QUESTIONS FOR TOPICAL REVIEW.

CHAPTER VI.

"THE CIRCULATION."

The Blood—Its Plasma and Corpuscles—Coagulation of the Blood—The Uses of the Blood—Transfusion—Change of Color—The Organs of the Circulation—The Heart, Arteries, and Veins—The Cavities and Valves of the Heart—Its Vital Energy—Passage of the Blood through the Heart—The Frequency and Activity of its Movements—The Pulse—The Spygmograph—The Capillary Blood-vessels—The Rate of the Circulation—Assimilation—Injuries to the Blood-vessels.

I. The Blood.—Every living organism of the higher sort, whether animal or vegetable, requires for the maintenance of life and activity, a circulatory fluid, by which nutriment is distributed to all its parts. In plants, this fluid is the sap; in insects, it is a watery and colorless blood; in reptiles and fishes, it is red but cold blood; while in the nobler animals and man, it is the red and warm blood.

2. The blood is the most important, as it is the most abundant, fluid of the body; and upon its presence, under certain definite conditions, life depends. With the exception of a few tissues, such as the hair, the nails, and the *cornea* of the eye, blood everywhere pervades the body, as may be proven by puncturing any part with a needle. The total quantity of blood in the body is estimated at about one-eighth of its weight, or eighteen pounds.

3. The color of the blood, in man and the higher animals, as is well known, is red; but it varies from a bright scarlet to a

dark purple, according to the part whence it is taken. "Blood is thicker than water," as the adage truly states, and has a glutinous quality. It has a faint odor, resembling that peculiar to the animal from which it is taken.

4. When examined under the microscope, the blood no longer appears a simple fluid, and its color is no longer red. It is then seen to be made up of two distinct parts: first, a clear, colorless fluid, called the *plasma;* and secondly, of a multitude of minute solid bodies, or corpuscles, that float in the watery plasma. The plasma, or nutritive liquid, is composed of water richly charged with materials derived from the food, viz., albumen, which gives it smoothness and swift motion; fibrin; certain fats; traces of sugar; and various salts.

5. The Blood Corpuscles.—In man, these remarkable "little bodies,"—for that is the meaning of the word *corpuscles*—are of a yellow color, but by their vast numbers impart a red hue to the blood. They are very small, and if piled one above another, it would take at least 14,000 of them to stand an inch high.

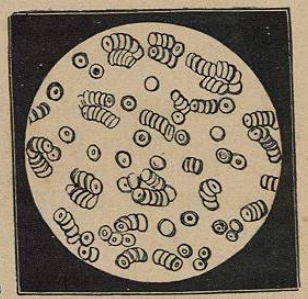

FIG. 18.—THE BLOOD CORPUSCLES HIGHLY MAGNIFIED.

6. The corpuscles, just described, are known as the *red* blood-corpuscles. Beside these, and floating along in the same plasma, are the white corpuscles. These are fewer in number, but larger and globular in form. They are colorless, and their motion is less rapid than that of the other variety. The total number of both varieties of these little bodies in the blood is enormous. It is calculated that in a cubic inch of that fluid there are eighty-three millions, and at least five hundred times that number in the whole body.

7. Coagulation.—The blood, in its natural condition in the body, remains perfectly fluid; but, within a few minutes after its removal from its proper vessels, a change takes place. It begins to coagulate, or assume a semi-solid consistence. If allowed to stand, after several hours it separates into two distinct parts, one of them the coagulum, or clot, which is heavy and sinks; and the other, a clear, straw-colored liquid, called serum, which covers the clot.

8. In this law of coagulation of the blood is our safeguard against death by hemorrhage, or loss of blood. If coagulation were impossible, the slightest injury in drawing blood would prove fatal. Whereas now, in ordinary small wounds, bleeding ceases, because the blood, as it coagulates, stops the mouths of the injured blood-vessels. When the larger vessels are cut or torn, it is commonly sufficient to close them by a temporary pressure; for in a few minutes the clot will form and seal them up. In still more serious cases, where the blood-vessel is of large size, the surgeon is obliged to tie a "ligature" about it, thereby preventing the force of the blood-current from washing away the clots, which, forming within and around the vessel, close it effectually.

9. The Uses of the Blood.—The blood is the great provider and purifier of the body. It both carries new materials to all the tissues, and removes the worn out particles of matter. This is effected by the plasma. It both conveys oxygen and removes carbonic acid. This is done through the corpuscles.

10. Change of Color.—The blood undergoes a variety of changes in its journey through the system. As it visits the different organs it both gives out and takes up materials. In one place it is enriched, in another it is impoverished. By reason of these alterations in its composition, the blood also changes its color. In one part of the body it is bright red, or arterial; in another it is dark blue, or venous. In the former case it is pure and fit for the support of the tissues; in the latter, it is impure and charged with worn-out materials. (The details of the change from dark to bright will be given in the chapter on Respiration.)

11. Circulation.—The blood is in constant motion during life. From the heart, as a centre, a current is always setting toward the different organs; and from these organs a current is constantly returning to the heart. In this way a ceaseless circular movement is kept up, which is called the Circulation of the Blood. This stream of the vital fluid is confined to certain fixed channels, the blood-vessels. Those branching from the heart are the arteries; those converging to it are the veins. The true course of the blood was unknown before the beginning of the seventeenth century. In 1619 it was discovered by the illustrious William Harvey. Like many other great discoverers, he suffered persecution and loss, but unlike some of them, he was so fortunate as to conquer and survive opposition. He lived long enough to see his discovery universally accepted, and himself honored as a benefactor of mankind.

12. The Heart.—The heart is the central engine of the circulation. In this wonderful little organ, hardly larger than a man's fist, resides that sleepless force by which, during the whole of life, the current of the blood is kept in motion. It is placed in the middle and front part of the chest, inclining to the left side. The heart-beat may be felt and heard between the fifth and

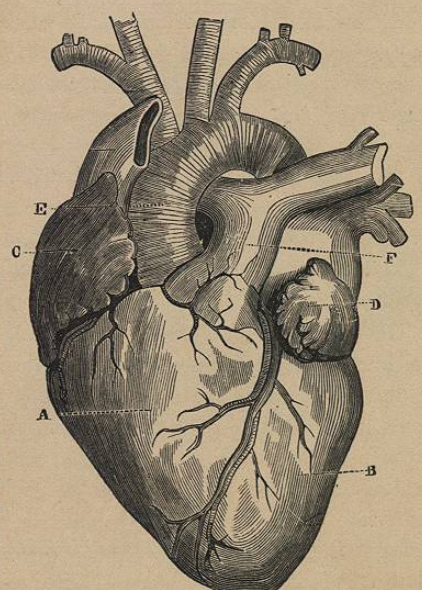

FIG. 19.—THE HEART AND LARGE VESSELS.

A, Right Ventricle.
B, Left "
C, Right Auricle.
D, Left Auricle.
E, Aorta.
F, Pulmonary Artery

sixth ribs, near the breast-bone. The shape of the heart is conical, with the point downward and in front. The base, which is upward, is attached so as to hold it securely in its place, while the point is freely movable. To avoid friction, the heart is enclosed between two layers of serous membrane, which forms a kind of sac. This membrane is as smooth as satin, and itself secretes a fluid in sufficient quantities to keep it at all times well lubricated. The lining membrane of the heart, likewise, is extremely delicate and smooth.

13. The Cavities of the Heart.—The heart is hollow, and so partitioned as to contain four chambers or cavities; two at the base, known as the *auricles*, from a fancied resemblance to the ear of a dog, and two at the apex or point, called *ventricles*. An auricle and a ventricle on the same side, communicate with each other, but there is no opening from side to side. The right side always carries the dark or venous blood, and the left always circulates the bright or arterial blood.

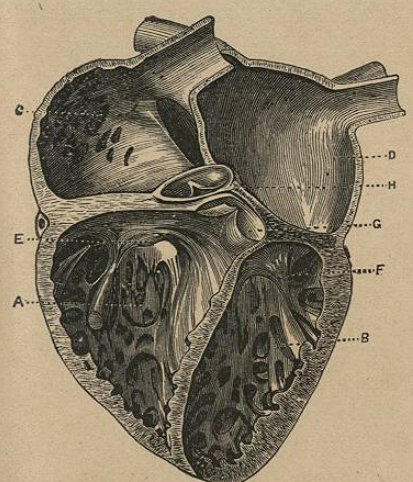

FIG. 20.—SECTION OF THE HEART.

A, Right Ventricle.
B, Left "
C, Right Auricle.
D, Left Auricle.
E, F, Inlets to the Ventricles.
G, Pulmonary Artery.
H. Aorta.

14. If we examine the heart, we at once notice that though its various chambers have about the same capacity, the walls of the ventricles are thicker and stronger than those of the auricles. This is a wise provision, for it is by the powerful action of the former that the blood is forced to the most remote regions of the

body. The auricles, on the contrary, need much less power, for they simply discharge their contents into the cavities of the heart near at hand and below them—into the ventricles.

15. Action of the Heart.—The substance of the heart is of a deep red color, and its fibres resemble those of the voluntary muscles by which we move our limbs. But the heart's movements are entirely involuntary. The advantage of this is evident; for if it depended upon us to will each movement, our entire attention would be thus engaged, and we would find no time for study, pleasure, or even sleep. The action of the heart consists in alternate contractions and expansions. During contraction the walls come forcibly together, and thus drive out the blood. Then they expand and receive a renewed supply. These movements are called *systole* and *diastole*. The latter may be called the heart's period of repose; and although it lasts only during two-fifths of a heart-beat, or about a third of a second, yet during the day it amounts to more than nine hours of total rest.

16. A remarkable property of the tissue of the heart is its intense vitality. For while it is more constantly active than any other organ of the body, it is the last to part with its vital energy. This is especially interesting in view of the fact that after life is apparently extinguished, as from drowning, or poisoning by chloroform, there yet lingers a spark of vitality in the heart, which, by continued effort, may be fanned into a flame so as to revivify the whole body.

17. Passage of the Blood through the Heart.—Let us now trace the course of the blood through the several cavities of the heart. In the first place, the venous blood, rendered dark and impure by contact with the changing tissues of the body, returns to the right heart by the veins. It enters and fills the right auricle during its expansion; the auricle then contracts and fills the right ventricle. Almost instantly, the ventricle contracts forcibly and hurries the blood along the great artery of the lungs, to be purified in those organs. Secondly, having completed the circuit of the lungs, the pure and bright arterial blood enters the left auricle. This now contracts and fills the left ventricle, which cavity, in its turn, contracts and sends the blood forth on its journey again through the system. This general direction from right to left is the uniform course of heart-currents.

18. The mechanism which compels this regularity is as simple as it is beautiful. Each ventricle has two openings, an inlet and an outlet, each of which is guarded by strong curtains, or valves. These valves open freely to admit the blood entering from the right, but close inflexibly against its return. Thus, when the auricle contracts, the inlet valve opens; but as soon as the ventricle begins to contract, it closes promptly. The contents are then, so to speak, cornered, and have but one avenue of escape, that through the outlet valve into the arteries beyond. As soon as the ventricle begins to expand again, this valve shuts tightly and obstructs the passage. The closing of these valves occasions the two heart-sounds, which we hear at the front of the chest.

19. Frequency of the Heart's Action.—The alternation of contraction and expansion constitutes the heart-beats. These follow each other not only with great regularity, but with great rapidity. The average number in an adult man is about seventy-two in a minute. Heat, exercise, and food increase its action; cold, fasting, and sleep diminish it. Posture, too, has a curious influence; for if while sitting, the beats of the heart number seventy-one, standing erect will increase them to eighty-one, and lying down will lower them to sixty-six.

20. The modifying influence of mental emotions is very powerful. Sudden excitement of feeling will cause the heart to palpitate, or throb violently. Depressing emotions sometimes temporarily interrupt its movements, and the person faints in consequence. Extremes of joy, grief, or fear, have occasionally suspended the heart's action entirely, and thus caused death.

21. Again, if we estimate the amount of blood expelled by each contraction of the ventricle at four ounces, then the weight of the blood moved during one minute will amount to eighteen pounds; and in the course of a lifetime, over one hundred and fifty thousand tons. These large figures indicate, in some measure, the immense labor necessary to carry on the interior and vital operations of our bodies.

22. The Arteries.—The tube-like canals which carry the blood away from the heart are the arteries. Their walls are made of tough, fibrous materials, so that they sustain the mighty impulse of the heart, and are not ruptured. In common with the heart, the arteries have a delicately smooth lining membrane. They are also elastic, and thus re-enforce the action of the heart: they always remain open when cut across, and after death are always found emptied of blood.

23. The early anatomists observed this condition, and supposing that the same condition existed during life, came to the conclusion that these tubes were designed to act as air-vessels, hence the name artery, from Greek words which signify "containing air." This circumstance affords us an illustration of the mistaken notions of the ancients in reference to the internal operations of the body. Cicero speaks of the arteries as "conveying the breath to all parts of the body."

24. The arterial system springs from the heart by a single trunk, like a minute and hollow tree, with numberless branches. As these branches leave the heart they divide and subdivide, continually growing smaller and smaller, until they can no longer be traced with the naked eye. If, then, we continue the examination by the aid of a microscope, we see these small branches sending off still smaller ones, until all the organs of the body are penetrated by arteries.

25. The Pulse.—With each contraction of the left side of the heart, the impulse causes a wave-like motion to traverse the entire arterial system. If the arteries were exposed to view, we might see successive waves speeding from the heart to the

smallest of the branches, in about one-sixth part of a second. The general course of the arteries is as far as possible from the surface. This arrangement is certainly wise, as it renders them less liable to injury, the wounding of an artery being especially dangerous. It also protects the arteries from external and unequal pressure, by which the force of the heart would be counteracted and wasted. Accordingly, we generally find these vessels hugging close to the bones, or hiding behind the muscles and within the cavities of the body.

26. In a few situations, however, the arteries lie near the surface; and if we apply the finger to any of these parts, we will distinctly feel a throbbing motion taking place in harmony with the heart-beat. This is part of the wave-motion just mentioned, and is known as "the pulse." All are familiar with the pulse at the wrist; but the pulse is not peculiar to that position, for it may be felt in the neck, at the temple, and elsewhere, especially near the joints.

27. Since the heart-beat makes the pulse, whatever affects the former affects the latter also. Accordingly, the pulse is a good index of the state of the health, so far as the health depends upon the action of the heart. It informs the physician of the condition of the circulation in four particulars: its rate, regularity, force, and fullness; and nearly every disease modifies in some respect the condition of the pulse.

28. The Veins.—The vessels by which the blood returns to the heart are the veins. At first they are extremely small; but uniting together as they advance, they constantly increase in size, reminding us of the way in which the fine rootlets of the plant join together to form the large roots, or of the rills and rivulets that flow together to form the large streams and rivers. In structure, the veins resemble the arteries, but their walls are much less elastic. They are more numerous, and communicate with each other freely in their course, by means of interlacing branches.

29. But the chief point of the distinction is in the presence

of the valves in the veins. These are little folds of membrane, disposed in such a way, that they open only to receive blood flowing toward the heart, and close against a current in the opposite direction. Their position in the veins on the back of the hand may be readily observed, if we first obstruct the return of blood by a cord tied around the forearm or wrist. In a few minutes the veins will appear swollen, and upon them will be seen certain prominences, about an inch apart. These latter indicate the location of the valves, or, rather, they show that the vessels in front of the valves are distended by the blood, which cannot force a passage back through them.

FIG. 21.—THE VALVES OF THE VEINS.

30. This simple experiment proves that the true direction of the venous blood is toward the heart. That the color of the blood is dark, will be evident, if we compare the hand thus bound by a cord with the hand not so bound. It also proves that the veins lie near the surface, while the arteries are beneath the muscles, well protected from pressure; and that free communication exists from one vein to another. If now we test the temperature of the constricted member by means of a thermometer, we will find that it is colder than natural, although the amount of blood is larger than usual. From this fact we infer, that whatever impedes the venous circulation tends to diminish vitality; and hence, articles of clothing or constrained postures, that confine the body or limbs, and hinder the circulation of the blood, are to be avoided as injurious to the health.

31. The Capillaries.—A third set of vessels completes the list of the organs of the circulation, namely, the *capillary* vessels, so called (from the Latin word *capillaris*, hair-like), because of their extreme fineness. They are, however, smaller than any hair, having a diameter of about $\frac{1}{3000}$ of an inch, and can be observed only by the use of the microscope. These vessels are

the connecting link between the last of the arteries and the first of the veins. The existence of these vessels was unknown to Harvey, and was the one step wanting to complete his great discovery. The capillaries were not discovered until 1661, a short time after the invention of the microscope.

32. The circulation of the blood, as seen under the microscope, in the transparent web of a frog's foot, is a beautiful sight, possessing more than ordinary interest from the fact that something very similar is taking place in our own bodies on a much grander scale. It is like opening a secret page in the history of our own frames. We there see distinctly the three classes of vessels with their moving contents; first, the artery, with its torrent of blood rushing down from the heart, secondly, the vein, with its slow, steady stream flowing in the opposite direction; and between them lies the network of capillaries so fine

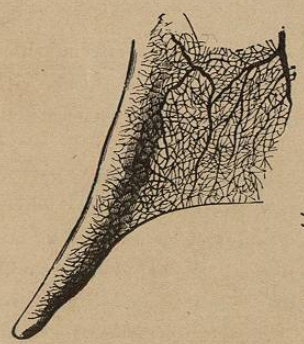

FIG. 22.—WEB OF A FROG'S FOOT, slightly magnified.

FIG. 23.—MARGIN OF FROG'S WEB, magnified 30 diameters.

that the corpuscles can pass through only "in single file." The current of the capillaries has an uncertain or swaying motion, hurrying first in one direction, then hesitating, and then turning back in the opposite direction, and sometimes the capillaries contract so as to be entirely empty. Certain of the tissues are destitute of capillaries; such are cartilage, hair, and a few others

on the exterior of the body. In all other structures, networks of these vessels are spread out in countless numbers; so abundant is the supply, that it is almost impossible to puncture any part with the point of a needle without lacerating tens, or even hundreds of them.

33. The capillaries are elastic, and may so expand as to produce an effect visible to the naked eye. Let a grain of sand lodge in the eye and irritate it, and in a short time the white of the eye will be "blood-shot." This appearance is due to an increase in the size of these vessels.

34. Rapidity of the Circulation.—That the blood moves with great rapidity is evident from the almost instant effects of certain poisons, as prussic acid, which act through the blood. Experiments upon the horse, dog, and other inferior animals, have been made to measure its velocity. If a substance, which is capable of a distinct chemical reaction (as *potassium ferrocyanide*, or *barium nitrate*), be introduced into a vein on one side of a horse, and blood be taken from a distant vein on the other side, its presence may be detected at the end of thirty or thirty-two seconds. In man, the blood moves with greater speed, and the circuit is completed in twenty-four seconds.

35. What length of time is required for all the blood of the body to make a complete round of the circulation? This question cannot be answered with absolute accuracy. But we find that, under ordinary circumstances, all the blood makes one complete rotation every two minutes; passing successively through the heart, the capillaries of the lungs, the arteries, the capillaries of the extremities, and through the veins.

36. Assimilation.—The crowning act of the circulation, the furnishing of supplies to the different parts of the body, is effected by means of the capillaries. The organs have been wasted by use; the blood has been enriched by the products of digestion. Here, within the meshes of the capillary network, the needy tissues and the needed nutriment are brought together. By some mysterious chemistry, each tissue selects and

withdraws from the blood the materials it requires, and converts them into a substance like itself. This conversion of lifeless food into living tissue is called assimilation. The process probably takes place at all times, but the period especially favorable for it is during sleep. Then the circulation is slower and more regular, and most of the functions are at rest. The body is then like some trusty ship, which after a long voyage is "hauled up for repairs."

37. Injuries to the Blood-vessels.—It is important that every one should be able to discriminate between an artery and a vein, in the case of a wound, and if we remember the physiology of the circulation it will be impossible to make a mistake. For, as we have already seen, hemorrhage from an artery is much more dangerous than that from a vein. The latter tends to cease spontaneously after a short time. The arterial blood flows away from the heart with considerable force, in jets: its color, bright scarlet. The venous blood flows toward the heart from that side of the wound furthest from the heart; its stream being continuous and sluggish; its color dark. In an injury to an artery, pressure should be made between the heart and the wound; while in the case of a vein that persistently bleeds, it should be made upon the vessel beyond its point of injury.

38. Effects of Alcohol upon the Heart.—The first symptoms after a moderate dose of alcohol is an increase of the heart's action, a flushing of the face, a sensation of warmth within, a general glow without, and some other appearances of increased vitality. The action has been that of a spur or goad. It has caused strength to be expended instead of increasing it, and, in fact, costs the system whatever amount of force is necessary to expel it; so that there is a loss of strength, and not a gain.

39. The late Dr. Parkes made a careful study of the amount of strain put upon the heart by alcohol. He found that it increased both the number and force of the heart's pulsations. The period of rest between the beats is reduced, and, consequently, the heart's nutrition must be interfered with. He estimates, in

one set of experiments, that the extra work of the heart, induced by alcohol, was equivalent to the lifting of 15.8 tons one foot daily; and during two days, 24 tons in excess of the regular work.

40. Alcohol as a Fat Producer.—Alcohol is said to diminish waste and to make those "fleshy" who use it. This may well be the case in those—and the proportion is not small—who are rendered sluggish and sleepy by it. The fat which they acquire is the fat of inaction. If we may judge of the true influence of alcohol by experiments on the lower animals, that are compelled to take it pure, we will not grant it any fattening power.

41. There is a certain "fatty degeneration" in man—the result of alcohol-drinking—that is very disastrous, namely a deposit of fat in the muscles of the body. This is destructive or weakening to muscular power, and when it evinces itself in the heart it creates a change that is to be dreaded as sapping the strength of the one particular organ that should be strong in drinkers. It attacks them at a vital spot.

42. The blood also undergoes a fatty change which greatly impairs its work of nourishing the body.

The Blood.—"You feel quite sure that blood is red, do you not? Well, it is no more red than the water of a stream would be if you were to fill it with little red fishes. Suppose the fishes to be very, very small, as small as a grain of sand, and closely crowded together through the whole depth of the stream, the water would look red, would it not? And this is the way in which the blood looks red: only observe one thing; a grain of sand is a mountain in comparison with the little red bodies that float in the blood, which we have likened to little fishes. If I were to tell you they measured about the 3200th part of an inch in diameter, you would not be much the wiser; but if I tell you that in a single drop of blood, such as might hang on the point of a needle, there are a million of these bodies, you will perceive that they are both very minute and very numerous. Not that any one has ever counted them, as you may suppose, but this is as close an estimate as can be made in view of what is known of their minute size."—*Macé's History of a Mouthful of Bread.*

(*For further matter on Alcohol and Narcotics see p. 120.*)

TABLE OF THE PRINCIPAL ARTERIES.

(See Figure opposite Page 75.)

The Head.

Internal Ca-rot'id, Ver'te-bral, } Supply the brain.

Oph-thal'mic, supplies the eye.

External Ca-rot'id gives off..... { **Lin'gual,** supplies the tongue. **Fa'ci-al,** supplies the lower part of the face. **Tem'po-ral,** supplies the upper part of the head and face

The Trunk.

The A-or'ta, arising from the heart, is the main arterial trunk.
Cor'o-na-ry, supplies the walls of the heart.
Bron'chi-al, supplies the lungs.
In-ter-cos'tals, supply the walls of the chest.
Gas'tric, supplies the stomach.
He-pat'ic, supplies the liver.
Splen'ic, supplies the spleen.
Re'nal, supplies the kidney.
Mes-en-ter'ics, supply the bowels.
Spi'nal, supplies the spinal cord.

The Upper Limb.

Branches of the Ax-il-la'ry, supply the shoulder.
" " **Bra'chi-al,** supply the arm.
" " **Ra'di-al, Ul'nar,** } supply the forearm and fingers.

The Lower Limb.

Branches of the Fem'o-ral, supply the hip and thigh.
" " **Pop-li-te'al, Tib'i-al, Per-o-ne'al,** } supply the leg and foot.

QUESTIONS FOR TOPICAL REVIEW.

CHAPTER VII.

RESPIRATION.

The Object of Respiration—The Lungs—The Air-Passages—The Movements of Respiration—Expiration and Inspiration—The Frequency of Respiration—Capacity of the Lungs—The Air we breathe—Changes in the Air from Respiration—Changes in the Blood—Interchange of Gases in the Lungs—Comparison between Arterial and Venous Blood—Respiratory Labor—Impurities of the Air—Dust—Carbonic Acid—Effects of Impure Air—Nature's Provision for Purifying the Air—Ventilation.

1. The Object of Respiration.—In one set of capillaries, or hair-like vessels, the blood is impoverished in order that it may support the different members and organs of the body. In another capillary system the blood is refreshed and again made fit to sustain life. The former belongs to the greater or *systemic* circulation; the latter to the lesser or *pulmonary*, the lungs, in which organs it is situated. The blood sent from the right side of the heart to the lungs is venous, dark, impure, and of a nature hurtful to the tissues. But when the blood returns from the lungs to the left side of the heart, it has become arterial, bright, pure, and no longer injurious. This marvelous purifying change is effected by means of the very familiar act of respiration, or breathing.

2. The Lungs.—The lungs are the special organs of respiration. There are two of them, one on each side of the chest, which cavity they, with the heart, almost wholly fill. The lung-substance is soft, elastic, and sponge-like. Under pressure