupil, and regulate or prescribe the activity of the cervical sympathetic system of nerves. There is here also a spinal respiratory center.

In the lumbar enlargement are centers controlling the rectum, bladder and the genital organs and the movements of the lower limbs.

THE CRANIAL AND SPINAL NERVES

The **cranial nerves**—twelve pairs—differ from the spinal in being directly attached to some part of the brain and, usually, in carrying, in each pair, either afferent or efferent fibers alone. They are known by numbers from before backwards and also have synonyms indicating their function. The **first,** or **olfactory**; **second** or **optic**; **eighth,** or **auditory**; and **ninth,** or **glossopharyngeal,** are concerned with smelling, seeing, hearing and tasting and are described with the organs of special sense.

The **third,** or **motor oculi**; **fourth,** or **patheticus**; and

sixth or **abducent** all carry motor impulses to the muscles which move the eyeball. Their function is, therefore, sufficiently indicated by their distribution.

The **fifth,** or **trifacial,** resembles a spinal nerve in rising by a motor and a sensory root, only the sensory is in front and the larger of the two. It is emphatically the *neuralgic* nerve, so frequently does this painful affection attack the sensory branches of this widely distributed nerve. Its synonym of *trifacial* is derived from its splitting into three divisions and leaving the skull by three openings. One division, the *ophthalmic* conveys news from the mucous membrane and part of the skin of the nose, the eyeball and lacrimal gland, forehead and upper eyelid; the next, *upper maxillary* (jaw) is the afferent nerve from the skin covering the upper jaw, side of the nose, upper lip and lower lid and from the teeth and gum of the upper jaw the tonsils and nasal and throat mucous membrane. The third division, *inferior maxillary,* does the same work for the lower jaw and its surroundings, including the tongue and salivary glands, the skin at the back of the ear running to the top of the head, and takes all the efferent fibers which are distributed to the muscles which move the lower jaw. The nerve resembles a spinal nerve also in possessing an enlargement called a *ganglion* on its afferent root in which these fibers arise, the branches or roots of the ganglion furnishing the connection with the brain. This arrangement is identical with that of the spinal and other cranial nerves which contain mixed fibers.

The **eleventh** and **twelfth,** or **hypoglossal,** nerves contain none but efferent (motor) fibers. The eleventh is distributed to very important muscles of the neck and back and is often connected with the surgical affection called *wry neck.*

The twelfth conveys efferent impulses to those muscles which depress the hyoid bone, to the tongue and many of the muscles which move that organ.

While the **seventh,** or **facial,** nerve proper contains none but efferent fibers, mainly distributed to those small bundles which move the face and change its expression—hence *muscles of expression,*—it is connected with a part intermediate between itself and the auditory called *chorda tympani* or nerve of Wrisberg, which supplies the salivary glands with vasodilator and secretory fibers. The seventh is the nerve concerned in facial paralysis.

The **ninth,** or **glossopharyngeal,** is also a mixed nerve. The motor fibers are distributed to the muscles of the pharynx and base of the tongue, while secretory fibers are carried to the parotid gland.

The sensory fibers conduct impulses from part of the mucous membrane of the tongue, the pharynx, Eustachian tube and tympanic cavity. The origin of this nerve is from the medulla.

The **tenth, vagus** or **pneumogastric,** also springs from the medulla just below the ninth and is, like it, a mixed nerve. It is the most widely distributed of all the cranial nerves, some of its branches reaching such functionally different organs as the larynx, heart, lungs, stomach, and intestines, even so far as the large intestine. The motor (efferent) fibers go to the intrinsic muscles of the larynx, while others go to the plain muscles of the digestive tract, including part of the large intestine; while the afferent fibers bring sensory impulses from the mucous membrane of the larynx, trachea and lungs, esophagus, stomach, intestines, gall bladder and its duct. The nerve carries inhibitory fibers to the heart and secretory fibers to the pancreas and the glands of the stomach. It is the agent, therefore, by which the voice is produced, the air passages guarded against irritants and excited to expel them; the heart regulated, glands of the stomach and the pancreas incited to activity and the musculature of the swallowing and digestive organs stimulated to perform their functions.

The **spinal nerves,** unlike the cranial, always spring from the spinal cord by two roots, an anterior, motor, connected with the anterior column and adjacent gray horn, and a posterior sensory connected with the posterior columns and the gray matter of the posterior horn. After emerging there is formed, on the posterior root only, a ganglion from whose cells the posterior root really springs. This ganglion is the *trophic* center of this root; i.e., that mass of cells which is so essential to the health and activity of a tissue that without it death of the tissue and degeneration will occur. This is proved by cutting one nerve between the ganglion and the cord and another between the ganglion and periphery, in the latter case only will the nerve degenerate. Beyond the ganglion the two roots unite to form the spinal nerves as we dissect them. In all regions except the thoracic, spinal nerves thus formed communicate more or less intimately with one another to form anatomic *plexuses,* from which the ultimate branches of distribution are derived. In these plexiform communications there is a redistribution of fibers in such a way that some nerves emerge which are entirely afferent, some entirely efferent, but most are, like the parent trunks, mixed. The plexuses are *cervical, brachial, lumbar* and *sacral* and *coccygeal.*

The **cervical** plexus supplies the skin over the neck, upper part of the chest, back of the head and thorax and muscles in the same region.

One branch, of more importance, is the *phrenic,* or chief inspiratory nerve since it carries motor impulses to the most important of the inspiratory muscles, the diaphragm.

The **brachial plexus** is largely devoted to the upper extremity. One of its branches supplies the *serratus magnus,* an accessory respiratory muscle, but most of them are mixed nerves some of the fibers of which convey cutaneous sensations from all parts of the upper extremities, while motor branches supply all the muscles which move this great lever, even those muscles which spread out over the back and chest.

The **thoracic nerves** run mainly between the ribs—intercostal nerves—supplying motor impulses to the muscles of the same name, which makes them respiratory nerves, while their sensory fibers convey cutaneous sensations from the skin of the thorax and a large part of the abdomen. The lower thoracic nerves supply the broad muscles of the abdomen and are thus expiratory agents.

The **lumbar plexus** gives rise to those nerves which supply sensation to the skin from where the last intercostal leaves off to where the sacral plexus takes up the work, and motor impulses in the same area. The first of the lumbar nerves supplies the skin over the upper, outer part of the hip and others carry the distribution over the front and inner side of the thigh and, by one long branch, along the inner side of the leg as far as the big toe. The skin over the external genitals is supplied in part by this plexus. The muscles supplied are those forming the lower part of abdominal wall, some in the back of the abdomen and pelvis and those on the front and inner side of the thigh. Briefly the muscles which flex or adduct the thigh or extend the knee, receive their impulses through the lumbar plexus.

The **sacral** and **coccygeal** nerves supply motor and sensory fibers to the external genitals, the hip, back of the thigh and all of the leg and foot, except the inner side of these parts which receive their supply from the lumbar plexus.

THE AUTONOMIC SYSTEM

The chain of ganglia and nerve fibers which lies on each side of the vertebral column is usually called *sympathetic,* because it was formerly supposed that sympathetic or reflex impulses were carried by it. The more recent name, *autonomic* is derived from words meaning "a law unto itself," and is appropriate because this system of nerves is entirely independent of the conscious will; i.e., is independent of that portion of the brain which consciously directs. That some of these fibers are connected with the brain through cranial nerves is apparent and all are under the control of some portion of the brain; but that only means that there are brain areas over which man exercises no control. Some of the ganglia of this system are found in the skull and are connected with cranial nerves, notably the *ciliary* which gives branches to the iris or pupil; but the larger number lie along the spinal column and are connected with nearby spinal nerves by two roots—a *white* (medullated) fiber which runs from nerve to ganglion and a *gray* (nonmedullated) fiber which passes from ganglion to nerve which afterwards distributes it to nonstriated muscle fiber. Through the spinal and cranial nerves, the sympathetic ganglia are connected with the central nervous system in these regions (1) through the third nerve with the midbrain, (2) through the seventh, ninth, and tenth with the medulla, and (3) through the spinal nerves, from the first thoracic to the second lumbar, with the spinal cord. The branch connecting the spinal nerve and ganglion is called *preganglionic,* while the branch passing from the ganglion to the muscle fiber is the *post-ganglionic.* There are three autonomic ganglia in the neck, but their motor fibers are derived from the upper thoracic nerves and, after joining the sympathetic trunk in the thorax, ascend in it to the cervical ganglia; which, however, give off gray communicating branches to the cervical nerves which in turn carry them to the plain muscle fibers in the regions to which they are distributed. Other ganglia, the *collateral* are found in the thorax, abdomen and pelvis, and still others, the *terminal,* in the walls of the viscera.

The activities of this extensive nervous system are directed to plain muscle fiber wherever situated. The muscle in the walls of blood vessels, however remote from the ganglia, that in the bronchi and their subdivisions, in the intestinal canal, in the iris and the genitourinary tract, in glands and other plain muscular organs throughout the body, all is innervated by the autonomic system.

Two opposed activities are characteristic of muscular fiber *contraction,* by which its ends are brought nearer together, and *relaxation* by which the ends are separated. Most plain muscle is arranged in circular or longitudinal layers around some tubular body. Contraction of the circular fibers diminishes the size of the tube; relaxation enlarges it. Contraction of the longitudinal fibers shortens the tube; relaxation lengthens it. Apply this to a blood vessel and one sees that contraction is equivalent to constriction and relaxation to dilatation.

The best known fibers of the sympathetic are those which excite constriction of blood vessels, hence called *vasoconstrictor* fibers. The less well understood are the relaxers, hence called *vasodilator*. The two are *vasomotor*. Emotions may excite the activity of these nerves. The face pales with fear and flushes with shame or anger—vasoconstriction and vasodilatation. Exercise will excite the dilators, cold the constrictors. It is obvious that this is a form of reflex action, but of reflex action controlled by higher nervous centers, neither under the control of the will nor independent of the subconscious brain.

Enlarging or decreasing the size of the intestines; contracting the bladder or uterus, changing the amount of blood which flows through the kidneys, the salivary and other glands, altering the size of the pupil or of the bronchioles are among the many activities of these widely distributed nerves.

The nerve fibers derived from the tenth cranial, which *inhibit*, or slow, the heartbeat, are carried to the heart muscle through the sympathetic plexus situated on the aorta. They are designated *bulbar* autonomic fibers, as distinguished from the *accelerator* fibers derived from the upper thoracic spinal nerves and joining the same cardiac plexus before distribution.

Other bulbar autonomic fibers are carried by the ninth, seventh, and third nerves. Those from the latter pass to the ciliary ganglion and from it to the muscle of the iris which regulates the amount of light entering the pupil; or to the ciliary muscle which regulates accommodation of the eye for near or distant vision, while the similar fibers of the seventh and ninth probably reach the tongue, through the chorda tympani and lingual for the anterior two-thirds and the ninth for the posterior third, and supply vasomotor fibers to those organs.

CHAPTER X

THE SPECIAL SENSES

We have already seen that the recognition of pain, pressure, heat, and cold and muscular sensibility are conducted by nerve paths as much specialized for their purposes as is the nerve of vision; but long habit has applied the term **special senses** to the organs of **taste, smell, vision,** and **hearing**.

TASTE AND SMELL

These special senses are so intimately associated that it is difficult to make a clear distinction between them, except that the four qualities, *sweet, salt, sour* and *bitter* or combinations of the four are appreciated without assistance from the olfactory sense. Except these four, all our so-called taste sensations, are really olfactory sensations, the nerves of smell being stimulated by the substance eaten either before it is placed in the mouth or after it has been swallowed, the odoriferous particles, in the latter case, entering the back of the nose in the current of expired air which follows the act of swallowing.

The nerves which carry sensations of taste to the brain are the *glossopharyngeal* for the posterior one-third of the tongue, fauces and palate, and the *lingual,* or *gustatory,* branch of the fifth for the anterior two-thirds of the tongue. The taste fibers in the gustatory, however, are derived from the *chorda tympani* of the seventh. The lingual really carries fibers of cutaneous sensibility which endow the tongue with painful, tactile, or pressure and temperature sensations. One's sense of taste, then, is highly complex, being easily associated with, or influenced by, temperature, touch and odor.

The numerous papillæ of the tongue are provided with certain cells ending in hairlike projections which are peripheral taste organs. From these the sense of taste is conveyed along the nerve paths mentioned to a point in the *temporosphenoidal* lobe, just behind the smell center, where the center for taste is thought to be located.

Because of their number and complexity, it is difficult to classify taste sensations. The bitter, sweet, acid and salt may be, and are, so often mingled not only with each other, but with odors which we associate with things tasted in the past that we can not separate the various classes of stimulation. An apple, for instance, is usually a combination of sweet and sour, but the flavor so highly appreciated would be lost if the olfactory nerves were destroyed. It is for this reason that food "loses its taste" when we suffer from colds, particularly if both the back and front of the nose is stopped by secretion. The distribution of the four cardinal tastes is not clear, but the back of the tongue and fauces are more sensitive to bitter and the front to sweet stimuli. There is some evidence that there are four separate end organs and nerve fibers for the four fundamental tastes.

A substance which is insoluble can not be tasted. A piece of clean metal or glass stimulates the cutaneous sensations when applied to the tongue, but gives no sense of taste. Substances in solution, or capable of being rapidly dissolved in the saliva, give rise to sensations of taste, probably through a chemical reaction in which the hairlike process is involved. Heat or cold, when excessive, interferes with the acuteness of taste. Smaller quantities of bitter substances can be tasted than of any other, while acid, sweet, and salt each require larger amounts, salt the largest. Some substances give different sensations on different parts of the tongue, as sulphate of soda which is merely salty at the tip of the tongue, but bitter at the back. Certain substances dissolved in the blood give rise to sensations of taste. The bile in the blood in jaundice causes a bitter taste, while the sugar in diabetes causes a sweet taste.

THE OLFACTORY SENSE

The course of olfactory sensations is from the end organs of smell in the roof and upper part of the sides of each nostril, along the olfactory nerves to the bulb and thence to the base of the brain at the lower and inner part of the temporosphenoidal lobe just in front of the center for taste.

The smell sense is one of the oldest in the history of life. When highly developed it was not only of great defensive strength in enabling its possessor to detect the presence of enemies, but was of equal offensive service in the pursuit of prey. In man it has dwindled to such an extent that he vaguely defines odors as pleasant or disagreeable, while a dog can still detect the odor, of a man, imperceptible usually to himself and associates, and follow him unerringly after hours have elapsed and pick him out of a crowd of others.

The substances which arouse, or stimulate, the sense of smell, give off inappreciable particles, probably gaseous in form, which are carried by inhaled air to the end organs of the olfactory nerve, are there dissolved by the moisture present and chemically stimulate the hair processes. Many odors, like those of fruits, wines, and many foods are habitually confounded with the sense of taste. Some disagreeable, or foul odors are simply associated in our memories with disagreeable impressions and may be agreeable to other persons. The garlic or onion odor and that of musk, excite pleasurable sensations in some and only disagreeable sensation in others. These effects are probably memories and not differences in the character of the chemical reaction in different individuals. The olfactory nerves are easily fatigued, when stimulated for too long a period, or with too much of the odor. The amount of gaseous material which can be detected is infinitesimally small. Camphor can be detected when only one part is present in four hundred thousand, vanillin (the active principle of vanilla), one part in ten million, while other substances can be detected in amounts still more minute.

VISION

Essentially the organ of **vision** is an apparatus by which an image of objects may be thrown on a mirror, composed of nerve terminals sensitive to light, the sensation, or impulse, thus produced being conducted along paths of nerve tissue to the gray matter covering a certain area of the brain. The particular region of the brain is the *cuneate* portion of the occipital lobe, and the path of conduction is by the optic tracts, chiasm and nerves from the *retina,* the concave nervous mirror in which the object is reflected. We actually see with the brain, just as we feel with the brain. If the cuneate area be destroyed we are blind no matter how perfect the remainder of the seeing apparatus may be.

Rays of light are vibrations of the ether which surrounds us, differing in length and rapidity for different

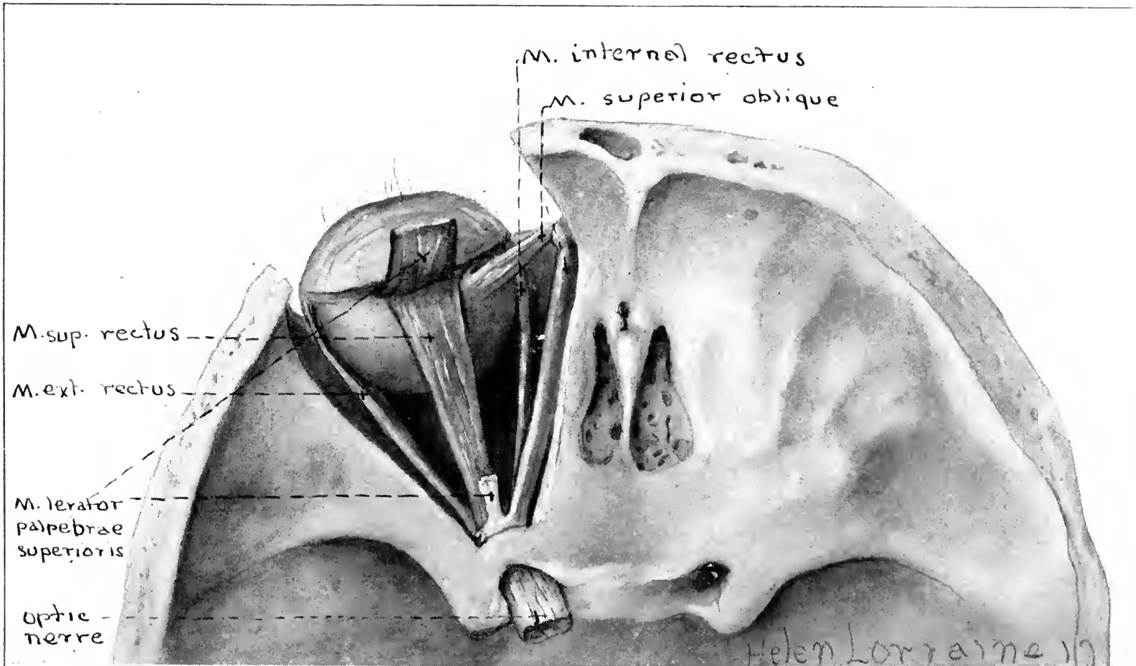

Fig. 28.—Orbital muscles.

colors. The slowest vibrations are red. The most rapid violet. A mixture of all the colors of the spectrum makes white light, or light without color, a result of the mingling of the various rates of vibration of the different colors. In order that the eye may serve its purpose without constantly turning the head, the eyeball is provided with *ocular* muscles which can move the ball in all directions; and, that the amount of light may be neither too

Fig. 29.—Section through the anterior portion of the eye: *C,* the cornea; *I,* the iris (note the circular muscular fibers cut across at the margin); *L,* the lens; *Ci,* the ciliary process; *S,* the suspensory ligament; *Scl,* the sclerotic or outer protective coat of the eye. (From a preparation by P. M. Spurney.) (Pearce-Macleod, *Fundamentals of Human Physiology.*)

great nor too little, provision must be made for regulating the size of the opening through which light is admitted to the interior of the eyeball. This is accomplished by putting a curtain, with a hole in the middle, in the fore part of the eyeball, and providing it with muscular fibers which can increase or diminish the size of the hole.

Light, however, does not travel in a straight line when it passes from a medium of one density to that of a greater density. If one places a straight stick in a glass of water, no matter how clear, the stick appears to be bent. This bending of the light rays is called *refraction.* When light passes into the eyeball, it is leaving a medium of little density—the air—and passing through substances of greater density,—the structures in the eyeball in front of the retina.

If light is transmitted through a doubly convex, transparent body, the rays will be bent in such a way that behind the body they will all come together at one point. This is *focusing* the rays. The rays of light travel on lines parallel with one another; and are practically all parallel when emitted from objects at a distance of twenty feet. If the *lens,* the convex transparent body, be of uniform curvature on both surfaces, the ray which passes through the exact center will be perfectly straight; but those which enter above will be bent down, those from below, up; and those from each side, towards the central ray. Hence they will all be thrown on the intercepting surface as a cone whose apex is the point behind the lens corresponding to the bending or refracting power of that lens, and whose base will be the back of the lens. If, however, the object from which the light is reflected be too near the front of the lens, the rays are not parallel, will not strike the lens at the same angle, and will be unequally bent and throw a blurred and indistinct image on the intercepting surface. The distance between the lens and receiving surface at which the point of the light cone is intercepted is the *main focus.* The distance between the front of the lens and the illuminated object at which the rays from that object enter the lens as parallel rays is the *near* point; i.e., the nearest point to the eye at which that object can be distinctly seen. Nearer than this the object is blurred. If the convexity of the lens be increased, if it becomes more nearly a perfect sphere, the bending of the rays will be increased equally and the focal point will be closer to the back of the lens. Conversely, flattening the lens would diminish the refraction and the focus would be at a more distant point behind the lens. In order to see clearly, therefore, the eye must have the power of *accommodating* itself to the distance of the objects, since the power of seeing at a fixed

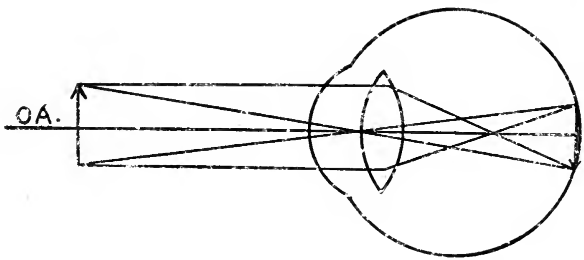

Fig. 30.—Formation of image on retina. *O.A.* is the optic axis. (Pearce-Macleod, *Fundamentals of Human Physiology.*)

distance only would be of very little use. This purpose might be accomplished either by moving the lens backwards and forwards or by flattening or bulging of the lens. In some fishes the former method is observed, but in mammals the latter is the uniform rule. This action of the eye is called *accommodation* and is carried out by a muscular arrangement to be explained.

Inverted Images.—When an image is thrown through a small opening, on a deeply concave mirror, the rays from the top of the object reflected strike on the lower and those from the bottom on the upper part of the concavity. Hence the image is *inverted*. All objects reflected by or impressed on the retina are thus inverted, but our brains have become so accustomed to reverse them that we are never even aware of the fact. It is conceivable that there could be such a disturbance of mental processes as to change this automatic mental action and make us see everything upside down.

The eyeball consists of an outside, middle, and inner coat. The outer coat is mainly protective, except for its anterior fifth, the **cornea,** which transmits and refracts light. The middle coat is vascular and the inner coat is the active part responding to light as a stimulus.

The **cornea** is placed in front of the iris and lens and behind the lens is the *vitreous* humor which is separated from the retina by a very delicate membrane. The cornea and the lens are the chief refracting media. The iris is the perforated curtain which regulates the amount of light.

The **iris,** the colored portion of the eye, has circular muscular fibers which surround the pupil and can, by contracting, decrease its size. There are also radiating fibers which can widen or dilate the pupil. If either should stick to the lens, in front of which they lie, the pupil would be contracted or dilated unequally and appear as a jagged instead of a circular opening.

The *lens, crystalline lens,* is surrounded by an elastic membrane called its capsule. This membrane is connected with a muscle, the ciliary, which is in turn fastened to the middle or choroid coat. In the normal condition, where the eyes are used to view distant objects, the ciliary muscle is at rest and the elastic capsule flattens the lens without fatigue to itself; but when the eye must accommodate itself for near vision, the muscle contracts, draws the choroid forward, relaxing the capsule while the lens, by its own elasticity, becomes more convex, mainly by bulging forward, since it meets with less resistance in that direction. This is the power of *accommodation* for near vision and varies greatly in its range in different people and at different ages. The near point is closest to the eye in youth and increases rapidly with age. At ten it is less than three inches, while at sixty it is more than a yard—a distance at which moderate print can not be read. There is practically no far point. Distant objects are visible in proportion to their size. But the nearest point at which the rays of light are parallel may be called the distant point.

A normal eye is called **emmetropic.** An abnormal eye, not one affected by acute disease, may be **myopic, hypermetropic** or **presbyopic.**

It has been stated that if the lens is too convex the focal point will fall closer to the lens. The rays would then form a cone and, if they are not intercepted, disperse again forming a second cone whose apex would begin at the apex of the first cone. This would result in *diverging* rays striking on the retina and an indistinct image. The same result would follow if the retina were too far from the lens, i.e., if the eye were too long. This is actually the case in the *myopic* or near-sighted eye. The latter name indicates that, to get a clear image, the object must be brought nearer the eye so that *divergent* instead of parallel, rays may be thrown on the lens. Glasses which break up the parallel into diverging rays would, therefore, correct this defect. Children are not usually born myopic but have, or acquire, perhaps more frequently the latter, weakness of the coats of the eyeball which give way under the strain of reading by bad light or in improper positions and the eye becomes too long.

Hypermetropic, or far-sighted, eyes have just the opposite defect. The eye is too short for the convexity of the lens and the cone is intercepted by the retina

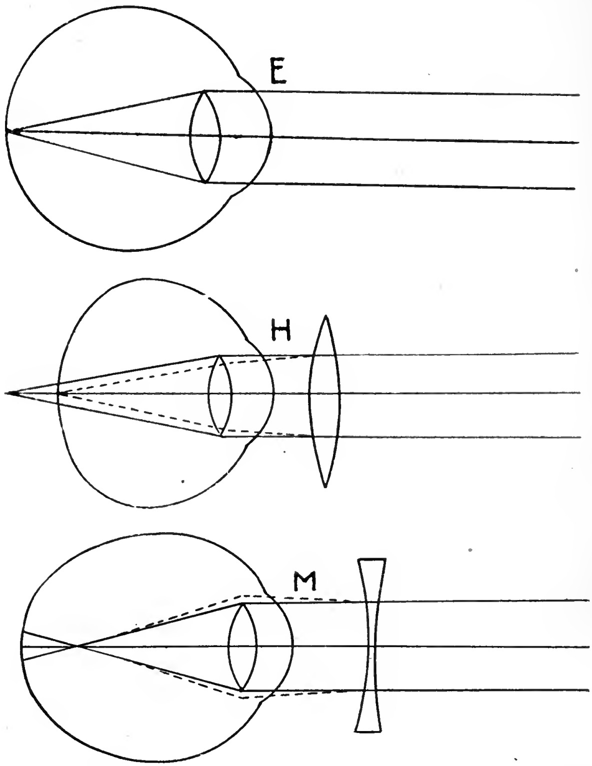

Fig. 31.—Errors in refraction: *E* shows the formation of the image on the retina in the normal or emmetropic eye; *H* shows the condition in long-sight, or hypermetropia, where the eyeball is too short; *M* shows the condition in short-sight, or myopia, where the eyeball is too long. (Pearce-Macleod, *Fundamentals of Human Physiology.*)

before its apex is reached. The same blurring occurs as in the myopic eye but for the opposite reason. Hence glasses which *converge* the rays are here necessary. This condition is usually congenital.

Presbyopia is old-sightedness. Here the lens has become so hard that the power of accommodation is lost. It usually begins between the fortieth and fiftieth years. Distant vision remains good, but the power of accommodation for near vision is lost.

If the surfaces of the cornea and lens be not segments of a true sphere, there is another error of refraction called *astigmatism* or inability to see a point. It is often combined with the near- or far-sighted defect.

The muscles which move the eye ball are supplied by the third, fourth and sixth cranial nerves. The fibers of the ciliary muscle and iris, nonstriated, are supplied by the ciliary ganglion of the sympathetic system, which receives motor fibers from the third and sensory from the fifth. There are constrictor and dilator fibers for the pupil, constrictors being stimulated by strong light and dilators by weak.

HEARING

The organ of **hearing** is of such minute and complex anatomic formation that only an outline will be given.

A very simple, diagrammatic, conception is that of a membrane which vibrates as the result of blows struck by air waves, the membrane being attached to levers which create waves in a fluid which is in contact with the terminals of the auditory nerve which conveys the stimulus to a definite area of the brain. A tense membrane vibrates at a given rate only, and responds to high or low rates of vibration as the membrane is stretched or relaxed. A drum is essentially a membrane stretched across a circle, and such a membrane, when struck, causes air waves or vibrations at a given number each second; but if the membrane be stretched at one part and relaxed at another, it will practically act as two drums, the tenser segment vibrating more, and the relaxed less, rapidly. At the bottom of our ears we have a membrane **(tympanic)** familiarly known as the "ear-drum" which can be relaxed or stretched to respond to blows of different character. The nerve terminals themselves are arranged to respond to waves

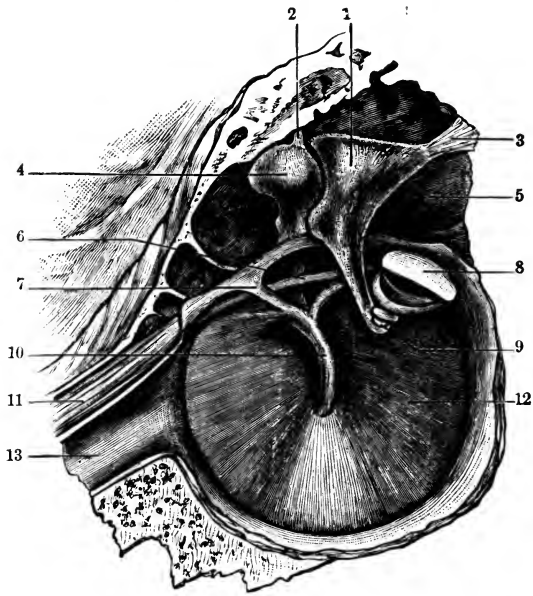

Fig. 32.—Tympanum of right side with the auditory ossicles in place (Morris): *1*, incus (like bicuspid tooth) with one process (*3*) attached to wall of tympanum and the other running downwards to articulate at *9* and *8*, the stapes; *10*, head of malleus attached to tympanic membrane. (From Howell's *Physiology*.)

of different lengths; i.e., vibrations which may be as many as four thousand or as few as thirty to the second.

In man the external ear is of little use in gathering sound and concentrating it upon the drum, though it seems to serve its purpose much better in many lower animals. The tympanic membrane closes the auditory canal and is in contact with the air on both sides—on the outer side with the atmosphere and on the inner with the inspired air as it reaches the back of the nose. This arrangement secures equal pressure on the two faces of the membrane and its importance is readily seen in the impaired sense of hearing when the nose is blocked up by a cold "in the head." Attached to the inner face of this drum and stretching across the middle ear (tympanic cavity) is a chain of minute bones (auditory ossicles) so arranged that they act as a bent lever which moves with every vibration of the drum and conveys these waves to a second drum which closes an opening by which the middle would otherwise communicate with the inner ear. The latter is the part in which the nerve terminals are located. Briefly described the organ consists of a basement membrane stretched from the flanges of a screwlike center to the surrounding wall, on which rest the ends of nerve cells which terminate in hairlike processes in contact with which is a very delicate membrane which is moved by the waves created in the fluid (endolymph) which bathes the organ. The movements of the overlying membrane are communicated to the hairs and these in turn stimulate the nerve cells and the impulse or sensation is conveyed to the brain.

Not all sound is conveyed through the external ear. The sound of our own voices is, in part at least, conveyed through the bones of the head. A tuning fork placed on the teeth will be heard so long as its vibrations can excite movements of the ossicles. A simpler experiment is to stop the ears and apply the teeth to a watch, whose ticking can be heard plainly through the teeth.

The **auditory,** or **eighth** nerve is not entirely given over to conveying sound waves. A part of this nerve is distributed to the semicircular canals and, apparently, conducts sensation to that part of the cerebellum which aids in maintaining equilibrium. They are not the only nerve fibers which convey impulses necessary for this function, but are important paths for such stimuli.

The auditory canal, which is nearly an inch in length,

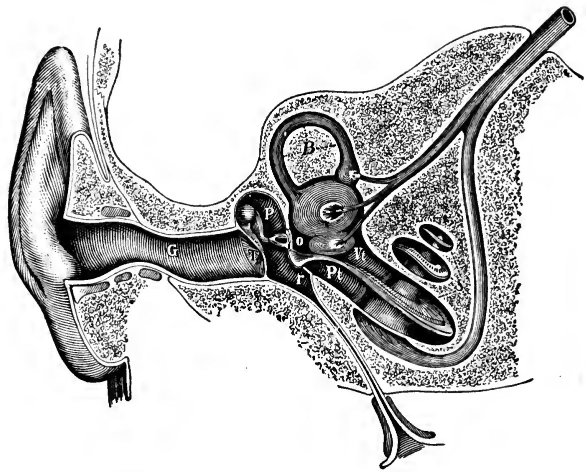

Fig. 33.—Semidiagrammatic section through the right ear (Czermak); *G*, external auditory meatus; *T*, membrana tympani; *P*, tympanic cavity or middle ear with the auditory ossicles stretching across it and the Eustachian tube (*E*) entering it; *o*, oval window; *r*, round window; *B*, semicircular canals; *S*, cochlea; *Vt*, upper canal of cochlea; *Pt*, lower canal of cochlea. (From Howell's *Physiology*.)

is the site of the accumulation of that mixture of the secretion of the sebaceous glands with worn-out cells which we call "ear wax." It is often present in amounts sufficient to impair acuteness of hearing and must be softened and removed, a duty frequently falling upon the nurse.

That our sense of the location and distance from which sounds come is not very acute, is a matter of common

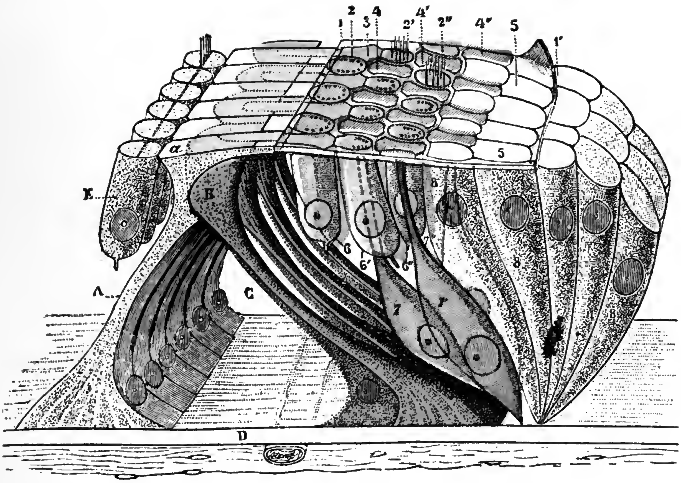

Fig. 34.—Diagrammatic view of the organ of Corti (Testut): *D*, basilar membrane; *A*, *B*, inner and outer rods of Corti; *6*, *6'*, *6"*, hair cells; *7*, *7'*, supporting cells. (From Howell's *Physiology*.)

observation. When we wish to locate a sound we instinctively call in the aid of other senses, the eye notably, and look about us to see if vision can accurately place what hearing only suggests. It is said that the location of sound is more definite when both ears are employed.

CHAPTER XI

SLEEP

Sleep is not only necessary to rest a tired mind and body, but more essential to life than food itself. Complete fasting has extended over periods measured by weeks, but *total* absence of sleep for four or five days is likely to end fatally. The imperative nature of the demand for sleep is shown in the thousands of cases in which soldiers have slept on horseback, while marching and even when on sentry duty, when the penalty is death. Notwithstanding the universality of this physiologic function, we are almost entirely in the dark as to its mechanism, a fact sufficiently proved by the number of theories advanced and the contradictory nature of the evidence adduced in their support. Some of the changes which occur during sleep are established and may be accepted as proved.

Not only is night, when many forms of work must cease for want of light, the time during which most people sleep, but there seems little reason to doubt the statement that night sleep is more restful than that during daylight. "Daylight sleep, in fact, is less recuperative and less profound and unbroken than night sleep." (Luciani). Sleep is usually preceded by drowsiness, indicated by a pricking sensation in the eyes, drooping of the upper lid, probably from fatigue of the muscle which supports it, dulling of the mind and inability to fix the attention. Usually we compose ourselves, the drowsiness deepens until we lose all idea of our surroundings and deep sleep succeeds, to be followed by a lighter slumber until this in turn gives way to a condition quite similar to drowsiness, a half consciousness of our surroundings, an arousing of attention until we are completely conscious or "awake." Sleep, in healthy adults, usually lasts from seven to eight hours, though the time given or required varies greatly with the individual and with age. Newborn infants sleep from eighteen to twenty hours a day, old people five or six. In other words when growth is most active, sleep is most needed. In the old there is no growth and comparatively little repair, while, during the active period of life, though growth has stopped, repair is steady and imperative.

The depth of sleep varies greatly. Normally it would seem that the first two hours are characterized by the deepest sleep, which gives way to a lighter type which, in its turn, is succeeded by more profound unconsciousness a short time before waking. Nearly all secretions are diminished during sleep. The tears, which moisten the eyeballs and lids, are nearly absent even in drowsiness, the dryness of the mouth and throat on waking are evidence of the lack of salivary secretion, while the high color and comparatively small amount of urine accumulated during the night, show that at least the watery part of the urine is decreased. On the contrary perspiration increases to such an extent that it has been asserted that as much is produced during seven sleeping as in fourteen waking hours. Respiration is slower in sleep and often becomes intermittent, particularly in children and the old, and the costal type of breathing is the rule. The heart beats more slowly, though it is said to increase in rapidity near the waking hour. Superficial blood vessels are dilated and congested, while there is an appreciable fall in body temperature, the lowest occuring between midnight and three in the morning.

Not all of our senses fall asleep at the same time or to the same degree. Light is first lost, in fact we deliberately cut off the light by closing the lids. Hearing is never so completely abolished and sensitiveness to touch is present in all but the most profound slumber. Taste and the sense of smell are almost completely abolished. It seems that loss of sensibility of all kinds is due to a change in the cortex of the brain and not in either the peripheral nerve terminals or in the conducting paths. While our muscles are relaxed, they will carry out coordinated movements without our being conscious either of the stimulus, like tickling the nose or lids, or of the movement to brush away the offending body. Of course, frequent repetition of the stimulus will awaken one. Sleep, however, while mainly affecting the brain, is not confined to it. All of our tissues and organs sleep.

There are many theories of sleep but the chief ones are chemical or circulatory.

A chemical theory supposes that the body forms, during waking hours, substances of a more or less poisonous character which, when accumulated in sufficient quantity prevent (inhibit) the activity of the cortex; or that an increase in the acid waste products of the body will exercise the same influence.

A circulatory theory explains the periodic occurrence of sleep by assuming that there is an absence of sufficient blood in the brain (*anemia*) to keep up its normal activity, and that sleep follows, basing the theory largely on the well-established fact that experimental interference with the blood supply of the brain will produce unconsciousness. The theory supposes that the vasomotor center in the medulla becomes fatigued during the day's work, allows the vessels in other parts of the body to dilate and hold more blood and automatically decreases the amount flowing through the brain. No theory has met all the objections. We can, in effect, say nothing confidently save that sleep is necessary, that it follows bodily more than mental activity and that some conditions, notably mental worry, may produce a condition (*insomnia*) most trying to patient, physician, and nurse, and sometimes beyond the power of drugs.

Dreams are attendants of sleeping hours which have not been satisfactorily explained. They at least serve to show that all of the brain is not asleep, or not profoundly asleep; but whether we dream during the entire sleeping period and remember only those dreams which immediately precede waking, or whether we dream only when in the light, or disappearing, sleep which precedes returning consciousness, is a matter entirely unsettled.

Hypnotic sleep should be mentioned, but not discussed. Many observers doubt its occurrence while those who believe in its existence can furnish no satisfactory explanation of the phenomenon.

The sleep induced by drugs should be alluded to. It is neither so restful nor so recuperative as normal sleep, though it may be much more profound. The type of drug-induced sleep will vary with the hypnotic employed and with the dose, as well as with the susceptibility of the patient and his drug habits and antecedents.

CHAPTER XII

REPRODUCTION

The organs concerned in reproduction are, in the female, the **ovary** which produces the egg or cell from which the new being is to be formed, the **fallopian tube,** which conveys the egg to the **uterus,** which is the hatching apparatus, and the **vagina** through which the egg is fertilized and the child born.

Menstruation is seen in the female only. It begins usually in the fourteenth or fifteenth year and recurs at intervals of about 28 days until the "change of life," climacteric, or menopause, which occurs between the forty-fifth and fiftieth years. The appearance of the menstrual flow is earlier in warm than in cold climates; and the cessation of the function varies greatly in different individuals. Removal of the ovaries causes an artificial menopause. It is clear, then, that the activity of the ovary is periodic and is responsible for menstruation; but the actual flow of blood is a function of the uterus, probably in preparation for the reception of the fertile egg. The lining (mucous) membrane of the uterus thickens and becomes engorged with blood four or five days before the appearance of the flow. There follows a period, usually of four days, in which there is hemorrhage into the uterus and the swollen membrane is cast off and this is followed by about a week of regeneration during which time the membrane returns to its normal condition. The next twelve days constitute the resting period.

In perfectly healthy women the other body functions are scarcely affected by the recurrence of the menstrual period. There is usually some slight lack of well being and the woman's efficiency is not quite up to the normal standard. Any further symptoms must be referred not to menstruation but to some diseased condition affecting either the generative or some adjacent viscera.

The ovum (egg) is probably carried into the fallopian tube by the cilia on its extremity, and meets the male cell (spermatazoon) shortly after the entrance of the ovum into that tube. Usually the now fertilized ovum is swept into the uterine cavity and becomes attached to the wall of the uterus where the placenta is formed and remains until the termination of pregnancy; but, owing to unknown causes, the impregnated ovum is sometimes arrested in the tube and an effort is made to produce the fetus in that narrow passage. This is a *tubal pregnancy,* whose natural history ends in rupture of the tube and the death of the mother, unless the condition is discovered and relieved by surgical interference. In rare cases the ovum is impregnated in the peritoneal cavity, never entering the tube, constituting a true abdominal pregnancy.

The **placenta** is the organ which conveys air and nourishment to the fetus during uterine life. The fetus is never in contact with the mother's blood, and, though its own heart beats, is dependent upon the maternal heart to drive blood containing both food and oxygen into the placenta from which it is carried into the fetal vessels. Between the fetus and the mother's blood are interposed tissues which permit diffusion through them in a way similar to that by which the mother's own tissues are nourished by her blood stream. In other words the fetus is, practically, a part of the mother's body.

Parturition is the act of bringing the child into the world. The "term of pregnancy" is about ten lunar months (280 days) from the time of the last menstruation. Delivery is accomplished by involuntary contraction of the uterine muscle fiber aided by voluntary contraction of the diaphragm and the muscles of the abdominal wall. The cause of the uterine contractions is unknown, though possibly a hormone produced by the mammary gland may excite them.

The **mammary** gland begins to enlarge and form secreting alveoli shortly after pregnancy is established and towards the end secretes a small amount of a fluid called *colostrum*. After delivery the gland is actively stimulated and rapidly enlarges. For a few days the secretion retains the character of colostrum, but, usually on the third or fourth day, the flow of milk has become well established.

There is some evidence that the fetus forms a hormone which stimulates growth of the mammary gland, but inhibits its secretion. This substance is withdrawn when the fetus is born and its removal permits the functional activity of the gland.

That the mammary gland is under the control of the central nervous system is indicated by the effects of various emotions upon its secretion; but there are no known secretory nerves, though there are vasoconstrictor and vasodilator fibers as in the other glands.

The male cell which fertilizes the ovum is secreted by the testicle, an organ analogous to the ovary of the female.

CHAPTER XIII

GROWTH AND OLD AGE

The rate of growth does not increase from birth to maturity and then decline, but declines steadily from the impregnation of the ovum until death. The fetus grows most rapidly during the first month of uterine life—the *rate* of growth declining from this time until the end—the average child nearly triples its weight at birth in its first year, but only gains about twenty-five per cent during the second year, and at a still lower rate for each succeeding year. Other changes indicate the gradual loss of the power of living always—bones become more brittle, cartilage more rigid, muscles less elastic, all changes which, while serving a useful purpose in some cases, none the less show that animals begin to die before they are born, and that, independent of disease, death is as natural a process as birth. As few, however, die a natural death, a death which is simply the wearing out of the protoplasm of which the body is made, we have little or no idea of the number of years which a perfectly healthy person might live if no disease or accident intervened to bring life to a sudden termination. The only authentic case of great longevity is that of Thomas Parr (usually known as "old Parr") who reached the age of one hundred and fifty-two years, and is supposed to have been brought to an untimely end by high living and drinking.

The rate of growth, up to the time of puberty (the development of the sexual functions) is greater in girls than in boys. Girls between twelve and fifteen are better developed than boys of that age, while beyond fifteen the boy's growth is stimulated while the girl's is moderated. Consequently the male overtakes and passes the female. Growth, particularly of the skeleton, is not arrested by underfeeding. The thymus and pituitary glands form hormones which stimulate the growth of the skeleton, which will, in the underfed, continue to grow at the expense of the other tissues, notably the muscles. Possibly some such internal secretion, or the derangement of an internal secretion, is influential in the growth of tumors, such as cancer. Whether man may learn to control, by proper diet, the rate and amount of growth, is still unknown; but the indications are that a further knowledge of the internal secretions may point out the method by which dwarfism and gigantism may be avoided and a uniform growth may be attained. A much larger proportion of ingested food is utilized for growth in the lower animals than in man. In a large number of mammals it has been determined that 340 out of every thousand calories is used for growth, while man employs but five per cent for the same purpose.

After growth ceases, our food is employed in creating energy and effecting repair. Gradually the protoplasm loses its power of growth, maturity is reached, decline begins, and death finally terminates the existence of the individual. With no intervening disease or injury, and with perfect food and surroundings, probably the ultimate end would be reached by the simultaneous death, or wearing out, of all the tissues, and life would end like the wonderful "One-Hoss Shay"—

> "All at once and nothing first,—
> Just as bubbles do when they burst."

APPENDIX

CHEMICOPHYSICS

If we reflect upon all that surrounds us, even ourselves, we find that we may classify the sources of all our impressions under the heads of **matter, energy, and spirit.** (Mallet).

Matter is any thing which occupies space. Hence liquids, gases and solids are all forms of matter, and our common experience proves that these substances may be measured and determined to have *length, breadth,* and *thickness* or any of these qualities. When matter extends in but one direction it has length; when in two, we speak of it as *area.*

Mass is the amount of matter contained in any body under examination.

Divisibility.—All matter is capable of being divided. We may break up a piece of iron or one of chalk into many particles; but finally a subdivision is reached beyond which we are, so far, unable to go. This last subdivision is so minute as to be invisible and is called an *atom,* the unit by which different forms of matter unite with similar units of other forms to create combinations.

Matter, as has been seen, exists in three states, liquid, gaseous and solid. Matter in any state has its peculiarities which we designate the *properties of matter.* Thus a body may be elastic, returning to its original form after bending or twisting; porous, having spaces between its particles in which other matter may insinuate itself —an apparent exception to the law of *impenetrability,* i.e., no two bodies can occupy the same space at the same time; compressible, depending on its porosity; and containing properties by which matter may be converted into energy.

Energy is capacity for work and is made known to us by changes in matter. Some of the many forms of energy are *mechanical energy, gravity, cohesion, adhesion, heat, light, electricity, and chemical energy.*

Mechanical energy changes the condition of masses of matter as respects motion or rest (Mallet). The use of water to turn a mill wheel is an illustration of mechanical energy by that natural force which we call *gravity.* It is simply the weight of the water which turns the wheel. If the water is too small in quantity or the wheel too heavy, no movement will result. If the mass of water is great in proportion to the resistance of the wheel, the motion will be rapid. Hence mechanical energy is dependent on the mass to be moved.

Gravity is the mutual attraction which masses of matter exert upon each other. It increases with the masses concerned and decreases with their distance from one another. The earth, the largest mass of matter with which we are familiar, attracts whatever is unsupported in proportion to its density and the measure of this attraction is the *weight of the body.* Various systems of measuring weight are used, the avoirdupois in English-speaking countries and the Metric in France. The Metric system, however, is becoming universal in science.

Specific gravity, or **specific weight** means the weight of a given body when compared with the weight of a known standard. For liquids and solids the standard is distilled water at four degrees centigrade, and for gases hydrogen at zero centigrade.

Instruments for determining the specific gravity of liquids are called *hydrometers.* They are made of glass with weight in the bottom, a bulb in the middle, and a stem containing a scale at the top. When placed in a liquid they sink to a certain level, and the specific gravity is then read from the scale. Specific names are given modifications of these instruments intended for definite liquids, as *urinometer, lactometer,* etc., for urine and milk.

Cohesion and Adhesion.—Cohesion is the force by which the particles of matter of the *same kind* are held together. The particles of a bar of iron for instance *cohere* or are held together by cohesion. Adhesion is that form of energy by which masses of matter of *different kinds* are held together, as when a carpenter joins two pieces of wood with glue. It is obvious that cohesive energy must be exerted in greatly different measure in different masses. It is powerfully shown in the bar of iron and inappreciably in a volume of water. Cohesion, therefore, acts not only at immeasurably small distances, but with such varying force as to determine the hardness of the diamond or the softness of wax. Adhesion is sometimes employed to remove one substance from another, as in the process of filtration through charcoal to remove coloring matter. Matter is said to be *hard* when it requires great force to scratch it; *brittle,* when it breaks only from violent blows; *tenacious,* when it resists stretching; *malleable* when it can be beaten into thin sheets, and *ductile* when it can be pulled out into fine strands, like wire.

Crystals are solid substances bounded by plane faces and definite angles (Bliss and Olive). The process of forming crystals is called crystallization.

PROPERTIES OF LIQUIDS

If a small tube is inserted into a glass of water it will be seen that the water in the tube rises to a higher level than that in the glass. This is due to *cohesion* between the particles of water and *adhesion* between the water and the tube, the adhesion being, in this case, the stronger. If the experiment is repeated, but mercury substituted for water, the column in the tube will be lower than the level of the mercury in the glass. Here the cohesion of the particles of mercury is stronger than the adhesion of the mercury to the tube.

Diffusion is another property of liquids by which two liquids of different specific gravity will mix without shaking even though the lighter be placed at the top. This does not apply to liquids not soluble in each other. If the two liquids are separated by a thin membrane they will still mix, a process called *dialysis.* Some fluids will not mix in this way. Those which diffuse through a membrane are called *crystalloid,* and those which will not diffuse are called *colloid.*

Solution.—When matter, solid, liquid or gaseous, is permanently mixed with liquid, forming a uniform body which does not separate on standing, the one is said to be dissolved in the other, or a *solution* has been formed. The most familiar example is the solution of sugar in coffee, or other drink, to sweeten it. When it is desired to separate a solid from a liquid in which it has been dissolved, the liquid is passed through some porous material to which the solid adheres, leaving the liquid behind. This process is called *filtration.* Many solids in solution can not be extracted by this process, but some can be with much saving of time and labor.

PROPERTIES OF GASES

The most striking characteristic of all gases is their tendency to expand indefinitely in all directions, especially when heated, and to mix with other gases by a process similar to the diffusion of liquids. The opposite character, extreme compressibility, is equally striking. Indeed, under sufficient pressure accompanied by a very low temperature, gases may be compressed until they become liquid. This tendency to expansion permits ventilation by the simple process of opening the window. The warmer gas tends to expand and rise to the window while the colder gas (air) from the outside tends to sink to the floor. There are thus two currents of gas at all times, one entering and one leaving through the same opening. The atmospheric air is composed of gases which, however light, still have weight sufficient to exert a pressure of about fifteen pounds to the square inch, or to sustain a column of mercury of about thirty inches in height. It is upon this atmospheric pressure that the barometer is based.

HEAT, LIGHT, AND ELECTRICITY

Heat is a *form of motion.* Not only is this true, but heat may be converted into motion or motion into heat. All matter, even the densest, is supposed to contain minute spaces between the molecules of which it is composed, which spaces are filled with an elastic and imponderable *ether* which permits absolute freedom of vibratory movement of the particles. If the movement is at a rapid rate, the heat will be great; if at a lower velocity, the heat will be less, but heat is always present, even in ice. This is called the *undulatory theory* of heat.

The most striking constant action of heat is to cause expansion. If the expansion is in but one direction, it is called *linear,* if in two, *superficial,* and in three *cubical.* Of course expansion really always takes place in three directions. Thus steel rails on a railway expand chiefly in a linear direction, because their bulk in this direction is greatest, but they also expand superficially and cubically. Changes in volume, therefore, result from increase or loss of heat. Advantage is taken of this fact to make the instrument with which the degree of heat is measured—the thermometer. Matter which absorbs moisture contracts under the influence of heat, because the rise in temperature expels the moisture. Wood and paper are good examples of such bodies.

Temperature is not heat, but is simply a measure of the *hotness* of a given body. A *degree* of temperature is a unit for measuring hotness as a stick of thirty-six inches is a unit for measuring goods. The thermometer is simply a glass tube containing a substance which expands rapidly in the presence of heat or contracts when some of the heat is removed. Mercury and alcohol are the two substances in chief use for this purpose—mercury because it remains liquid in any but extreme heat or cold, and alcohol because it is practically unfreezable.

The scale of a thermometer is arrived at by finding two constant points—that of melting ice and that of boiling water. In the centigrade scale the melting point of ice is marked zero, while in the Fahrenheit, thirty-two degrees indicate this point. The boiling point of water is marked 100 in centigrade and 212 in Fahrenheit. One degree Fahrenheit is equal to $5/9$ degree centigrade. To convert Fahrenheit to centigrade, therefore, subtract 32 and multiply by $5/9$.

Example: $104° - 32 = 72. \quad 72 \times 5/9 = \frac{360}{9} = 40°$ C.

To convert centigrade into Fahrenheit multiply by 9, divide by 5, and add 32.

Example: $36° \times 9 = 324$. $324 \div 5 = 64.8$. $64.8 + 32 = 96.8°$ F.

Heat is transmitted by *conduction, radiation,* and *convection.* Hold a poker in the fire until the end is red hot and you will find the part in the hand uncomfortably warm. This is heat transmitted by *conduction,* Place water in a vessel and apply heat to the bottom. The heated particles of water rise to the top. This is transmitting by *convection.* When sitting before an open fire one often places a screen between the fire and one's person to prevent the radiation of the heat rays. If the air were heated uniformly by the fire the screen would be no protection. This is *radiation* of heat.

Heat is employed to liquefy solids (*fusion*), to alter organic bodies as in roasting, to separate volatile from less volatile matter (vaporization), to destroy organic life as in sterilization and, particularly by the chemist, in many other processes.

LIGHT

Light is the agent which, by its action on the retina, excites in us the sensation of vision. All bodies, as well as the celestial spaces, are filled by an extremely subtle elastic medium, which is called the *luminiferous ether.* (Ganot). The luminosity of a body is due to rapid vibrations of its molecules. These vibrations are communicated to the ether and through it to the terminals of the optic nerve in the retina.

Sources of Light.—The chief source of light is the sun; but light is obtained by chemical combination, heat, electricity and phosphorescence. Heat produces light only when bodies have their temperature raised to five or six hundred degrees. Chemical combinations produce light also by heat, since luminous flames are simply gases which contain solids heated to incandescence. Phosphorescence is exhibited by decaying wood, or fish, by glowworms, etc.

Some bodies, like wood, metals and many others, completely stop light and are called *opaque*. Others, like glass, air, and clear water allow light to pass and are called *transparent* or *diaphanous;* while others permit only a portion of the light to pass, thin porcelain for instance, and are said to be *translucent*. No body transmits all of the light which falls upon it, but even the most transparent absorb some of the rays.

Propagation of Light.—A medium is any space or substance which light can traverse (Ganot) and is called *homogeneous* when its density is the same in all parts, like air. Through all homogeneous media light is transmitted in a straight line. Light emanates from a luminous body in all directions (Ganot), but changes its direction when it strikes a medium of different density. If the new medium is impenetrable, light will be *reflected;* if penetrable, *refracted*.

When a beam of sunlight passes through a small opening it forms a small pencil-like bundle of rays. If these strike a polished surface they are bent or turned away from the surface at the *same angle at which they struck it*. The angle at which the entering sunbeam struck the polished surface is called the *angle of incidence;* while that at which it turns away is called the *angle of reflection*. The rule, therefore, is that "the angle of reflection is equal to the angle of incidence." As is the case of passing through a medium, not all the light is reflected, but some is always absorbed by the reflecting surface while some is irregularly reflected as *diffused* light. It is diffused light which makes nonluminous bodies visible. "From the inside of our rooms we well see external objects, for they are powerfully illuminated; but from the outside we only see confusedly the objects in the interior for they receive but little light." It is the great diffusion on the outside and the slight amount inside which causes the difference. When the room is illuminated at night the opposite is true.

Refraction.—When light passes obliquely from a less dense through a denser medium it is bent away from its original path or *refracted* (from a Latin word meaning broken). Glass is denser than air. A lens is a piece of glass which may be flat on one side and hollow on the other—*planoconcave*—flat on one side and bulging on the other—*planoconvex,*—bulging on both sides—*biconvex* or *double convex,*—or concave on both sides—*biconcave* or double *concave.* A ray passing through the exact center of any lens is not bent; but a ray which strikes obliquely, as any ray not in the exact center must strike on concave or convex surfaces, is bent *toward* a common center in convex and *away from* the center in concave lenses, or the rays are *converged* by convex and *diverged* by concave lenses. As animal eyes have double convex lenses which do not always fit the eye in which they are found, oculists make use of this principle of refraction to place glasses in front of the eye to converge or diverge the rays and thus correct the refractive error of the natural eye.

The point at which all of the rays must meet after passing through a lens is called its "focal point." The more convex a lens, the nearer to the lens is the focal point; i.e., the more abruptly it breaks or bends the rays. The path through the center of the lens is its *principal axis* and parallel rays emitted from the lens are converged to this principal axis forming the focus. Concave lenses diverge the rays emitted and have no actual focus.

Prisms.—"A prism is any transparent medium comprised between two plane faces inclined to each other." A ray of light passing through a prism is not only refracted, but is broken up into the different colors of which light is composed. The undulatory theory teaches that light is dependent upon vibrations of the ether. The different colored rays vibrate at different rates—red, the slowest, at 458 millions of millions a second, and violet, the swiftest, at a rate of 727 millions of millions a second. Between these extremes the other colors are interspersed, with varying rates for each, in the order, violet, indigo, blue, green, yellow, orange and red.

ELECTRICITY AND MAGNETISM

"Symmers' theory assumes that every body contains an indefinite amount of subtile imponderable matter which is called *electrical* fluid," formed by the union of two fluids distinguished as positive and negative; that in the natural state the two neutralize each other, but that they can be separated by friction and other means, one never appearing without the other, though either may be present in excess of the other, so that a body may be either *positively* or *negatively* electrified. "Electricities of the same kind repel one another, and electricities of opposite kinds attract each other." Electricity circulates freely over some bodies and does not circulate over others. The first are called *conductors* and the second *nonconductors*.

Electricity may be frictional when produced by rubbing, but some bodies, like glass, give positive while others give negative electricity. "The human body, when rubbed with silk, becomes negatively charged, with wool, positively charged."

Chemical electricity is the result of the action of an acid on two metals, frequently zinc and carbon. That which is acted on most readily, zinc in this instance, is called the *positive* plate, indicated by the plus sign +, while the one which resists the acid more is the *negative* plate, indicated by the minus sign —.

Such plates, united by copper wires, which are good conductors, form, when immersed in an acid solution, a *galvanic cell.* "The ends of the wires leading from the plates are called *electrodes,* the positive plate (+) called the *cathode* or *negative pole,* while that connected with the negative plate (—) is the *anode* or *positive pole.* A battery is a combination of a number of cells" (Bliss and Olive).

Some of the terms employed in electrical science are the *volt,* or unit of electromotive force; the *ampere* or unit of quantity which passes through a standard conductor in a given time; the *ohm* or unit of resistance offered by a copper wire 250 feet long and a twentieth of an inch thick, and the *watt,* or unit of work.

When an electric current is passed through a Crookes tube it produces a ray which has the power of passing through and illuminating bodies impenetrable to ordinary light. These are called "x-rays," or Roentgen rays, and have proved of immense service to the medical profession in locating foreign bodies, fractures and many other conditions formerly very obscure.

MAGNETISM

The horseshoe magnet, so familiar as a toy, is the com monest and best known display of magnetic force. Any piece of steel may be magnetized and when this has been done, it is found to have a positive and a negative pole, just as electricity. If the rod of steel so treated is broken there are two magnets, each with its two poles, and this may be repeated again and again with the same result. The natural magnet is an oxide of iron which has the power of attracting other metals. Just as is the case with the electric current, like poles repel and unlike poles attract each other.

The chief use of magnetism is in the mariner's compass which enables the sailor night or day, cloudy or fair, always to know the direction in which the ship sails, and renders navigation a thing of certainty instead of pure guess work. It is of great service, also, in removing minute pieces of iron or steel from the eye or from wounds inflicted by such fragments.

CHEMISTRY

Matter is constantly undergoing changes which are either *physical* or *chemical*. If sugar is dissolved in water, neither sugar nor water is changed. The sugar may be extracted and the same amounts of water and sugar remain. But when iron rusts on exposure to air, a part of the iron has joined some of the oxygen of the air and a new product has been formed. The first case is purely physical and the second chemical. The first is a *mixture*, the second a *chemical combination*. In the first illustration neither substance has been changed in character; in the second both have been altered, and, while in either the process may be reversed and both elements recovered, the method of recovery is different —the one physical and the other chemical. Chemical changes are called *reactions* and are of two kinds, i.e.,

synthetic, when combinations are made, and **analytic** when they are broken up. The force which makes two or more elements unite to form a new mass of matter is called *chemical affinity* and acts on different elements with varying degrees of violence at inappreciable distances.

"**Chemistry** is that science which treats of the composition of matter and the changes in composition." (Bliss and Olive).

Elements.—Those substances which have resisted every effort to reduce them to simpler forms are known as *elements.* Iron, silver, gold, potash, soda, oxygen, etc., are examples of these primary bodies. A table of elements with their atomic weights and symbols is appended. To save space and time, the whole name of an element is not written when a chemical combination is to be expressed by a *formula,* but the first letter of the name of the element is used as a capital, followed by a small letter taken from the name when the names of two elements begin with the same letter. Thus H is the symbol of hydrogen and Hg the symbol of mercury, the official name of which is hydrargyrum; or Fe (ferrum) iron, while F stands for fluorine. Elements can not be divided into simpler bodies, but every element is composed of invisible particles called *atoms* and as atoms, however small, none the less have weight, the symbols of the elements represent an atom of that element which has a weight, as compared with some other element used as a standard, called its *atomic weight.* As hydrogen is the lightest of known elements, it has been selected as the standard. The symbol "H" means one atom of hydrogen having a weight represented by the figure 1, while the volume of oxygen of the same cubic measure of the volume of hydrogen is found to weigh 15.88 times the volume of hydrogen. Therefore, in the table of elements, hydrogen is represented by the letter "H" and its atomic weight by the figure 1, while oxygen is represented by the symbol or letter "O" and its atomic weight by the figures 15.88. In the same way uranium, the heaviest of all elements, is represented by the symbol "U," and the atomic weight by the figures 239.5—i.e., it is two hundred thirty-nine and a half times heavier than hydrogen with which it is compared. Atoms, of course, can not be separated and weighed; so the atomic weight is not an actual but a relative weight. When more than one atom occurs in any chemical combination, small figures placed at the right of the symbol indicate the number of atoms engaged in that combination. Thus H_2O means two atoms of hydrogen combined with one of oxygen to form the chemical combination of *water*. These three atoms, thus united, form a *molecule*, and the *molecular* weight of a substance is the sum of the atomic weights of the elements entering into its combination.

Examples: H_2O = Hydrogen 2 atoms weighing 2
Oxygen 1 atom " 15.88

Hydrogen 2 atoms weighing	2
Oxygen 1 atom "	15.88
Molecular weight of water	17.88

The formula of ammonia is H_3N or

Hydrogen 3 atoms weighing	3
Nitrogen 1 atom "	13.93
Molecular weight of ammonia	16.93

Hydrochloric acid is represented by the formula HCl or

Hydrogen 1 atom weighing	1
Chlorine 1 " "	35.18
Molecular weight of hydrochloric acid	36.18

It will be noted that in these three combinations, hydrogen is represented by one, two, and three atoms for chlorine, oxygen and ammonia. The number of atoms of each element required to enter into combination with another element is called *valence*, or "that property of an element which determines the number of atoms of another element which its atom can hold in combination." One atom of hydrogen can never hold in combination more than one atom of another element. For this reason hydrogen is the standard of measure for valence as well as for atomic weight. Those elements which combine with one atom of hydrogen are called *monads*, or *univalent*, with two, *diads*, or *divalent*, with three, *triads* or *trivalent* etc.

In writing out the result of chemical changes one finds that all the elements entering into the change can be expressed by an equation in which the signs + or —, and of equality =, may be employed. every atom in the substances on the left of the sign of equality must be accounted for on the right of that sign, if the change is correctly interpreted. Thus: nitrate of silver, when acted on by hydrochloric acid, is changed into chloride of silver and nitric acid expressed by the following equation:

$$AgNO_3 + HCl = AgCl + HNO_3$$

On the left we have one atom of silver, one of nitrogen and three of oxygen, combined to form nitrate of silver. To this we add one atom of hydrogen and one of chlorine, combined to form hydrochloric acid. The change which takes place is that the chlorine displaces the molecule NO_3 which is joined by the hydrogen and the result is that on the right we now have one atom of silver combined with one of chlorine, forming chloride of silver, while one atom of hydrogen has joined one of nitrogen and three of oxygen to form nitric acid; but, while we have two new substances, we have exactly the same number of atoms. Such changes result when the chemical affinity of one element is stronger than that of another. In this example nitrogen, an inert substance whose chemical affinities are not strong, is replaced by chlorine whose affinity is strong and active.

Acids.—"An acid is a substance consisting of hydrogen and a nonmetallic element or radical, which usually has a sour taste, turns litmus red, and is capable of reacting with a base to form a salt and water." In the example given above the radical (the nonmetallic element which combined with hydrogen) is made up of one atom of nitrogen and three of oxygen. When, therefore, acids combine with *bases* to form salts, it is the *radical* which thus combines, i.e., in silver nitrate $AgNO_3$, the nitric acid having lost its hydrogen which combined with O to form water and was replaced by an atom of H.

Acids which have but one element of H to be replaced in combination with bases are called *monobasic*, those with two, *dibasic*, etc.

Bases.—"A base is a compound in which a metallic element is linked to hydrogen by means of oxygen, turns litmus blue, and is capable of reacting with an acid, forming a salt and water."

Bases have a group of oxygen and hydrogen (OH) atoms called *hydroxyl* and the bases themselves are called *hydroxides*. If there is one OH group the base is *monoacid*, if two, *diacid*, etc.

Salts.—These substances are "products of the interaction of acids and bases." A base like sodium hydroxide may be converted into common table salt (sodium chloride) and water. The change is expressed in the following formula:

$NaOH$	+	HCl	=	$NaCl$	+	H_2O
Sodium Hydroxide		Hydrochloric acid		Sodium Chloride		Water

One atom of soda (Na) looses a molecule composed of an atom of O and one of H, and is joined by an atom of chlorine taken from a molecule of hydrochloric acid whose hydrogen made the second atom of that element necessary to form a molecule of water.

It was never the writer's intention to compose a textbook of chemistry and physics but to give a bare outline which would be of assistance to those students of physiology who have not had a proper course in those subjects. The student is, therefore, referred to regular works for further enlightenment.

SYMBOLS AND ATOMIC MASSES ("WEIGHTS") OF THE ELEMENTS

NAME	SYMBOL	ATOMIC WEIGHT	AT. WT. (*approx.*)
Aluminum, ...	Al	26.9	27.
Antimony (*Stibium*), . . .	Sb	119.1	119.
Argon, ...	A	39.6 ?	
Arsenic, ...	As	74.4	74.5
Barium, ...	Ba	136.4	136.5
Beryllium, ...	Be	9.03	9.
Bismuth, ...	Bi	206.9	207.
Boron, ...	B	10.9	11.
Bromine, ...	Br	79.36	79.5
Cadmium, ...	Cd	111.6	
Cæsium, ...	Cs	132.	
Calcium, ...	Ca	39.7	40.
Carbon, ...	C	11.91	12.
Cerium, ...	Ce	139.	
Chlorine, ...	Cl	35.18	35.
Chromium, ...	Cr	51.7	
Cobalt, ...	Co	58.56	
Copper (*Cuprum*), ...	Cu	63.1	63.
Erbium, ?	Eb	164.8	
Fluorine, ...	F	18.9	19.
Gadolinium, ?	Gd	155.	
Gallium, ...	Ga	69.5	
Germanium, ...	Ge	71.5	
Gold (*Aurum*), ...	Au	195.7	
Helium, ...	He	4. ?	
Holmium, ?	Ho	162.	
Hydrogen, ...	H	1.	1.
Indium, ...	In	113.1	
Iodine, ...	I	125.9	126.
Iridium, ...	Ir	191.5	
Iron (*Ferrum*), ...	Fe	55.6	55.5
Krypton, ...	Kr	81.2 ?	
Lanthanum, ...	La	137.	
Lead (*Plumbum*), ...	Pb	205.35	205.5
Lithium, ...	Li	6.98	7.
Magnesium, ...	Mg	24.18	24.
Manganese, ...	Mn	54.6	54.5
Mercury (*Hydrargyrum*), .	Hg	198.8	199.
Molybdenum, ...	Mo	95.3	
Neodymium, ...	Nd	142.5	

Symbols and Atomic Masses ("Weights") of the Elements

NAME	SYMBOL	ATOMIC WEIGHT	AT. WT. (*approx.*)
Neon, ...	Ne	19.9 ?	
Nickel, ...	Ni	58.3	
Niobium, ...	Nb	93.3	
Nitrogen, ...	N	13.93	14.
Osmium, ...	Os	189.6	
Oxygen, ...	O	15.88	16.
Palladium, ...	Pd	105.2	
Phosphorus, ...	P	30.77	31.
Platinum, ...	Pt	193.3	193.5
Polonium, ?	Po	?	
Potassium, (*Kalium*) . . .	K	38.86	39.
Praseodymium, ...	Pr	139.4	
Radium, ?	Ra	?	
Rhodium, ...	Ro	102.2	
Rubidium, ...	Rb	84.76	
Ruthenium, ...	Ru	100.9	
Samarium, ?	Sa	148.9	
Scandium, ...	Sc	43.8	
Selenium, ...	Se	78.5	
Silicon, ...	Si	28.2	28.
Silver, (*Argentum*) . . .	Ag	107.12	107.
Sodium, (*Natrium*) . . .	Na	22.88	23.
Strontium, ...	Sr	86.94	87.
Sulphur, ...	S	31.83	32.
Tantalum, ...	Ta	181.6	
Tellurium, ...	Te	126. ?	
Terbium . ?	Tb	158.8	
Thallium, ...	Tl	202.6	
Thorium, ...	Th	230.8	
Thulium, . ?	Tu	170.	
Tin (*Stannum*)	Sn	117.6	117.5
Titanium	Ti	47.7	
Tungsten (*Wolfram*) . . .	W	182.6	
Uranium, ...	Ur	237.7	
Vanadium, ...	V	50.8	
Xenon, ...	X	127. ?	
Ytterbium, . ?	Yb	172.	
Yttrium, ...	Yt	88.3	
Zinc, ...	Zn	64.9	65.
Zirconium, ...	Zr	90.	

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