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 of the finger, it crackles, and when thrown into water it floats; these properties are due to the presence of air in the minute air-cells of the lungs. To facilitate the movements necessary to these organs, each of them is provided with a double covering

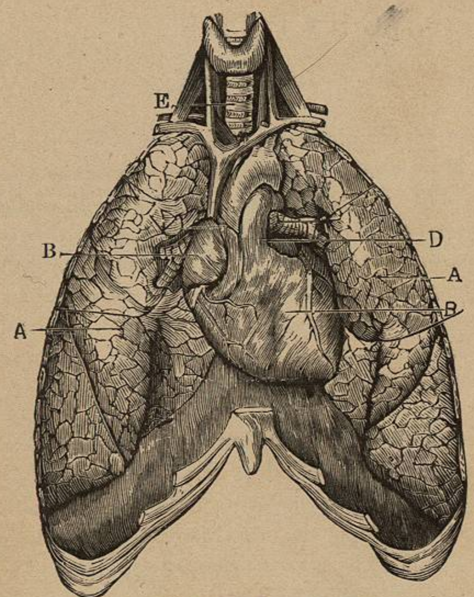

Fig. 24.—Organs of the Chest.
A, Lungs. D, Pulmonary Artery.
B, Heart. E, Trachea.

of an exceedingly smooth and delicate membrane, called the *pleura*. One layer of the pleura is attached to the walls of the chest, and the other to the lungs; and they glide one upon the other, with utmost freedom. Like the membrane which envelops the heart, the pleura secretes its own lubricating fluid, in quantities sufficient to keep it always moist.

3. The Air-Passages.—The lungs communicate with the external air by means of certain air-tubes, the longest of which, the *trachea*, or windpipe, runs along the front of the neck

(Figs. 24, E, and 25). Within the chest this tube divides into two branches, one entering each lung; these in turn give rise to numerous branches, or bronchial tubes, as they are called, which gradually diminish in size until they are about one-twenty-fifth of an inch in diameter. Each of these terminates in a cluster

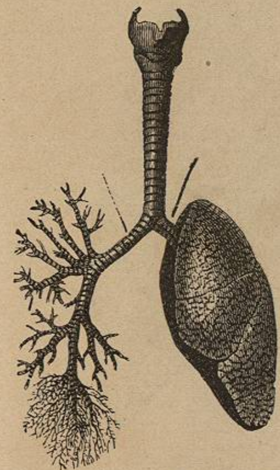

Fig. 25.—Larynx, Trachea, and Bronchial Tubes.

Fig. 26.—Diagram and Section of the Air-cells.

of little pouches, or "air-cells," having very thin walls, and covered with a capillary network, the most intricate in the body (Fig. 25).

4. These tubes are somewhat flexible, sufficiently so to bend when the parts move in which they are situated; but they are greatly strengthened by bands or rings of cartilage which keep the passages always open; otherwise there would be a constantly-recurring tendency to collapse after every breath. The lung-substance essentially consists of these bronchial tubes and terminal air-cells, with the blood-vessels ramifying about them (Fig. 26). At the top of the trachea is the larynx, a sort of box of cartilage, across which are stretched the vocal cords.

Here the voice is produced chiefly by the passage of the respired air over these cords, causing them to vibrate.

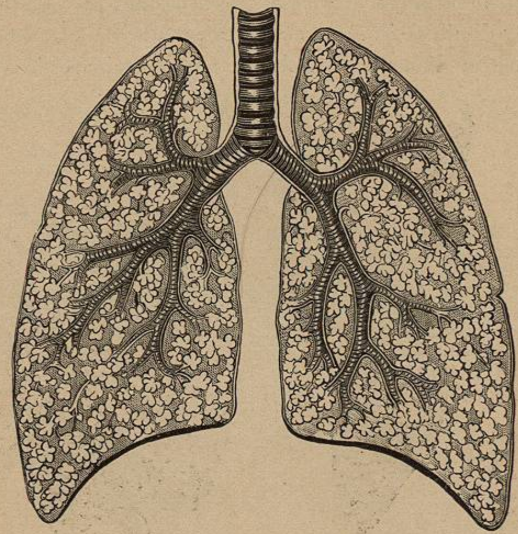

Fig. 27.—Section of the Lungs.

5. Over the opening of the larynx is found the *epiglottis*, which fits like the lid of a box at the entrance to the lungs, and closes during the act of swallowing, so that food and drink shall pass backward to the œsophagus, or gullet (Fig. 27). Occasionally it does not close in time, and some substance intrudes within the larynx, when we at once discover, by a choking sensation, that "something has gone the wrong way," and, by coughing, we attempt to expel the unwelcome intruder. The air-passages are lined through nearly their whole extent with mucous membrane, which keeps them in a constantly moist condition.

6. The Movements of Respiration.—The act of breathing has two parts—(1), *inspiration*, or drawing air into the lungs, and (2), *expiration*, or forcing it out again. In inspiration, the chest extends in its length, breadth, and height. The motion

outwards and upwards can be observed every time we draw a full breath, and is caused by a lifting of the ribs. But the motion downwards is not so apparent, as it is caused by a muscle

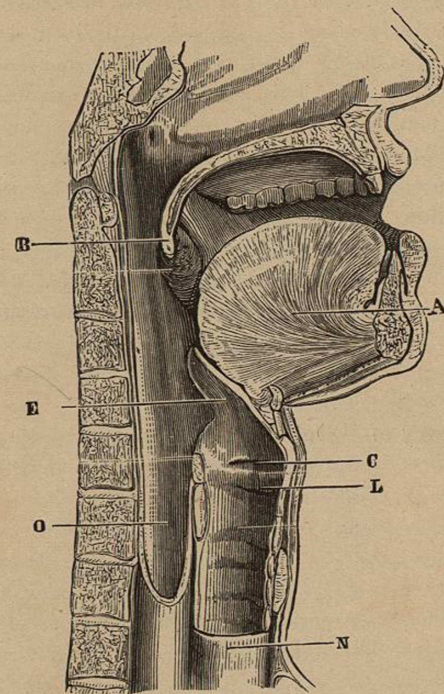

Fig. 28.—Section of Mouth and Throat.

A, The Tongue. B, The Uvula. C, Vocal Cord. E, Epiglottis. L, Larynx. N, Trachea. O, Œsophagus.

within the body called the *diaphragm*. This is the thin partition which separates the chest from the abdomen, rising like a dome within the chest (Fig. 9). With every inspiration, the diaphragm contracts, and in so doing, approaches more nearly a level surface, and thus enlarges the capacity of the chest. Laughing, sobbing, hiccoughing, and sneezing are caused by the spasmodic or sudden contraction of the diaphragm. The special power of this muscle is important in securing endurance, or "long wind," as it is commonly expressed; which may be obtained mainly by practice. It is possessed in a marked degree by the mountaineer, the oarsman, and the trained singer. As the walls of the chest extend, the lungs expand, and the air rushes in to fill them. This constitutes an inspiration. The habit of taking frequent and deep inspirations, in the erect position, with the shoulders thrown back, tends greatly to increase the capacity and power of the organs of respiration.

7. Expiration is a less powerful act than inspiration. The diaphragm relaxes and ascends in the form of a dome; the ribs descend and contract the chest; while the lungs themselves, being elastic, assist to drive out the air. The latter passes out through the same channels by which it entered. At the end of each expiration there is a pause, or period of repose, lasting about as long as the period of action.

8. Frequency of Respiration.—It is usually estimated that we breathe once during every four beats of the heart, or about eighteen times in a minute. When the action of the heart is hurried, a larger amount of blood is sent to the lungs, and, as the consequence, they must act more rapidly. Occasionally, the heart beats so very forcibly that the lungs cannot keep pace with it, and then we experience a peculiar sense of distress from the want of air. This takes place when we run until we are "out of breath."

9. Although, as a general rule, the work of respiration goes on unconsciously and without exertion on our part, it is nevertheless under the control of the will. We can increase or diminish the frequency of its acts at pleasure, and we can "hold the breath," or arrest it altogether for a short time. From twenty to thirty seconds is ordinarily the longest period in which the breath can be held; but if we first expel all the impure air from the lungs, by taking several very deep inspirations, the time may be extended to one and a half or even two

minutes. This should be remembered, and acted upon, before passing through a burning building, or any place where the air is very foul.

10. The air is not a simple element, as the ancients supposed, but is formed by the mingling of two gases, known to the chemist as oxygen and nitrogen, in the proportion of one part of the former to four parts of the latter. These gases are very unlike, being almost opposite in their properties: nitrogen is weak, inert, and cannot support life; while oxygen is powerful, and incessantly active; and is the essential element which gives to the atmosphere its power to support life and combustion. The discovery of this fact was made in 1778 by the French chemist, Lavoisier.

11. Changes in the Air from Respiration.—Air that has been once breathed is no longer fit for respiration. An animal confined within it will sooner or later die; so, too, a lighted candle placed in it will be at once extinguished. If we collect a quantity of expired air and analyze it, we shall find that its composition is not the same as that of the inspired air. When the air entered the lungs it was rich in oxygen; now it contains twenty-five per cent. less of that gas. Its volume, however, remains nearly the same; its loss being replaced by another and very different gas, which the lungs exhale, called *carbonic acid*, or, as the chemist terms it, *carbon dioxide.*

12. The expired air has also gained moisture. This is noticed when we breathe upon a mirror, or the window-pane, the surface being tarnished by the condensation of the watery vapor given off by the lungs. In cold weather, this causes the fine cloud which is seen issuing from the nostrils or mouth with each expiration, and contributes in forming the feathery crystals of ice which decorate our window-panes on a winter's morning.

13. Changes in the Blood from Respiration.—The most striking change which the blood undergoes by its passage through the lungs, is the change of color from a dark blue to bright red. That this change is dependent upon respiration has been fully proved by experiment. If the trachea, or windpipe, of a living animal be so compressed as to exclude the air from the lungs, the blood in the arteries will gradually grow darker, until its color is the same as that of the venous blood. When the pressure is removed the blood speedily resumes its bright hue. Again, if an animal breathe an atmosphere containing more oxygen than atmospheric air, the color changes from scarlet to vermilion, and becomes even brighter than arterial blood. This change of color is not of itself a very important matter, but it indicates a most important change of composition.

14. The air, as we have seen, by respiration loses oxygen and gains carbonic acid: the blood, on the contrary, gains oxygen and loses carbonic acid. Oxygen is the food of the blood corpuscles; while the articles we eat and drink go more directly to the plasma of the blood. The air, then, it is plain, supplies one kind of food, while our articles of diet supply another. But there is this difference, our lung food is needed constantly, while ordinary food is taken at distinct intervals. Again, as the demand of the system for food is expressed by the sensation of hunger, so the demand for air is marked by a painful sensation called suffocation.

15. Interchange of Gases in the Lungs.—But the air and the blood do not come in contact—they are separated by the walls of the air-cells and of the blood-vessels,—how then do the two gases, oxygen and carbonic acid, exchange places? Moist animal membranes have a property which enables them to transmit gases through their substance, although they are impervious to liquids. This may be beautifully shown by suspending a bladder containing dark venous blood in a jar of oxygen. At the end of a few hours the oxygen will have diminished, the blood will be scarlet in color, and carbonic acid will be found in the jar.

16. If this interchange takes place outside of the body, it must take place much more perfectly within it, where the circumstances are of the most favorable character. The walls of

the vessels and the air-cells are thin and moist, and the currents of air and blood are in constant motion. Both parts of this process of exchange are equally important. Without oxygen life ceases; if carbonic acid is not thrown off, it acts like a poison, producing unconsciousness, convulsions, and even death.

17. Difference between Arterial and Venous Blood.—The following table presents the essential points of difference in the appearance and composition of the blood, before and after its passage through the lungs:

	VENOUS BLOOD.	ARTERIAL BLOOD.
Color,	Dark blue,	Scarlet.
Oxygen,	8 per cent.,	18 per cent.
Carbonic Acid,	15 to 20 per cent.	6 per cent. or less.
Water,	More,	Less.

The temperature of the blood varies considerably; but the arterial stream is generally warmer than the venous. The blood imparts heat to the air while passing through the lungs, and consequently the contents of the right side of the heart have a higher temperature than the contents of the left side.*

18. Amount of Respiratory Labor.—During ordinary calm respiration, we breathe eighteen times in a minute; and twenty cubic inches of air pass in and out of the lungs with every breath. From this we calculate that the quantity of air which hourly traverses the lungs is about thirteen cubic feet, or seventy-eight gallons; and daily, not less than three hundred cubic feet, an amount nearly equal to the contents of sixty barrels.

19. Impurities of the Air.—The oxygen in the atmosphere is of such prime importance, and its proportion is so nicely adjusted to the wants of man, that any gas or volatile substance which supplants it must be regarded as a hurtful impurity. All gases, however, are not alike injurious. Some, if inhaled, are necessarily fatal; *arseniuretted hydrogen* being one of these, a single bubble of which destroyed the life of its discoverer, Gehlen. Others are not directly dangerous, but because they

* "Bernard has succeeded in establishing the following facts with regard to the temperature (of the blood) in various parts of the circulatory system in dogs and sheep: 1. The blood is warmer in the right than in the left cavities of the heart. 2. It is warmer in the arteries than in the veins, with a few exceptions."—*Physiology of Man, Flint.*

arsinureted

take the place of oxygen, and exclude it from the lungs, they do harm. To this latter class belongs carbonic acid.

20. Most of the actively poisonous gases have a pungent or offensive odor; and, as may be inferred, almost all bad smells indicate the presence of substances unfit for respiration. Accordingly, as we cannot see or taste these impurities, the sense of smell is our principal safeguard against them. In this we recognize the forethought which has stationed this sense, like a sentinel, at the entrance of the air-passages, to give us warning of approaching harm. Take, as an example, the ordinary illuminating gas of cities, from which so many accidents happen. How many more deaths would occur from it by suffocation and explosion, if we were not made aware of leakage by means of its disagreeable odor.

21. "Man's greatest enemy is his own breath," it is said; but chiefly because of the organic matter it contains. Organic matter exists in increased measure in the expired breath of sick persons, and impart to it, at times, a putrid odor. This is especially true in diseases which, like typhus and scarlet fever, are referable to a blood poison. In such cases the breath is one of the means by which nature seeks to expel the offending material from the system. Hence, those who visit or nurse fever-sick persons should obey the oft-repeated direction, "not to take the breath of the sick." At such times, if ever, fresh air is demanded, and not for the sick alone, but also for those who take care of them.

22. Dust in the Air.—In a lecture on this subject by Professor Tyndall, he remarks that, "by breathing through a cotton wool respirator, the noxious air of the sick room is restored to practical purity. The air thus filtered, attendants may breathe unharmed. In all probability, the protection of the lungs will be the protection of the whole system. For it is exceedingly probable that the germs which lodge in the air-passages are those which sow epidemic disease in the body. If this be so, then disease can certainly be warded off by filters of cotton wool.

23. Carbonic Acid in the Air.—This gas exists naturally in the air in small quantities. In the open air, men seldom suffer from carbonic acid, for, as we shall see presently, nature provides for its rapid distribution, and even turns it to good use. But its ill effects are painfully evident in the abodes of men, in which it is liable to collect as the waste product of respiration and of that combustion which is necessary for lighting and warming our homes. A man exhales one-half cubic foot of carbonic acid per hour; a single gas-burner liberates five cubic feet in the same time, and therefore spoils as much air as ten men. A fire burning in a grate or stove emits some impure gases, and at the same time abstracts from the air as much oxygen as twelve men would consume in the same period, thus increasing the relative amount of carbonic acid in the air. From furnaces, as ordinarily constructed, this and other gases are constantly leaking and poisoning the air of tightly-closed apartments.

24. Effects of Impure Air.—Carbonic acid, in its pure form, is irrespirable, causing rapid death by suffocation. Air containing forty parts per thousand of this gas (the composition of the expired breath) extinguishes a lighted candle, and is fatal to birds; when containing one hundred parts, it no longer yields oxygen to man and other warm-blooded animals; and is of course speedily fatal to them. In smaller quantities, this gas causes headache, labored respiration, palpitation, unconsciousness, and convulsions.

25. Another unmistakable result of living in and breathing foul air is found in certain diseases of the lungs, especially consumption. For many years the barracks of the British army were constructed without any regard to ventilation; and during those years a large number of men died of consumption. At last the government began to improve the condition of the buildings, giving larger space and air-supply; and as a consequence, the mortality from that disease has diminished more than one-third.

26. The lower animals confined in the impure atmosphere of stables and menageries suffer from the same diseases as man. Those brought from a tropical climate, and requiring to be closely housed, generally die of consumption. In the Zoological gardens of Paris, this disease affected nearly all monkeys, until care was taken to introduce fresh air by ventilation; and then it almost wholly disappeared.

27. Nature's Provision for Purifying the Air.—We have seen that carbonic acid is heavier than air, and is poisonous. Why, then, does it not sink upon and overwhelm mankind with a silent, unseen wave of death? Among the gases there is a force more potent than gravity, which forever prevents such a tragedy. It is known as the diffusive power of gases. It acts according to a definite law, and with irresistible force, compelling gases, when in contact, to mingle until they are thoroughly diffused. The added influence of the winds is useful, by insuring more rapid changes in the air; air in motion being perfectly wholesome. The rains also wash the air.

28. We have seen that the whole animal creation is constantly taking oxygen from the air, and as constantly adding to it vast volumes of a gas hurtful to all kinds of animals, even in small quantities. How, then, does the air retain unchanged its life-giving properties? The uniformly pure state of the air is secured by means of the vegetable creation. Carbonic acid is the food of the plants, and oxygen is its waste product. The leaves are its lungs, and under the stimulus of sunlight a vegetable respiration is set in motion, the effects of which are just the reverse of that of animals. Thus nature purifies the air, and at the same time builds up two beautiful and useful worlds —the life of each growing out of the decay of the other.

29. Ventilation.—Since the external atmosphere, as provided by nature, is always pure, and since the air in our dwellings and other buildings is almost always impure, it becomes imperative that there should be a free communication from the one to the other. This we aim to accomplish by ventilation. As our houses are

ordinarily constructed, the theory of ventilation, "to make the internal as pure as the external air," is seldom carried out. Doors, windows, and flues, the natural means of replenishing the air, are too often closed against the precious element. Special means, or special attention, must therefore be used to secure even a fair supply of fresh air. This is still more true of those places of public resort, where large numbers of persons crowd together.

30. If there are two openings in a room, one as a vent for foul air and the other an inlet for atmospheric air, and if the openings be large, in proportion to the number of air consumers, the principal object will be attained. Thus, a door and window, each opening into the outer air, will ordinarily ventilate a small apartment; or a window alone will answer, if it be open both above and below, and the open space at each end be not less than one inch for each occupant of the room, when the window is about a yard wide. The direction of the current is generally from below upward, since the foul, heated air tends to rise. Its rate need not be rapid; a "draught," or perceptible current, is never necessary to good ventilation. The temperature of the air admitted may be warm or cold. It is thought by many that if the air is cold, it is pure; but this is an error, since cold air will receive and retain the same impurities as warm air.

31. Shall we open our bedrooms to the night air? Florence Nightingale says, in effect, that night air is the only air that we can then breathe. "The choice is between pure air without and impure air within. Most people prefer the latter,—an unaccountable choice. An open window, most nights in the year, can hurt no one. In great cities, night air is the best and purest to be had in twenty-four hours. I could better understand, in towns, shutting the windows during the day than during the night."

32. Animal Heat.—The temperature of the human body is about 100° Fahr., and remains about the same through winter and summer, in the tropics as well as in the frozen regions of the north. It may change temporarily within the range of about twelve degrees; but any considerable, or long-continued elevation or diminution of the bodily heat is certain to result disastrously.

33. The regulation of the temperature of the body is effected by means of perspiration, and by its evaporation. So long as the skin acts freely and the air freely absorbs the moisture, the heat of the body does not increase, for whenever evaporation takes place, it is attended with the abstraction of heat—that is, the part becomes relatively colder. This may be tested by moistening some part of the surface with cologne, ether, or other volatile liquid, and then causing it to evaporate rapidly by fanning. The principle that evaporation produces cold has been ingeniously and practically employed, in the manufacture of ice, by means of freezing machines.

QUESTIONS FOR TOPICAL REVIEW.

	PAGE
1. What is the object of respiration?	91
2. What are the special organs of respiration?	91
3. In what organs does a change in the blood take place?	91
4. What is the nature of the change?	91
5. Where are the lungs situated, and what is the character of the substance of which they are composed?	91
6. Describe the facilities provided for the lung movements	92
7. Describe the trachea, or windpipe	92
8. Describe the bronchial tubes, and their uses	93
9. What can you state in relation to the epiglottis?	94
10. Describe the movements necessary to the act of perfect respiration	94
11. What is the diaphragm, and what is its office?	95
12. How may the organs of respiration be so improved as to increase their capacity and power?	96
13. What is stated in relation to the frequency of respiration?	96
14. To what extent may the act of respiration be subjected to our wills?	96
15. What is the air, and what are its parts?	97
16. What is the character of the air that has been just breathed?	97
17. Why is it that such air is not fit for respiration?	97
18. What are the effects, as recorded in notable cases, of confinement in places the air of which has been breathed "over and over?"	97
19. What can you state of changes in the blood from respiration?	97
20. What of the air, as an article of food?	98

	PAGE
21. What, on the subject of interchange of gases in the lungs	98
22. Explain the difference between arterial and venous blood	99
23. Explain, if you can, the cause of the difference	99
24. In relation to the amount of labor exerted in respiration	99
25. In relation to the deleterious properties of different gases	99
26. What are the properties of carbonic acid gas	100
27. Describe the effects of carbonic acid gas?	101
28. What are the general effects of breathing any impure atmosphere?	101
29. What are Nature's provisions for purifying the air?	102
30. What hints and directions are given on the subject of ventilation?	102
31. How is temperature of the body regulated and sustained?	104